FINAL PROGRAM

SRS
Scoliosis Research Society

SYDNEY Australia 2026

61st ANNUAL MEETING

OCTOBER 6-10, 2026

International Convention Centre Sydney
Sydney • Australia

CORPORATE PARTNERS

We are pleased to acknowledge and thank those companies that provided financial support to SRS in 2026. Support levels are based on total contributions throughout the year and include the Annual Meeting, IMAST, Global Outreach Scholarships, Edgar Dawson Memorial Scholarships, SRS Traveling Fellowships, and the Research, Education, and Outreach (REO) Fund.

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Thank you!

SRS would like to thank the following supporters who provided grant support to the 61st Annual Meeting:

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ANNUAL MEETING VENUE

International Convention Centre (ICC) Sydney
14 Darling Drive
Sydney, NSW 2000, Australia

THIS MEETING IS SUPPORTED BY:

business events sydney

NSW GOVERNMENT

All information as of September 16, 2026

Scoliosis Research SOCIETY

SRS Office 555 East Wells Street, Suite 1100, Milwaukee, WI 53202
P: 414.289.9107 | F: 414.276.3349 | E: info@srs.org | W: www.srs.org

MEMBER BUSINESS MEETING AND LUNCH

Friday, October 9 | 12:15-13:30
Parkside Ballroom | Level 2

A hot lunch will be provided

All SRS members are invited to the 2026 Member Business Meeting. This meeting is an opportunity to hear a summary of the many activities of the Society over the last year.

The agenda will include:

- Reports from the various SRS committees presented by each Council
  - Communication
  - Education
  - Finance
  - Governance
  - Research
- Updates on SRS activities, programs and financial state
- Report from the 2026 Traveling Fellows
- Voting on Report, the Slate of Officers and the 2026-2027 Nominating Committee (e-vote)

Attendance at the Member's Business Meeting is an opportunity to not only hear updates but actively participate in shaping the future of our Society. We encourage ALL MEMBERS to attend.

Scoliosis Research Society

MEETING INFORMATION

The Scoliosis Research Society gratefully acknowledges Orthofix and OrthoPediatrics for their grant support of the Pre-Meeting Course.

PRESIDENT'S MESSAGE

It is my sincere pleasure to welcome you to the 61st SRS Annual Meeting in Sydney Australia.

This meeting represents the realization of the Society's vision - to be the global leader in spine research and education - and this year's program was chosen from the best abstracts and proposals which support that vison. With more than 180 podium papers, and 80 E-Point presentations, attendees will be exposed to an array of topics, from pediatric and adult scoliosis to operative techniques, long term follow up, machine learning and everything in between.

I want to personally thank our Education Committee co-chairs Nicholas Fletcher, MD and Eric Klineberg, MD, for arranging our Pre-Meeting Course, two Half Day Courses and three Lunch-time Symposiums, along with the Annual Meeting Scientific Program Committee co-chairs Kariman Abelin-Genevois, MD, PhD, and W. G. Stuart Mackenzie, MD, an outstanding job putting our abstract program together. This will be an impactful week for all attendees, and I expect packed rooms and animated discussion.

As always, the SRS Annual Meeting kicks off with the Hibbs Society meeting on Tuesday afternoon, chaired by last year's SRS Traveling Fellows. This session will go beyond standard academic presentations by focusing on real world complexity, difficult choices, lessons learned, and the evolution of surgical wisdom.

In keeping with our meeting theme — Bridges and Transitions — we will discuss career journey transitions in the Pre-Meeting Course and how to bridge the anatomical transitional zones of the spine in Half-Day Course 1, from the occipitocervical region all the way to the lumbosacral region.

Our program begins on Wednesday afternoon with the first abstract session — continuing the SRS tradition to highlight research in AIS. Following this session, the Opening Ceremonies will commence at 17:20. We will be announcing several important grant and service awards, acknowledging our industry partners, and present the Walter P. Blount Humanitarian Award to Saumyajit Basu, MD for his outstanding service to those with spinal deformities and his enduring generosity to the underserved areas, our profession and Society.

The Opening Ceremonies will also feature the Steel Lecture, and I am very excited to hear our invited lecturer, David Hunt on the topic "Rum, Botany and the Lash." David, an entertaining speaker and noted expert on Australian history will transport the audience "to the convict colony that, within the span of a single human life, would become the wealthiest society in the world." Check out his biography on page 13 of the Final Program.

Thursday morning kicks off with sessions from the scientific program, followed by the Harrington Lecture featuring Todd J. Albert, MD on the topic, "The View from the Second Mountain: Transitions in Deformity, Career, and Life." We will also present the Lifetime Achievement Award to a member who has exhibited long and distinguished service to SRS and to spinal deformity research and care, the esteemed David W. Polly, Jr., MD. Learn more about Dr. Polly on page 15 of the Final Program.

This program offers a rich variety of sessions, and a few include a newer format — debates — such as the Half-Day Course 2 on Thursday, a Debate Style Discussion: Different Approaches to Different Problems. Join an outstanding panel of internationally recognized pediatric and adult spine surgeons for a fast-paced, debate-style session covering a variety of topics.

Thursday also includes our Industry Workshops in the morning and during lunch. Each workshop is programmed by a single-supporting company and features presentations on topics and technologies, anchored by experts in spinal surgery. Find the full schedule on page 240 of the Final Program.

Friday will be a full day of scientific sessions beginning with the Hibbs Award-Nominated Papers, as well as the Presidential Address. The agenda for the lunchtime Member Business Meeting will include reports from the various SRS committees, updates on SRS activities and programs, and voting. Attendance at the Member Business Meeting is an opportunity to actively participate in shaping the future of our Society. I highly encourage ALL MEMBERS to attend.

The Member Information Session: One World, One Spine, One SRS is for the SRS-curious and will take place at the same time as the Member Business Meeting. This program highlights the role of the Scoliosis Research Society as a global platform for research, education, mentorship, surgeon well-being, and academic leadership. This will be an excellent networking forum for our attendees who are not yet members.

The day concludes with the Farewell Reception at 19:30, hosted at the Australian Museum which features "22+ million specimens and objects that tell the stories of Australia and the Pacific - from ancient fossils and living species to minerals and cultural heritage."

We close the meeting with a half-day of scientific sessions on Saturday, including the Transfer of the Presidency to Ferran Pellisé, MD, PhD.

Serving as President of the Scoliosis Research Society over the past year has been an incredible honor. This Board of Directors is a dedicated body that wants to see the Society grow substantially over the next decade. We also lead a strategic planning session that, once enacted, will move the SRS into a more prominent position as the leader in spinal research and education. It is a great time to be an SRS member and I wish you a wonderful and productive meeting!

Suken A. Shah, MD, SRS President

ANNUAL MEETING COMMITTEES

SRS PRESIDENT

Suken A. Shah, MD

SRS EDUCATION COUNCIL CHAIR

Ronald A. Lehman Jr., MD

ANNUAL MEETING SCIENTIFIC PROGRAM COMMITTEE

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W.G. Stuart Mackenzie, MD, Co-Chair
Jennifer Bauer, MD, MS
Alan H. Daniels, MD
Meric Enercan, MD
Michael J. Faloon, MD, MS
Arvindera Ghag, MD, FRCSC
Jeff Gum, MD
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Brian Neuman, MD
Kedar Padhye, MD
Martin Repko, MD, MS
Reuben CC Soh, MBBS, MMedOrth, FRCS
Alekos Theologis, MD

ANNUAL MEETING EDUCATION COMMITTEE

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Eric Klineberg, MD, Co-Chair
Andre Andujar, MD
Ali Baaj, MD
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Saumyajit Basu, MD
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Dustin A. Greenhill, MD
Munahimbala Hamweemba, MD
Arun R. Hariharan, MD, MS
Morgan Jones, MBChB, BSc Hons, MSc
Eren O. Kuris, MD
A. Noelle Larson, MD
Michal Latalski, MD, PhD, DSc
Joseph M. Lombardi, MD
Anthony L. Mikula, MD
Venu Nemani, MD, PhD
William Phillips, MD
Cristina Sacramento Dominguez, MD, PhD
Rajendra Sakhrekar, MD
Alpaslan Senkoylu, MD
Sara S. van Nortwick, MD
John S. Vorhies, MD
Michelle Welborn, MD

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Jay Turner, MD, PhD
Hanneke M. van West, MD
Karen Weissman, MD, PhD

MEETING INFORMATION

MEETING DESCRIPTION

The Scoliosis Research Society (SRS) Annual Meeting is a forum for the realization of the Society's mission and goals: the improvement of patient care for those with spinal deformities. Five faculty-led instructional course lectures, 188 abstract papers, and 80 E-Point Presentations will be presented on an array of topics, including adolescent idiopathic scoliosis, neuromuscular scoliosis, growing spine, kyphosis, adult deformity, minimally invasive surgery, and machine learning.

LEARNING OBJECTIVES

Upon completion of the Annual Meeting, participants should be able to:

1. Discuss clinical decision making regarding transition of care from adolescence to early adulthood with a focus on indications for surgical intervention and coordination of across specialties to allow continuity of care.
2. Outline the key components to sagittal plane analysis and surgical planning with a particular focus on surgical goals in both pediatric and adult patients.
3. Recognize and identify a variety of strategies for the care and management of complex spinal deformity across a spectrum of geographical regions.
4. Improve knowledge of the region specific treatment options for patients with spinal deformity at the OC, CT, TL, and LS junctions.
5. Recognize the career transitions that physicians undergo as they progress from early career neophyte to seasoned veteran. Increase awareness of career challenges including imposter syndrome, midcareer plateau, second victim syndrome, and the decision to exit one's surgical career.

TARGET AUDIENCE

Spine surgeons (orthopaedic and neurological surgeons), residents, fellows, nurses, nurse practitioners, physician assistants, engineers, and company personnel.

ABSTRACT VOLUME

All abstracts accepted for presentation at the 61st Annual Meeting are published in the Final Program.

ATTIRE

Business (suits) or business casual attire (polo or dress shirt, sport coat) are appropriate for all Annual Meeting sessions; ties are not required.

CELL PHONE PROTOCOL

Please ensure that cell phone ringers, pagers and electronic devices are silenced or turned off during all sessions.

CME INFORMATION

ACCME Accreditation Statement

The Scoliosis Research Society (SRS) is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians.

Credit Designation

The Scoliosis Research Society (SRS) designates this live activity for a *maximum of 28.25 AMA PRA Category 1 Credit(s)*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Maintenance of Certification (MOC) Credit

Successful completion of this CME activity, which includes participation in the evaluation component, enables the learner to earn credit toward the CME of the American Board of Orthopaedic Surgery's Maintenance of Certification program. It is the CME activity provider's responsibility to submit learner completion information to ACCME for the purpose of granting ABOS credit.

DISCLOSURE OF FINANCIAL RELATIONSHIPS

It is the policy of SRS to ensure balance, independence, objectivity, and scientific rigor in all educational activities. In accordance with this policy, SRS identifies all financial relationships held with an ineligible company* by individuals in a position to influence or control the content of a CME activity. Relevant financial relationships are mitigated by SRS to ensure that all scientific research referred to, reported, or used in a CME activity conforms to the generally accepted standards of experimental design, data collection, and analysis. Complete disclosures can be found in the final program.

**An ineligible company is one whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.*

EMERGENCY & FIRST AID

The International Convention Centre (ICC) Sydney is fully prepared to handle emergency requests and first aid. Contact an SRS Staff person for support. Remember to note all emergency exits within the venue.

E-POINT PRESENTATION KIOSKS

There are over 80 E-Point Presentations to view on the E-Point Presentation kiosk located in The Gallery, Level 2.

EVALUATIONS

Please take time to complete the Annual Meeting evaluation. The meeting evaluation is available online on the AM26 Meeting App. Your input and comments are essential in planning future Annual Meetings.

MEETING INFORMATION

FDA STATEMENT (UNITED STATES)

Some drugs and medical devices demonstrated during this course have limited FDA labeling and marketing clearance. It is the responsibility of the physician to be aware of drug or device FDA labeling and marketing status.

INSURANCE/LIABILITIES AND DISCLAIMER

SRS will not be held liable for personal injuries or for loss or damage to property incurred by participants or guests at the Annual Meeting including those participating in tours, social events or virtually. Participants and guests are encouraged to take out insurance to cover losses incurred in the event of cancellation, medical expenses, or damage to or loss of personal effects when traveling outside of their own countries.

SRS cannot be held liable for any hindrance or disruption of the Annual Meeting proceedings arising from natural, political, social, or economic events, or other unforeseen incidents beyond its control. Registration of a participant or guest implies acceptance of this condition.

The materials presented at this Continuing Medical Education activity are made available for educational purposes only. The material is not intended to represent the only, nor necessarily best, methods or procedures appropriate for the medical situations discussed, but rather is intended to present an approach, view, statement, or opinion of the faculty that may be helpful to others who face similar situations.

SRS disclaims all liability for injury or other damages resulting to any individual attending a scientific meeting and for all claims that may arise out of the use of techniques demonstrated therein by such individuals, whether these claims shall be asserted by a physician or any other person.

INTERNET ACCESS

Wireless Internet access is available throughout the meeting space of the ICC.
To log on select...
Network = SRS Annual Meeting
Password = 61SRS2026

LANGUAGE

Presentations and course materials will be provided in English.

LOST & FOUND

Please feel free to stop by the SRS Registration Desk if you have lost or found an item during the Annual Meeting.

MEETING APP

Scan the QR code on the back of your badge to open the event platform. Enter your email and you'll receive a one-time code to sign in.

Once in the app, view the full agenda, speakers, supporters, and networking opportunities with other delegates.

Save it to your home screen from your browser's menu for quick access to live updates throughout the event.

NAME BADGES

Official name badges are required for admission to all Annual Meeting sessions, breaks and lunches. Meeting delegates will receive a name badge with their registration materials. Name badges are required to be worn while inside the meeting venue, as badges will be used to control access to sessions and activities. Delegates are cautioned against wearing their name badges while away from the venue, as badges draw unwanted attention to your status as visitors to the city.

NO SMOKING POLICY

Smoking is not permitted during any Annual Meeting activity or event.

PHOTOGRAPHY POLICY

SRS will be taking photographs throughout the Annual Meeting. SRS will use these photos in publications and to produce related literature and products for public release. Individuals photographed will not receive compensation for the use and release of these photos and will be deemed to have consented to the use and release of photos in which they appear. If you are opposed to being photographed, please immediately notify the photographer or an SRS staff member if your picture is taken. Thank you for your cooperation.

REGISTRATION DESK

Location: Registration Desk 3 | Ground Level

Tuesday, October 6	08:00 – 17:00
Wednesday, October 7	06:30 – 19:00
Thursday, October 8	06:30 – 16:00
Friday, October 9	07:00 – 17:30
Saturday, October 10	07:30 – 11:30

SESSION RECORDING ACCESS

All registered meeting delegates will receive a private link to the recordings of all sessions within 4-6 weeks after the meeting.

SIMULTANEOUS TRANSLATION

To connect to real-time translation during the sessions, join through Wordly on the Meeting App or scan the QR code on the sign outside the meeting room.

Darling Harbour Theatre

Parkside Ballroom

Pyrmont Theatre

MEETING INFORMATION

SPEAKER READY ROOM

Presenters may upload their PowerPoint presentations in the Speaker Ready Room. Please upload presentations no later than 24 hours before the session is scheduled to begin.

Location: Speaker Prep Centre | Ground Level

Tuesday, October 6	11:30 – 17:00
Wednesday, October 7	07:00 – 18:30
Thursday, October 8	07:00 – 16:00
Friday, October 9	07:00 – 18:00
Saturday, October 10	07:30 – 11:30

SPECIAL NEEDS

If you have any health issues for which you may require special accommodation or assistance, please notify an SRS staff member. SRS will make every effort to accommodate any special needs.

SRS HISTORICAL DISPLAY

Location: The Gallery | Level 2

Discover the unique spine history of Australia at the SRS Historical Display. The SRS Historical Committee, in conjunction with Drs. Angus Gray, Michael B. Johnson, John Tuffley, Peter Cundy, and SRS Archivist Katie Dold, MLS, present a display exploring the notable contributions to spine and spine deformity surgery from those across Australia's states.

Selections from interviews of important contributors to the study of spinal deformity will be featured on a video monitor alongside the Historical Display.

SRS MEMBERSHIP TABLE

Location: The Gallery | Level 2

Stop by the SRS Membership Table for more information about becoming an SRS member, application status, upcoming meetings, and more.

VIDEO RECORDING PROHIBITED

SRS does not allow personal video recording of presentations of any kind. SRS holds the right to confiscate any and all recordings taken of any of the presentations. All session rooms will be recorded and will be available to delegates after the meeting on the SRS website.

WHO CAN ATTEND

Annual Meeting invites those who include spinal surgery techniques or technology in their profession, including spine surgeons (both orthopedic and neurological surgeons), residents, fellows, nurses, nurse practitioners, physician assistants, engineers, and company personnel.

Scientific Sessions for Registered Attendees Only

As an international medical professional organization, SRS is required to adhere to the guidelines set forth by MedTech Europe in its Code of Ethical Business Practice. This ensures compliance with the regulations of non U.S. institutions and maintains alignment with SRS's industry partners. Within this code it states that "It is not appropriate for a Guest of a Healthcare Professional to attend either Company Events (including satellite symposia) or Third Party Organised Educational Events (unless the individual qualifies as participant in their own right), nor is it appropriate, in the interest of maintaining scientific exchange, for a Guest to participate in related hospitality during such Events (for example, lunches, industry booths and coffee breaks) even when the Healthcare professional pays for the Guest's expense.

Under the MedTech Europe Code of Ethical Business Practice a guest is defined as "spouses, partners, family or guests of the Healthcare Professionals, or other person *who does not have a bona fide professional interest in the information being shared at an Event*."

Join the conversation surrounding the SRS Annual Meeting by including **#SRSAM26** in your social media posts.

@ScoliosisResearchSociety
@srs_org
@srs_org
@Scoliosis Research Society
@srs_org
@srs_org

SESSION AND EVENT INFORMATION

HIBBS SOCIETY MEETING – $50

Tuesday, October 6 | 13:00–17:00
Location: Parkside Ballroom | Level 2
Available to registered delegates for an additional fee of $50

Over the years, the Russell A. Hibbs Society, formed in 1947 as an international travel club for continuing medical education and furthering orthopaedic knowledge, has held an educational meeting at the SRS Annual Meeting. These meetings address difficult and complex issues that do not lend themselves to the usual kind of scientific presentations. The meeting encourages interaction among international participants and highlights new ideas, new concepts, and reports on personal experience. The Hibbs Society Meeting is planned by the SRS Traveling Fellows and will feature updates on deformity treatments.

OPENING CEREMONIES AND WELCOME RECEPTION

Wednesday, October 7
Opening Ceremonies | 17:20–19:00
Location: Darling Harbour Theatre | Level 2
Welcome Reception | 19:00–21:00
Location: The Gallery | Level 2
Available at no charge to meeting delegates, $50 per guest

The Annual Meeting will officially begin with the Opening Ceremonies and this year's Howard Steel Lecturer, David Hunt. The Opening Ceremonies are the kickoff to the Annual Meeting, giving the Society the opportunity to highlight award and research winners, thank our donors and corporate partners, and includes the presentation of the Walter P. Blount Humanitarian Award.

A hosted reception featuring hors d'oeuvres, cocktails, and reunions with colleagues and friends will immediately follow the Opening Ceremonies. If you would like to purchase guest ticket(s), you may do so at the SRS Registration Desk.

INDUSTRY WORKSHOPS

Thursday, October 8 | 07:00–08:00
Thursday, October 8 | 12:30–14:00
Location: Varied | Refer to the Meeting App or Final Program for schedule and program information.

Delegates are encouraged to attend the industry workshops. Each workshop is programmed by a single-supporting company and features presentations on topics and technologies selected by the company. Breakfast and Lunch will be available during the applicable workshop times. CME credits are not available for workshops.

Industry workshops will be hosted by: Arthrex, ATEC Spine, Australian Pacific Medical Pty Ltd, Carlsmed, DePuy Synthes, Globus Medical, Highridge Medical, Medtronic, Orthofix, SI-BONE and VB Spine.

MEMBER BUSINESS MEETING

Friday, October 9 | 12:15–13:30
Location: Parkside Ballroom | Level 2

All SRS members are invited to the Member Business Meeting. The agenda will include reports from the various SRS committees, updates on SRS activities and programs, and voting. Attendance at the Members Business Meeting is an opportunity to not only hear updates but actively participate in shaping the future of our Society. We encourage ALL MEMBERS to attend. A hot lunch will be provided.

MEMBERSHIP INFORMATION SESSION

Friday, October 9 | 12:15–13:30
Location: Meeting Room C2.2-3 | Level 2

One World, One Spine, One SRS: A Lunchtime Educational and Networking Meeting for Non-Members.

FAREWELL RECEPTION – $50

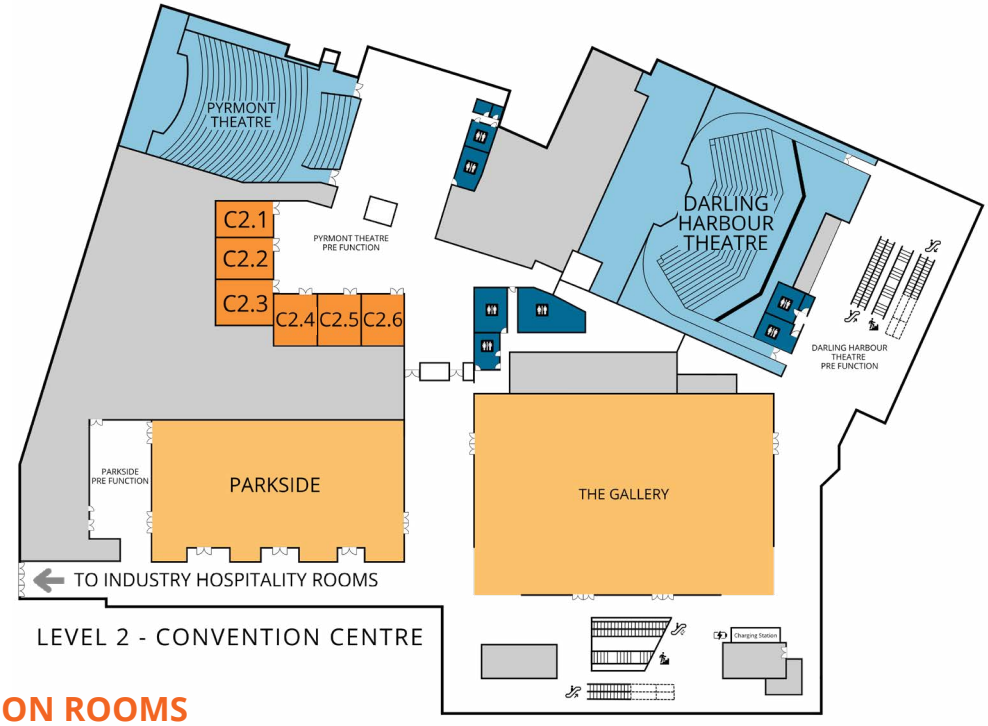
Friday, October 9 | 19:30–22:00
Location: Australian Museum
Available to registered delegates for an additional fee of $50, $150 per guest

Registration is required and tickets must be purchased in advance. A limited number of tickets may be available onsite, please stop at the registration desk for information and ticket availability. Tickets are $50 for registered attendees and $150 per guest.

Attire is cocktail or business.

MEETING SPACE FLOORPLANS

INTERNATIONAL CONVENTION CENTRE (ICC) SYDNEY



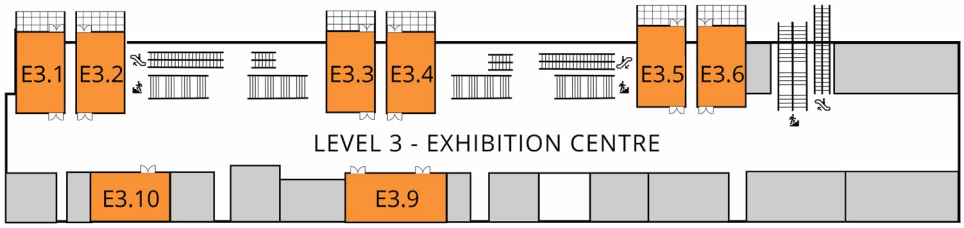
SESSION ROOMS

ROOM	FUNCTION
Darling Harbour Theatre	General Session, Concurrent Sessions
Pyrmont Theatre	Concurrent Sessions
Parkside Ballroom	Concurrent Sessions

INDUSTRY WORKSHOPS

07:00 – 08:00	
ROOM	**COMPANY**
Meeting Room C2.1	VB Spine
Meeting Room C2.2	SI-BONE
Meeting Room C2.3	Highridge Medical
Meeting Room C2.4	Arthrex
Meeting Room C2.5	Australian Pacific Medical

12:30 – 14:00	
ROOM	**COMPANY**
Meeting Room C2.1	DePuy Synthes
Meeting Room C2.2	Orthofix
Meeting Room C2.3	Medtronic
Meeting Room C2.4	Globus Medical
Meeting Room C2.5	Carlsmed
Meeting Room C2.6	ATEC Spine



INDUSTRY HOSPITALITY ROOMS

ROOM	COMPANY
Meeting Room E3.1	Orthofix
Meeting Room E3.2	DePuy Synthes
Meeting Room E3.3	ATEC Spine
Meeting Room E3.4	Globus Medical

ROOM	COMPANY
Meeting Room E3.5	Medtronic
Meeting Room E3.6	Highridge Medical
Meeting Room E3.10	VB Spine

MEETING OUTLINE

Tuesday, October 6, 2026		
07:00 – 08:00	Committee Chair Breakfast* (by invitation only)	Room C2.3
08:00 – 16:30	Committee and Council Meetings*	Varied: C2-Rooms
08:00 – 17:00	Registration Open	Ground Level
11:30 – 17:00	Speaker Ready Room Open	Speaker Prep Centre
13:00 – 17:00	**Hibbs Society Meeting** ● ■ ○	Parkside Ballroom
18:00 – 21:30	SRS Leadership Dinner* (by invitation only)	Offsite
Wednesday, October 7, 2026		
06:30 – 19:00	Registration Open	Ground Level
07:00 – 18:30	Speaker Ready Room Open	Speaker Prep Centre
07:00 – 08:00	Women In Spine Breakfast*	Parkside Ballroom
08:00 – 09:50	**Pre-Meeting Course** ●	Darling Harbour Theatre
09:50 – 10:15	Refreshment Break	The Gallery
10:15 – 12:00	**Pre-Meeting Course** ●	Parkside Ballroom
12:00 – 12:15	Lunch Pick-Up	The Gallery
12:15 – 13:15	**LTS 1** | The Patient Transition from Pediatric to Adulthood: A Case-Based Panel Discussion ■ ○ **LTS 2** | Sagittal Plane: Development and Planning Across the Ages ■ ○ **LTS 3** | Treating Complex Curves Around the Globe ■ ○	Darling Harbour Theatre Parkside Ballroom Pyrmont Theatre
13:15 – 13:30	Break	
13:30 – 15:00	**Abstract Session 1** | Adult Spinal Deformity I: Optimizing Alignment, Why It Matters ○	Darling Harbour Theatre
15:00 – 15:20	Refreshment Break	The Gallery
15:20 – 17:05	**Abstract Session 2** | Adolescent Idiopathic Scoliosis I ■	Darling Harbour Theatre
17:05 – 17:20	Break	
17:20 – 19:00	Opening Ceremonies*	Darling Harbour Theatre
19:00 – 21:00	Welcome Reception*	The Gallery
Thursday, October 8, 2026		
06:30 – 16:00	Registration Open	Ground Level
07:00 – 16:00	Speaker Ready Room Open	Speaker Prep Centre
07:00 – 08:00	L.E.A.D. Breakfast* (by invitation only)	Parkside Ballroom
07:00 – 08:00	Industry Workshops* (5 Concurrent Sessions)	Varied: see Meeting App
08:00 – 09:50	**Abstract Session 3A** | Adult Spinal Deformity II ○ **Abstract Session 3B** | Progress Report: Discussing Outcomes in Adolescent Idiopathic Scoliosis ■	Darling Harbour Theatre Pyrmont Theatre
09:50 – 10:10	Refreshment Break	The Gallery
10:10 – 12:15	**Abstract Session 4** | Translational/Basic Science **Harrington Lecture** | The View from the Second Mountain: Transitions in Deformity, Career, and Life **Lifetime Achievement Award**	Darling Harbour Theatre
12:15 – 12:30	Lunch Pick-Up	The Gallery
12:30 – 14:00	Industry Workshops* (6 Concurrent Sessions)	Varied: see Meeting App

● **Early Career** ■ **Pediatric/Adolescent** ○ **Adult Spinal Deformity** ▲ **Neurosurgery** **denotes Non-CME Session/Activity*

MEETING OUTLINE

Thursday, October 8, 2026 (continued)		
14:00 – 14:10	Refreshment Break	The Gallery
14:10 – 15:55	L.E.A.D. SRS Cohort Session* (by invitation only)	Parkside Ballroom
14:10 – 15:55	**Half-Day Course 1** | Anatomical Transition Zones ■ ○ ▲ **Abstract Session 5** | Anything but Fusion: Non-Op and VBT in AIS ■	Darling Harbour Theatre Pyrmont Theatre
16:00 – 17:30	SRS Traveling Fellows Alumni Reception* (by invitation only)	Room C2.6
Friday, October 9, 2026		
06:30 – 07:30	Past Presidents' Breakfast* (by invitation only)	Room C2.3
07:00 – 17:30	Registration Open	Ground Level
07:00 – 18:00	Speaker Ready Room Open	Speaker Prep Centre
08:00 – 09:50	**Abstract Session 6** | Hibbs Award-Nominated Papers	Darling Harbour Theatre
09:50 – 10:10	Refreshment Break	The Gallery
10:10 – 11:50	**Abstract Session 7** | Syndromic/ Neuromuscular & Presidential Address ■ ▲	Darling Harbour Theatre
12:15 – 13:30	**Member Business Meeting*** (lunch pick-up at 11:50 in The Gallery)	Parkside Ballroom
12:15 – 13:30	**Membership Information Session:** One World, One Spine, One SRS: A Lunchtime Educational and Networking Meeting for Non-Members* (lunch pick-up at 11:50 in C2.2-3 Foyer)	Room C2.2-3
13:30 – 13:45	Break	
13:45 – 15:30	**Half-Day Course 2** | Debate-Style Discussion: Different Approaches to Different Problems ■ ○ **Abstract Session 8** | Adult Spinal Deformity III: Optimizing Patient Condition: The Game Changer ○	Darling Harbour Theatre Pyrmont Theatre
15:30 – 15:50	Refreshment Break	The Gallery
15:50 – 18:00	**Abstract Session 9A** | Quality/Safety/Value/Complication **Abstract Session 9B** | Early Onset Scoliosis & Kyphosis ■	Darling Harbour Theatre Pyrmont Theatre
18:30 – 19:30	President's Reception* (by invitation only)	Offsite
19:30 – 22:00	Farewell Reception* (ticket required)	Offsite
Saturday, October 10, 2026		
07:00 – 08:00	SRS Board of Directors Meeting*	Room C2.3
07:30 – 11:30	Registration Open	Ground Level
07:30 – 11:30	Speaker Ready Room Open	Speaker Prep Centre
08:00 – 10:10	**Abstract Session 10** | Adolescent Idiopathic Scoliosis III, Award Presentation & Transfer of the Presidency ■	Darling Harbour Theatre
10:10 – 10:30	Refreshment Break	Darling Harbour Theatre Foyer
10:30 – 12:15	**Abstract Session 11** | Miscellaneous & Cervical ▲	Darling Harbour Theatre
12:15	SRS 61st Annual Meeting Concludes	

● **Early Career** ■ **Pediatric/Adolescent** ○ **Adult Spinal Deformity** ▲ **Neurosurgery** **denotes Non-CME Session/Activity*

WIRELESS INTERNET

Network: SRS Annual Meeting | **Password:** 61SRS2026

GUEST LECTURES

HOWARD STEEL LECTURE | RUM, BOTANY AND THE LASH

Wednesday, October 7

David Hunt

David Hunt is an unusually tall and handsome man who enjoys writing his own biographical notes. David has changed the way Australian history is communicated with his award-winning and bestselling *Girt* series and his speech at TEDx Sydney 2017. He was a writer and presenter on the History Channel's *Aussie Inventions That Changed The World* and wrote and co-presented Rum, Rebels and Ratbags, which made it to #1 on the Australian podcast charts. He also wrote and presented an animated video series on Australian history for the National Museum of Australia, has regularly featured on television and radio and in print, and has dashed off a couple of children's picture books. David has a birthmark that looks like Tasmania, only smaller and not as far south.

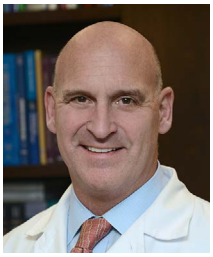
Rum, Botany and The Lash

Welcome to Sydney, a city that traces its name back to Dionysius, the Greek god of wine and drunken excess; a city promoted by British playboy botanist Joseph Banks to house Britain's unwanted pickpockets, sheep thieves and Irishmen; a city that built the Rum Hospital, less charitably known as the Sydney Slaughterhouse, where windows were locked to prevent the patients from escaping, food was cooked in crowded wards because the hospital's kitchen was being used as a morgue, and nurses would throw warm meat at their charges.

Let David Hunt transport you (without the leg chains and floggings and for less than seven years) to the convict colony that, within the span of a single human life, would become the wealthiest society in the world.

HARRINGTON LECTURE | THE VIEW FROM THE SECOND MOUNTAIN: TRANSITIONS IN DEFORMITY, CAREER, AND LIFE

Thursday, October 8



Todd J. Albert, MD

Dr. Todd J. Albert is the Richard Rogers Chair and Surgeon-in-Chief Emeritus at Hospital for Special Surgery in New York City. He is also Professor of Orthopaedics at Weill Cornell Medical College.

Prior to HSS, he served as Chair of Orthopaedics and President of the Rothman Institute at Thomas Jefferson University in Philadelphia from 2006-2014.

He graduated magna cum laude from Amherst College, received his doctor of medicine degree from the University of Virginia School of Medicine, completed a residency in orthopaedic surgery at Thomas Jefferson University Hospital where he was named outstanding chief resident, and performed a fellowship in spinal surgery at the Minnesota Spine Center.

Dr. Albert serves on the boards of several scholarly journals, including: *Spine, The Journal of Spinal Disorders and Techniques*, and is a member of medical associations including the American Academy of Orthopaedic Surgery, Cervical Spine Research Society, the Scoliosis Research Society, International Society for Study of the Lumbar Spine, North American Spine Society, Association of Bone and Joint Surgeons and many others.

He is Past President of The Cervical Spine Research Society and the Scoliosis Research Society and the Association of Bone and Joint Surgeons.

Dr. Albert has published over 450 scientific articles, authored over 100 book chapters, presented his research both nationally and internationally, and served as chairman at numerous courses. He has published several textbooks on spinal surgery, including: *Tricks of The Trade: Spine Surgery, Surgical Approaches to the Spine, Mastercases: Spine Surgery, Physical Examination of the Spine, Spinal Deformities, The Essentials, Cervical Spine Challenges and the multivolume Operative Techniques in Orthopaedic Surgery.*

Over the last five years he has worked in private equity and created TJA Partners, a firm focusing on leadership coaching and consultation. He is a Co-founder and CMO of See All AI and CMO of Legent Health. He continues to actively do what he loves most: practicing spinal surgery and focusing on improving treatments for cervical spine patients.

He lives in New York City with his wife Barbara. They have 3 Adult Children, one of whom is married, a beautiful granddaughter and a new daughter-in-law.

2026 SRS AWARDS

2026 WALTER P. BLOUNT HUMANITARIAN AWARD

Presented for outstanding service to those with spinal deformity and for generosity to the profession and Society. The 2026 Blount award will be presented on Wednesday, October 7.

Saumyajit Basu, MD

Dr. Saumyajit Basu was born in 1968 in a traditional family of doctors, completed his medical school in 1992 from Calcutta Medical College with the University Gold Medal in Medicine and subsequently finished his postgraduate degree and training in Orthopedics, securing the securing 1st position in MS (Ortho) at the University of Calcutta in 1997, and was awarded the President's Gold Medal.

Moving on to the UK, he became a fellow of the Royal College of Surgeons of Edinburgh, FRCSEd in 1998. He then came back to India and was awarded the Diplomate, National Board of Orthopedics, DNB, in 1999. He went back to the UK, completing his Spinal Fellowship at the Center for Spinal Studies, Queens Medical Center, Nottingham.

Presently working as the Departmental Head and Lead Spine Surgeon at Kothari Medical Center, Kolkata, INDIA; this is the one of the busiest spine centers in India with about 2,000 surgeries annually and 10,000 patients seen at clinics. Though his main areas of interest are Spinal Deformities and Cervical Spine, he has performed over 15,000 spinal surgeries in his 24 years of practice, all of which are recorded in Electronic Medical Records.

Dr. Basu functions as the Program Director of various clinical and research fellowships in spine - Fellowship of National Board (FNB), Association of Spine Surgeons of India (ASSI), along with visiting fellowships of AO Spine, APSS and SSWB Visiting Fellowship.

He has been in leadership roles in multiple national and international societies including the Chair of Regional Course Committee, Scoliosis Research Society (SRS) – 2022-25, President, Association of Spine Surgeons of India (ASSI) – 2023-25, President, Spine Society of West Bengal (SSWB) – 2021-23, Board Member of Asia Pacific Spine Society (APSS) – 2024-26 and is currently a Steering Committee Member, AO Spine Knowledge Forum (Deformity)

He has received multiple research awards and grants, in the last few years on a wide range of topics like Functional MRI in back pain, Microbiome in Cervical Disc, Genetics of AIS and is currently involved in setting up a multicentric database on non-operative treatment of ASD.

He has to his credit, about 300 podium presentations in regional/national/international meetings with nearly 100 indexed journal publications and book chapters.

Dr. Basu is the founder of a not-for-profit organization, "Spine Research Foundation" and is the Managing Trustee with huge social commitments of funding patients of complex spinal deformities who desperately need but cannot afford surgical treatment. To date he has performed nearly 500 free surgeries for these patients in the last 16 years and is committed to double the number of these patients in the next few years.

2026 SRS AWARDS

2026 LIFETIME ACHIEVEMENT AWARD

Presented to a member who has exhibited long and distinguished service to SRS and to spinal deformity research and care. The 2026 Lifetime Achievement awards will be presented on Thursday, October 8.

David W. Polly, Jr., MD

Dr. David W Polly Jr is Professor Emeritus of Orthopaedic Surgery at the University of Minnesota. He graduated from the United States Military Academy at West Point. He is Army Airborne Ranger and Pathfinder qualified and served two years in the Army Corps of Engineers. His military career continued in medical school at the Uniformed Services University of the Health Sciences in Bethesda, Maryland; followed by training at Walter Reed Army Medical Center as an intern; at the Walter Reed Army Institute of Research as a surgical researcher and a resident in Orthopaedic surgery. Dr. Polly did his Spine Fellowship at the University of Minnesota and returned to Walter Reed as Chief of Spine Surgery, where he helped establish the first combined orthopaedic and neurosurgery spine service. He then went on to serve as Chair of the Department of Orthopaedic Surgery and Rehabilitation at Walter Reed until the fall of 2003 when he retired from the Army. At that time, he returned to the University of Minnesota as the Chief of Spine Surgery and served in that role until his retirement in 2025. During much of that time, he also practiced at Twin Cities Shriners. His clinical career was marked by his passion for caring for patients. While retiring from clinical practice in April 2025, he continues to engage in spinal research and surgical education, continuing to move the field forward and train the next generation.

An accomplished researcher with over 350 publications and >24,500 citations, the common thread is to do impactful research by answering the questions: what are we doing, what are the results, and can we do better?

Dr. Polly's SRS involvement began as a Fellow in 1991, only missing one meeting due to a military deployment. In addition to many research presentations, Dr. Polly has contributed a life of service to the SRS, serving on committees, the board of directors, as secretary, and then SRS President in 2015-16. Continuing to exude his focus on training the next generation, he served as the SRS Senior Traveling Fellow in 2024, guiding the group on a journey of discovery about the world and field of spine deformity, all while building deep life-long connections.

While the SRS has always been his societal home, Dr. Polly has contributed his time to many organizations dedicated to advancing spine surgery including AAOS, Spine Summit, ASR, NASS, SMISS, ISASS. A founding member of the Spinal Deformity Study Group, he initiated and contributed to the radiographic measurement manual, which is still referenced today. He was co-chair of the Degenerative Spine Study Group and participated in the Spine Oncology Study Group; and he is an emeritus member of the AO Knowledge Forum Deformity steering committee.

Dr. Polly has continued to be a leading thinker, innovator, and teacher, in new techniques to advance patient care, from thoracic pedicle screw fixation to interbody fixation and fusion, as well as working with others on minimizing the density of spinal implants without compromising the outcome, through the Minimize Implants Maximize Outcomes RCT for pedicle screw density in AIS, funded by OREF and SRS. He helped lead the international SILVIA RCT looking at pelvic fixation strategies in adult spinal deformity.

Dedicated to the principle that the greatest compliment to the teacher is to have the student exceed the teacher, he has taught and mentored surgeons in training and colleagues in the United States and around the world.

To know Dr. Polly is to know of his fondness for "bad dad jokes." His favorite bad dad joke is- why didn't the skeleton climb the mountain? Didn't have the guts!

ANNUAL MEETING AWARDS

The 2026 Annual Meeting awards for the best basic/translational science and clinical research papers (Russell A. Hibbs Awards) and the best basic/translational science and clinical research E-Point Presentation (John H. Moe and Louis A. Goldstein Awards) will be presented on Saturday, October 10.

60TH ANNUAL MEETING RUSSELL A. HIBBS AWARDS

Presented to the best basic science and clinical research papers at the 60th Annual Meeting.

2025 Hibbs Award for Best Basic Science/Translational Research Paper

Spinal Growth Regulation by Interfering Chondrocytes Function in Growth Plate is a Potential Treating Method for Scoliosis: Preliminary Study in Piglets

Zhaoquan Zhang, MD; Zhibo Song, MD; Yingsong Wang, MD; Zhi Zhao, MD; Ni Bi, MD; Jingming Xie, MD; Tao Li, MD; Li Zhang, MD; Ying Zhang, MD; Zhiyue Shi, MD

2025 Hibbs Awards for Best Clinical Research Paper

Wait to Operate: Surgery Demonstrated No Pulmonary Benefit Compared to Non-Operative Treatment in EOS Patients.

Amy L. McIntosh, MD; Charles E. Johnston, MD; Tiffany Thompson, BS; JP Rathbun, BS; Chan-Hee Jo, PhD; Karina A. Zapata, PhD, PT, DPT

60TH ANNUAL MEETING JOHN H. MOE AND LOUIS A. GOLDSTEIN AWARDS

Presented to the best basic science and clinical research E-Point Presentation at the 60th Annual Meeting.

2025 John H. Moe Award for Best Basic Science/Translational Research E-Point Presentation

Collagen X Biomarker (Cxm) is Predictive of Growth Cessation in Idiopathic Scoliosis

Michelle C. Welborn, MD; Asal Roudbari, BS; Reza Zandehshahvar, PhD; Pascal Van Hentenryck, PhD; Amer F. Samdani, MD; Robert H. Cho, MD; Joseph D. Stone, MD; Selina C. Poon, MD; Vishwas R. Talwalkar, MD; Michal Szczodry, MD; Purnendu Gupta, MD; James O. Sanders, MD; Susan Sienko, PhD

2025 Louis A. Goldstein Award for Best Clinical Research E-Point Presentation

Growth Modulation Does Not Improve 3D Axial Rotation After VBT: A 3D Multi-Center Analysis

Melanie E. Boeyer, PhD; Samuel Hawkins, BS; Vladislav Husyev, BS; Stefan Parent, MD, PhD; Peter O. Newton, MD; Burt Yaszay, MD; Harms Study Group; Dan Hoernschemeyer, MD

MEETING AGENDA

The Scoliosis Research Society gratefully acknowledges Globus Medical, Medtronic, Orthofix and VB Spine for their grant support of the Women in Spine Breakfast.

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MEETING AGENDA

TUESDAY, OCTOBER 6, 2026

Program (topics, timing, and faculty) is subject to change.

13:00 - 17:00 Parkside Ballroom

Hibbs Society Meeting

Co-Chairs: Sebastien Pesenti, MD, PhD; Reuben CC Soh, MBBS, FRCS; Nan Wu, MD

13:00 - 14:15 | Hibbs Society 1 - From Knife to Judgment: The Surgeon's Journey in Deformity Care ●

Case 1: Infection
Moderator: Lawrence G. Lenke, MD

13:00 - 13:01 **Case Presentation**
Lawrence G. Lenke, MD

13:01 - 13:05 **Case 1: Infection - Junior Presentation**
Javier Pizones, MD, PhD

13:05 - 13:09 **Case 1: Infection - Senior Presentation**
Ajoy Prasad Shetty Tonse, MS Orth

13:09 - 13:18 **Discussion**

Case 2: Congenital
Moderator: Reuben CC Soh, MBBS, FRCS

13:18 - 13:19 **Case Presentation**
Reuben CC Soh, MBBS, FRCS

13:19 - 13:23 **Case 2: Congenital - Junior Presentation**
Brice Ilharreborde, MD, PhD

13:23 - 13:27 **Case 2: Congenital - Senior Presentation**
Daniel J. Sucato, MD

13:27 - 13:36 **Discussion**

Case 3: Osteoporosis
Moderator: Reuben CC Soh, MBBS, FRCS

13:36 – 13:37 **Case Presentation**
Reuben CC Soh, MBBS, FRCS

13:37 - 13:41 **Case 3: Osteoporosis - Junior Presentation**
Dong-Gune Chang, MD, PhD

13:41 - 13:45 **Case 3: Osteoporosis - Senior Presentation**
Ahmet Alanay, MD

13:45 - 13:54 **Discussion**

Case 4: OI
Moderator: Lawrence G. Lenke, MD

13:54 - 13:55 **Case Presentation**
Lawrence G. Lenke, MD

13:55 - 13:59 **Case 4: OI - Junior Presentation**
Michelle C. Welborn, MD

13:59 - 14:03 **Case 4: OI - Senior Presentation**
Suken A. Shah, MD

14:03 - 14:12 **Discussion**

14:12 - 14:15 **Wrap-Up**

● Early Career ■ Pediatric/Adolescent ○ Adult Spinal Deformity ▲ Neurosurgery **denotes Non-CME Session/Activity*

14:15 - 15:25 | Hibbs Society 2 - My Most Challenging Cases of Pediatric Spine Deformity ● ■

Case 1: VBT
Moderator: Jianguo Terry Zhang, MD

14:15 - 14:16 **Case Presentation**
Jianguo Terry Zhang, MD

14:16 - 14:20 **Case 1: VBT - Junior Presentation**
Jason Pui Yin Cheung, MBBS, MMedSc, MS, MD

14:20 - 14:24 **Case 1: VBT - Senior Presentation**
Amer F. Samdani, MD

14:24 - 14:32 **Discussion**

Case 2: Neuromuscular
Moderator: Jianguo Terry. Zhang, MD

14:32 - 14:33 **Case Presentation**
Jianguo Terry Zhang, MD

14:33 - 14:37 **Case 2: Neuromuscular - Junior Presentation**
Joshua M. Pahys, MD

14:37 - 14:41 **Case 2: Neuromuscular - Senior Presentation**
Stefan Parent, MD, PhD

14:41 - 14:49 **Discussion**

Case 3: Syndrome Scoliosis
Moderator: Sebastien Pesenti, MD, PhD

14:49 - 14:50 **Case Presentation**
Sebastien Pesenti, MD, PhD

14:50 - 14:54 **Case 3: Syndrome Scoliosis - Junior Presentation**
Caglar Yilgor, MD

14:54 - 14:58 **Case 3: Syndrome Scoliosis - Senior Presentation**
Christina Hardesty, MD

14:58 - 15:06 **Discussion**

Case 4: Early Onset Scoliosis
Moderator: Sebastien Pesenti, MD, PhD

15:06 - 15:07 **Case Presentation**
Sebastien Pesenti, MD, PhD

15:07 - 15:11 **Case 4: Early Onset Scoliosis - Junior Presentation**
Steven W. Hwang, MD

15:11 - 15:15 **Case 4: Early Onset Scoliosis - Senior Presentation**
Jean Albert Ouellet, MD, FRCS(C)

15:15 - 15:23 **Discussion**

15:23 - 15:25 **Wrap-Up**

15:25 - 15:45 Refreshment Break | The Gallery

15:45 - 17:00 | Hibbs Society 3 - My Most Challenging Cases of Adult Spine Deformity ●○

Case 1: Cervical
Moderator: Nan Wu, MD

15:45 - 15:46 **Case Presentation**
Nan Wu, MD

15:46 - 15:50 **Case 1: Cervical - Junior Presentation**
Lee A. Tan, MD

15:50 - 15:54 **Case 1: Cervical - Senior Presentation**
Khaled M. Kebaish, MD

15:54 - 16:03 **Discussion**

● Early Career ■ Pediatric/Adolescent ○ Adult Spinal Deformity ▲ Neurosurgery **denotes Non-CME Session/Activity*

MEETING AGENDA

TUESDAY, OCTOBER 6, 2026

Program (topics, timing, and faculty) is subject to change.

Case 2: Severe Adult Scoliosis
Moderator: Nan Wu, MD

16:03 - 16:04 **Case Presentation**
Nan Wu, MD

16:04 - 16:08 **Case 2: Severe Adult Scoliosis - Junior Presentation**
Jeffrey Gum, MD

16:08 - 16:12 **Case 2: Severe Adult Scoliosis - Senior Presentation**
Munish C. Gupta, MD, MBA

16:12 - 16:21 **Discussion**

Case 3: Proximal Junctional Kyphosis
Moderator: Steven D. Glassman, MD

16:21 - 16:22 **Case Presentation**
Steven D. Glassman, MD

16:22 - 16:26 **Case 3: Proximal Junctional Kyphosis - Junior Presentation**
Peter G. Passias, MD

16:26 - 16:30 **Case 3: Proximal Junctional Kyphosis - Senior Presentation**
Praveen V. Mummaneni, MD

16:30 - 16:39 **Discussion**

Case 4: Biomarker
Moderator: Steven D. Glassman, MD

16:39 - 16:40 **Case Presentation**
Steven D. Glassman, MD

16:40 - 16:44 **Case 4: Biomarker - Junior Presentation**
Brett Rocos, MD, FRCS (Tr & Orth)

16:44 - 16:48 **Case 4: Biomarker - Senior Presentation**
Ferran Pellisé, MD, PhD

16:48 -16:57 **Discussion**

16:57 - 17:00 **Wrap-Up**

● Early Career ■ Pediatric/Adolescent ○ Adult Spinal Deformity ▲ Neurosurgery **denotes Non-CME Session/Activity*

07:00 - 08:00 Women in Spine Breakfast* | Parkside Ballroom

08:00 - 12:00 **Darling Harbour Theatre**

Pre-Meeting Course (PMC): From First Case to Last Case: A Career Lifecycle in Deformity Surgery ●

Moderators: Eric O. Klineberg, MD & Megan Johnson, MD

08:00 - 08:50 **PMC 1 - Early Career: Identity, Growth, and Reality: Years 0-5 in Practice**

08:00 - 08:08 **The Growth Mindset in Spine Surgery**
Megan Johnson, MD

08:08 - 08:16 **From Fellowship to Real Practice: The First Plateau**
Caglar Yilgor, MD

08:16 - 08:24 **Mistakes Along the Way (That No One Warned You About)**
Nicholas D. Fletcher, MD

08:24 - 08:34 **Discussion**

08:34 - 09:16 **PMC 2 - A Marathon and Not a Sprint: The Spine Surgeon's Toolkit for Longevity**

08:34 - 08:42 **The Spine Surgeon as an Athlete: How to Keep Yourself Healthy and in the Game for the Long Haul**
Suken A. Shah, MD

08:42 - 08:50 **Prehab and Post Game Recovery: How to Prepare for Big Days and Recover from Big Cases or Devastating Complications**
Todd J. Albert, MD

08:50 - 08:58 **Group Effort: How Building a Team Around You from Extenders to Co-Surgeons Can Help Extend Your Career**
Rajiv K. Sethi, MD, PhD

08:58 - 09:06 **Technical Assistance: How Enabling Technologies and Advanced Robotics Will Help Extend Our Careers and Not Replace Us**
Aaron Buckland, MBBS, FRACS

09:06 - 09:16 **Discussion**

09:16 - 09:50 **PMC 3 - Mid-Career: Plateaus, Deliberate Practice, and Burnout**

09:16 - 09:24 **The Intermediate Plateau: When You're "Good" but Not Getting Better**
Javier Pizones, MD, PhD

09:24 - 09:32 **Deliberate Practice for the Experienced Surgeon**
Christopher P. Ames, MD

09:32 - 09:40 **When Surgery Gets Hard**
Michael G. Vitale, MD, MPH

09:40 - 09:50 **Discussion**

09:50 - 10:15 Refreshment Break | The Gallery

10:15 - 11:15 **PMC 4 - Coaching, Leadership and Mentorship**

10:15 - 10:45 **Coaching Approaches for Leading Self and Others: Implications for Career Engagement and Continued Personal Growth**
Sean O'Connor, PhD, MappSC Coach Psych. BSc Psych.

10:45 - 11:15 **Panel Discussion**
Todd J. Albert, MD; Haemish A. Crawford, FRCS; Sean O'Connor, PhD, MappSC Coach Psych. BSc Psych.; Brian Hsu, MD; Serena S. Hu, MD

● Early Career ■ Pediatric/Adolescent ○ Adult Spinal Deformity ▲ Neurosurgery **denotes Non-CME Session/Activity*

MEETING AGENDA

WEDNESDAY, OCTOBER 7, 2026

Program (topics, timing, and faculty) is subject to change.

11:15 - 12:00 PMC 5 - Late Career: Judgment, Leadership, and Exit

11:15 - 11:23 **Judgment Over Technique**
Juan S. Uribe, MD

11:23 - 11:31 **Practice Management as a Late-Career Strategy**
Peter O. Newton, MD

11:31 - 11:39 **When Is It Time to Quit Operating?**
David W. Polly Jr, MD

11:39 - 11:47 **Assessment Skills and Creating a Meaningful Exit**
Kenneth MC. Cheung, MD, MBBS, FRCS

11:47 - 11:57 **Discussion**

11:57 - 12:00 **Closing Comments**

12:00 - 12:15 Lunch Pick-Up | The Gallery

12:15 - 13:15 Darling Harbour Theatre *(concurrent session)*

Lunchtime Symposia 1: The Patient Transition from Pediatric to Adulthood: A Case-Based Panel Discussion ■○

Moderators: Michael Selby, MD & Burt Yaszay, MD

Panel 1: Young Adult with Untreated AIS

12:17 - 12:19 **Case 1: M/F Ages 20-30 with Main Th Scoliosis**
Michael Selby, MD

12:19 - 12:21 **Case 2: M/F Ages 17 with 40 Degree T/L Scoliosis**
Michael Selby, MD

12:21 - 12:35 **Panel Discussion**
Patrick J. Cahill, MD; Marinus de Kleuver, MD, PhD; Michael A. Galgano, MD; Eric O. Klineberg, MD; Heiko Koller, MD; Kota Watanabe, MD, PhD

12:35 - 12:45 **Discussion**

Panel 2: Understanding the Risk of Degenerative Arthritis

12:47 - 12:49 **Case 1: Treated AIS Long Fusion to L3 (wedged 3/4 disc)**
Burt Yaszay, MD

12:49 - 12:51 **Case 2: Thoracolumbar Tether**
Burt Yaszay, MD

12:51 - 13:05 **Panel Discussion**
Ahmet Alanay, MD; Jennifer M. Bauer, MD, MS; Kenny YH. Kwan, BMBCh(Oxon), FRCSEd; Amer F. Samdani, MD; Michael Selby, MD

13:05 - 13:15 **Discussion**

● Early Career ■ Pediatric/Adolescent ○ Adult Spinal Deformity ▲ Neurosurgery **denotes Non-CME Session/Activity*

12:15 - 13:15 Parkside Ballroom *(concurrent session)*

Lunchtime Symposia 2: Sagittal Plane: Development and Planning Across the Ages ■ ○

Moderators: Kariman Abelin Genevois, MD & Caglar Yilgor, MD

12:15 - 12:25 **Development of the Sagittal Plane**
Sebastien Pesenti, MD, PhD

12:25 - 12:35 **Assessment of Normal Standing Alignment in Adults**
Jeffrey M. Hills, MD

12:35 - 12:45 **Discussion**

12:45 - 12:55 **Planning Realignment in Adolescent Idiopathic Scoliosis**
Brice Ilharreborde, MD, PhD

12:55 - 13:05 **Planning Realignment in Adult Spinal Deformity**
Caglar Yilgor, MD

13:05 - 13:15 **Discussion**

12:15 - 13:15 Pyrmont Theatre *(concurrent session)*

Lunchtime Symposia 3: Treating Complex Curves Around the Globe ■ ○

Moderators: Cristina Sacramento Dominguez, MD & John S. Vorhies, MD

Session 1: Large-Magnitude Curves in Adolescents

12:15 - 12:20 **Patient Population and Pre-Operative Optimization Strategies**
Kwadwo Poku Yankey, MD

12:20 - 12:25 **Preoperative and Intraoperative Resources for Severe Deformity**
Nan Wu, MD

12:25 - 12:27 **Moderated Q&A**

12:27 - 12:29 **Case Presentation**
Kwadwo Poku Yankey, MD

12:29 - 12:35 **Discussion**

Session 2: Early and Late Presentation in Adult Spinal Deformity

12:35 - 12:40 **Late Presentation in ASD: Aging, Metabolic Health, Inflammatory Modulation and Tissue Optimization**
Emmanuelle Ferrero, MD, PhD

12:40 - 12:45 **Early Presentation in ASD: When are MIS Techniques an Appropriate Strategy?**
Jianguo Terry Zhang, MD

12:45 - 12:47 **Moderated Q&A**

12:47 - 12:49 **Case Presentation**
Emmanuelle Ferrero, MD, PhD

12:49 - 12:55 **Discussion**

Session 3: Early-Onset Syndromic and Neuromuscular Deformity

12:55 - 13:00 **How Does Implant Availability Affect My Transition Point from Non-Operative to Operative Care?**
Andre Luis F. Andujar, MD

13:00 - 13:05 **How I Design a Growth Friendly Surgical Strategy**
Kristopher M. Lundine, MD

13:05 - 13:07 **Moderated Q&A**

13:07 - 13:09 **Case Presentation**
Kristopher Lundine, MD

13:09 - 13:15 **Discussion**

13:15 - 13:30 **Break**

● Early Career ■ Pediatric/Adolescent ○ Adult Spinal Deformity ▲ Neurosurgery **denotes Non-CME Session/Activity*

MEETING AGENDA

WEDNESDAY, OCTOBER 7, 2026

Program (topics, timing, and faculty) is subject to change.

13:30 - 15:00 Darling Harbour Theatre

Abstract Session 1: Adult Spinal Deformity I: Optimizing Alignment, Why It Matters ○

Moderators: Venu Nemani, MD, PhD & Aaron Buckland, MBBS, FRCSA

13:30 - 13:35 **Introduction**

13:35 - 13:39 **Paper #1: The Role of L5–S1 in Determining Lumbar Shape: Segmental Determinants of Normal L1PA**
Jeffrey M. Hills, MD; Alexander T. Yahanda, MS; Tyler K. Williamson, MD, MS, BS; JeanCharles Le Huec, MD, PhD; Camilo A. Molina, MD; Brandon B. Carlson, MD; Zeeshan M. Sardar, MD; Hee-Kit Wong, MD, PhD; Kazuhiro Hasegawa, MD, PhD; Lawrence G. Lenke, MD; Michael P. Kelly, MD

13:39 - 13:43 **Paper #2: The Sacro-acetabular Angle: A Morphologic Property That Helps Predict Positional Spinopelvic Parameters**
Chien Yew Kow, MD; Farbod Moghaddam, BS; Timothy Lasswell, MD; Taryn Ludwig, MD, PhD; May Choi, MD; Michael P. Kelly, MD; *Fred H. Nicholls, MD*

13:43 - 13:47 **Paper #3: Vertebral-Pelvic Angle-Based Classification Identifies Degenerative Sagittal Alignment Patterns**
Jun Ouchida, MD; Sadayuki Ito, MD; Naoki Segi, MD; Hiroaki Nakashima, MD, PhD; Shiro Imagama, MD, PhD

13:47 - 13:56 **Discussion**

13:56 - 14:00 **Paper #4: Association of Kyphotic and Lordotic Apices and the Thoracolumbar Inflection Point with Regional and Global Sagittal Alignment in 410 Asymptomatic Adults**
Fred H. Nicholls, MD; Christopher J. Nielsen, MD; Fatemeh Alavi, PhD; Stephen J. Lewis, MD, FRCS(C)

14:00 - 14:04 **Paper #5: Strategic Adjustment of Segmental Lumbar Lordosis to Optimize L1-Pelvic Angle Offset and Minimize Mechanical Complications After Long-Level Lumbar Fusion Surgery**
Myung-Hoon Shin, MD, PhD

14:04 - 14:08 **Paper #6: Four Distinct Pelvic Response Patterns Following Adult Spinal Deformity Surgery: A Multivariate Trajectory Analysis**
Jonathan Elysee, MS; *Renaud Lafage, MS*; Bassel G. Diebo, MD; Christopher P. Ames, MD; Shay Bess, MD; Alan H. Daniels, MD; Robert K. Eastlack, MD; Munish C. Gupta, MD, MBA; Richard Hostin, MD; Khaled M. Kebaish, MD; Eric O. Klineberg, MD; Gregory M. Mundis Jr, MD; David O. Okonkwo, MD, PhD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; International Spine Study Group

14:08 - 14:17 **Discussion**

14:17 - 14:21 **Paper #7: Gait Stability Seems to Deteriorate with Age and Sagittal Malalignment Severity**
Ibrahim Hamati; Abir Massaad, PhD; Rami Rachkidi, MD, MS; Moustapha Rteil; Gilles Prince; Michel Al Ammouri; Yamen Beyh; Frederic Maatouk; Josef Lattouf; Jean-Pierre Saad; Mohamad Hajj Youssef; Mohammad Ibrahim Karam, PhD, MS; *Virginie Lafage, PhD*; Ismat Ghanem, MD, MS; Ayman Assi, PhD

14:21 - 14:25 **Paper #8: Mechanical Complications in Functional vs Normative Alignment Targets in Adult Spinal Deformity: Should There be Adjustments for Age?**
Alexander Kucherina, BS; Renaud Lafage, MS; *Yashar Javidan, MD*; Bassel G. Diebo, MD; Alex Soroceanu, MD, FRCS(C); Jeffrey Gum, MD; Gregory M. Mundis Jr, MD; Justin S. Smith, MD, PhD; Peter G. Passias, MD; Han Jo Kim, MD; Kojo D. Hamilton, MD, FAANS; Lawrence G. Lenke, MD; Munish C. Gupta, MD, MBA; Christopher P. Ames, MD; Eric O. Klineberg, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Shay Bess, MD; Themistocles S. Protopsaltis, MD; International Spine Study Group

14:25 - 14:29 **Paper #9: Full Body Radiographs with Knee Flexion Assessment in Sagittal Deformity: Does Lower Extremity Compensation Independently Inform Alignment Correction?**
David D. Liu, MD; Breton Line; Feyza Achilova; Bassel G. Diebo, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Richard Hostin, MD; Peter G. Passias, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Themistocles S. Protopsaltis, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Munish C. Gupta, MD, MBA; Brett Rocos, MD, FRCS; Jeffrey Mullin, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Christopher P. Ames, MD; Lawrence G. Lenke, MD; Sang Hun Lee, MD, PhD; Khaled M. Kebaish, MD; Shay Bess, MD; Alan H. Daniels, MD; International Spine Study Group

14:29 - 14:38 **Discussion**

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14:38 - 14:42 **Paper #10: Go Big or Lay-Up in Revision Adult Spinal Deformity Surgery? Contrasting the Trade-Off Between Achieving Optimal Alignment with Early Complication vs. Suboptimal Alignment Without Complication**
Scott Zuckerman, MD; Harsh Jain, MBBS; *Byron F. Stephens, MD*; Thomas Buell, MD; Nima Alan, MD; Sang Hun Lee, MD, PhD; David O. Okonkwo, MD, PhD; Stephen J. Lewis, MD, FRCS(C); Jeffrey Mullin, MD; Peter G. Passias, MD; Darryl Lau, MD; Anthony L. Mikula, MD; Jay D. Turner, MD, PhD; Joshua Bunch, MD; Brandon B. Carlson, MD; Michael P. Kelly, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Eric O. Klineberg, MD; Han Jo Kim, MD; Breton Line; Themistocles S. Protopsaltis, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Khaled M. Kebaish, MD; Paul Park, MD; Praveen V. Mummaneni, MD; Munish C. Gupta, MD, MBA; Jeffrey Gum, MD; Alan H. Daniels, MD; Bassel G. Diebo, MD; Richard Hostin, MD; Justin K. Scheer, MD; Lawrence G. Lenke, MD; Frank Schwab, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; International Spine Study Group

14:42 - 14:46 **Paper #11: Radiographic Evaluation of ASD and its Relationship with Longitudinal Changes in Sagittal Spinal Alignment**
Takuya Murazumi, MD; Tetsuya Kobayashi, MD, PhD; Issei Senoo, MD; Hiroki Okayasu, MD; Kozaburo Mizutani, MD; Kengo Sasai, MD; Shoichi Saino, MD; Hiroshi Ito, MD

14:46 - 14:50 **Paper #12: Why Success After Adult Spinal Deformity Surgery Depends on How Success is Defined: Insights from a Composite Outcome Framework**
Renaud Lafage, MS; Blerta Budani, BS; Ayman Mohamed, MD; Bassel G. Diebo, MD; Christopher P. Ames, MD; Shay Bess, MD; Alan H. Daniels, MD; Robert K. Eastlack, MD; Munish C. Gupta, MD, MBA; Richard Hostin, MD; Khaled M. Kebaish, MD; Eric O. Klineberg, MD; Gregory M. Mundis Jr, MD; Mitsuru Yagi, MD, PhD; David O. Okonkwo, MD, PhD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; International Spine Study Group

14:50 - 15:00 **Discussion**

15:00 - 15:20 Refreshment Break | The Gallery

15:20 - 17:05 Darling Harbour Theatre

Abstract Session 2: Adolescent Idiopathic Scoliosis I ■

Moderators: Laurel C. Blakemore, MD & Meric Enercan, MD

15:20 - 15:24 **Paper #13: High Accuracy, Strong Reliability, and Test–Retest Stability in Identifying New Transverse Plane Modifiers of the SRS–Lenke–Aubin 3D Classification of AIS**
Lawrence G. Lenke, MD; Carl Eric Aubin, PhD, P.Eng; Delphine Aubin, MS; Michael G. Vitale, MD, MPH; Virginie Lafage, PhD; Brice Ilharreborde, MD, PhD; A Noelle Larson, MD; Jeffrey Mullin, MD; Michelle C. Welborn, MD; Takashi Kaito, MD, PhD; Justin S. Smith, MD, PhD

15:24 - 15:28 **Paper #14: Beyond the 2D Lenke Classification: Clinically Relevant Insights from Transverse-Plane Descriptors of the SRS-Lenke-Aubin 3D Framework in Lenke 1 AIS**
Carl Eric Aubin, PhD, P.Eng; Brice Ilharreborde, MD, PhD; Lawrence G. Lenke, MD; Takashi Kaito, MD, PhD; A Noelle Larson, MD; Delphine Aubin, MS; Christiane Caouette, PhD; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Jeffrey P. Mullin, MD; Michelle C. Welborn, MD

15:28 - 15:32 **Paper #15: A Quantitative CT-Based Analysis of Vertebral Rotational Asymmetry and Pulmonary Function in Scoliosis**
Beomsu Kim, MD; Ihnseok Chae, MD; Jeuk Lee, MD; Sung Taeck Kim, MD; Bong-Soon Chang, MD, PhD; Sam Yeol Chang, MD; Hyoungmin Kim, MD

15:32 - 15:41 **Discussion**

15:41 - 15:45 **Paper #16: Adolescent Idiopathic Scoliosis with a Major Proximal Thoracic Curve: a Rare Type not Included in the Lenke Classification System - The Incidence, Radiographic Characteristics and Surgical Strategy**
Huafeng Zhang, MD; Yu-Cheng Yao, MD; Ben Long Shi, MD; Saihu Mao, MD; Zhen Liu, MD, PhD; Zezhang Zhu, MD, PhD; Yong Qiu, PhD

15:45 - 15:49 **Paper #17: Proximal Thoracic-Predominant Lenke 2 Curves Have Important Surgical Differences**
Zaid Elsabbagh, BS; Ysa Le, BS; William ElNemer, BS; Daniel Badin, MD; Peter O. Newton, MD; Suken A. Shah, MD; *Paul D. Sponseller, MD*

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MEETING AGENDA

WEDNESDAY, OCTOBER 7, 2026

Program (topics, timing, and faculty) is subject to change.

15:49 - 15:53 **Paper #18: Variation in Flexibility Imaging Techniques in Adolescent Idiopathic Scoliosis (AIS): A Multicenter Study**
Alexander Park, BS; Michael W. Brown, BS; Mehdi Elfilali, BA; Joshua Akosa, BS; Michael G. Vitale, MD, MPH; Harms Study Group; *Benjamin D. Roye, MD*

15:53 - 16:02 **Discussion**

16:02 - 16:06 **Paper #19: Accuracy of IS-GROWTH Predictions of the Risk of Reaching the Clinically Significant Thresholds of 30°, 45° And 50° In Idiopathic Scoliosis Patients**
Stefano Negrini, MD, PhD; *Greta Jurenaite, MD;* Fabio Zaina, MD; Francesco Negrini, MD

16:06 - 16:10 **Paper #20: The Closing Triradiate Cartilage Stage Identifies Accelerated Curve Progression in Idiopathic Scoliosis**
Hong Zhang, MD; Judy-Mae Lima, BS; Chan-Hee Jo, PhD; Daniel J. Sucato, MD, MS

16:10 - 16:14 **Paper #21: Deep Learning of Apical Intervertebral Disc MRI Predicts Scoliosis Progression Independent of Radiographic Parameters**
Conor Timothy Boylan, MBChB, MSc, BSc, MRCS Ed; Louis Anandaputra; Chuck H. Lam, BSc; Maximillian Moss, MBChB; Duncan Loader; Muhammad Othman Shafiq, OMSB-Orth; Insiya Hashim, MBBS; David S. Marks, MBBS, FRCS; Arin M. Ellingson, PhD; Morgan Jones, FRCS, MBChB

16:14 - 16:23 **Discussion**

16:23 - 16:27 **Paper #22: Can Machine Learning Optimize Fusion Selection in Thoracic Adolescent Idiopathic Scoliosis? – A Dual-center Cohort Study with External Validation**
Soren Ohrt-Nissen, MD, PhD; Jason Pui Yin Cheung, MD, MBBS, MS, FRCS; Prudence Wing Hang Cheung, PhD; Martin Heegaard, MD, PhD; Laerke C. Ragborg, MD, PhD; Thomas Borbjerg. Andersen, MD, PhD; Xihe Tony. Kuang; Martin Gehrchen, MD, PhD; *Benny T. Dahl, MD, PhD*

16:27 - 16:31 **Paper #23: Updated Guidance on Lower Instrumented Vertebra Horizontalization in Lenke C Curves after Selective Thoracic Fusion: The Concept of Dynamic Lumbar Curve Behavior**
Josephine R. Coury, MD; Ying Yu, MD; Eduardo C. Beauchamp, MD; Mehdi Elfilali, BA; Justin L. Reyes, MS; Nicholas Laskay, MD; Evan Joiner, MD; Lawal A. Labaran, MD; Matthew Elliot. Simhon, MD; Zeeshan M. Sardar, MD; Benjamin D. Roye, MD; Lawrence G. Lenke, MD; Michael G. Vitale, MD, MPH

16:31 - 16:35 **Paper #24: Long-Term Clinical and Radiographic Outcomes of Stopping Fusion at L3 in Structural Lumbar Curves Despite Standing and Bending X-rays Indicated to Stop at L4: A Minimum 20-Year Follow Up**
Mustafa Buğra Ayaz, MD; Ibrahim Dag, MD; Hamisi Mwarindano Mraja, MD; Ahmet Hamdi Olcar, MD; Burak Abay, MD; Ilyas Dolas, MD; Sinan Kahraman, MD; Selhan Karadereler, MD; *Meric Enercan, MD;* Azmi Hamzaoglu, MD

16:35 - 16:44 **Discussion**

16:44 - 16:48 **Paper #25: Rate and Risk of Curve Progression in Moderate AIS following Skeletal Maturity**
Firoz Miyanji, MD, FRCS(C); Abdullah AlDuwaisan, FRCS(C); Baron S. Lonner, MD; Paul D. Sponseller, MD; Tracey P. Bastrom; Burt Yaszay, MD; Stefan Parent, MD, PhD; Amer F. Samdani, MD; Harms Study Group; Peter O. Newton, MD

16:48 - 16:52 **Paper #26: Later Menarche Tracks with AIS Curve Severity—Clinical Association and Genetic Causality in 5,891 Patients**
Ryutaro Tanaka, MD; Takuro Iwami, MD; Yoshiro Yonezawa, MD, PhD; Nao Otomo, MD, PhD; Kazuki Takeda, MD, PhD; Shiro Ikegawa, MD, PhD; Morio Matsumoto, MD, PhD; Masaya Nakamura, MD, PhD; Chikashi Terao, MD, PhD; Kota Watanabe, MD, PhD

16:52 - 16:56 **Paper #27: Sacral Slanting Predicts Residual Disc Wedging After Fusion to L3 in AIS**
Hiroyuki Nakarai, MD; Daiki Urayama, MD; Hideki Nakamoto, MD, PhD; So Kato, MD, PhD; Yasushi Oshima, MD, PhD; Yuki Taniguchi, MD, PhD

16:56 - 17:05 **Discussion**

17:05 - 17:20 **Break**

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17:20 - 19:00 Darling Harbour Theatre

Opening Ceremonies*

17:20 - 17:24 **Welcome to Australia**
Metropolitan Local Aboriginal Land Council (MLALC)

17:24 - 17:28 **Welcome to Sydney**
Andrew K. Cree, FRCSA; Brian Hsu, MD

17:28 - 17:32 **Presidential Message**
Suken A. Shah, MD

17:32 - 17:36 **Acknowledgement of SRS Donors**
Gregory M. Mundis, Jr., MD

17:36 - 17:40 **Announcement of the Beschloss Donation**
Laurel C. Blakemore, MD

17:40 - 17:43 **Douglas C. Burton, MD Best Adult Deformity Paper Announcement**
Justin S. Smith, MD, PhD

17:43 - 17:47 **SRS-Cotrel Foundation Basic Science Research Grant Award**
Brice Ilharreborde, MD, PhD

17:47 - 17:51 **Biedermann Innovation Award Winner**
Markku Biedermann

17:51 - 17:55 **SRS Research Grant Award Winners**
Walter H. Truong, MD, FRCS(C), FAOA

17:55 - 18:02 **Presentation of Blount Humanitarian Award**
Selina C. Poon, MD

18:02 - 18:20 **Importance of our Corporate Partners & Acknowledgment of Corporate Supporters**
Han Jo Kim, MD

18:20 - 18:25 **Introduction of Howard Steel Lecturer**
Suken A. Shah, MD

18:25 - 18:55 **Howard Steel Lecture**
David Hunt

18:55 - 19:00 **Closing Remarks**
Suken A. Shah, MD

19:00 - 21:00 The Gallery

Welcome Reception*

A hosted reception featuring hors d'oeuvres, cocktails, and reunions with colleagues and friends will immediately follow the Opening Ceremonies.

Available at no charge to meeting delegates, Guest(s) of registered attendee: $50, per guest. If you would like to purchase guest ticket(s), please stop at the Registration Desk.

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MEETING AGENDA

THURSDAY, OCTOBER 8, 2026

Program (topics, timing, and faculty) is subject to change.

07:00 - 08:00 **C2.1 - C2.5 Meeting Rooms** *(5 concurrent sessions)*

Industry Workshops*

Each workshop is programmed by a single-supporting company and will feature presentations on topics selected by the company. Please see page 240 to view the detailed schedule. A hot breakfast will be offered.

Please note: CME credits are not available for Industry Workshops

08:00 - 09:50 **Darling Harbour Theatre** *(concurrent session)*

Abstract Session 3A: Adult Spinal Deformity II ○

Moderators: Jeffrey Gum, MD & Javier Pizones, MD, PhD

08:00 - 08:05 **Welcome**

08:05 - 08:09 **Paper #28: Is There a Cervical Alignment Threshold Warranting Cervical Inclusion in the Construct of Thoracolumbar ASD Patients?**
Peter G. Passias, MD; Mohammad Daher, MD, BS; David D. Liu, MD; Pratibha Nayak, PhD; Hong Joo Moon, MD; Sang Hun Lee, MD, PhD; Justin K. Scheer, MD; Anthony L. Mikula, MD; Han Jo Kim, MD; Darryl Lau, MD; Bassel G. Diebo, MD; Alan H. Daniels, MD; Gregory M. Mundis Jr, MD; Robert K. Eastlack, MD; Jeffrey Mullin, MD; Praveen V. Mummaneni, MD; Themistocles S. Protopsaltis, MD; Kojo D. Hamilton, MD, FAANS; Thomas Buell, MD; Jeffrey Gum, MD; Breton Line; Richard Hostin, MD; Alex Soroceanu, MD, FRCS(C); Dean Chou, MD; Michael Y. Wang, MD; Eric O. Klineberg, MD; Richard G. Fessler, MD, PhD; Justin S. Smith, MD, PhD; Lawrence G. Lenke, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Frank Schwab, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Christopher P. Ames, MD; International Spine Study Group

08:09 - 08:13 **Paper #29: Does Proximal Thoracic Rod Contour Influence PJK Risk in Adult Spinal Deformity?**
Harsh Jain, MBBS; Advith Sarikonda, BS, BA; Ranbir Ahluwalia, MD; Tyler Zeoli, MD; Iyan Younus, MD; Omar Zakieh, MBBS; Hani Chanbour, MD; Bayard Wilson, MD; *Byron F. Stephens, MD*; Scott Zuckerman, MD

08:13 - 08:17 **Paper #30: The Gradual Decay of the Proximal Junctional Angle following Thoracolumbar fusion of Adult Spine Deformity**
Wesley M. Durand, MD; Ahmed Sulieman, MD; Tej Azad, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Breton Line; Richard Hostin, MD; Peter G. Passias, MD; Bassel G. Diebo, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Alan H. Daniels, MD; Gregory M. Mundis Jr, MD; Themistocles S. Protopsaltis, MD; Justin S. Smith, MD, PhD; Kojo D. Hamilton, MD, FAANS; Munish C. Gupta, MD, MBA; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Christopher P. Ames, MD; Lawrence G. Lenke, MD; Shay Bess, MD; Sang Hun Lee, MD, PhD; Khaled M. Kebaish, MD; International Spine Study Group

08:17 - 08:26 **Discussion**

08:26 - 08:30 **Paper #31: Does Postoperative UIV–L1 Alignment Predict Proximal Junctional Kyphosis After Adult Spinal Deformity Surgery?**
Harsh Jain, MBBS; Advith Sarikonda, BS, BA; Ranbir Ahluwalia, MD; Tyler Zeoli, MD; Iyan Younus, MD; Hani Chanbour, MD; Bayard Wilson, MD; Byron F. Stephens, MD; Scott Zuckerman, MD

08:30 - 08:34 **Paper #32: Development of a Novel Sagittal Segmental Phenotyping System for Mechanical Complication Risk Stratification in Degenerative Lumbar Scoliosis Surgery**
Weipeng Qiu, MD; Zhuoran Sun, MD; Weishi Li, MD

08:34 - 08:38 **Paper #33: Lumbar Alignment Transitions: The Relationship of Lumbar Lordosis Distribution with Proximal Junctional Kyphosis and Pseudoarthrosis**
Travis Kotzur, MD; Lane H. McCoy, BS; R. Adams Cowley II, MD; Neset Tang, MD; Munish C. Gupta, MD, MBA; Nicholas A. Pallotta, MD, MS; Brian J. Neuman, MD

08:38 - 08:47 **Discussion**

08:47 - 08:51 **Paper #34: Dynamic Gait-Related Sagittal Decompensation After a 10-Minute Walking Test Predicts Revision-Requiring Proximal Junctional Kyphosis**
Junseok Bae, MD; SangHo Lee, MD, PhD

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08:51 - 08:55 **Paper #35: Predicting Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery in the Early Postoperative Period with High Accuracy Using a Machine Learning-Based Scoring Model**
Ted Shi, BS; Justin L. Reyes, MS; Varun Arvind, MD, PhD; Cole Morrissette, MD, MS; Mark Herbert, MD; Roy Miller, MD; Gabriella Greisberg, BS; Fthimnir Hassan, MPH; Eduardo C. Beauchamp, MD; Zeeshan M. Sardar, MD; Ronald Lehman Jr, MD; Lawrence G. Lenke, MD; Joseph M. Lombardi, MD

08:55 - 08:59 **Paper #36: Do Supplementary Rod Constructs Influence the Rate of Proximal Junctional Kyphosis? A Multicenter Study**
Ahmed Sulieman, MD; Tej Azad, MD; Harsh Jain, MBBS; Advith Sarikonda, BS, BA; Virginie Lafage, PhD; Renaud Lafage, MS; Breton Line; Richard Hostin, MD; Peter G. Passias, MD; Bassel G. Diebo, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Alan H. Daniels, MD; Gregory M. Mundis Jr, MD; Themistocles S. Protopsaltis, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Munish C. Gupta, MD, MBA; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Christopher P. Ames, MD; Lawrence G. Lenke, MD; Shay Bess, MD; Sang Hun Lee, MD, PhD; Byron F. Stephens, MD; Scott Zuckerman, MD; *Khaled M. Kebaish, MD*; International Spine Study Group

08:59 - 09:08 **Discussion**

09:08 - 09:12 **Paper #37: The Breakdown on Breakage: Why Pre-bent Rods Outperform Manual Contouring in ASD Surgery**
Garima Paul, MD; Matthew Miyasaka, AB; Alexander Kucherina, BS; Mina Eskandar, MS, BS; Constance Maglaras, PhD; Themistocles S. Protopsaltis, MD; Tina Raman, MD

09:12 - 09:16 **Paper #38: The Over-Widening Phenomenon as a Risk Factor for Rod Fracture after Deformity Corrective Surgery using Anterior Column Realignment in Patients with Degenerative Sagittal Imbalance**
SungMin Kim, MD, PhD; Yong-Chan Kim, MD, PhD; Inseok Son, MD; XiongJie Li, MD; LinJin Mao, MD

09:16 - 09:20 **Paper #39: Rod Fractures After Adult Spinal Deformity Surgery: What Happens After 2-years?**
Harsh Jain, MBBS; Albert Cordoves, BS; Emma Ye, BA; Advith Sarikonda, BS, BA; Hani Chanbour, MD; Tyler Zeoli, MD; Ranbir Ahluwalia, MD; *Iyan Younus, MD*; Soren Jonzzon, MD; Byron F. Stephens, MD; Bayard Wilson, MD; Scott Zuckerman, MD

09:20 - 09:29 **Discussion**

09:29 - 09:33 **Paper #40: Rethinking ASD in 3D: How Scoliosis Correction Interacts with Sagittal Alignment and PJK**
Ahmed Sulieman, MD; Goutham Yalla, MD; Tej Azad, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Breton Line; Richard Hostin, MD; Peter G. Passias, MD; Bassel G. Diebo, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Alan H. Daniels, MD; Gregory M. Mundis Jr, MD; Themistocles S. Protopsaltis, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Munish C. Gupta, MD, MBA; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Christopher P. Ames, MD; Lawrence G. Lenke, MD; Shay Bess, MD; Sang Hun Lee, MD, PhD; *Khaled M. Kebaish, MD*; International Spine Study Group

09:33 - 09:37 **Paper #41: Evolution of Surgical Strategy in Adult Spinal Deformity: A Longitudinal Analysis of Sagittal Alignment and 2-Year Outcomes Across 18 Years**
Emil Haikal, MD; Renaud Lafage, MS; Jonathan Elysee, MS; Bassel G. Diebo, MD; Christopher P. Ames, MD; Shay Bess, MD; Alan H. Daniels, MD; Robert K. Eastlack, MD; Munish C. Gupta, MD, MBA; Jeffrey Gum, MD; Richard Hostin, MD; Khaled M. Kebaish, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Lawrence G. Lenke, MD; Gregory M. Mundis Jr, MD; David O. Okonkwo, MD, PhD; Pierce D. Nunley, MD; Peter G. Passias, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; International Spine Study Group

09:37 - 09:41 **Paper #42: Fate of the Unfused Distal Lumbar Coronal Curve After Scoliosis Correction in Children versus Adults: A Collaborative Study Group Analysis**
Alan H. Daniels, MD; David D. Liu, MD; Amer F. Samdani, MD; Bassel G. Diebo, MD; Peter O. Newton, MD; Michael Farias, BS; Feyza Achilova; Lawrence G. Lenke, MD; Jeffrey Gum, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Shay Bess, MD; *Keith R. Bachmann, MD*; Harms Study Group; International Spine Study Group

09:41 - 09:50 **Discussion**

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MEETING AGENDA

THURSDAY, OCTOBER 8, 2026

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08:00-09:50 **Pyrmont Theatre** *(concurrent session)*

Abstract Session 3B: Progress Report: Discussing Outcomes in AIS ■

Moderators: Reuben CC Soh, MBBS, FRCS & Stefan Parent, MD, PhD

08:00 - 08:05 **Welcome**

08:05 - 08:09 **Paper #43: Thoracic Kyphosis Restoration Is Associated with Improvement of the L1 Pelvic Angle in Thoracic Adolescent Idiopathic Scoliosis**
Yusuke Hori, MD, PhD; Takashi Namikawa, MD, PhD; Masaki Kawamura, MD; Masahiro Ohno, MD; Kazuki Ohki, MD; Akira Matsumura, MD, PhD

08:09 - 08:13 **Paper #44: Global Sagittal Equilibrium in Pediatric Scoliosis is Maintained Postoperatively via Compensations Rather than Construct Optimization**
Deniz Kara, MD; Bryan Menapace, MD, MBA; Daniel Bouton, MD; Robert Bernstein, MD; Joseph Ivan Krajbich, MD; Jeffrey M. Hills, MD; Michelle C. Welborn, MD; Rebecca GraceTracey, RN; Cindy Nguyen, PA-C; Michael P. Kelly, MD; *Chinmay Paranjape, MD, MHSc*

08:13 - 08:17 **Paper #45: Impact of Three-Dimensional Thoracic Hypokyphosis on Lower Cervical Degeneration and Cervical Alignment After Deformity Correction in Adolescent Idiopathic Scoliosis**
Hong Jin Kim, MD, PhD; *Chang Hwa Ham, MD, PhD*; Subin Lim, MD; Hyung Rae Lee, MD; Jae Hyuk Yang, MD, PhD; Seung Woo Suh, MD, PhD

08:17 - 08:26 **Discussion**

08:26 - 08:30 **Paper #46: Preoperative Thoracic Kyphosis, Not Implant Choice or Navigation, Predicts Proximal Junctional Kyphosis in Adolescent Idiopathic Scoliosis**
Eddie Geagea, MD; Manas Peddiboyina, MS; *John Lovejoy, MD*

08:30 - 08:34 **Paper #47: Sagittal Profiles and their Reciprocal Changes Manifesting in Proximal Junctional Kyphosis in Adolescent Idiopathic Scoliosis**
Hong Jin Kim, MD, PhD; *Hyung Rae Lee, MD*; Subin Lim, MD; Jae Hyuk Yang, MD, PhD; Seung Woo Suh, MD, PhD

08:34 - 08:38 **Paper #48: Does T4PA–L1PA Mismatch Matter? Patient-Reported Outcomes After Posterior Fusion for Adolescent Idiopathic Scoliosis: Min 20 years Follow-up**
Ibrahim Dag, MD; Hamisi Mwarindano Mraja, MD; Mustafa Buğra Ayaz, MD; Ahmet Hamdi Olcar, MD; Ilyas Dolas, MD; *Sinan Kahraman, MD;* Meric Enercan, MD; Selhan Karadereler, MD; Azmi Hamzaoglu, MD

08:38 - 08:47 **Discussion**

08:47 - 08:51 **Paper #49: How can we minimize disc wedging and trunk shift after selective thoracic fusions in AIS?**
Joshua M. Pahys, MD; Tej Azad, MD; Alexander J. Schupper, MD; Amer F. Samdani, MD; Terrence G. Ishmael, MBBS; Firoz Miyanji, MD, FRCS(C); Suken A. Shah, MD; Peter O. Newton, MD; Harms Study Group, Steven W. Hwang

08:51 - 08:55 **Paper #50: The Role of Vertebral Rotation Discrepancy for Add-on Phenomenon in Thoracic Curves of Adolescent Idiopathic Scoliosis**
Hong Jin Kim, MD, PhD; Hyung Rae Lee, MD; *Subin Lim, MD*; Jae Hyuk Yang, MD, PhD; Seung Woo Suh, MD, PhD

08:55 - 08:59 **Paper #51: ΔUIV Tilt Correction ≥10° Is an Independent Risk Factor for Left PSI at 2 Years in Lenke 1 AIS**
Ryutaro Tanaka, MD; *Kazuki Takeda, MD, PhD;* Takahito Iga, MD, PhD; Toshiki Okubo, MD, PhD; Masahiro Ozaki, MD, PhD; Satoshi Suzuki, MD, PhD; Narihito Nagoshi, MD, PhD; Morio Matsumoto, MD, PhD; Masaya Nakamura, MD, PhD; Kota Watanabe, MD, PhD

08:59 - 09:08 **Discussion**

09:08 - 09:12 **Paper #52: Distal Instrumentation Failure After Posterior Spinal Fusion in Adolescent Idiopathic Scoliosis: Incidence, Risk Factors, and Radiographic Impact**
Myeong Geun Song, MD; *Chang Ju Hwang, MD, PhD*; Dong-Ho Lee, MD, PhD; Jae Hwan Cho, MD, PhD; Sehan Park, MD, PhD; Wan Soo Park, MD

09:12 - 09:16 **Paper #53: What Factors Allow Us to Predict Ideal Radiographic Outcomes at 2 and 5 Years in Selective Thoracic Fusion in Lenke C AIS?**
Tej Azad, MD; Michael Rothbaum, MD; Joshua M. Pahys, MD; Amer F. Samdani, MD; Terrence G. Ishmael, MBBS; Todd F. Ritzman, MD; Firoz Miyanji, MD, FRCS(C); Suken A. Shah, MD; Peter O. Newton, MD; Harms Study Group; *Steven W. Hwang, MD*

● **Early Career** ■ **Pediatric/Adolescent** ○ **Adult Spinal Deformity** ▲ **Neurosurgery** **denotes Non-CME Session/Activity*

09:16 - 09:20 **Paper #54: Lumbar Curve Correction is Durable at 5 Years After Thoracic Fusion in Patients with Open Triradiate Cartilage**
Scott Yang, MD; Bailey Ingalls, MD; Tracey Bryan, MS; Jennifer M. Bauer, MD, MS; Paul D. Sponseller, MD; Suken A. Shah, MD; Peter O. Newton, MD; Burt Yaszay, MD; Harms Study Group

09:20 - 09:29 **Discussion**

09:29 - 09:33 **Paper #55: Health Related Quality of Life Assessment Using the Srs-22 Questionnaire Comparing Adolescent Idiopathic Scoliosis (AIS) versus Adult Idiopathic Scoliosis (AdIS) who had undergone Posterior Spinal Fusion (PSF): A Propensity Score Matched Study**
Chris Yin Wei Chan, MD, MSOrth; Amanda Weng Yee. Leong, MBBS; Van Jet Leong, MBBS; Hui Chin Ting, MBBS; Zhi Sean Teng, MBBS; Chee Kidd Chiu, MBBS, MSOrth; Mun Keong Kwan, MBBS, MSOrth

09:33 - 09:37 **Paper #56: Age Matters: Increased Perioperative Morbidity in Young Adults Compared to Adolescents Undergoing Posterior Spinal Fusion for Idiopathic Scoliosis**
Vivien Chan, MD, MS; Luke Maclean, MD, PhD; Prudhvi Kodali, BA; Justin L. Reyes, MS; Mehdi Elfilali, BA; Michael G. Vitale, MD, MPH; Zeeshan M. Sadar, MD, MS; David L. Skaggs, MD, MMM

09:37 - 09:41 **Paper #57: Longitudinal Patient-Reported Outcomes Following Spinal Fusion for Adolescent Idiopathic Scoliosis: Recovery Trajectories and Implications for Surgical Timing**
Wai Wang Chau, MS; Alec Lik Hang Hung, FRCS; *Adam Yiu Chung Lau, FRCS*

09:41 - 09:50 **Discussion**

09:50 - 10:10 Refreshment Break | The Gallery

10:10 - 12:15 Darling Harbour Theatre

Abstract Session 4: Translational/Basic Science, Harrington Lecture, & Lifetime Achievement Award

Moderators: Brian J. Neuman, MD & Caglar Yilgor, MD

10:10 - 10:14 **Paper #58: The Evolution of Sagittal Alignment in Pediatric Population: A Study of 500 Typically Developing Children**
Anuj Gupta, MD; Alexander Aretakis, MD; Satoshi Takada, MD; Peter G. Gabos, MD; Petya Yorgova, MS; Andrea Elsby, BS; *Suken A. Shah, MD*

10:14 - 10:18 **Paper #59: Defining Whole Spine Sagittal Alignment Parameters in Normal Population: Prospective Analysis of 50000 Patients**
Sung Hyeon Noh, MD, PhD

10:18 - 10:22 **Paper #60: Does everyone with a given PI have the same L1PA? The importance of L4S1 in Sagittal Alignment**
Stephen J. Lewis, MD, FRCS(C); Fatemeh Alavi, PhD; Christopher J. Nielsen, MD; Fred H. Nicholls, MD

10:22 - 10:31 **Discussion**

10:31 - 10:35 **Paper #61: Establishing Lumbar Apex Pelvic Angle (LaPA) as the Rosetta Stone of Spinal Shape**
Sleiman Haddad, MD, PhD, FRCS; Lluis Vila Castillo, MD; Susana Nunez Pereira, MD, PhD; Anika Pupak, PhD, BS; Javier Pizones, MD, PhD; Michael P. Kelly, MD; Jeffrey M. Hills, MD; Frank Kleinstuck, MD; Ahmet Alanay, MD; Ibrahim Obeid, MD; Ferran Pellisé, MD, PhD; Yann Phillippe Charles, MD, PhD; European Spine Study Group ESSG

10:35 - 10:39 **Paper #62: Using Artificial Intelligence to Capture CT Films with Smartphones for Automatic Recognition of Osteoporosis**
Junyu Li, MD; Da Zou, MD; Liangyuan Wang, MD; Yongqiang Wang, MD; Zhuoran Sun, MD; *Miao Yu, MD;* Weishi Li, MD

10:39 - 10:43 **Paper #63: Utilizing a Supervised Machine Learning Strategy to Automate Detection of Bony Fusion Using X-Rays in Lumbar Fusion Surgery ‡**
Rushikesh S. Joshi, MD; Edward S. Harake, BS; Todd C. Hollon, MD; Paul Park, MD

10:43 - 10:52 **Discussion**

10:52 - 10:56 **Paper #64: Development and Validation of the Three-dimensional Depth Sensor Imaging System for Non-invasive Scoliosis Screening**
Chen Liu, MD; Shao Chen, MD; Xiao-min Chen, MD; Yin-ling Sun, MD; Kai-qi Wang, MD; Honggen Du, MD

‡ SRS Funded Research Grant

● **Early Career** ■ **Pediatric/Adolescent** ○ **Adult Spinal Deformity** ▲ **Neurosurgery** **denotes Non-CME Session/Activity*

MEETING AGENDA

THURSDAY, OCTOBER 8, 2026

Program (topics, timing, and faculty) is subject to change.

10:56 - 11:00 **Paper #65: Machine Learning Prediction of Cobb Angle from 3D Surface Topography in Adolescent Idiopathic Scoliosis: A Radiation-Free Alternative**
Jose Maria Gonzalez Ruiz, PhD; Stephan Rothstock, PhD; Javier Pizones, MD, PhD

11:00 - 11:04 **Paper #66: XR-GAN Enables Radiation-Free Radiograph Synthesis After Posterior Spinal Fusion in Adolescent Idiopathic Scoliosis: Toward Remote Follow-Up**
Nan Wu, MD; *Jingxi Su, ME;* Aoran Maheshati, MD; Baitao Liu, MD; Kexin Xu, MS; Xiangjie Yin, MD; Jianguo Terry. Zhang, MD

11:04 - 11:13 **Discussion**

11:13 - 11:17 **Paper #67: Impaired Laminin-Dystroglycan/Integrin Signaling from Fibro-Adipogenic Progenitor Drives Deep Paravertebral Muscle Strength Imbalance in Adolescent Idiopathic Scoliosis**
Xuan Huang, MD; Jiafeng Dai, MD; Zhen Wang, MD; Junduo Zhao, MD; Haoyu Cai, MD; Hongyi Zhou, MD; Yutian Niu, MD; Yizhen Huang, MD; Heng Sun, MD; Yong Zhang, PhD; Jianxiong Shen, MD

11:17 - 11:21 **Paper #68: Unilateral Intradiscal Injection of Vosoritide-Loaded PLGA Microspheres Induces Asymmetric Spinal Growth in Juvenile Rabbits**
Xiaochen Yang, MD; Yingsong Wang, MD; Zhi Zhao, MD; Jingming Xie; Ying Zhang, MD; Tao Li, MD; Ni Bi, MD; Zhiyue Shi, MD; Li Zhang, MD; Zhibo Song, MD; Zhaoquan Zhang, MD; Quan Li, MD; Yingliang Liu, MD

11:21 - 11:25 **Paper #69: Increasing Opioid Dose Impairs Spinal Fusion in a Rat Model ‡**
Dillon Stone, MD; Garrison Bentz, BS; Jonathan Dalton, MD; Lane H. McCoy, BS; Simon Y. Tang, PhD; Dessislava Markova, PhD; Munish C. Gupta, MD, MBA; *Mark Lambrechts, MD*

11:25 - 11:34 **Discussion**

11:35 - 11:40 **Harrington Lecture Introduction**
Suken A. Shah, MD

11:40 - 12:00 **Harrington Lecture | The View From the Second Mountain: Transitions in Deformity, Career, and Life**
Todd J. Albert, MD

12:00 - 12:15 **Presentation of the Lifetime Achievement Award**
Ferran Pellisé, MD, PhD

12:15 - 12:30 Lunch Pick-Up | The Gallery

12:30 - 14:00 C2.1 - C2.6 Meeting Rooms

Industry Workshops* *(6 concurrent sessions)*

Each workshop is programmed by a single-supporting company and will feature presentations on topics selected by the company. Please see page 241 to view the detailed schedule. A hot lunch will be offered.

Please note: CME credits are not available for Industry Workshops

14:00 - 14:10 Refreshment Break | The Gallery

14:10 - 15:55 Darling Harbour Theatre *(concurrent session)*

Half-Day Course 1: Anatomical Transition Zones ■○▲

Moderators: Arun R. Hariharan, MD, MS; Anthony L. Mikula, MD

14:10 - 14:13 **Introduction**
Arun R. Hariharan, MD, MS; Anthony L. Mikula, MD

Mini-Lectures

14:15 - 14:21 **Occipitocervical Junction Fixation Strategies**
Seung-Jae Hyun, MD, PhD

14:21 - 14:25 **Discussion**

14:25 - 14:31 **Cervicothoracic Junction - Key Radiographic Parameters, Level Selection, and Technical Pearls**
Venu Nemani, MD

‡ SRS Funded Research Grant

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14:31 - 14:35 **Discussion**

14:35 - 14:41 **Thoracolumbar Junction - Tailoring Alignment Goals and Avoiding Revisions**
Firoz Miyanji, MD, FRCS(C)

14:41 - 14:45 **Discussion**

14:45 - 14:51 **Lumbosacral Junction: Fractional Curves and Special Considerations**
Alekos Theologis, MD

14:51 - 14:55 **Discussion**

14:55 - 15:01 **The Spine-Hip Interface at the Thoracolumbar and Lumbosacral Junction: When Hip Pathology Drives Level Selection**
Robert K. Eastlack, MD

15:01 - 15:05 **Discussion**

Pediatrics Debates

Pelvic Fixation Dogma in Neuromuscular and Syndromic Deformity: Who Really Needs It?
Moderator: Lindsay M. Andras, MD

15:05 - 15:10 **Always Fuse to The Pelvis in Non-Ambulator and Never in an Ambulator**
Vidyadhar V. Upasani, MD

15:10 - 15:15 **It's OK to Stop Short of the Pelvis in a Non-Ambulator and Go to The Pelvis in an Ambulator**
Haemish A. Crawford, FRCS

15:15 - 15:23 **Discussion**

Adult Junction Debates

Proximal Junction Kyphosis Prophylaxis Techniques
Moderator: Gregory M. Mundis Jr, MD

15:23 - 15:28 **Tethers, Cement, Hooks: You Need It All**
Justin K. Scheer, MD

15:28 - 15:33 **You Don't Need Junctional Prophylaxis Gimmicks - Alignment is All That Matters**
Mitsuru Yagi, MD, PhD

15:33 - 15:38 **Discussion**

Lumbosacral Junctional Interbody Fusion
Moderator: Francis Lovecchio, MD

15:38 - 15:43 **Lumbosacral Junctional Interbody Fusion | I Always Do an Interbody at L5-S1**
Benjamin D. Elder, MD, PhD

15:43 - 15:48 **Lumbosacral Junctional Interbody Fusion | An L5-S1 Interbody is a Waste of Time**
Han Jo Kim, MD

15:48 - 15:53 **Discussion**

15:53 - 15:55 **Closing Comments**
Arun R. Hariharan, MD, MS; Anthony L. Mikula, MD

14:10-15:55 **Pyrmont Theatre** *(concurrent session)*

Abstract Session 5: Anything but Fusion: Non-Op and VBT in AIS ■

Moderators: Steven W. Hwang, MD & Stephanie Da Paz, MD

14:10 - 14:14 **Paper #70: Consensus-Based Guidelines for Research in Bracing in Idiopathic Scoliosis by the SRS Comprehensive Care Committee in Collaboration with SOSORT**
Alexander Park, BS; Michael W. Brown, BS; Mehdi Elfilali, BA; Caglar Yilgor, MD; Tom PC. Schlosser, MD, PhD; Stefano Negrini, MD, PhD; Sabrina Donzelli, MD; Brian Smith, MD; *Benjamin D. Roye, MD*

14:14 - 14:18 **Paper #71: Doomed to fail? Early Brace Adherence Predicts Long Term Brace Wear Behavior**
Erica Olfson, BS; Anne Boeckmann, BS; David C. Thornberg, BS; *Daniel J. Sucato, MD, MS*; Amy Lynn. McIntosh, MD; Brandon A. Ramo, MD; Jaysson T. Brooks, MD; Megan Johnson, MD

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MEETING AGENDA

THURSDAY, OCTOBER 8, 2026

Program (topics, timing, and faculty) is subject to change.

14:18 - 14:22 **Paper #72: A Step Closer to Bringing Idiopathic Scoliosis Monitoring at Home: A Smartphone App Accurately Generates Digital Twins in 624 Pediatric Patients**
Paolo Brigato, MD; Gianmario Sangiovanni, PhD; Sabina Fehric, MSc; Kevin Smit, MD; Andrew Tice, MD; Firoz Miyanji, MD, FRCS(C); Stefan Parent, MD, PhD; Neil Saran, FRCS(C); Thierry A. Odent, MD, PhD; Anne TabardFougere, PhD; Natahly Gavira, MD; Romain Dayer, MD; *Jean Albert Ouellet, MD, FRCS(C)*

14:22 - 14:30 **Discussion**

14:30 - 14:34 **Paper #73: Casting and Bracing are Associated with Worsening Quality of Life (QOL) in Early Onset Scoliosis (EOS) Patients – Does QoL Improve with Surgery?**
Brigid S. Kennedy, MPhil; Sumeet Garg, MD; Benjamin D. Roye, MD; Mark A. Erickson, MD; Michael G. Vitale, MD, MPH; Carol A. Janney, PhD; *Ying Li, MD;* Pediatric Spine Study Group

14:34 - 14:38 **Paper #74: Boys with Adolescent Idiopathic Scoliosis Treated with Nighttime Bracing Have Similar Outcomes to Girls**
Karina Amani. Zapata, PhD, DPT; James McGinley, BS; *Daniel J. Sucato, MD, MS*; Katherine Beard, BS; Kara Davis, MS, CPO; Chan-Hee Jo, PhD; Megan Johnson, MD

14:38 - 14:42 **Paper #75: Nighttime Bracing is Equivalent to Full-time Bracing in Avoiding Curve Progression to Surgery in AIS Curves 20-35°**
Karina Amani. Zapata, PhD, DPT; Banahene Glover, BS; Alexander Palma, BA; Kara Davis, MS, CPO; Chan-Hee Jo, PhD; Brandon Ramo, MD; *Megan Johnson, MD*

14:42 - 14:50 **Discussion**

14:50 - 14:54 **Paper #76: Impact of Skeletal Maturity in Vertebral Body Tethering: Early Outcomes from a Prospective, Multicenter Study**
Hans Nugraha, MD; Lawrence Lee. Haber, MD; Dan Hoernschemeyer, MD; Patrick J. Cahill, MD; Amer F. Samdani, MD; Firoz Miyanji, MD, FRCS(C); Peter O. Newton, MD; *Kevin M. Neal, MD*; A Noelle Larson, MD

14:54 - 14:58 **Paper #77: Prospective, Multicenter Comparison of Hybrid and Bilateral VBT in the Treatment of Idiopathic Scoliosis**
Firoz Miyanji, MD, FRCS(C); Sager Hanna, MD; Shaina Sim, BS; Amer F. Samdani, MD; Baron S. Lonner, MD; Joshua M. Pahys, MD; Ahmet Alanay, MD; Stefan Parent, MD, PhD; Abdullah AlDuwaisan, FRCS(C); Peter O. Newton, MD

14:58 - 15:02 **Paper #78: Defining Multidomain "Success" After Vertebral Body Tethering for Adolescent Idiopathic Scoliosis**
Mina Eskandar, MS, BS; Alexander Kucherina, BS; Garima Paul, MD; Constance Maglaras, PhD; Themistocles S. Protopsaltis, MD; Tina Raman, MD; *Juan Carlos Rodriguez-Olaverri, MD*

15:02 - 15:10 **Discussion**

15:10 - 15:14 **Paper #79: Double Major Curves in AIS: Results of a Novel Hybrid Approach Combining Thoracic Fusion with Lumbar Vertebral Body Tethering**
Amer F. Samdani, MD; Alexander J. Schupper, MD; Joshua M. Pahys, MD; Emily Nice, BS; Sanaa Jackson, BS; Terrence G. Ishmael, MBBS; Steven W. Hwang, MD

15:14 - 15:18 **Paper #80: First 30 AIS Patients Treated with Posterior Fusion of Structural Disc Levels (SDL) And Fusionless Treatment of Non-SDL Had Preserved ROM And Less Fusion: A Prospective Study**
Saechin Kim, MD, PhD; Nadim J. Kheir, MD; Philip Hanna; Hao-Hua Wu, MD

15:18 - 15:22 **Paper #81: What Could Possibly Go Wrong? A Comprehensive Assessment of Complications Following Vertebral Body Tethering**
Kevin M. Neal, MD; Melanie E. Boeyer, PhD; Maty Petcharaporn, BS; John S. Vorhies, MD; A Noelle Larson, MD; Lawrence Lee. Haber, MD; Stefan Parent, MD, PhD; Michelle Claire Marks; Suken A. Shah, MD; Harms Study Group; Firoz Miyanji, MD, FRCS(C)

15:22 - 15:30 **Discussion**

15:30 - 15:34 **Paper #82: Tether Breakage Across First-Generation and Second-Generation Vertebral Body Tethering Devices**
Thomas A. Coleman, BS; Andrew Kim, BS; Vineet Desai, MD; Stefan Parent, MD, PhD; Firoz Miyanji, MD, FRCS(C); Ahmet Alanay, MD; Sulagna Sarkar, MS; Jason Brett. Anari, MD; Brett Lullo, MD; Harms Study Group; *Patrick J. Cahill, MD*

15:34 - 15:38 **Paper #83: Does Larger-Diameter Tether Improve Outcomes After Vertebral Body Tethering? A 4 mm vs. 5 mm Comparative Study**
Alice Baroncini, MD, PhD; Jil Frank; Miguel Pishnamaz, MD; Per D. Trobisch, MD

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15:38 - 15:42 **Paper #84: Who Breaks and Why? A Validated Predictive Model of Tether Failure After Vertebral Body Tethering in Adolescent Idiopathic Scoliosis**
Garima Paul, MD; Alexander Kucherina, BS; Mina Eskandar, MS, BS; Matthew Miyasaka, AB; Constance Maglaras, PhD; Themistocles S. Protopsaltis, MD; Tina Raman, MD; *Juan Carlos Rodriguez-Olaverri, MD*

15:42 - 15:46 **Paper #85: Is rhBMP-2 Worth the Risk? A Data-Driven Look at Fusion Outcomes and rhBMP-2 Related Complication Burden in High-Risk Adult Spinal Deformity Patients**
Duby Okonkwo, BS; Harsh Jain, MBBS; Nick De Oliveira, BA; Sam Kavarana, BS; Advith Sarikonda, BS, BA; Bayard Wilson, MD; Byron F. Stephens, MD; *Scott Zuckerman, MD*

15:46 - 15:55 **Discussion**

16:00 - 17:30 **Meeting Room C2.6**

SRS Traveling Fellows Alumni Reception* *(by invitation only)*

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MEETING AGENDA

FRIDAY, OCTOBER 9, 2026

Program (topics, timing, and faculty) is subject to change.

08:00 - 09:50 Darling Harbour Theatre

Abstract Session 6: Hibbs Award-Nominated Papers

Moderators: Kariman Abelin Genevois, MD & W.G. Stuart Mackenzie, MD

08:00 - 08:05 **Welcome & Introduction to the Hibbs Award**

08:05 - 08:11 **Paper #86: Preclinical Targeting of the Osteopontin–α5β1 Integrin Axis Reveals a Disease-Modifying Mechanism in Adolescent Idiopathic Scoliosis †**
Alain Moreau, PhD; Mohamed Elbakry, PhD; Anita Franco, MS

08:11 - 08:17 **Paper #87: A Single DNA-Based Polygenic Risk Score for Adolescent Idiopathic Scoliosis Improved by Patient-Derived Paravertebral Muscle Gene-Activity Data †**
Takuro Iwami, MD; Nao Otomo, MD, PhD; Yoshinao Koike, MD; Akari Suzuki, PhD; Raku Son, MD, PhD; Anas M. Khanshour, PhD; Ming Yue, PhD; Yoshiro Yonezawa, MD, PhD; Kazuki Takeda, MD, PhD; Akiko Oguchi, MD, PhD; Xiaoxi Liu, PhD; Jason Pui Yin Cheung, MD, MBBS, MS, FRCS; Shiro Ikegawa, MD, PhD; Morio Matsumoto, MD, PhD; Unnur Thorsteinsdottir, PhD; Yasuhiro Murakawa, MD, PhD; YouQiang Song, PhD; Carol A Wise, PhD; Masaya Nakamura, MD, PhD; Chikashi Terao, MD, PhD; Kota Watanabe, MD, PhD

08:17 - 08:23 **Paper #88: Gut Microbiome–Derived TMAO Pathway as a Central Metabolic Driver of Biological Aging in Adult Spinal Deformity † ‡**
Mitsuru Yagi, MD, PhD; Keitaro Ito, MD, PhD; Ryo Mizukoshi, MD; Norihiro Isogai, MD, PhD; Haruki Funao, MD, PhD; Naobumi Hosogane, MD, PhD; Christopher P. Ames, MD; Retsu Fujita, PhD

08:23 - 08:37 **Discussion**

08:37 - 08:43 **Paper #89: Genetic Study of 100 Idiopathic Early-Onset Scoliosis Families Provides New Hypotheses to Explain its Pathogenesis †**
Nao Otomo, MD, PhD; Yared Kidane, PhD; Behrooz A. Akbarnia, MD; Charles E. Johnston, MD; Amy Lynn. McIntosh, MD; Jonathan J. Rios, PhD; Brandon A. Ramo, MD; Carol A Wise, PhD

08:43 - 08:49 **Paper #90: Surgical vs Nonsurgical Treatment in Patients Living with Adolescent Idiopathic Scoliosis (AIS): A Target Trial Emulation with 30 Years of Follow-up § ‡**
Javier Pizones, MD, PhD; Javier Munoz Laguna, MS; Anika Pupak, PhD, BS; Yann Phillippe Charles, MD, PhD; Kenny YH. Kwan, BMBCh(Oxon), FRCSEd; Manuel Rigo, MD; Lucia Moreno-Manzanaro, BS; Antonia Matamalas, MD, PhD; Alejandro Gomez-Rice, MD, PhD; Susana Nunez Pereira, MD, PhD; Sleiman Haddad, MD, PhD, FRCS; Jwalant Mehta, FRCS; Nasir A. Quraishi, PhD, FRCS; Satoshi Suzuki, MD, PhD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Munish C. Gupta, MD, MBA; Miquel SerraBurriel, PhD; Ferran Pellisé, MD, PhD; ESSG History Study Group

08:49 - 08:55 **Paper #91: Does Early Administration of Disease Modifying Therapy (DMT) Prevent Early Onset Scoliosis (EOS) in Spinal Muscular Atrophy (SMA) §**
Hiroko Matsumoto, PhD; Yuri Ota, MD, PhD; Thomas A. Coleman, BS; Lennert Plasschaert, MD; Joyce Huang; Amy Pasternak; Allan Glanzman, PT, DPT, PCS; Jason Brett. Anari, MD; Elena Losina, PhD; Robert J. Graham, MD; Ron El Hawary, MD, MSc; Patrick J. Cahill, MD; Brian D. Snyder, MD, PhD

08:55 - 09:09 **Discussion**

09:09 - 09:15 **Paper #92: Tranexamic Acid Dosing in Deformity Spine Surgery: A 3-Year Prospective Randomized Comparison of Low-Dose versus High-Dose Regimens §**
Sharif Ahmed. Jonayed, MBBS, MS

09:15 - 09:21 **Paper #93: Casting and Bracing as a Bridging Strategy to Delay Surgery in Young Children with Thoracolumbar and Lumbar Formation-Failure Congenital Scoliosis §**
Kazuki Kawakami, MD; Noriaki Kawakami, MD; Tetsuya Ohara, MD; Hiroaki Nakashima, MD, PhD; Shiro Imagama, MD, PhD; Hiroko Matsumoto, PhD

09:21 - 09:27 **Paper #94: Non-Operative Treatment for Adult Spinal Deformity: Long Term Results of a Biopsychosocial Intervention – A Prospective Cohort Study With a Mean Follow-Up of 8 Years §**
Philip Horsting, MD; Evelien Hoevenaars; Michiel Beekhuizen, MD, PhD; John O'Dowd, MD; *Marinus de Kleuver, MD, PhD;* Miranda L. Van Hooff, PhD

09:27 - 09:33 **Paper #95: Ten-Year Natural History and Clinical Impact of Distal Adding-on After Posterior Spinal Fusion for Lenke 1A/2A Adolescent Idiopathic Scoliosis §**
Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Kazuhiro Hasegawa, MD, PhD; Hideki Tashi, MD; Keitaro Minato, MD, PhD; Yohei Shibuya, MD; Masayuki Sato, MD; Mio Kubota, MD, PhD; Hiroyuki Kawashima, MD, PhD

09:33 - 09:49 **Discussion**

09:49 - 09:50 **Audience Vote**

§ Hibbs Award Nominee – Best Clinical Paper † Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

09:50 - 10:10 Refreshment Break | The Gallery

10:10 - 11:50 **Darling Harbour Theatre**

Abstract Session 7: Syndromic/ Neuromuscular & Presidential Address ■▲

Moderators: Arvindera Ghag, MD, FRCS & Karen A. Weissmann, MD, PhD

10:10 - 10:14 **Paper #96: Multicenter Treatment Patterns and Surgical Outcomes in Marfan Syndrome Associated Scoliosis**
Mehdi Elfilali, BA; Michael W. Brown, BS; Alexander Park, BS; David Gorman, BA/MPH; Omar Taha, BS; Matthew Weintraub, BS; Daniel J. Hedequist, MD; Purnendu Gupta, MD; Joshua M. Pahys, MD; Paul D. Sponseller, MD; Benjamin D. Roye, MD; Pediatric Spine Study Group; *Michael G. Vitale, MD, MPH*

10:14 - 10:18 **Paper #97: A Two-Year International Retrospective Cohort Study Comparing the Efficacy and Complication Rates of the OWSER and MCGR Systems in the Treatment of Spinal Muscular Atrophy**
Mareille Post, MD; Luca Fabio Colombo, MD; Marco Ramella, MD; Lotfi Miladi, MD; Jean-Paul Kaleeta Maalu, MD; Louis Boissiere, MD; Moyo C. Kruyt, MD, PhD; Jeroen Renkens, MD; Esther Janssen, PhD; Barend J. Van Royen, MD, PhD

10:18 - 10:22 **Paper #98: Scoliosis in Pediatric Severe Osteogenesis Imperfecta: A Multicenter Study of Progression and Surgical Outcomes**
Cynthia V. Nguyen, MD; Alfonso Ocampo, MD; Bryan Menapace, MD, MBA; Selina C. Poon, MD

10:22 - 10:31 **Discussion**

10:31 - 10:35 **Paper #99: Intraoperative Neuromonitoring in Neuromuscular Scoliosis: Feasibility, Obstacles, Outcomes, and Resolution**
Terrence G. Ishmael, MBBS; Joshua M. Pahys, MD; Steven W. Hwang, MD; *Alexander Schupper, MD*; Tracey Bryan, MS; Suken A. Shah, MD; Jaysson T. Brooks, MD; Stefan Parent, MD, PhD; Paul D. Sponseller, MD; Peter O. Newton, MD; Harms Study Group; Amer F. Samdani, MD

10:35 - 10:39 **Paper #100: Perioperative Complication Severity is Associated with GMFCS Sub-Classification in Cerebral Palsy**
Jessica Siragusa, MBA; Sydney Thai, BS; Furqan Ahmed, BS; Krystell E Ceballos Alvarez, BS; *Paul D. Sponseller, MD*; Amit Jain, MD, MBA

10:39 - 10:43 **Paper #101: Longer Operative Times are Associated with Increased Morbidity in Pediatric Neuromuscular Scoliosis Surgery**
Luke Maclean, MD, PhD; Andrea Simmonds, MD; David L. Parsons, MD, FRCS; David L. Skaggs, MD, MMM; *Vivien Chan, MD, MS*

10:43 - 10:52 **Discussion**

10:52 - 10:56 **Paper #102: Sacro-Alar Angle as a Morphologic Predictor of S2AI Screw Infeasibility in Pediatric Neuromuscular Scoliosis with Pelvic Asymmetry**
Juan Pablo. Arispe, MD; Eduardo Galaretto, MD; *Sofia Frank, MD;* Norberto C. Fernandez, MD; Nicolas Bacaloni, MD; Leonel Shteinberg, MD; Cristian Fuster, PhD; Esteban Robledo, PhD; Carlos Alberto. Tello, MD, PhD

10:56 - 11:00 **Paper #103: Long Term Follow-up of Non-ambulatory Children with Cerebral Palsy (CP) Treated for Spine and Hip Pathoanatomy**
Rachel Lee. DiFazio, PhD, RN; Meghana Venkatesh, MS; Patricia E. Miller, PhD, MS; Judith Anne. Vessey, PhD, RN; Benjamin J. Shore, MD; *Brian D. Snyder, MD, PhD*

11:00 - 11:04 **Paper #104: The Price of Alignment: Cost Drivers in Posterior Fusion for Neuromuscular Scoliosis**
Jeremy Siu; Vanessa Toomey, MD; Jacquelyn N. Valenzuela-Moss, MPH; Tyler Tetreault, MD; Lindsay M. Andras, MD; *Michael J. Heffernan, MD*

11:04 - 11:13 **Discussion**

11:13 - 11:15 **2027 IMAST Preview**
Joshua M. Pahys, MD; Zeeshan M. Sardar, MD

11:16 - 11:19 **2027 Annual Meeting Preview**
Venu M. Nemani, MD, PhD; Michelle C. Welborn, MD

11:19 - 11:22 **2027 Annual Regional Courses Preview**
Ronald A. Lehman, Jr., MD

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11:22 - 11:25 **Acknowledgment of 2026 Awards & Scholarship Winners**
Selina C. Poon, MD

11:25 - 11:30 **Introduction of the President**
Ferran Pellisé, MD, PhD

11:30 - 11:50 **Presidential Address**
Suken A. Shah, MD

11:50 - 12:15 Lunch Pick-Up

SRS Member Lunch Pick-Up | The Gallery
Non-Member Lunch Pick-Up | C2.2-3 Room Foyer

12:15 - 13:30 Parkside Ballroom

Member Business Meeting*

All SRS members are invited to the Member Business Meeting. The agenda will include reports from the various SRS committees, updates on SRS activities and programs, and voting. Attendance at the Member Business Meeting is an opportunity to not only hear updates but actively participate in shaping the future of our Society. We encourage ALL MEMBERS to attend. A hot lunch will be provided.

12:15 - 13:30 Meeting Room C2.2-3

One World, One Spine, One SRS: A Lunchtime Educational and Networking Meeting for Non-Members*

Moderators: Marinus de Kleuver, MD, PhD; Muharrem Yazici, MD

Section 1: The sine qua non of Good Clinical Practice: A Mentally and Physically Healthy Surgeon

12:15 - 12:20 **Practicing Safely in a Medicolegal World: How to Stay Away from Malpractice Without Practicing Defensive Medicine**
Robert K. Eastlack, MD

12:20 - 12:25 **The Surgeon as the Instrument: Physical Endurance, Mental Focus, and Sustainable Excellence**
Todd Albert, MD

12:25 - 12:30 **When the Surgeon Becomes the Second Victim: Recovering After Complications, Adverse Events and Outcomes**
Marinus de Kleuver, MD, PhD

12:30 - 12:35 **Discussion**

Section 2: Scientific World Citizenship: SRS as a Facilitator of Academic Leadership and Global Networking

12:35 - 12:40 **Traveling Fellowship as a Transformative Academic Journey: Seeing the World Through Another Surgeon's Eyes**
Kariman Abelin Genevois, MD, PhD

12:40 - 12:45 **The LEAD Program: From Young Surgeon to Global Academic Leader**
Christina Hardesty, MD

12:45 - 12:50 **Scholarship Programs and Global Equity: Opening the Door for Talent Everywhere**
Qianyu Zhuang, MD

12:50 - 12:55 **Discussion**

Section 3: Answering Difficult Spinal Deformity Questions in the Language of SRS

Case 1: Severe Pediatric Kyphosis After Spinal Infection: How Early Is Too Early for Reconstruction?

12:55 - 12:58 **Case Presentation**
Saumyajit Basu, MD

12:58 - 13:05 **Discussion**

13:05 - 13:07 **Case Resolution**
Saumyajit Basu, MD

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Case 2: Progressive Neuromuscular Deformity in a Medically Fragile Child: When Does Surgery Serve the Patient Best?

13:07 - 13:10 **Case Presentation**
Muharrem Yazici, MD

13:10 - 13:17 **Discussion**

13:17 - 13:19 **Case Resolution**
Muharrem Yazici, MD

13:19 - 13:29 **How to Become an SRS Member**
Gregory M. Mundis, Jr., MD

13:29 - 13:30 **Closing Message**
Marinus de Kleuver, MD, PhD; Muharrem Yazici, MD

13:30 - 13:45 **Break**

13:45 - 15:30 Darling Harbour Theatre *(concurrent session)*

Half Day Course 2: Debate-Style Discussion: Different Approaches to Different Problems ■○

Moderators: Ronald A. Lehman, Jr., MD; Daniel J. Sucato, MD, MS

Pediatric Transition Debates

Are We Ready to Fully Adopt VBT for AIS?

13:45 - 13:50 **Yes - Motion Preservation is Key**
Amer F. Samdani, MD

13:50 - 13:55 **No - Fusion is King**
Tenner Guillaume, MD

13:55 - 14:02 **Discussion**

Pedicle Screw Placement in 2026

14:02 - 14:07 **Freehand/Fluoro More Efficient**
Heiko Koller, MD, PhD

14:07 - 14:12 **Enabling Technology is Here to Stay**
David L. Skaggs, MD, MMM

14:12 - 14:20 **Discussion**

Bracing Paradigm: Should the Goals Change?

14:20 - 14:25 **Stay the Historical Course: Prevent Progression**
Kenny Y.H. Kwan, BMBCh(Oxon), FRCSEd

14:25 - 14:30 **Permanent Improvement Should be the Goal**
Michael B. Johnson, MD, PhD

14:30 - 14:37 **Discussion**

Transition Debates

Tethers Are "Great", But What to Do When They Fail?

14:37 - 14:42 **Peds: Revision Tether - Keep the Motion**
Peter O. Newton, MD

14:42 - 14:47 **Peds/Adult: Do What You Should Have Done in the First Place - Fuse Them!**
Ronald A. Lehman, Jr., MD

14:47 - 14:55 **Discussion**

AIS vs. AdIS - When to Intervene?

14:55 - 15:00 **Peds: The Earlier the Better**
Baron S. Lonner, MD

15:00 - 15:05 **Adult: "Let Them Be Kids" - Wait Until They Become Young Adults!**
Joseph M. Lombardi, MD

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15:05 - 15:12 **Discussion**

High Grade Sponydlolisthesis: Are the Considerations Different?

15:12 - 15:17 **Peds: Grade 4 - Should We Reduce? Risks and Outcomes**
Qianyu Zhuang, MD

15:17 - 15:22 **Adult: Grade 4 - This is a Different Animal (A/P vs. All Post) - Restore Sagittal Alignment**
Khaled M. Kebaish, MD

15:22 - 15:30 **Discussion**

13:45-15:30 **Pyrmont Theatre** *(concurrent session)*

Abstract Session 8: Adult Spinal Deformity III: Optimizing Patient Condition: The Game Changer ○

Moderators: Marc Khalife, MD, PhD, MS & Ferran Pellisé, MD, PhD

13:45 - 13:49 **Paper #105: Biological Age Predicts Short-Term Outcomes After Adult Spinal Deformity Surgery**
Ritvik Jillala, BS; Arjun Menta, BS; Patrick Kramer, MD; Jawad M. Khalifeh, MD; Liam Hughes, MD; Jacob Jo, MD; Daniel Lubelski, MD; Timothy Witham, MD; *Tej Azad, MD*

13:49 - 13:53 **Paper #106: Surgical Correction of ASD Is Associated with Slower Epigenetic Age Acceleration**
Travis Kotzur, MD; Lane H. McCoy, BS; John OMalley, MD; Nicholas A. Pallotta, MD, MS; Munish C. Gupta, MD, MBA; *Brian J. Neuman, MD*

13:53 - 13:57 **Paper #107: Insulin-like Growth Factor Outperforms Sarcopenia as a Predictor of Postoperative Recovery**
Alexander Upfill-Brown, MD, MS; Han Jo Kim, MD; Anthony Lewis, BS; Annika Bay, MD; Atahan Durbas, MD; Andrea Pezzi, MD; Mihir Dekhne, MD; David Foley, MD; Gregory Kazarian, MD; Christopher Yoo, BS; Chierika O Ukogu, MD; Zora Hahn, BS; Matthew E. Cunningham, MD, PhD; *Francis Lovecchio, MD*

13:57 - 14:06 **Discussion**

14:06 - 14:10 **Paper #108: Osteosarcopenia of the Spine Drives Mechanical Complications After Thoracolumbar Adult Spine Deformity Operations**
David Chung, MD; Weston Wright, BS; Justin K. Scheer, MD; Alexander Tuchman, MD; *Corey T. Walker, MD*

14:10 - 14:14 **Paper #109: Preoperative Musculoskeletal Burden Predicts 1-Year Junctional Complications After Adult Spinal Deformity Surgery**
Bassel G. Diebo, MD; *Joseph E. Nassar, BS;* Michael Farias, BS; Micheal Raad, MD; Feyza Achilova; Virginie Lafage, PhD; Renaud Lafage, MS; Richard Hostin, MD; Peter G. Passias, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Themistocles S. Protopsaltis, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Munish C. Gupta, MD, MBA; Brett Rocos, MD, FRCS; Jeffrey Mullin, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Christopher P. Ames, MD; Lawrence G. Lenke, MD; Sang Hun Lee, MD, PhD; Khaled M. Kebaish, MD; Shay Bess, MD; Alan H. Daniels, MD; International Spine Study Group

14:14 - 14:18 **Paper #110: Adult Spinal Deformity Surgery in Patients with Lower Extremity Weakness: Do Preoperative Neurologic Deficits Influence Outcomes?**
Scott Zuckerman, MD; Harsh Jain, MBBS; Byron F. Stephens, MD; Thomas Buell, MD; Nima Alan, MD; Sang Hun Lee, MD, PhD; David O. Okonkwo, MD, PhD; Stephen J. Lewis, MD, FRCS(C); Jeffrey Mullin, MD; Peter G. Passias, MD; Darryl Lau, MD; *Anthony L. Mikula, MD*; Jay D. Turner, MD, PhD; Joshua Bunch, MD; Brandon B. Carlson, MD; Michael P. Kelly, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Eric O. Klineberg, MD; Han Jo Kim, MD; Breton Line; Themistocles S. Protopsaltis, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Khaled M. Kebaish, MD; Paul Park, MD; Praveen V. Mummaneni, MD; Munish C. Gupta, MD, MBA; Jeffrey Gum, MD; Alan H. Daniels, MD; Bassel G. Diebo, MD; Richard Hostin, MD; Justin K. Scheer, MD; Lawrence G. Lenke, MD; Frank Schwab, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; International Spine Study Group

14:18 - 14:27 **Discussion**

14:27 - 14:31 **Paper #111: Impact of Enhanced Recovery After Surgery (ERAS) Protocol on Postoperative Pain and Clinical Recovery in Adult Spinal Deformity Surgery**
Yu-Cheng Yao, MD; Jing-Yang Liou, MD, PhD; Hsin-Yi Wang, MD; Po-Hsin Chou, MD, PhD; Shih-Tien Wang, MD

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14:31 - 14:35 **Paper #112: Implications of Non-Tobacco Nicotine Use on Adult Spinal Deformity Surgery**
Shanthi Deivanayagam, BS; Kendyl Howell, BS; Bradley M. Rao, BS; Madeline Hasson, BS; Josephine Coury, MD; Taylor Jackson, MD; Michael Strong, MD, PhD, MS; Omkar Anaspure, BS; Ziad Hassan, BS; David Casper, MD; Amrit Khalsa, MD; Lawrence G. Lenke, MD; *Andrew S. Zhang, MD*

14:35 - 14:39 **Paper #113: Utility of Chemical Anticoagulation After Adult Spinal Deformity Surgery: A Retrospective Cohort Study**
Bradley M. Rao, BS; Ziad Hassan, BS; Amanda M. Moser, MD, BA; Omkar Anaspure, BS; Madeline Hasson, BS; *Tensae Assefa, MD*; Nnaemeka Okorie, MD; Josephine Coury, MD; Taylor Jackson, MD; Michael Strong, MD, PhD, MS; David Casper, MD; Amrit Khalsa, MD; Lawrence G. Lenke, MD; Andrew S. Zhang, MD

14:39 - 14:48 **Discussion**

14:48 - 14:52 **Paper #114: Diagnostic and Predictive Value of Upright–Supine Imaging for Treatment Selection in Degenerative Lumbar Spondylolisthesis - A Two-Year PROM Based Comparison with Flexion Extension Radiographs**
Tom Folkerts, MD; Julia Wimmer, MD; Anna-Maria Mielke, MD; Lukas Schonnagel, MD; Bruno Verna, MD; Pedro Augusto Rocha Torres, MD; Paul Koehli, MD; Jiaqi Zhu; Jennifer Shue, MS; Roland Duculan, MD; Andrew A. Sama, MD; Federico P. Girardi, MD; Frank P. Cammisa Jr, MD; Carol A. Mancuso, MD; Marco D. Burkhard, MD; Alexander P. Hughes, MD

14:52 - 14:56 **Paper #115: More is better! Multicenter Analysis of Failure Rates and Risk Factors Between Bilateral Single and Multiple Pelvic Fixation in Adult Spinal Deformity Surgery**
Pawel P. Jankowski, MD; Paritash Tahmasebpour, MD; Spencer Matthews, MS; Christopher J. Kleck, MD; David C. Ou-Yang, MD; David W. Polly Jr, MD; Jiandong Hao, BS; Harsh Jain, MBBS; Jack Strobeck, BS; Aaron Hockley, MD; Robert K. Eastlack, MD; Benjamin D. Elder, MD, PhD; Sohaib Hashmi, MD; Scott Zuckerman, MD; Daniel M. Sciubba, MD; Peter G. Passias, MD

14:56 - 15:00 **Paper #116: Comparison of Perioperative Outcomes and Frailty in Minimally Invasive and Open Surgery for Adult Spinal Deformity: A Multi-Center Analysis**
David D. Liu, MD; Jay Kumar, MD; Jang Yoon, MD, MS; Praveen V. Mummaneni, MD; Vivian P. Le, MPH; Dean Chou, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Adam S. Kanter, MD; David O. Okonkwo, MD, PhD; Paul Park, MD; Neel Anand, MD, Mch. Orth; Pierce D. Nunley, MD; Michael Y. Wang, MD; Jay D. Turner, MD, PhD; Richard G. Fessler, MD, PhD; Ricardo Fontes, MD, PhD; *KaiMing G. Fu, MD, PhD*; Andrew K. Chan, MD; Nima Alan, MD; Peter G. Passias, MD; Shay Bess, MD; Juan S. Uribe, MD; International Spine Study Group

15:00 - 15:09 **Discussion**

15:09 - 15:13 **Paper #117: Early Postoperative Neurologic Course is the Primary Determinant of Long-Term Lower Extremity Motor Recovery After ASD Surgery**
Fthimnir Hassan, MPH; Lawrence G. Lenke, MD; Erik Lewerenz, BS; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Peter G. Passias, MD; Eric O. Klineberg, MD; Kojo D. Hamilton, MD, FAANS; Jeffrey Gum, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Khaled M. Kebaish, MD; Alan H. Daniels, MD; Robert K. Eastlack, MD; Munish C. Gupta, MD, MBA; Gregory M. Mundis Jr, MD; Richard Hostin, MD; Juan S. Uribe, MD; Neel Anand, MD, Mch. Orth; Jay D. Turner, MD, PhD; Pierce D. Nunley, MD; Michael Y. Wang, MD; Adam S. Kanter, MD; Lee A. Tan, MD; Praveen V. Mummaneni, MD; Christopher I. Shaffrey, MD; Christopher P. Ames, MD; Shay Bess, MD; International Spine Study Group

15:13 - 15:17 **Paper #118: Neurologic Deficit Recovery After Revision Pedicle Subtraction Osteotomy for Fixed Sagittal Imbalance in Previously Fused Adults and its Impact on Patient-Reported Outcomes**
Julio J. Jauregui, MD; Sapan Patel, BS; Hershil Patel, BS; Maksim A. Shlykov, MD, MS; Michael Kelly, MD; Rohit Kaul. Bhan, MD, MS; Camilo A. Molina, MD; Tomas Ries, MD; Laviel Fernandez, MD; Taryn E. LeRoy, MD; Keith H. Bridwell, MD; Munish C. Gupta, MD, MBA

15:17 - 15:21 **Paper #119: Understanding Bilateral MEP Changes during Cord Level Spinal Deformity Surgery: Etiology, Significance and Response**
Brian J. Neuman, MD; Stephen J. Lewis, MD, FRCS(C); Lawrence G. Lenke, MD; Ferran Pellisé, MD, PhD; Ahmet Alanay, MD; Justin S. Smith, MD, PhD; Yong Qiu, PhD; Nasir A. Quraishi, PhD, FRCS; Saumyajit Basu, MS (Ortho), DNB (Ortho), FRCS (Ed); Go Yoshida, MD, PhD; Randolph Gray, MBBS, FRCS; Zeeshan M. Sardar, MD; Michael P. Kelly, MD

15:21 - 15:30 **Discussion**

15:30 - 15:50 Refreshment Break | The Gallery

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15:50 - 18:00 **Darling Harbour Theatre** *(concurrent session)*

Abstract Session 9A: Quality/Safety/Value/Complications

Moderators: Jennifer M. Bauer, MD, MS & Sleiman Haddad, MD, PhD, FRCS

15:50 - 15:54 **Paper #120: Development of an Intraoperative Assessment Tool for Predicting Critical Care Transfer Following Major Posterior Spine Surgery**
Devika Shenoy, BS; Katelyn E. Parsons, BS; Evelyn Hunter, BS; Andrew Lopolito, BS; HuiJie Lee, PhD; Lexie Z. Yang, MB; Bo Hu, PhD; *Brett Rocos, MD, FRCS*

15:54 - 15:58 **Paper #121: Efficacy of Oral Silodosin for Preventing Postoperative Urinary Retention (POUR) Following Elective Spine Surgery: A Single-Blind Randomized Controlled Trial**
Vidyadhara Srinivasa, MD, MS; Dinesh Iyer, MS; Abhishek Soni, MD; Balamurugan Thirugnanam, MS,

15:58 - 16:02 **Paper #122: Delayed Extubation following Corrective Surgery for Severe Kyphoscoliosis: What are the Roles of Pulmonary Arterial Hypertension and Chronic Respiratory Failure?**
Zhen Liu, PhD; Xiaodong Qin, PhD; Saihu Mao, MD; Xiaokang Wang, MD; Yong Qiu, PhD; Zezhang Zhu, MD, PhD

16:02 - 16:11 **Discussion**

16:11 - 16:15 **Paper #123: Transitioning from Preoperative Control to Postoperative Risk: Loss of Postoperative Glycemic Control Increases Pseudoarthrosis After Adult Spinal Deformity Surgery**
Travis Kotzur, MD; Lane H. McCoy, BS; *Mark Lambrechts, MD*; Alex Miller, MD; Brian J. Neuman, MD

16:15 - 16:19 **Paper #124: Recombinant Human Bone Morphogenetic Protein-2 (BMP) Reduces Long-Term Cost by Decreasing Revision Surgery in Adult Spinal Deformity**
David D. Liu, MD; *Shay Bess, MD;* Breton Line; Christopher P. Ames, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Jeffrey Gum, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Eric O. Klineberg, MD; Alan H. Daniels, MD; Munish C. Gupta, MD, MBA; Kojo D. Hamilton, MD, FAANS; Richard Hostin, MD; Praveen V. Mummaneni, MD; Pierce D. Nunley, MD; David O. Okonkwo, MD, PhD; Michael P. Kelly, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Khaled M. Kebaish, MD; Han Jo Kim, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; International Spine Study Group

16:19 - 16:23 **Paper #125: Does Osseointegrative Pelvic Fixation Eliminate Traditional Pelvic Fixation Loosening?**
Obiajulu Agha, MD; Bahar Shahidi, PhD; Gautham Prabhakar, MD; Timothy Choi, MD; Gregory M. Mundis Jr, MD; Robert K. Eastlack, MD

16:23 - 16:32 **Discussion**

16:32 - 16:36 **Paper #126: Evolution of Minimally Invasive Adult Spinal Deformity Surgery Over Time: A Multi-Center Study**
Jay Kumar, MD; David D. Liu, MD; Jang Yoon, MD, MS; Dean Chou, MD; *Robert K. Eastlack, MD*; Gregory M. Mundis Jr, MD; Adam S. Kanter, MD; David O. Okonkwo, MD, PhD; Paul Park, MD; Neel Anand, MD, Mch. Orth; Pierce D. Nunley, MD; Juan S. Uribe, MD; Jay D. Turner, MD, PhD; Michael Y. Wang, MD; Richard G. Fessler, MD, PhD; Ricardo Fontes, MD, PhD; KaiMing G. Fu, MD, PhD; Andrew K. Chan, MD; Nima Alan, MD; Vivian P. Le, MPH; Peter G. Passias, MD; Shay Bess, MD; Praveen V. Mummaneni, MD; International Spine Study Group

16:36 - 16:40 **Paper #127: Prophylactic Concave-side Decompression and Spinal Cord Medialization Reduces Neurological Complications in Severe Kyphoscoliosis with Type 3 Cord Morphology**
Yutong Dai, MD; Ben Long Shi, MD; Zhen Liu, PhD; Saihu Mao, MD; Yong Qiu, PhD; *Zezhang Zhu, MD, PhD*

16:40 - 16:44 **Paper #128: Long-Term Neurological Outcomes Following Significant Intraoperative Neuromonitoring Alarms: A Longitudinal Study of 115 Patients with Severe Spinal Deformities**
Tianyuan Zhang, MD, PhD; Junlin Yang, MD, PhD; Yaolong Deng, MD

16:44 - 16:53 **Discussion**

16:53 - 16:57 **Paper #129: Current Intra-Operative Neuromonitoring Protocols Fail to Reliably Detect New Neurological Deficits in 3COs Performed Below the Conus**
Stephen J. Lewis, MD, FRCS(C); Ran Ankory, MD; So Kato, MD, PhD; Justin S. Smith, MD, PhD; Michael P. Kelly, MD; Brian J. Neuman, MD; Munish C. Gupta, MD, MBA; Christopher J. Nielsen, MD; Yukihiro Matsuyama, MD, PhD; Yong Qiu, PhD; Lawrence G. Lenke, MD

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16:57 - 17:01 **Paper #130: Machine Learning (ML) in Intraoperative Neuromonitoring (IONM): Updated Model Integrating Hemodynamic Data Detects Changes 35 Minutes Earlier Than Traditional IONM Surveillance**
Varun Arvind, MD, PhD; Anil Mendiratta, MD; Mehdi Elfilali, BA; Madeline C. Monness, BSA; Erik Williams, BS; Miles Bomback, BA, MPH; Michael W. Brown, BS; Alexander Park, BS; Omar Taha, BS; Matthew Weintraub, BS; *Michael G. Vitale, MD, MPH*

17:01 - 17:05 **Paper #131: Influence of Baseline IONM Data Quality on Neuromonitoring Performance and Surgical Actions in Pediatric Spinal Deformity Surgery**
Christopher K. Bozorgmehr, BS; Leah Rakers, MBS, CNIM; *Scott John Luhmann, MD*

17:05 - 17:14 **Discussion**

17:14 - 17:18 **Paper #132: Free hand vs navigation guided pedicle screw insertion in scoliosis - an analysis of 5000 screws using intra operative low dose CT scan**
Ahmad Hussien, MD; Sai Balasubramanian, MBBS, MS; Paul Cool, FRCS; Jayesh Trivedi, FRCS; Neil T. Davidson, MBBS, FRCS; *Sudarshan Munigangaiah, FRCS*

17:18 - 17:22 **Paper #134: 10-Year Review of 24,140 Freehand Pedicle Screws Placed in the Thoracic, Lumbar and Sacral Spine for Pediatric and Adult Spinal Deformity: Is This Still a Relevant Technique?**
Meredith Luhmann, BS; Amrit Singh, MPH; Erik Lewerenz, BS; *Lawrence G. Lenke, MD*

17:22 - 17:26 **Paper #135: How Low Can We Go? Can We Further Reduce Radiation Exposure During Scoliosis Radiographic Examination?**
Rachelle Imbeault; Marjolaine Roy-Beaudry; Justin Dufresne; Sylvain Deschenes, PhD; *Stefan Parent, MD, PhD*

17:26 - 17:35 **Discussion**

17:35 - 17:39 **Paper #136: Implant Density and Deformity Angular Ratio Predict Risk of Complications in Three-Column Osteotomies**
Travis S. CreveCoeur, MD; Alexander J. Schupper, MD; Amer F. Samdani, MD; Joshua M. Pahys, MD; Terrence G. Ishmael, MBBS; Benjamin A. Schmidt, BA; Joshua McCalister-Afflick, BS; Emily Nice, BS; *Steven W. Hwang, MD*

17:39 - 17:43 **Paper #137: Rod Diameter, Material, and Texture Influence Screw-Rod Fixation Strength in Spinopelvic Construct**
Cale J. Hendricks, BS; Samuel Hendricks, BS; *David W. Polly Jr, MD;* Arin M. Ellingson, PhD

17:43 - 17:47 **Paper #138: Time-to-Failure Analysis of Implant Constructs in Severe Spinal Deformity Surgery: Seven-Year Outcomes from a West African Cohort**
Kwadwo Poku Yankey, MD; Derrick Nyantakyi Owusu, MS; Arthur Sackeyfio, MD; Sarah Kyerewaa. Obiri, BS; Liudmila Gross, MD; Irene Adorkor. Wulff, MD; Francis Addai, MD; Benjamin Hayfron. Blackson, MD; Oheneba BoachieAdjei, MD

17:47 - 17:51 **Paper #139: Do Patient-Specific Precontoured Rods Justify a Ten-Fold Increase in Cost Compared with Manual Contouring in Adolescent Spinal Deformity Surgery?**
Matthew Miyasaka, AB*; Alexander Fleisher, BS;* Kingsley Ogelle, BS; Alexander Kucherina, BS; Mina Eskandar, MS, BS; Garima Paul, MD; Constance Maglaras, PhD; Themistocles S. Protopsaltis, MD; Juan Carlos Rodriguez-Olaverri, MD

17:51 - 18:00 **Discussion**

15:50-18:00 Pyrmont Theatre *(concurrent session)*

Abstract Session 9B: Early Onset Scoliosis & Kyphosis ■

Moderators: Arun Hariharan, MD, MS & Haemish Crawford, FRACS

15:50 - 15:54 **Paper #140: Intraoperative Neuromonitoring Alerts During Surgery for Congenital Spinal Deformity: Prevalence, Risk Factors, and Outcomes in a Prospective Study of 100 Patients**
Anuj Gupta, MD; Brett Shannon, MD; Petya Yorgova, MS; Paul D. Sponseller, MD; Oheneba Boachie-Adjei, MD; Jennifer M. Bauer, MD, MS; Burt Yaszay, MD; Purnendu Gupta, MD; Kwadwo Poku Yankey, MD; Munish C. Gupta, MD, MBA; Lawrence G. Lenke, MD; Peter O. Newton, MD; Michael P. Kelly, MD; Amer F. Samdani, MD; Joshua M. Pahys, MD; Daniel J. Sucato, MD, MS; David B. Bumpass, MD; *Suken A. Shah, MD*

15:54 - 15:58 **Paper #141: Impact of Age at Growing Rod Insertion on Final T1-T12 Spinal Height**
Blake K. Montgomery, MD; Patrick J. Cahill, MD; Scott John. Luhmann, MD; Jason Brett. Anari, MD; Simon Y. Tang, PhD; Pediatric Spine Study Group; Michael J. Heffernan, MD; Brett Lullo, MD

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MEETING AGENDA

FRIDAY, OCTOBER 9, 2026

Program (topics, timing, and faculty) is subject to change.

15:58 - 16:02 **Paper #142: Physical Function of Early-Onset Scoliosis: An International Multisite Prospective Study**
Karina Amani. Zapata, PhD, DPT; Tiffany Thompson, BS; Terrence G. Ishmael, MBBS; Arthur Sackeyfio, MD; Kwadwo Poku Yankey, MD; Michelle C. Welborn, MD; Benjamin A. Schmidt, BA; Amareesa Robinson, BS; Sarah Kyerewaa. Obiri, BS; Hayley Shelton; Joshua McCalister-Afflick, BS; *Jayson Brooks, MD*; Pediatric Spine Study Group; Amy Lynn. McIntosh, MD

16:02 - 16:11 **Discussion**

16:11 - 16:15 **Paper #143: Proximal Junctional Kyphosis in Distraction-Based Growth-Friendly Treatment: Definition, Risk Factors, and Timeline**
Ataberk Beydemir, MD; Rafik Ramazanov, MD; Mehmet Berktas, MD; Mehmet Ayvaz, MD; Gokhan Halil. Demirkiran, MD; *Muharrem Yazici, MD*

16:15 - 16:19 **Paper #144: Crankshaft Phenomenon and Its Related Factors Following Traditional Growing Rod Surgery in Early-Onset Scoliosis: A Computed Tomography-based Analysis**
Hong Jin Kim, MD, PhD; Hyung Rae Lee, MD; Subin Lim, MD; *Jae Hyuk Yang, MD, PhD*; Seung Woo Suh, MD, PhD

16:19 - 16:23 **Paper #145: Implant Survival after Graduation by "Observation" in Patients Treated with Growing Rods: A 10-year Follow-up Study**
Ana Hurtado, MD; Gloria Talavera, MD; Lucia Moreno-Manzanaro, BS; Irene Zarcos, MD; Jose Miguel Sanchez-Marquez, MD, PhD; Nicomedes FernandezBaillo, MD; *Javier Pizones, MD, PhD*

16:23 - 16:32 **Discussion**

16:32 - 16:36 **Paper #146: Staged Growing-Rod Implantation Is Associated with Lower Rates of Reoperation-Requiring Complications in Extremely Severe Early-Onset Scoliosis**
Kota Watanabe, MD, PhD; Satoshi Suzuki, MD, PhD; Kazuki Takeda, MD, PhD; Takahito Iga, MD, PhD; Toshiki Okubo, MD, PhD; Masahiro Ozaki, MD, PhD; Narihito Nagoshi, MD, PhD; Morio Matsumoto, MD, PhD; Masaya Nakamura, MD, PhD

16:36 - 16:40 **Paper #147: Growth Guidance or Posterior Based Distraction in EOS: Can the Modified Clavien-Dindo-Sink Classification System Tell Them Apart?**
Rayyan Abid; Jason Brett. Anari, MD; *Christina K. Hardesty, MD*; Katerina M. Kourpas, AB; Stone R. Streeter, BS; Pediatric Spine Study Group

16:40 - 16:44 **Paper #148: Revision Surgery for Deep Surgical Site Infection Differs by Instrumentation Type but Is Not Associated with Inferior Patient-Reported Outcomes in Early-Onset Scoliosis**
Antti Juhani. Saarinen, MD, PhD; John T. Smith, MD; Paul D. Sponseller, MD; Amer F. Samdani, MD; John (Jack) M. Flynn, MD; Michael G. Vitale, MD, MPH; Pediatric Spine Study Group; *Ilkka J. Helenius, MD, PhD*

16:44 - 16:53 **Discussion**

16:53 - 16:57 **Paper #149: Radiographic and Functional Outcomes for Sagittal Alignment in Growth Rod Graduates: Are We Able to Rebuild it?**
Anuj Gupta, MD; Brett Shannon, MD; Benjamin Crain, MD; Petya Yorgova, MS; Paul D. Sponseller, MD; Lindsay M. Andras, MD; Pediatric Spine Study Group; *Suken A. Shah, MD*

16:57 - 17:01 **Paper #150: Effect of Distraction-based Growth Friendly Implants on Spinopelvic Parameters and Health-Related Quality of Life after Growth-Friendly Spine Surgery in EOS Patients at a Minimum of 5 Years Follow-up**
Todd F. Ritzman, MD; Dominick A. Tuason, MD; Jaime A. Gomez, MD; Patrick J. Cahill, MD; Mark A. Erickson, MD; Sumeet Garg, MD; Scott John. Luhmann, MD; Paul D. Sponseller, MD; Michael G. Vitale, MD, MPH; Pediatric Spine Study Group

17:01 - 17:05 **Paper #151: Long-term Outcomes in Adulthood Following Traditional Growing Rods for Early-Onset Scoliosis**
Masaaki Ito, MD, PhD; Teppei Suzuki, MD, PhD; Koki Uno, MD, PhD

17:05 - 17:14 **Discussion**

17:14 - 17:18 **Paper #152: Congenital Scoliosis: An Update to Its Natural History and Clinical Approach**
Mihir Sharma, BS; Alexander Bhatt, MS; Jason Brenner, BS; Ashlyn Callan, MS; Priya Singh, MD; Edina Gjonbalaj, BS; Pediatric Spine Study Group; Jacob F. Schulz, MD; Leila Mehraban Alvandi, PhD; *Jaime A. Gomez, MD*

17:18 - 17:22 **Paper #153: The Interesting Morphological Changes of Adjacent Vertebra after Posterior Hemivertebrectomy with Unilateral Short Segment Fusion for Long-Term Follow-up in Children**
Xuhong Xue, MD, PhD; Kai Li, MD; Sheng Zhao, MD

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17:22 - 17:26 **Paper #154: Three Year Results of a Randomized Controlled Trial Comparing Two Novel Distraction-Based Devices for Neuromuscular Early Onset Scoliosis**
Justin VC. Lemans, MD, PhD; Casper S. Tabeling, MD; Hilde W. Stempels; Agnita Stadhouder, MD; Jeroen Renkens, MD; Lotfi Miladi, MD; Tom PC. Schlosser, MD, PhD; René M. Castelein, MD, PhD; Moyo C. Kruyt, MD, PhD

17:26 - 17:35 **Discussion**

17:35 - 17:39 **Paper #155: Spinopelvic Alignment Parameters using the T4L1PA Hip Axis Predicts PJK and Reoperation in Scheuermann's Kyphosis Correction**
Brandon A. Ramo, MD; Jesse Patton. Robinette, MD; Anna McClung-Booth; Matthew Siebert, MD; Megan Johnson, MD

17:39 - 17:43 **Paper #156: Aiming to Stop More Proximally When Determining Distal Fusion Level According to Stable Sagittal Vertebra in Scheuermann's Kyphosis. Comparison of Two X-ray Methods: Lateral Traction Under General Anesthesia vs Standing Full-spine Lateral X-ray**
Hamisi Mwarindano Mraja, MD; Ibrahim Dag, MD; Sepehr Asadollahmonfared, MD; Mustafa Buğra Ayaz, MD; Ahmet Hamdi Olcar, MD; Burak Abay, MD; Mehmet Zamanoglu, MD; Ilyas Dolas, MD; Sinan Kahraman, MD; *Meric Enercan, MD;* Selhan Karadereler, MD; Azmi Hamzaoglu, MD

17:43 - 17:47 **Paper #157: Operative Treatment for Scheuermann Kyphosis: A Comparison of Outcomes Between Adult and Adolescent Patients**
Alan H. Daniels, MD; Amer F. Samdani, MD; Michael Farias, BS; Joseph E. Nassar, BS; David D. Liu, MD; Bassel G. Diebo, MD; Peter O. Newton, MD; Feyza Achilova; Lawrence G. Lenke, MD; Jeffrey Gum, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Shay Bess, MD; *Baron S. Lonner, MD*; Harms Study Group; International Spine Study Group

17:47 - 17:56 **Paper #158: Surgical Treatment of Post-tuberculosis Kyphosis with Ossification of Ligamentum Flavum: Identification of the Primary Causes of Neurological Deficits**
Jiahao Zhang, MD; Jiale Zhu, MS; Yan Zeng, MD

17:56 - 18:00 **Discussion**

18:30 - 19:30 President's Reception* (by invitation only)

19:30 - 22:00 Farewell Reception* (ticket required)

Open to all registered attendees and guests of registered attendees. Registration is required and tickets must be purchased in advance. Tickets are $50 for registered attendees and guest tickets may be purchased for $150 per guest.

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MEETING AGENDA

SATURDAY, OCTOBER 10, 2026

Program (topics, timing, and faculty) is subject to change.

08:00 - 10:10 Darling Harbour Theatre

Abstract Session 10: Adolescent Idiopathic Scoliosis III, Award Presentation & Transfer of the Presidency ■

Moderators: Michelle Welborn, MD & Reuben CC Soh, MBBS, FRCS

08:00 - 08:04 **Paper #159: Predicting the Benefit of Bracing for Adolescent Idiopathic Scoliosis Using Sanders Maturity Stages**
Lori A. Dolan, PhD; Stuart Leslie Weinstein, MD; *Donna J. Oeffinger, PhD*; Richard Michael Schwend, MD; BrAIST Study Group

08:04 - 08:08 **Paper #160: In-brace Correction May Gate the Effect of Wear Time on Curve Regression in AIS Bracing**
Tomoyuki Asada, MD, PhD; Toshiaki Kotani, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Yasushi Iijima, MD, PhD; Yusuke Setojima, MD; Kotaro Sakashita, MD; Yosuke Ogata, MD; Shohei Minami, MD, PhD; Seiji Ohtori, MD; Yasuhiro Homma, MD, PhD

08:08 - 08:12 **Paper #161: In-Brace Correction, Wear-time Compliance, and Outcomes in TLSO Bracing for Adolescent Idiopathic Scoliosis**
Donna J. Oeffinger, PhD; Shelby White, PhD; Vincent Prusick, MD; Vishwas R. Talwalkar, MD

08:12 - 08:21 **Discussion**

08:21 - 08:25 **Paper #162: Radiographic and Pulmonary Function Outcomes in Lenke 4-6 (TL/L-Dominant) Adolescent Idiopathic Scoliosis: Relationship to Diaphragm Intrusion**
Zaid Elsabbagh, BS; William ElNemer, BS; Eric Mao, BA; Peter G. Gabos, MD; Gregory Redding, MD; Baron S. Lonner, MD; Firoz Miyanji, MD, FRCS(C); Peter O. Newton, MD; Paul D. Sponseller, MD

08:25 - 08:29 **Paper #163: Contextualizing Chest Radiograph–Based Pulmonary Function Estimation in Scoliosis Using Multimodal Deep Learning**
Beomsu Kim, MD; Wounsuk Rhee, MD; Ihnseok Chae, MD; *Jeuk Lee, MD*; Sung Taeck Kim, MD; Bong-Soon Chang, MD, PhD; Sam Yeol Chang, MD; Hyoungmin Kim, MD

08:29 - 08:33 **Paper #164: Postoperative Anemia Predisposes to Serious Complications Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis**
Josephine R. Coury, MD; Fthimnir Hassan, MPH; Mehdi Elfilali, BA; Alexander Park, BS; Mia OConnell, BS; Michael W. Brown, BS; Justin L. Reyes, MS; Nicholas Laskay, MD; Evan Joiner, MD; Lawal A. Labaran, MD; Matthew Elliot. Simhon, MD; Zeeshan M. Sardar, MD; Benjamin D. Roye, MD; Michael G. Vitale, MD, MPH; Lawrence G. Lenke, MD

08:33 - 08:42 **Discussion**

08:42 - 08:46 **Paper #165: Biomechanical analysis of Ponte-osteotomies vs No Osteotomies in Adolescent Idiopathic Scoliosis (AIS) – Radiographic Analysis from Randomized Clinical Trial**
Matti Ahonen, MD, PhD; Johanna Syvänen, MD, PhD; Linda Helenius, MD, PhD; Jenni Jalkanen, MD, PhD; Aarno Nietosvaara, MD, PhD; Antti Juhani. Saarinen, MD, PhD; Ilkka J. Helenius, MD, PhD

08:46 - 08:50 **Paper #166: Determining the Optimal Extent of Rib Resection during Thoracoplasty with Respect to Pulmonary Function in Adolescent Idiopathic Scoliosis**
Hong Jin Kim, MD, PhD; Hyung Rae Lee, MD; Jae Hyuk Yang, MD, PhD; Subin Lim, MD; Seung Woo Suh, MD, PhD

08:50 - 08:54 **Paper #167: Effectiveness of Dual Rod Translation in Thoracic Kyphosis Restoration for AIS: A Comparison with the Conventional Technique**
Yusuke Hori, MD, PhD; Takashi Namikawa, MD, PhD; Masaki Kawamura, MD; Brando Guarrera, MD; Akira Matsumura, MD, PhD

08:54 - 09:03 **Discussion**

09:03 - 09:07 **Paper #168: Manual Rod Contouring is Non-Inferior to Patient-Specific Rods for Achieving Goal Alignment in Adolescent Idiopathic Scoliosis**
Conner Paez, MD; Julienne Ryland, DO; Alexandria Rundell, BS; Richard P. Steiner, PhD; *Todd F. Ritzman, MD;* Lorena Floccari, MD

09:07 - 09:11 **Paper #169: Patient-specific Rod Planning is Often Too Optimistic in Hypokyphotic Adolescent Idiopathic Scoliosis Patients**
Aren Joe Bizdikian, MD, MS; Jean-Charles Serero, MD; Anne Laure Simon, MD, PhD; *Brice Ilharreborde, MD, PhD*

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09:11 - 09:15 **Paper #170: Does Preoperative Pelvic Incidence Influence Postoperative Sagittal Balance? Evaluation of Standardized Rod Curvature in AIS Surgery**
Katsuhisa Yamada, MD, PhD; Akira Fukushima, MD; Soya Miura, MD; Terufumi Kokabu, MD; Takashi Ohnishi, MD, PhD; Hiroyuki Tachi, MD; Hideki Sudo, MD, PhD

09:15 - 09:24 **Discussion**

09:24 - 09:28 **Paper #171: Utilizing Intrathecal Morphine in Rapid Recovery Pathway Protocol for Economic Benefit**
Vishal Sarwahi, MD; Anabelle Cohen, BS; Alexander Morledge, BA; Katherine Eigo, BS; Effat Rahman, BS; Nora Donahue, BS; Sayyida Hasan, BS; Cole Dutton, BS; Peter Boucas, BS; Keshin Visahan, BS; Benita Liao, MD; Yungtai Lo, PhD; Jon-Paul P. DiMauro, MD; Terry D. Amaral, MD

09:28 - 09:32 **Paper #172: Radiographic-Cosmetic Discrepancy in Adolescent Idiopathic Scoliosis: Impact of Extremely Low BMI**
Zhen Liu, MD, PhD

09:32 - 09:36 **Paper #173: Revisions for Pseudoarthrosis in Adolescent Idiopathic Scoliosis: Strategies and Outcomes from a Multicenter Registry**
Alex Ryan La Poche, BS; Arun R. Hariharan, MD, MS; Amit Jain, MD, MBA; Amer F. Samdani, MD; John S. Vorhies, MD; Peter G. Gabos, MD; Peter O. Newton, MD; Burt Yaszay, MD; Craig R. Louer Jr, MD; Harms Study Group

09:36 - 09:45 **Discussion**

09:45 - 09:55 **Presentation of the Hibbs, Moe & Goldstein Awards**
Kariman Abelin Genevois, MD, PhD; W.G. Stuart Mackenzie, MD

09:55 - 10:05 **Transfer of the Presidency Introduction**
Suken A. Shah, MD

10:05 - 10:10 **Transfer of the Presidency Speech**
Ferran Pellisé, MD, PhD

10:10 - 10:30 Refreshment Break | Darling Harbour Theatre Foyer

10:30 - 12:15 Darling Harbour Theatre

Abstract Session 11: Miscellaneous & Cervical ▲

Moderators: Yong Hai, MD & Kedar P. Padhye, MD

10:30 - 10:34 **Paper #174: Influence of Cervical Range of Motion and Dynamic Cervical Sagittal Vertical Axis on Distal Junctional Kyphosis Following Adult Cervical Deformity Surgery**
Tej Azad, MD; Ahmed Sulieman, MD; Virginie Lafage, PhD; Robert K. Eastlack, MD; Jeffrey Gum, MD; Munish C. Gupta, MD, MBA; Richard Hostin, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Darryl Lau, MD; Gregory M. Mundis Jr, MD; Peter G. Passias, MD; Paul Park, MD; Frank Schwab, MD; Themistocles S. Protopsaltis, MD; Christopher P. Ames, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Khaled M. Kebaish, MD; *Sang Hun Lee, MD, PhD*; International Spine Study Group

10:34 - 10:38 **Paper #175: How Reliable is Intraoperative Neurophysiological Monitoring for Detecting Postoperative Deficits During Cervical Spine Surgery?**
Jacob Okulewicz, BS; Justin L. Reyes, MS; James YonHan. Chen, BA; Thomas Hunt, BA; Demetrius Bryson, BS; Shonik Ganjoo, BS; Hamzah Abbas, BS; Kenji Kaproth, BS; Joseph M. Lombardi, MD; Ronald Lehman Jr, MD; Daniel Riew, MD; *Zeeshan M. Sardar, MD*

10:38 - 10:42 **Paper #176: Does Preoperative Myelopathy Portend Worse Outcomes After Cervical Deformity Surgery?**
Scott Zuckerman, MD; Advith Sarikonda, BS, BA; Byron F. Stephens, MD; *Thomas Buell, MD*; Nima Alan, MD; Sang Hun Lee, MD, PhD; David O. Okonkwo, MD, PhD; Stephen J. Lewis, MD, FRCS(C); Jeffrey Mullin, MD; Peter G. Passias, MD; Darryl Lau, MD; Anthony L. Mikula, MD; Jay D. Turner, MD, PhD; Joshua Bunch, MD; Brandon B. Carlson, MD; Michael P. Kelly, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Eric O. Klineberg, MD; Han Jo Kim, MD; Themistocles S. Protopsaltis, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Daniel Riew, MD; Khaled M. Kebaish, MD; Paul Park, MD; Praveen V. Mummaneni, MD; Munish C. Gupta, MD, MBA; Jeffrey Gum, MD; Alan H. Daniels, MD; Bassel G. Diebo, MD; Richard Hostin, MD; Justin K. Scheer, MD; Lawrence G. Lenke, MD; Frank Schwab, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; International Spine Study Group

10:42 - 10:51 **Discussion**

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MEETING AGENDA

SATURDAY, OCTOBER 10, 2026

Program (topics, timing, and faculty) is subject to change.

10:51 - 10:55 **Paper #177: Pelvic Tilt Modifies the Effect of Cervicothoracic Kyphosis Correction on T1 Slope After Cervical Deformity Surgery**
Tej Azad, MD; Ahmed Sulieman, MD; Virginie Lafage, PhD; Robert K. Eastlack, MD; Jeffrey Gum, MD; Munish C. Gupta, MD, MBA; Richard Hostin, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Darryl Lau, MD; Gregory M. Mundis Jr, MD; Peter G. Passias, MD; Paul Park, MD; Frank Schwab, MD; Themistocles S. Protopsaltis, MD; Scott Zuckerman, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Khaled M. Kebaish, MD; *Sang Hun Lee, MD, PhD;* International Spine Study Group

10:55 - 10:59 **Paper #178: Is the Addition of Anterior Cervical Corpectomy Superior to Anterior Cervical Discectomy and Fusion Only for the Correction of Cervical Focal Kyphosis?**
Thomas Hunt, BA; Justin L. Reyes, MS; James YonHan. Chen, BA; Jacob Okulewicz, BS; Demetrius Bryson, BS; Shonik Ganjoo, BS; Hamzah Abbas, BS; Kenji Kaproth, BS; Joseph M. Lombardi, MD; Ronald Lehman Jr, MD; Daniel Riew, MD; Zeeshan M. Sardar, MD

10:59 - 11:03 **Paper #179: Cervical Pedicle Screws are not the Safest Lateral Mass Screws are Not the Best Fixation. What about Cervical Pedicle Inlet?**
Mahmoud AbuAlkebash, MD; *Jeffrey Gum, MD*; Haseeb Tariq, BS; Steven D. Glassman, MD

11:03 - 11:12 **Discussion**

11:12 - 11:16 **Paper #180: The Influence of Halo-Gravity and Halo-Pelvic Traction on Osteotomy Grades in Severe Spinal Deformities: A Retrospective Study Based on Predictive Modeling**
Zifang Huang, MD, PhD; Junlin Yang, MD, PhD; Lei He, MD, PhD; Pan Zhou, PhD

11:16 - 11:20 **Paper #181: Safety and Efficacy of One-Staged Spine-Shortening by Using Posterior Vertebral Column Resection for Severe Spinal Deformity Associated with Multiple Spinal Cord Malformation**
Junlin Yang, MD, PhD; Zifang Huang, MD, PhD; Pan Zhou, PhD; Lei He, MD, PhD

11:20 - 11:24 **Paper #182: Beyond Cord Compression: Instability is a major driver for neurological deficit in Active Thoracic Spinal Tuberculosis**
Ajoy Prasad Shetty Tonse, MS; Shanmuganathan Rajasekaran, MD, PhD, FRCSA, MCh; Harikrishna Ramasamy Raghuraj, MS

11:24 - 11:33 **Discussion**

11:33 - 11:37 **Paper #183: Does Surgical Approach Affect Reoperation Rate in Surgical Treatment of L4-5 Degenerative Spondylolisthesis?**
Pooria Salari, MD; Richard N. Chang, PhD; Jessica E. Harris, MS; Kathryn E. Royse, PhD; Harsimran S. Brara, MD; Elizabeth P. Norheim, MD; Akasha I. Barreto Vega, MS; Jacob H. Fennessy, MD

11:37 - 11:41 **Paper #184: Sagittal Spinal Shape Remodeling and Inflection Point Migration After Anterior Versus Posterior Short-Segment Lumbar Fusion**
Erh Ti Ernest Lin, MD; Yi Hsun Huang, MD; Jyun Hong Kuan, MD; Ben Long Shi, MD; Yi Chin Fong, MD, PhD; Yong Qiu, PhD; Yuan Shun Lo, MD, PhD

11:41 - 11:45 **Paper #185: Prevalence of Severe Sagittal Malalignment in Patients Undergoing Short-Segment Lumbar Fusion**
Michael Farias, BS; Joseph E. Nassar, BS; Manjot Singh, BS; Alex Hernandez, BS; Zvipo Chisango, BS; Gabriel Gonzalez, BS; Catherine Becker Hurley, MS; John Czerwein, MD; Bassel G. Diebo, MD; *Eren Kuris, MD*; Alan H. Daniels, MD

11:45 - 11:54 **Discussion**

11:54 - 11:58 **Paper #186: Surgeon Achievement of Computer-Assisted Planning Targets in Lumbar Fusion Surgery: A Learning Curve Analysis**
Catherine Becker Hurley, MS; Michael Farias, BS; Feyza Achilova; Gabriel Gonzalez, BS; Nicolas Carayannopoulos, BS; John Czerwein, MD; Dina Kaplan, BS; Joseph E. Nassar, BS; Bassel G. Diebo, MD; Eren Kuris, MD; Alan H. Daniels, MD

11:58 - 12:02 **Paper #187: Patient-Reported Outcomes in Pediatric Spondylolysis**
Samantha Snyder, BS; Vivien Chan, MD, MS; Sonja Kleven; James Caruso, MD; *Kenneth D. Illingworth, MD*; David L. Skaggs, MD, MMM

12:02 - 12:06 **Paper #188: Back in the Game: High Return-to-Sport Following Direct Pars Repair in Young Patients**
Sydney Thai, BS; Krystell E Ceballos Alvarez, BS; Emmanuel N. Menga, MD; Paul D. Sponseller, MD; Amit Jain, MD, MBA

12:06 - 12:15 **Discussion**

12:15 SRS 61st Annual Meeting Concludes

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ABSTRACTS

The Scoliosis Research Society gratefully acknowledges ATEC Spine and Highridge Medical for their grant support of the Lunchtime Symposia.

Podium Presentation Abstracts 50
E-Point Presentation Abstracts 174
Regional Scientific Meeting Abstracts 231

PODIUM ABSTRACTS

1. The Role of L5–S1 in Determining Lumbar Shape: Segmental Determinants of Normal L1PA

Jeffrey M. Hills, MD; Alexander T. Yahanda, MS; Tyler K. Williamson, MD, MS, BS; JeanCharles Le Huec, MD, PhD; Camilo A. Molina, MD; Brandon B. Carlson, MD; Zeeshan M. Sardar, MD; Hee-Kit Wong, MD, PhD; Kazuhiro Hasegawa, MD, PhD; Lawrence G. Lenke, MD; Michael P. Kelly, MD

Hypothesis
Pelvic incidence (PI) and individual lumbar segments contribute differentially to variation in L1 pelvic angle (L1PA) in asymptomatic individuals.

Design
Cross-sectional cohort.

Introduction
Lumbar alignment targets in spinal deformity surgery are typically defined at a regional level; however, achieving these targets requires segmental alignment planning. Understanding the normal relationship between PI and segmental lordosis, as well as the relative contribution of each segment to the overall lumbar shape is critical for achieving physiologic alignment.

Methods
A multinational cohort of asymptomatic volunteers > 18 years old with no radiographic evidence of disc degeneration or scoliosis was studied. Radiographic measurements were obtained from full spine radiographs (EOS Imaging, SA, France). Segmental lumbar lordosis from L1–L2 through L5–S1 and L1PA were measured. Univariate linear regression assessed the association between PI and segmental lordosis. Multivariable linear regression evaluated the relative contribution of PI and individual segmental lordosis values to L1PA. The relative importance of each variable was quantified using ΔR^2, calculated as the reduction in model R^2 following variable removal.

Results
Among 319 volunteers (60% female; median age 37 years [IQR, 27–47]), median PI was 52° (IQR, 45–58). Median segmental lordosis increased caudally from 2.1°(-0.2, 4.7) at L1–L2 to 22°(18, 27) at L5–S1. PI demonstrated small-to-modest positive associations with mid-lumbar segmental lordosis (R^2 = 0.06–0.15) but no meaningful association with L5–S1 lordosis ($R^2 \approx 0$)(Fig 1). For each 10° increase in PI, lordosis increased by 1.3° at L1-L2; 1.6° at L2-L3; 0.9° at L3-L4; and 1.7° at L4-L5. In multivariable modeling, PI and L5–S1 together explained over 90% of the variance in L1PA, with ΔR^2 contributions of 63% for PI and 28% for L5-S1.

Conclusion
In normal individuals, variation in L1PA is primarily determined by PI and L5–S1 lordosis, with L5–S1 acting independently of PI. Thus, attempting to achieve a target L1PA through increased correction of mid or cranial lumbar segments may produce a non-physiologic lumbar shape. Segmentally informed alignment strategies that respect the role of L5–S1 may better preserve normal lumbar alignment.

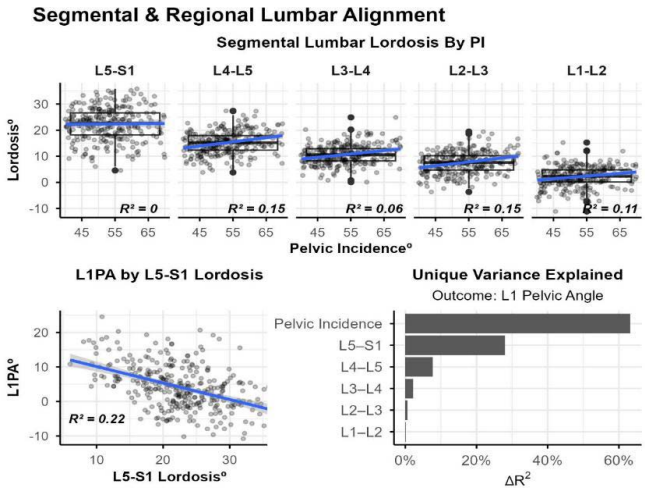

Fig 1. Segmental Lordosis by PI; L1PA by L5-S1 Lordosis; & L1PA variance explained by PI and segmental lordosis.

2. The Sacro-acetabular Angle: A Morphologic Property That Helps Predict Positional Spinopelvic Parameters

Chien Yew Kow, MD; Farbod Moghaddam, BS; Timothy Lasswell, MD; Taryn Ludwig, MD, PhD; May Choi, MD; Michael P. Kelly, MD; *Fred H. Nicholls, MD*

Hypothesis
The SAA contributes significantly to the prediction of positional sagittal spinopelvic parameters.

Design
Cross-sectional descriptive study in asymptomatic adult volunteers.

Introduction
Morphologic spinopelvic parameters carry inherent utility when assessing and correcting malalignment. This is especially true when they can be related to positional parameters. The sacro-acetabular angle (SAA) is an angle subtended by the S1 superior endplate and a line connecting the anterior and posterior acetabular walls (Fig 1). This morphologic parameter defines the version required to maintain motion of the hip within the physiologic arc for a given activity. As SAA is not intrinsic to commonly used sagittal morphologic properties such as Pelvic Incidence (PI), understanding its normative relationships with other measures of alignment may help with predicting highly variable positional parameters.

Methods
Full length EOS radiographs of adult (18-40) volunteers were obtained and segmented using Keops® online imaging platform. Subjects' clinical and radiological parameters including PI, L1PA, PT, SS and LL were measured and recorded. Association between SAA and

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subjects' demographics and spinopelvic parameters were determined using linear regression analyses.

Results
Five hundred volunteers obtained EOS scans, with subsequent exclusion of subjects with incidental scoliosis, spondylolisthesis, previous lower limb surgery, ODI>10, lumbosacral transitional anatomy and inadequate imaging, leaving 378 subjects included in the final analysis. Significant correlation was identified between SAA and spinopelvic parameters, with improved predictive power when PI was included in the model. Relationships between SS, PT, LL and L1PA were respectively correlated with SAA and PI as follows: SS = 0.41*PI + 0.39*SAA - 9.3 (R2=0.70) PT = 0.59*PI - 0.39*SAA + 9.3 (R2=0.55) LL = 0.24*PI + 0.63*SAA - 2.5 (R2=0.48) L1PA= 0.54*PI -18*SAA -8 (R2=0.64)

Conclusion
The SAA, a sagittal plane morphologic property, improves prediction of positional measures of alignment when combined with the PI, helping to explain the variability in overall sagittal alignment observed in healthy volunteers with similar PI. Identification of further morphologic properties is essential to understanding the drivers of upright posture and to the prevention of mechanical failure in the correction of spinal deformity.

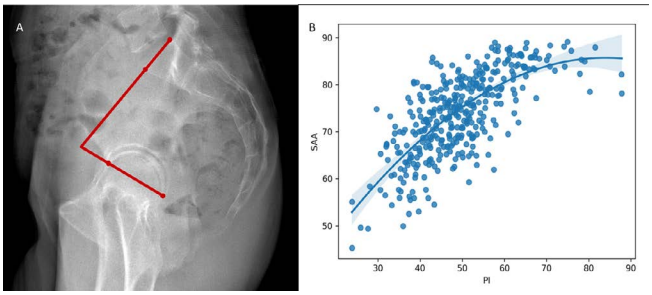


Fig 1: SAA (A) and its relationship to PI (B).

3. Vertebral-Pelvic Angle-Based Classification Identifies Degenerative Sagittal Alignment Patterns

Jun Ouchida, MD; Sadayuki Ito, MD; Naoki Segi, MD; Hiroaki Nakashima, MD, PhD; Shiro Imagama, MD, PhD

Hypothesis
VPA-based classification identifies degenerative sagittal alignment patterns that independently predict physical function.

Design
Cross-sectional observational study.

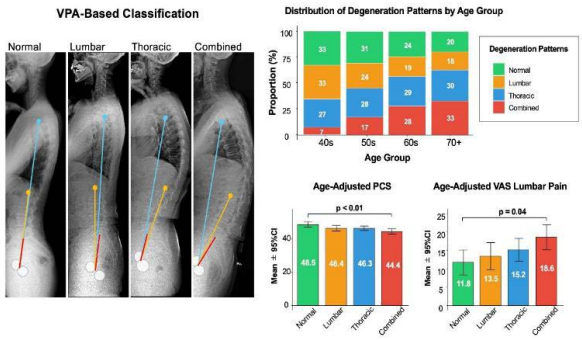
Introduction
Objective criteria for defining degenerative sagittal alignment in adults are lacking. VPA parameters, L1 pelvic angle (L1PA) for lumbar alignment and T4-L1 pelvic angle mismatch (T4-L1MM) for thoracic harmony, provide continuous measures of sagittal alignment relative to pelvic morphology. We developed a VPA-based classification to identify degenerative patterns and evaluated their clinical impact.

Methods
We analyzed 599 community-dwelling adults (age 40-90 years). Full-spine lateral radiographs were obtained and participants with vertebral fractures, prior spine or lower limb surgery, or neurological diseases were excluded. Based on L1PA deviation from target (0.5×PI-21°; threshold >+2°) and T4-L1MM (threshold >+1°), participants were classified as Normal, Lumbar-type, Thoracic-type, or Combined-type. Primary outcomes included SF-36 Physical and Mental Component Summaries, 10-meter walk speed, and VAS lumbar pain. Multivariable regression adjusted for age, sex, and BMI.

Results
Distribution was Normal 25.2% (n=151), Lumbar 21.4% (n=128), Thoracic 28.9% (n=173), and Combined 24.5% (n=147). Combined-type increased with age: 6.8% (40s) to 32.6% (70+, p<0.01). After adjustment, Combined-type showed worse outcomes than Normal: Physical Component Summary 48.5 vs 44.4 (difference 4.1 points, 95%CI: 1.6-6.6, p<0.01), gait speed 1.84 vs 1.58 m/s (difference 0.27 m/s, 95%CI: 0.15-0.38, p<0.01), VAS pain 11.8 vs 18.6 (difference 6.9 points, 95%CI: 0.5-13.2, p=0.04). Mental Component Summary showed no difference (p=0.25), indicating physical-specific impairment. No significant interaction between age and deformity was detected (p=0.78).

Conclusion
This VPA-based classification identified degenerative alignment in 74.8% of adults. Combined-type independently predicted physical impairment after adjusting for age, sex, and BMI, with consistent effects across all age groups.

Four degenerative patterns identified by VPA-based classification (left), Combined-type prevalence increased with age(upper right), and Combined-type showed significantly worse physical function and higher pain than Normal after age adjustment (lower right).



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4. Association of Kyphotic and Lordotic Apices and the Thoracolumbar Inflection Point with Regional and Global Sagittal Alignment in 410 Asymptomatic Adults

Fred H. Nicholls, MD; Christopher J. Nielsen, MD; Fatemeh Alavi, PhD; Stephen J. Lewis, MD, FRCS(C)

Hypothesis
Sagittal alignments apices and inflection point are associated.

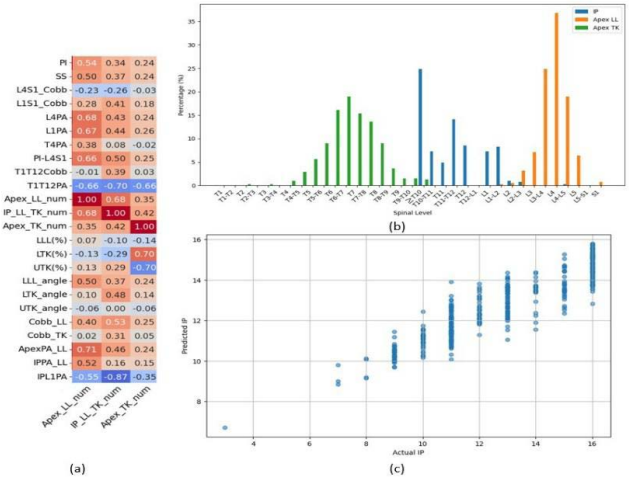
Design
Cross-sectional radiographic analysis

Introduction
Sagittal alignment is essential for biomechanical efficiency, yet regional and transitional curvature landmarks remain underexplored. The thoracolumbar inflection point and the kyphotic and lordotic apices define sagittal alignment by governing distribution of curvature. However, their relationships remain poorly defined. This study evaluated the association of these landmarks with key sagittal parameters in a population of asymptomatic adults.

Methods
Standing lateral full-spine EOS radiographs of 410 asymptomatic adult volunteers (55.8% female; age 20–39 years) were analyzed. Sagittal alignment parameters including pelvic incidence (PI), Cobb angles, vertebral pelvic angles (VPAs), upper and lower thoracic arc length normalized to total thoracic arc length (UTK%, LTK%) were measured. Correlation matrices and multivariable regression analyses were used to assess associations between apex and inflection point locations and sagittal parameters.

Results
The thoracolumbar inflection point (TLIP) was most commonly located at the T12–L1 disc (range T8 to L4–L5). TLIP location demonstrated a strong correlation with T1–T12 pelvic angle (r=0.70), indicating a close relationship between regional curvature distribution and global thoracolumbar inclination. Multivariable regression revealed lumbar lordosis apex location was influenced by pelvic incidence, distal lumbar curvature (L4–S1 Cobb) and T1–T12 pelvic angle (R^2=0.70). TLIP location was predicted by a combination of pelvic morphology, UTK, and thoracolumbar alignment parameters, including pelvic incidence, UTK%, T1–T12 pelvic angle, T1–T12 Cobb angle, and L4–S1 Cobb angle (R=0.85). Thoracic apex location was similarly governed by pelvic incidence, thoracic curvature distribution, and thoracolumbar inclination (R^2=0.78).

Conclusion
In asymptomatic adults, the locations of the thoracic and lumbar apices and the thoracolumbar inflection point are influenced by pelvic morphology and the regional distribution of sagittal curvature. The ability to predict apex and inflection point positions helps sagittal alignment restoration.



(a) Correlation matrix, (b) percentage distribution of thoracolumbar inflection point and apices, (c) predicted vs. actual IP

5. Strategic Adjustment of Segmental Lumbar Lordosis to Optimize L1-Pelvic Angle Offset and Minimize Mechanical Complications After Long-Level Lumbar Fusion Surgery

Myung-Hoon Shin, MD, PhD

Hypothesis
Based on the geometric definition of the L1-pelvic angle (L1PA) as the sum of L1 tilt and pelvic tilt (PT), we hypothesize that segmental lumbar lordosis—divided into upper (L1-L4) and lower (L4-S1) components—exhibits differentiated regulatory effects on these distinct sagittal components.

Design
Retrospective cohort study

Introduction
While the L1PA is a recognized predictor of postoperative balance, it is a composite parameter (L1PA = L1 tilt + PT). Understanding how segmental lordosis specifically influences these individual components is crucial for precise surgical planning. This study aims to evaluate the PI-stratified impact of segmental lordosis on L1PA offset to optimize postoperative outcomes and minimize MC risk.

Methods
We retrospectively analyzed 103 patients (67 females, 36 males) who underwent lumbar fusion of $\geq$ 4 levels with a minimum 2-year follow-up. The mean age of the cohort was 68.78 ± 6.38 years, with a mean follow-up period of 35.74 ± 11.02 months. Radiographic parameters included PI, L1PA, LLL (L4-S1), and ULL (L1-L4). L1PA offset was calculated as the deviation from the target L1PA (0.5 * PI - 19°). Patients were stratified into three groups based on PI: Low (< 45°), Medium (45–60°), and High (>

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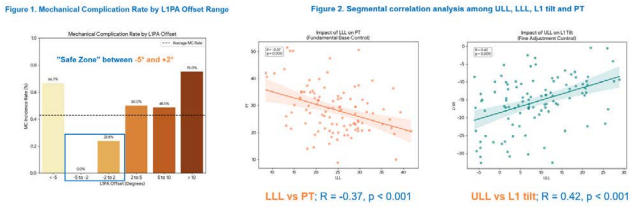
60°). Multivariate regression and ROC curve analyses were performed to identify optimal segmental targets.

Results
Statistical analysis confirmed the specialized roles of lumbar segments: LLL showed a significant negative correlation with PT (r = -0.375, p < 0.001$), establishing the foundational base by resetting pelvic compensation. Conversely, ULL demonstrated a significant positive correlation with L1 tilt (r = 0.425, p < 0.001), directly modulating the apical position of the L1 vertebra. A "Safe Zone" for L1PA offset was identified between -5 and+2°, associated with the lowest MC rate of 15.4%. MC rates were significantly higher in overcorrection (< -5°; 66.7%) and undercorrection (> +2°; 52.2%).

Conclusion
Maintaining the L1PA offset within the safe window of -5 to 2° is critical for reducing mechanical complications. Our findings suggest a strategic model where LLL serves as the foundational engine for pelvic un-compensation through its primary impact on PT, while ULL acts as a precision handle for apical alignment by directly determining L1 tilt.



Figures1 and 2

6. Four Distinct Pelvic Response Patterns Following Adult Spinal Deformity Surgery: A Multivariate Trajectory Analysis

Jonathan Elysee, MS; *Renaud Lafage, MS*; Bassel G. Diebo, MD; Christopher P. Ames, MD; Shay Bess, MD; Alan H. Daniels, MD; Robert K. Eastlack, MD; Munish C. Gupta, MD, MBA; Richard Hostin, MD; Khaled M. Kebaish, MD; Eric O. Klineberg, MD; Gregory M. Mundis Jr, MD; David O. Okonkwo, MD, PhD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; International Spine Study Group

Hypothesis
Distinct pelvic response patterns exist following low thoracic-to-pelvis fusion, with some patients demonstrating pelvic non-response despite adequate lordosis restoration.

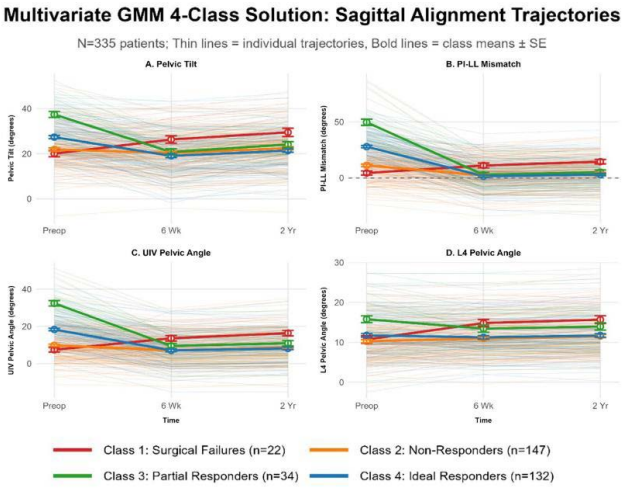
Design
Retrospective study of ASD patients who underwent posterior spinal fusion from low thoracic spine to pelvis with preop, 6wk, and 2yr follow ups. Patients with PJK at 2Y or revision surgery were excluded.

Introduction
ASD surgery aims to restore sagittal alignment through lordosis restoration, with the expectation that the pelvis will reciprocally de-rotate to restore global balance. Longitudinal trajectory of pelvic positioning in successfully fused patients without major mechanical complications remains poorly characterized.

Methods
Multivariate Growth Mixture Modeling (GMM) identified latent trajectory classes based on longitudinal patterns across all main outcome measures simultaneously.

Results
GMM identified four distinct trajectories (Details in Table 1): Class 1 (Surgical Failures, n=22) worsened despite favorable baseline alignment. Class 2 (Non-Responders, n=147) demonstrated unchanged pelvic tilt despite successful PI-LL correction. Class 3 (Partial Responders, n=34) achieved excellent correction of severe baseline deformity with minimal regression. Class 4 (Ideal Responders, n=132) maintained good correction throughout follow-up. Frailty was significantly different between groups (p = 0.039), especially between Ideal and Non-responder (p=0.036). PI was different between groups, with Surgical Failures and Partial Responders having slightly larger PI than other groups (60.6° & 61.2° vs 55.3° & 55.8°, p=0.008). At 2Y, there were no significant differences between groups in L4-S1 (range: 31.9°-35.1°, p=0.67), L1-S1 (range: 48.2°-55.9°, p=0.104), T10-L2 (range: -9.3° to -12.7°, p=0.069), T4-T12 (range: -46.8° to -43.5°, p=0.359). All groups achieved similar scores at 2Y, but there were significant differences in magnitude of improvement, Partial Responders (-26.57) group showed significantly greater reduction in ODI compared to both the Surgical Failures (-13.16, p = 0.031) and the Non-Responders (-16.44, p = 0.020).

Conclusion
GMM identified four distinct PT patterns, with nearly half of patients (44%) demonstrating PT non-response despite similar LL restoration. These findings highlight the need for construct-specific alignment strategies that account for individual pelvic compensation capacity.



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7. Gait Stability Seems To Deteriorate With Age And Sagittal Malalignment Severity

Ibrahim Hamati; Abir Massaad, PhD; Rami Rachkidi, MD, MS; Moustapha Rteil; Gilles Prince; Michel Al Ammouri; Yamen Beyh; Frederic Maatouk; Josef Lattouf; Jean-Pierre Saad; Mohamad Hajj Youssef; Mohammad I. Karam, MS, PhD; *Virginie Lafage, PhD;* Ismat Ghanem, MD, MS; Ayman Assi, PhD

Hypothesis
ASD with severe sagittal malalignment and of older age show more pronounced instability during gait.

Design
Retrospective analysis of prospectively collected data.

Introduction
Due to their spinal malalignment, ASD patients require increased energy expenditure to maintain stability in the Dubousset cone of economy, where the body center of mass (COM) oscillates. While recent studies showed that ASD patients often present with functional impairment, it is important to investigate factors influencing their gait stability.

Methods
174 ASD underwent biplanar Xrays, filled the ODI questionnaire and performed 3D gait analysis to calculate full-body kinematics. The COM was extracted in the 3 directions and normalized to subject's BMI. Corridors of normality, based on 44 controls, were established in the sagittal and horizontal planes and used to classify ASD patients into 4 groups: Inside corridors in both planes (Inside), outside sagittal corridor (Outside-Sag), outside horizontal corridor (Outside-Hor), outside corridors in both planes (Outside-Sag-Hor). Between-group comparisons were computed.

Results
ASD patients were classified as 55 Inside (mean age: 54y), 46 Outside-Hor (62y), 35 Outside-Sag (62y), and 38 Outside-Sag-Hor (66y, Fig.1). Outside-Sag-Hor patients had an increased SVA (67 vs 22mm), PI-LL (16 vs -3°) and an increased ODI (47 vs 33) compared to the Inside group. During gait, Outside-Sag-Hor patients had an increased ODHA angle both in sagittal (10 vs 5°) and frontal planes (5 vs 2°) and an increased trunk flexion (13 vs 6°). They presented a decreased hip (34 vs 42°) & knee (47 vs 59°) range of motion and a decreased walking speed (0.64 vs 0.98m/s; all $p<0.05$). Spino-pelvic and kinematics of Outside-Sag and Outside-Hor groups ranged between the Outside-Sag-Hor and Inside groups.

Conclusion
32% of ASD were able to walk within an economic zone, most probably due to their younger age and conserved muscle strength. ASD with moderate sagittal malalignment tend to walk outside the COM corridor in one plane. Older ASD with severe sagittal malalignment present gait instability in both planes. Thus, gait stability seems to deteriorate with age and sagittal malalignment severity. Future studies should investigate whether early rehabilitation programs may help avoid migration from one group to another.

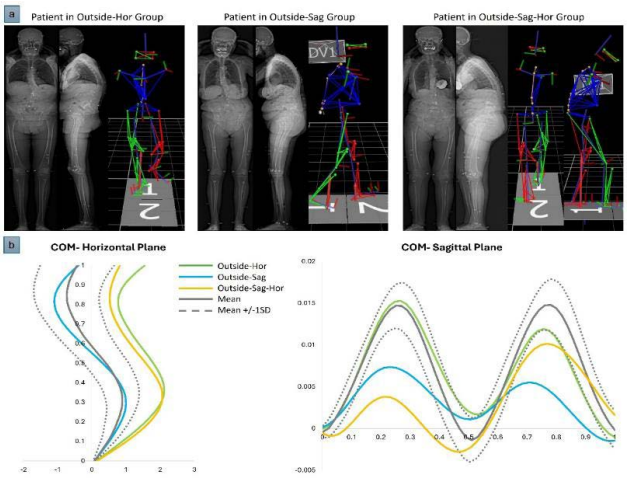

Fig.1-Examples of patients from each gait instability group (a) and their COM trajectory in the horizontal and sagittal planes (b).

8. Mechanical Complications in Functional vs Normative Alignment Targets in Adult Spinal Deformity: Should There be Adjustments for Age?

Alexander Kucherina, BS; Renaud Lafage, MS; *Yashar Javidan, MD;* Bassel G. Diebo, MD; Alex Soroceanu, MD, FRCS(C); Jeffrey Gum, MD; Gregory M. Mundis Jr, MD; Justin S. Smith, MD, PhD; Peter G. Passias, MD; Han Jo Kim, MD; Kojo D. Hamilton, MD, FAANS; Lawrence G. Lenke, MD; Munish C. Gupta, MD, MBA; Christopher P. Ames, MD; Eric O. Klineberg, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Shay Bess, MD; Themistocles S. Protopsaltis, MD; International Spine Study Group

Hypothesis
Functional PI-specific alignment targets result in fewer mechanical complications than normative strategies.

Design
Multicenter retrospective cohort study of a prospectively collected ASD database.

Introduction
Adult spinal deformity (ASD) realignment targets are increasingly tailored to pelvic incidence (PI). The T4–L1 hip axis aims to restore ideal parameters, while other studies suggest PI-specific targets that match expected functional status for age may reduce mechanical complications such as proximal junctional kyphosis (PJK) and proximal junctional failure (PJF).

Methods
Patients undergoing posterior spinal fusion for ASD with UIV>T4, LIV at S1, and 2-year follow-up were included. Alignment cohorts were defined using 6-week postoperative T4PA. Functional alignment was defined as T4PA within ±3° of a patient-specific target derived from PI and

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age-normative SF-36 Physical Component Score (PCS). Age-normative alignment was defined as T4PA within ±3° of an age- and PI-adjusted normative target. Age-independent normative alignment was defined as T4PA within ±2° of a PI-based target with L1PA = (0.5 × PI) − 19 and L1PA–T4PA mismatch between −3° and +1°. Outcomes included PJK (≥10° change), severe PJK (≥20° change), PJF, revision surgery, and health-related quality of life (HRQL). A composite severe failure endpoint included severe PJK, PJF, or revision for PJK/PJF.

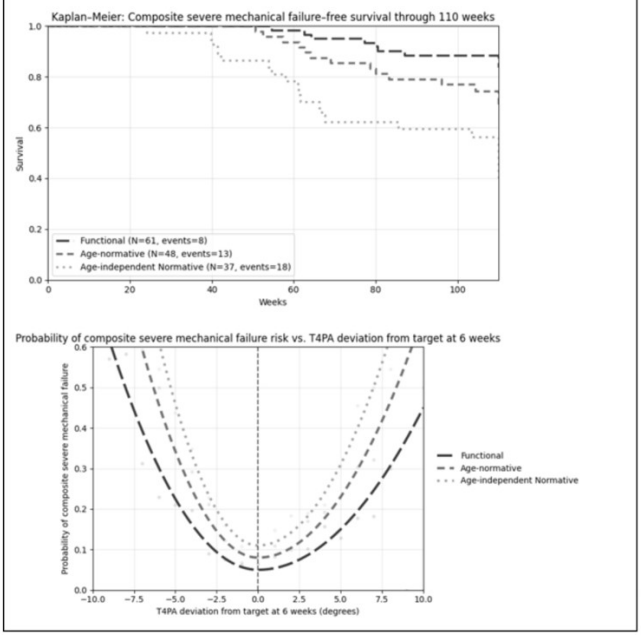
Results

Across strategies, increasing deviation from target T4PA at 6 weeks increased severe mechanical failure risk, with both overcorrection and undercorrection contributing. Functional alignment demonstrated significantly lower severe mechanical complications than both normative strategies. Composite severe failure occurred in 6.6% at 6 weeks and 11.5% at 2 years in the functional group, compared with 16.7% and 25.0% in the age-normative group and 24.3% and 37.8% in the age-independent normative group (p≤0.01). Two-year revision rates were lowest with functional alignment (4.9% vs 7.7% vs 11.6%). HRQL improved in all groups, with greater gains in disability and physical function in the functional cohort.

Conclusion

Functional, age-adjusted alignment targets using T4PA are associated with fewer severe mechanical complications following ASD surgery. Individualizing sagittal correction to age-related functional status may improve mechanical durability while preserving clinical benefit.

Figure 1. Kaplan–Meier Analysis of Composite Severe Mechanical Failure–Free Survival Through 110 Weeks by Alignment Strategy *and* Probability of Composite Severe Mechanical Failure as a Function of T4 Pelvic Angle Deviation from Target at 6 Weeks



9. Full Body Radiographs with Knee Flexion Assessment in Sagittal Deformity: Does Lower Extremity Compensation Independently Inform Alignment Correction?

David D. Liu, MD; Breton Line; Feyza Achilova; Bassel G. Diebo, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Richard Hostin, MD; Peter G. Passias, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Themistocles S. Protopsaltis, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Munish C. Gupta, MD, MBA; Brett Rocos, MD, FRCS; Jeffrey Mullin, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Christopher P. Ames, MD; Lawrence G. Lenke, MD; Sang Hun Lee, MD, PhD; Khaled M. Kebaish, MD; Shay Bess, MD; Alan H. Daniels, MD; International Spine Study Group

Hypothesis

Lower limb compensation is adequately assessed by pelvic tilt (PT), and therefore knee flexion (KF) is not independently associated with degree of sagittal correction.

Design

Retrospective cohort study

Introduction

Full-body imaging allows measurement of lower-limb alignment, with KF and PT representing compensation for sagittal malalignment. However, full-body radiographs are costly and not universally available. We evaluated the association of KF with degree of postop deformity correction and PT.

Methods

Adult spinal deformity patients with full-body radiographs without PJK were measured for KF, PT, PI, LL, thoracic kyphosis, SVA, and T4-L1 PA mismatch at preop and postop. Change in lordosis (ΔLL) from surgery was calculated. Regression analyses evaluated relationships between KF, radiographic correction, PT, ODI, and SRS-22 at preoperative, 6-week, and 2-year timepoints with Bonferroni correction. Multivariable regression and principal component analysis (PCA) were used to assess whether KF was independently associated with alignment changes.

Results

A total of 679 patients were included. Preop KF was strongly associated with ΔLL (r=0.48, p<0.0001). However, after regression of seven PCA dimensions of alignment and KF with ΔLL, KF had no association with ΔLL (r=0.04, p=0.25), ΔPI-LL (r=-0.05, p=0.13), or ΔSVA (r=0.02, p=0.57). Conversely, in patients with satisfactory postop alignment (|PI-LL|<10), 6-week KF was not associated with preop KF (r=0.04, p=0.30) or change in KF (r=-0.01, p=0.82). These findings were replicated on a surgeon level. KF was correlated with pathologic PT (PT > 20) at almost all timepoints (preop p<0.001, 6wk/2yr p<0.02, 1yr p=0.06), but not with normal PT (PT < 20; p=0.13 to 0.89). Finally, KF was not associated with ODI at any timepoint (p=1.0)

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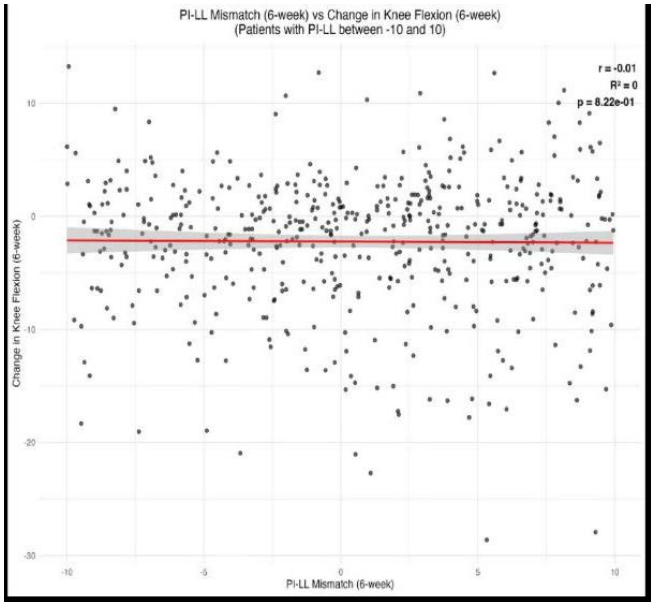
and not associated with SRS-22 preop or at 6 weeks (p>0.05). Higher KF correlated with lower SRS-22 at 2 years (r=-0.26, p<0.001).

Conclusion

Knee flexion (KF) was not independently associated with sagittal correction after controlling for other well-known spinopelvic parameters which are available without full-body radiographs. Residual KF remains associated with residual pelvic tilt. These findings suggest that knee flexion severity assessment compensation may not be required specifically for sagittal alignment planning, though its overall clinical utility warrant further investigation.



10. Go Big or Lay-Up in Revision Adult Spinal Deformity Surgery? Contrasting the Trade-Off Between Achieving Optimal Alignment with Early Complication vs. Suboptimal Alignment Without Complication

Scott Zuckerman, MD; Harsh Jain, MBBS; *Byron F. Stephens, MD;* Thomas Buell, MD; Nima Alan, MD; Sang Hun Lee, MD, PhD; David O. Okonkwo, MD, PhD; Stephen J. Lewis, MD, FRCS(C); Jeffrey Mullin, MD; Peter G. Passias, MD; Darryl Lau, MD; Anthony L. Mikula, MD; Jay D. Turner, MD, PhD; Joshua Bunch, MD; Brandon B. Carlson, MD; Michael P. Kelly, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Eric O. Klineberg, MD; Han Jo Kim, MD; Breton Line; Themistocles S. Protopsaltis, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Khaled M. Kebaish, MD; Paul Park, MD; Praveen V. Mummaneni, MD; Munish C. Gupta, MD, MBA; Jeffrey Gum, MD; Alan H. Daniels, MD; Bassel G. Diebo, MD; Richard Hostin, MD; Justin K. Scheer, MD; Lawrence G. Lenke, MD; Frank Schwab, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; International Spine Study Group

Hypothesis

In patients with a prior lumbar fusion undergoing adult spinal deformity (ASD) surgery, optimally aligned patients with an early complication have better patient-reported outcome metrics (PROMs) than those with suboptimal alignment without an early complication.

Design

Retrospective analysis of prospective multicenter study

Introduction

We compared 2-year PROMs and neurologic complications between patients with:1) optimal postoperative alignment and an early complication vs. 2) suboptimal alignment without an early complication.

Methods

A retrospective cohort study (2009-18) was performed of patients undergoing ASD surgery. Inclusion criteria were: ≥2-year follow-up, prior lumbar fusion, and preoperative sagittal malalignment. Optimal sagittal alignment was defined as L1-pelvic angle (L1PA) ±5° of goal. Cohort was binarized as:1) optimal alignment with an early complication vs. 2) suboptimal alignment without an early complication. Outcome variables were 2-year Scoliosis Research Society (SRS) satisfaction scores, Oswestry Disability Index (ODI), EQ-5D, Short Form 36 (SF-36) physical function scores, all subdomains, and neurologic function. Bivariate analysis was performed.

Results

Of 312 patients, 27 (8.7%) had optimal alignment but developed an early complication while 126 (40.4%) had suboptimal alignment without an early complication. At baseline and 2-years, both groups had similar total PROMs and satisfaction. Regarding PROM subdomains, those with optimal alignment had better 2-year mental health (SF-36 Q9B:4.8±0.6 vs. 4.1±1.0, p=0.002), vitality (SF-36Q9C:4.8±0.6 vs. 4.3±1.0, p=0.023), social functioning (4.7±0.5 vs. 4.2±1.1, p=0.008), and satisfaction with back relief (4.0±0.9 vs. 3.4±1.2, p=0.048). There were no significant differences in rates of new motor deficits (7.4% vs. 4.8%, p=0.631) or new radiculopathy (3.7% vs. 4.8%, p=1.000).

Conclusion

Though patients with optimal alignment and an early complication vs. suboptimal alignment without complication had similar total PROMs, upon subdomain testing, optimal alignment, even with an early complication, conferred better long-term mental health, social functioning, vitality, and perceived back pain relief.

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PROM	Optimal Alignment, with Early Complication	Suboptimal Alignment, No Early Complication	p-value
Baseline			
SRS Q4: Pain	1.2±0.5	1.5±1.0	0.017
6-Months			
SF36 Q3C: Physical Function – Ability to Climb Flight of Stairs	1.0±0.0	1.7±0.9	0.003
SF36 Q3E: Physical Function – Ability to Walk One Block	1.3±0.5	2.0±0.7	0.047
SF36 5A: Bodily Pain	5.0±0.0	3.4±1.2	<0.001
SF36 5C: Role Limitations Due to Physical health	5.0±0.0	3.5±1.4	<0.001
SSF36 9C: Energy/Fatigue	5.0±0.0	4.2±1.3	0.009
LSDI Q7: Difficulty Rising From Sitting Position	2.0±0.0	2.5±0.7	0.013
2-years			
SF36 Q9B: Mental Health – Feeling Downhearted/Blue	4.8±0.6	4.1±1.0	0.002
SF36 9C: Energy/Fatigue	4.8±0.6	4.3±1.0	0.023
SF36 9F: Mental Health - Feeling Calm an Peaceful	4.7±0.6	4.0±1.1	0.035
SF36 11A: Social Functioning – Does Physical or Emotional Health Interfere with Normal Social Activities?	4.7±0.5	4.2±1.1	0.008
SRS Q20 : Satisfaction with Level of Back Pain Relief	4.0±0.9	3.4±1.2	0.048

11. Radiographic evaluation of ASD and its relationship with longitudinal changes in sagittal spinal alignment

Takuya Murazumi, MD; Tetsuya Kobayashi, MD, PhD; Issei Senoo, MD; Hiroki Okayasu, MD; Kozaburo Mizutani, MD; Kengo Sasai, MD; Shoichi Saino, MD; Hiroshi Ito, MD

Hypothesis
Radiographic parameters reflecting lumbopelvic congruence and T4-L1-HA would predict longitudinal changes in sagittal alignment better than PI-LL mismatch.

Design
Longitudinal study using a community-based cohort with repeated radiographic assessment.

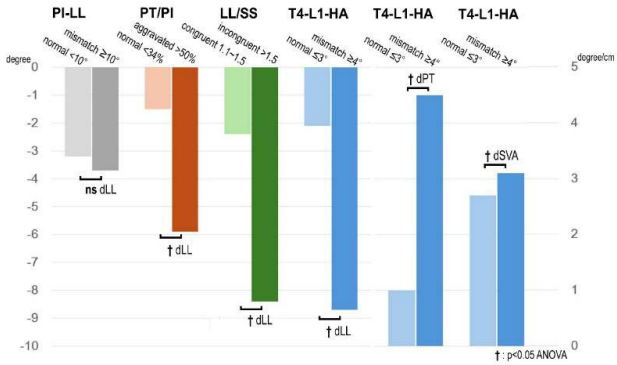
Introduction
SRS-Schwab adult spinal deformity (ASD) classification in 2012 popularized a pelvic incidence (PI) - lumbar lordosis (LL) mismatch < 10° as a benchmark. However, following studies indicated PI should explain only a fraction of the variation in LL. Age-related LL changes are also influenced by pelvic compensation, lumbopelvic congruity, and global balance. In 2022, the hip axis connecting T4 and L1 vertebral bodies to the center of the femoral head (T4-L1-HA) was reported as an alternative to sagittal vertical axis (SVA). This study investigated the relationship between radiographic ASD predictors and longitudinal changes in sagittal spinal alignment in a community-based cohort.

Methods
Female volunteers were recruited from a population registry and upright entire spine radiographs were used for radiographic measurement; thoracic kyphosis (TK), LL, PI, pelvic tilt (PT), sacral slope (SS), SVA, and T4-L1-HA. Baseline ASD predictors were defined as follows: PI-LL normal (<10°) and mismatch (≥10°), T4-L1-HA normal (≤3°) and mismatch (≥4°), pelvic compensation normal (PT/PI <34%) and aggravated (>50%), lumbopelvic congruence (LL/SS=1.1~1.5), and incongruence (LL/SS >1.5), according to previous studies.

Results
A total of 169 women (mean age 64.6±4.9 years) were followed for 8.6±3.7 years. Longitudinal changes were significant in LL (38.5±15.7°□ 34.8±18.0°), SVA (17.4±35.5mm □40.7±39.2 mm), PT (23.8±9.8°□ 25.5±11.3°), and T4-L1-HA (2.8±5.6°□4.9±6.3°). Baseline radiographic predictor of PI-LL was not related to longitudinal change in LL, while PT/PI and LL/SS showed significant associations with LL. Baseline T4-L1-HA predicted LL, PT and SVA modifications (Figure 1).

Conclusion
The T4-L1-HA showed a significant association with longitudinal changes, with cases of mismatch exhibiting greater changes in LL, PT and SVA. Recent studies have highlighted the variability in spinal alignment prediction using PI. This longitudinal study suggests that assessments not involving PI, such as lumbopelvic congruity and T4-L1-HA are important for understanding longitudinal modifications in ASD.

Figure 1. Baseline predictors and longitudinal radiographic changes



Baseline predictors and longitudinal radiographic changes

12. Why Success After Adult Spinal Deformity Surgery Depends on How Success is Defined: Insights from a Composite Outcome Framework

Renaud Lafage, MS; Blerta Budani, BS; Ayman Mohamed, MD; Bassel G. Diebo, MD; Christopher P. Ames, MD; Shay Bess, MD; Alan H. Daniels, MD; Robert K. Eastlack, MD;

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

PODIUM ABSTRACTS

Munish C. Gupta, MD, MBA; Richard Hostin, MD; Khaled M. Kebaish, MD; Eric O. Klineberg, MD; Gregory M. Mundis Jr, MD; Mitsuru Yagi, MD, PhD; David O. Okonkwo, MD, PhD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; International Spine Study Group

Hypothesis
To identify surgical and radiographic factors associated with multidimensional composite success after ASD surgery

Design
Retrospective multicenter study of 994 ASD treated between 2008 and 2018 with minimum 2-year follow-up

Introduction
ASD surgery outcomes are traditionally assessed using single metrics (e.g., disability, improvement, or revision). A multidimensional framework incorporating disability improvement, pain relief, and revision-free survival may better reflect comprehensive success.

Methods
Composite success required achievement in all 3 domains: disability (ODI ≤20 or improvement >14), leg pain (NRS ≤3 or improvement >3), and absence of reoperation for mechanical or neurologic complications. Associations between surgical techniques, postoperative alignment, and outcomes were evaluated using univariate analyses and multivariable logistic regression.

Results
Composite success was achieved in 42.8% (425/994) of patients, with individual domain success rates of 60.9% (disability), 64.8% (leg pain), and 81.2% (no reoperation). Domain-specific analyses revealed divergent and sometimes opposing effects of surgical procedures (Figure). On univariate analysis, composite success was associated with less extensive surgical intervention: lower rates of decompression (55% vs 63%), 3CO (14% vs 20%), LIV to ilium (75% vs 83%) (all p<0.05), as well as modestly but significantly better postoperative sagittal alignment (PT, TPA and SVA, all p <0.03). Multivariate analysis identified 3CO (OR 0.64, p=0.020), LLIF (OR 0.70, p=0.050), LIV to ilium (OR 0.62, p=0.005), post-operative TPA < 20° (OR 1.5, p=0.003) and lumbar Cobb > 15° (OR 1.6, p<0.001) as independently associated with composite success. However, after adjustment for baseline characteristics and deformity severity, no surgical technique or alignment parameter remained independently predictive

Conclusion
Although several surgical strategies and alignment targets were associated with better 2-year outcomes on univariate analysis, these associations did not persist after adjustment for baseline patient and deformity characteristics. Composite success appears more strongly driven by underlying patient factors than by specific procedures or radiographic thresholds. Finally, predictors differed across domains, reinforcing that reliance on a single metric may misrepresent patient benefit

		Decomp.	Osteo?	3CO?	Any IBF?	ALIF?	PLIF / TLIF?	LLIF?	LIV Ilium?	UIV: T1-6	UIV: T7-12	UIV: L1-5
ODI < 20	No	367 (65.07%)	387 (68.5%)	117 (20.71%)	386 (68.32%)	146 (25.84%)	190 (33.63%)	108 (19.12%)	481 (85.28%)	204 (36.1%)	263 (46.5%)	92 (16.3%)
	Yes	225 (52.45%)	307 (71.56%)	57 (13.29%)	272 (63.4%)	109 (25.47%)	116 (27.04%)	69 (16.12%)	318 (74.13%)	186 (43.4%)	188 (43.8%)	53 (12.4%)
p-value		0.000	0.329	0.002	0.119	0.942	0.027	0.241	0.000		0.044	
ODI MCID	No	282 (57.32%)	331 (67.14%)	94 (19.07%)	309 (62.68%)	113 (22.92%)	151 (30.63%)	88 (17.85%)	377 (76.63%)	196 (39.8%)	213 (43.2%)	76 (15.4%)
	Yes	310 (61.88%)	363 (72.46%)	80 (15.97%)	349 (69.66%)	142 (28.4%)	155 (30.94%)	89 (17.8%)	422 (84.23%)	194 (38.7%)	238 (47.5%)	69 (13.8%)
p-value		0.155	0.073	0.211	0.023	0.050	0.095	1.000	0.003		0.478	
Leg Pain <3	No	240 (66.85%)	250 (69.44%)	80 (22.22%)	253 (70.28%)	94 (26.11%)	121 (33.61%)	70 (19.44%)	304 (84.68%)	123 (34.2%)	167 (46.4%)	69 (19.2%)
	Yes	352 (55.52%)	444 (70.03%)	94 (14.83%)	405 (63.88%)	161 (25.43%)	185 (29.18%)	107 (16.9%)	495 (78.08%)	267 (42.1%)	284 (44.8%)	76 (12%)
p-value		0.000	0.886	0.004	0.043	0.821	0.153	0.343	0.012		0.003	
Les Pain MCID	No	356 (55.45%)	459 (71.38%)	118 (18.35%)	404 (62.83%)	164 (25.55%)	177 (27.53%)	113 (17.6%)	492 (76.64%)	284 (44.2%)	272 (42.3%)	82 (12.8%)
	Yes	236 (67.24%)	235 (66.95%)	56 (15.95%)	254 (72.36%)	91 (25.93%)	129 (36.75%)	64 (18.23%)	307 (87.46%)	106 (30.2%)	179 (51%)	63 (17.9%)
p-value		0.000	0.149	0.383	0.003	0.939	0.003	0.862	0.000		0.000	
Revision	No	123 (63.73%)	137 (70.98%)	43 (22.28%)	137 (70.98%)	60 (31.09%)	61 (31.61%)	44 (22.8%)	166 (86.01%)	74 (38.3%)	94 (48.7%)	24 (12.4%)
	Yes	469 (58.63%)	557 (69.54%)	131 (16.35%)	521 (65.04%)	195 (24.37%)	245 (30.59%)	133 (16.63%)	633 (79.13%)	316 (39.5%)	357 (44.6%)	121 (15.1%)
p-value		0.220	0.727	0.058	0.127	0.066	0.795	0.047	0.033		0.499	

13. High Accuracy, Strong Reliability, and Test–Retest Stability in Identifying New Transverse Plane Modifiers of the SRS–Lenke–Aubin 3D Classification of AIS

Lawrence G. Lenke, MD; Carl Eric Aubin, PhD, P.Eng; Delphine Aubin, MS; Michael G. Vitale, MD, MPH; Virginie Lafage, PhD; Brice Ilharreborde, MD, PhD; A Noelle Larson, MD; Jeffrey Mullin, MD; Michelle C. Welborn, MD; Takashi Kaito, MD, PhD; Justin S. Smith, MD, PhD

Hypothesis
The transverse-plane modifiers of the new SRS–Lenke–Aubin 3D classification can be identified with high accuracy and inter- and intra-assessor agreement.

Design
Test–retest usability and reliability study of AIS cases with standardized 2D and 3D displays and ground-truth comparison of the 2 transverse plane modifiers across two assessment sessions.

Introduction
The SRS-Lenke-Aubin 3D classification of AIS is recently published, but the ability to accurately recognize the new transverse plane modifiers is unknown.

Methods
Ten members of the SRS 3D Classification Task Force independently assessed 30 AIS cases (Lenke 1–6) across 2 sessions one week apart, with cases randomized per session. Cases were reviewed using radiographs with 2D measures, transverse views with key 3D measurements, and the standard Lenke classification. Participants assigned two transverse-plane modifiers of the new SRS–Lenke–Aubin 3D classification: ORPD (Orientation of the Regional Planes of Deformity: 1 <70°, 2 70–89°, 3 ≥90°) and AVR (Apical Vertebral Rotation: s <10°, m 10–19°, l ≥20°) for the proximal thoracic, main thoracic, and thoracolumbar/lumbar regions (6 values/case; 180 responses/participant/round). Accuracy was computed vs. a predefined ground truth. Within-round agreement was quantified using intraclass correlation coefficients

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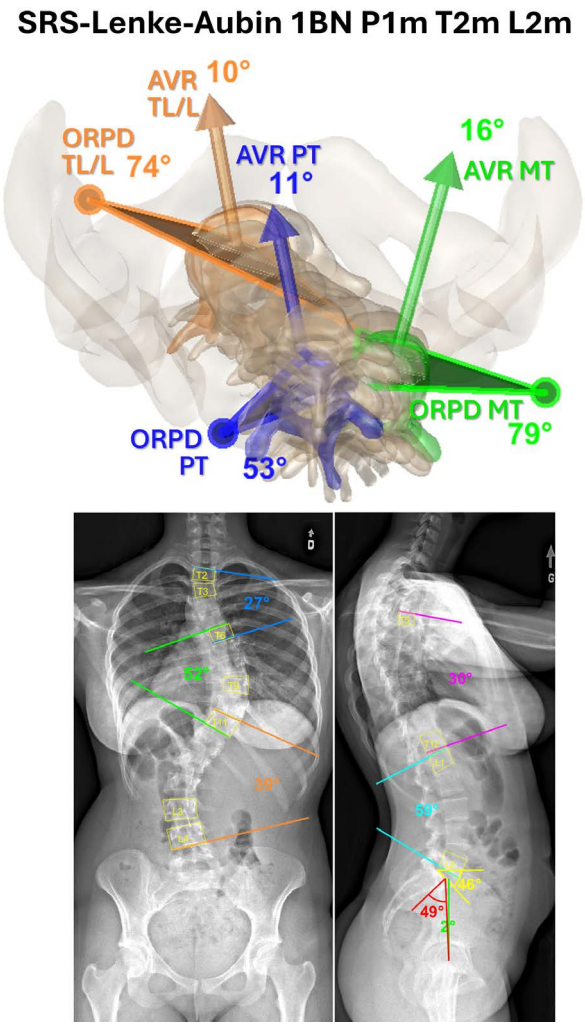
(ICC; two-way random-effects, absolute agreement) and Fleiss' kappa. Test–retest stability was assessed using exact agreement, quadratic weighted kappa (κw), and ICC. Completion time was summarized, excluding outliers using the 1.5×IQR rule.

Results
Accuracy vs. ground truth was 98.33% in Round 1 and 98.39% in Round 2, with exact test–retest agreement of 97.83%. Test–retest consistency was very high for both modifiers (pooled κw =0.957 for ORPD; 0.982 for AVR). Test–retest ICC(2,1) was 0.957 for ORPD and 0.983 for AVR; complementary two-way mixed-effects ICC(3,1) yielded similar values, confirming excellent temporal stability of modifier identification. Mean completion time (one outlier excluded) decreased from 24.2±9.3 to 20.2±7.2 min.

Conclusion
Across a broad spectrum of AIS cases, participants consistently identified the transverse-plane modifiers with very high accuracy, strong within-round agreement, and robust test–retest stability, supporting the usability and reliability of the new SRS-Lenke-Aubin 3D Classification framework.



Case example.

14. Beyond the 2D Lenke Classification: Clinically Relevant Insights from Transverse-Plane Descriptors of the SRS-Lenke-Aubin 3D Framework in Lenke 1 AIS

Carl Eric Aubin, PhD, P.Eng; Brice Ilharreborde, MD, PhD; Lawrence G. Lenke, MD; Takashi Kaito, MD, PhD; A Noelle Larson, MD; Delphine Aubin, MS; Christiane Caouette, PhD; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Jeffrey P. Mullin, MD; Michelle C. Welborn, MD

Hypothesis
Transverse-plane descriptors of the SRS–Lenke–Aubin 3D classification capture clinically relevant features of Lenke 1 AIS not fully captured by 2D Lenke modifiers or radiographic measures.

Design
Retrospective analysis using transverse-plane descriptors derived from the SRS–Lenke–Aubin 3D classification.

Introduction
Lenke 1 is the most common AIS pattern, yet assessment relies mainly on radiographic 2D measures. This study examined whether transverse-plane descriptors—orientation of the regional plane of deformation (ORPD), apical vertebral rotation (AVR) and apical 3D distance to the end-vertebrae line (DAEVL)—provide clinically relevant information beyond standard 2D characterization.

Methods
101 Lenke 1 AIS cases were 3D reconstructed from preop radiographs. ORPD, AVR, and DAEVL were analyzed in proximal thoracic (PT), main thoracic (MT), and thoracolumbar/lumbar (TL/L) regions and compared with 2D measures: Cobb, thoracic kyphosis (TK), lumbar lordosis (LL). Associations between Lenke modifiers and transverse-plane modifiers were assessed using contingency tables (χ^2, Cramér's V). Pearson correlations and multivariate regression evaluated regional coupling and independent coronal and sagittal contributions to ORPD. Subgroup analyses compared Lenke 1A, 1B, and 1C curves.

Results
ORPD showed no association with Cobb magnitude in thoracic regions, but a moderate association in TL/L. Cobb–AVR correlations were weak to moderate across regions. ORPD and AVR were independent in the thoracic spine yet moderately coupled in TL/L. Lower TK correlated with increased MT ORPD. LL was unrelated to TL/L ORPD. DAEVL was moderately associated with Cobb magnitude and selectively with ORPD and AVR, mainly in TL/L. Strong associations emerged between Lenke lumbar modifier and TL/L ORPD, and between thoracic sagittal profile modifier and MT ORPD ($p<0.01$). Multivariate analyses confirmed region-specific patterns, with MT ORPD driven by sagittal alignment and TL/L ORPD by coronal severity. 3D involvement increased from Lenke 1A to 1C.

Conclusion
In Lenke 1 AIS, substantial 3D heterogeneity was noted, with similar Cobb angles corresponding to markedly

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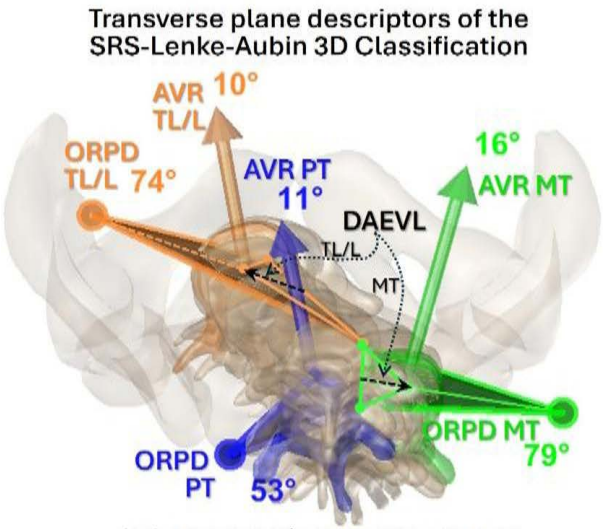
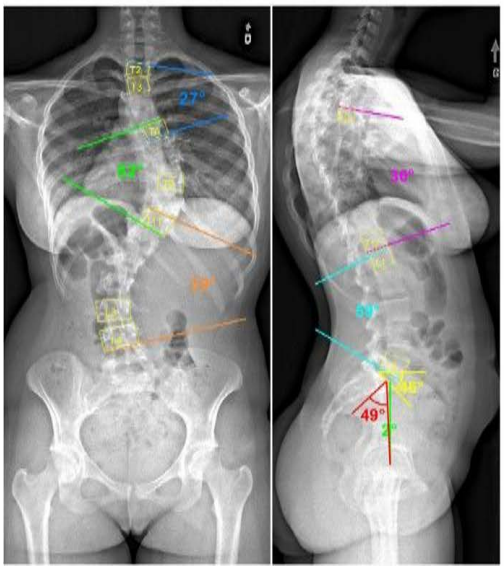
different transverse-plane patterns. ORPD, AVR and DAEVL therefore provide complementary, region-specific characterization beyond conventional 2D assessment, supporting their integration within the SRS–Lenke–Aubin 3D classification.



SRS-Lenke-Aubin 1BN P1m T2m L2m



15. A Quantitative CT-Based Analysis of Vertebral Rotational Asymmetry and Pulmonary Function in Scoliosis

Beomsu Kim, MD; Ihnseok Chae, MD; Jeuk Lee, MD; Sung Taeck Kim, MD; Bong-Soon Chang, MD, PhD; Sam Yeol Chang, MD; Hyoungmin Kim, MD

Hypothesis
We hypothesized that CT-derived global rotational asymmetry between the main and compensatory curves (ΔR(M–C)) is most strongly associated with pulmonary function test outcomes, reflecting integrated thoracic torsional burden in scoliosis.

Design
Retrospective cross-sectional cohort study.

Introduction
Scoliosis is a 3D deformity; axial rotation can distort thoracic geometry and reduce ventilatory capacity. Two-dimensional measures and single-level apical rotation may not capture global torsional imbalance. We evaluated CT-derived rotation indices and their association with pulmonary function in an etiologically heterogeneous cohort.

Methods
We reviewed 250 patients with scoliosis who underwent full-spine CT and spirometry within 1 year (2013–2025). Vertebral rotation was measured on axial CT using the Aaro–Dahlborn method. Indices included apical rotation (R(Apex)), 3-level mean apical rotation (R(Avg)), and rotational asymmetry between main and compensatory curves (ΔR(M−C)=|RM−RC|), where RM is the maximal main-curve rotation and RC is the maximal counter-rotation in the compensatory curve. Outcomes were FVC, FEV1, FVC%, and FEV1%. Pearson correlation and multivariable linear regression adjusted for age, sex, height, and weight were performed, with subgroup analyses by etiology.

Results
The cohort had a mean age of 15.6 ± 5.7 years; 49.6% were female. All rotation indices showed significant negative correlations with pulmonary function in the overall cohort. ΔR(M–C) showed strongest associations with FVC% ($r = -0.66$) and FEV1% ($r = -0.64$), as well as with absolute volumes (FVC, $r = -0.59$; FEV1, $r = -0.58$). In adjusted multivariate analyses, models incorporating ΔR(M–C) consistently demonstrated the highest explanatory performance compared with models based on R(Apex) or R(Avg). Subgroup analysis revealed the strongest associations in neurofibromatosis-related scoliosis ($r = -0.87$) and congenital scoliosis ($r = -0.71$). Associations were attenuated in neuromuscular subtypes and did not reach statistical significance in SMA.

Conclusion
CT-derived global rotational asymmetry between the main and compensatory curves is strongly associated with pulmonary function impairment in scoliosis and demonstrates superior explanatory performance to single-level rotation indices in adjusted models. Incorporating a CT-derived metric may complement traditional two-dimensional assessments for functional risk stratification.

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

16. Adolescent Idiopathic Scoliosis with a Major Proximal Thoracic Curve: A Rare Type not Included in the Lenke Classification System - the Incidence, Radiographic Characteristics and Surgical Strategy

Huafeng Zhang, MD; Yu-Cheng Yao, MD; Ben Long Shi, MD; Saihu Mao, MD; Zhen Liu, MD, PhD; Zezhang Zhu, MD, PhD; Yong Qiu, PhD

Hypothesis
Adolescent idiopathic scoliosis (AIS) with a major proximal thoracic curve is rare and not included in the Lenke classification system. There are few literatures about this type of AIS.

Design
This is a retrospective study.

Introduction
Adolescent idiopathic scoliosis (AIS) with a major proximal thoracic curve is rare and not included in the Lenke classification system. There are few literatures about this type of AIS. The purpose of this study is to investigate the incidence, radiographic characteristics and surgical strategy for AIS with a major curve at the PT area.

Methods
AIS patients with a major curve at the PT spine treated surgically from January 2014 to January 2024 were included in our study. All the patients were corrected by posterior spinal fusion with pedicle screws and were followed at least two years after surgery. We evaluated the pre- and post-operative Cobb angles of the curve, curve range, location of the apex, sagittal parameters, and shoulder balance-related parameters.

Results
There are 43 patients out of 3103 AIS patients (1.39%) were included in this study. The average age of the patients was 14.8 years (range 11 to 18 years). There are 19 females and 24 males. The patients were classified to non-structural main thoracic group(NSMT) , in which the main thoracic curve was corrected to less than 25° on supine push-bending films, and structural main thoracic group (SMT), in which the MT curve was structural. There are 23 patients in NSMT group and 20 patients in the SMT group. The mean pre-operative cobb angle of proximal thoracic curve in NSMT and SMT group was 48.96°±6.1° and 55.2±12.36° respectively. The mean pre-operative cobb angle of main thoracic curve in NSMT and SMT group was 39°±8.6° and 48±9.1° respectively. The mean post-operative cobb angle of proximal thoracic curve in NSMT and SMT group was 18.78°±4.9° and 23.8±6.18° respectively. The mean post-operative cobb angle of main thoracic curve in NSMT and SMT group was 12.0°±4.33° and 15.35±5.84° respectively.

Conclusion
We reported a cohort of AIS with a major proximal thoracic curve, which is relatively rare curve type. Individualized surgical strategies are warranted for these patients based on different curve patterns to ensure a favorable clinical outcome.

17. Proximal Thoracic-Predominant Lenke 2 Curves Have Important Surgical Differences

Zaid Elsabbagh, BS; Ysa Le, BS; William ElNemer, BS; Daniel Badin, MD; Peter O. Newton, MD; Suken A. Shah, MD; *Paul D. Sponseller, MD*

Hypothesis
Correction of proximal thoracic–predominant (PTP) Lenke 2 curves is improved with constructs providing concave upward force rather than bilateral downward hooks.

Design
Retrospective multicenter cohort study.

Introduction
Lenke 2 adolescent idiopathic scoliosis (AIS) typically features a dominant main thoracic (MT) curve with a smaller proximal thoracic (PT) curve. Rarely, the PT curve equals or exceeds the MT curve. This PTP configuration is poorly characterized. This study characterized PTP Lenke 2 curves and evaluated the impact of proximal fixation strategy on alignment.

Methods
AIS patients with Lenke 2 curves undergoing posterior spinal fusion were identified. PTP curves were defined by PT Cobb angle ≥ MT Cobb angle and compared with MT-predominant (MTP) curves. Outcomes included PT and MT Cobb angles, deformity angular ratio (DAR), T1 tilt, shoulder balance, and SRS-22 self-image scores. Proximal fixation strategy and PT Ponte osteotomy use were analyzed.

Results
Of 915 Lenke 2 patients, 38 (3.1%) had PTP curves. Compared with MTP, PTP patients had larger PT curves (52° vs 37°), smaller MT curves (50° vs 60°), higher PT DAR (10.1 vs 6.0), and greater preoperative T1 tilt (15.3° vs 5.2°; all p<0.01). PTP patients achieved greater PT correction (59% vs 48%) but lower MT correction (63% vs 70%) and higher two-year postoperative T1 tilt (9.4° vs 7.5°, p=0.01). SRS-22 self-image scores were higher in PTP patients pre- and postoperatively. Within the PTP cohort, concave upward UIV hook constructs achieved the lowest residual T1 tilt (5.8° ± 4.3°) compared with pedicle screw–dominant (7.2° ± 3.7°) and bilateral downward hook constructs (9.0° ± 5.3°; p=0.041), with lower rates of persistent left shoulder elevation (40% vs 62% vs 100%; p=0.028). PT Ponte osteotomies increased PT correction in PTP curves (68% vs 35%, p=0.04).

Conclusion
PTP Lenke 2 curves are a rare, distinct phenotype with high DAR, greater preoperative T1 tilt and different correction behavior than MTP curves. Successful management requires proximal thoracic mobilization, with concave upward pedicle hook fixation strategies and Ponte osteotomies in the PT curve, which are associated with improved cervicothoracic alignment.

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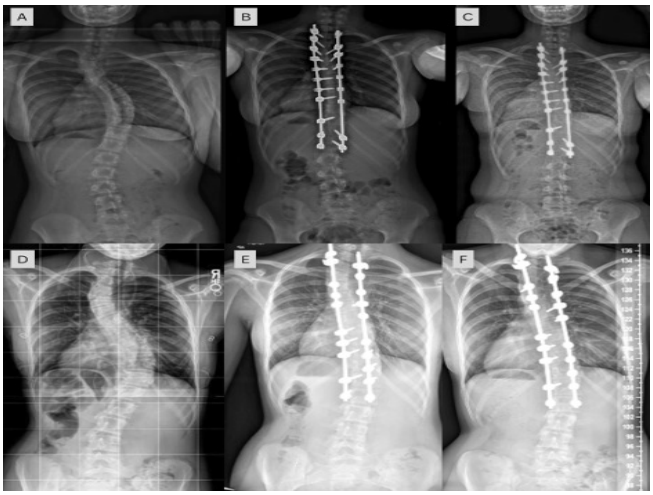

Representative AP radiographs of PTP Lenke 2 curves showing improved T1 leveling with concave UIV pedicle hook fixation (A–C) compared with bilateral downward hooks (D–F).

18. Variation in Flexibility Imaging Techniques in Adolescent Idiopathic Scoliosis (AIS): A Multicenter Study

Alexander Park, BS; Michael W. Brown, BS; Mehdi Elfilali, BA; Joshua Akosa, BS; Michael G. Vitale, MD, MPH; Harms Study Group; *Benjamin D. Roye, MD*

Hypothesis
We hypothesize there will be significant variations in radiographic bending technique usage and measurements between and within sites.

Design
Retrospective cohort review of a prospective registry.

Introduction
Curve flexibility in AIS posterior fusion surgery is critical for preoperative planning to help predict achievable correction, inform fusion level selection, and identify the need for adjudicative procedures. There are many variations of radiographic bending assessment (e.g., supine, standing, fulcrum, traction). However, there is no consensus on the optimal method. This study aims to evaluate the variation of radiographic flexibility techniques used within and between sites of a multicenter registry.

Methods
Surgical patients enrolled in a multicenter AIS registry between 2009 - 2025 were included. Demographic, thoracic and lumbar bending methods, and radiographic data were collected. Patients were matched into cohorts (N=57) by Lenke curve type (1-6), skeletal maturity (Risser 0-3 or 4-5), and Cobb angle (5° increments from 40-70°). Curve flexibility was measured using: 100*(Cobb – Bending Cobb)/Cobb. The spread of variance across cohorts within each technique was assessed using the Brown-Forsythe test. Within each cohort, the lowest-variance technique ("winner") was compared to the next-ranked techniques using paired variance ratio tests.

Results
2704 patients (15.2 ± 2.3 years old; 81% female at 24 sites were included. Supine bending was the most common thoracic (49%) and lumbar (57%) flexibility assessment method. 23/24 sites utilized the same bending method >95% of the time for thoracic and lumbar flexibility assessments. Brown-Forsythe testing demonstrated stable variability across cohorts within supine (p=0.137), standing (p=0.175), and fulcrum (p=0.752) bending. Most variance-based rankings across cohorts were not statistically significant (91%). However, supine bending accounted for 61% of all variance-based "wins" and was the winning technique in all statistically significant comparisons.

Conclusion
Supine bending was the most utilized curve flexibility assessment method, and sites were internally consistent with bending film methodology. Supine films demonstrated the lowest variance across matched patient cohorts, suggesting the highest reproducibility among current practices. These findings support the use of supine bending as the current standard flexibility assessment method.

Example of a matched cohort rank for patients with a Lenke 1 curve, Risser 0-3, and Cobb 50-55°

Matched Group (Lenke, Risser, Cobb)	First Place	N	Variance	Second Place	N	Variance	Third Place	N	Variance
1 | 0-3 | (50.0, 55.0]	supine bending	52	176.2	standing	41	356.7	fulcrum	8	570.3

19. Accuracy of IS-GROWTH Predictions of the Risk of Reaching the Clinically Significant Thresholds of 30°, 45° And 50° in Idiopathic Scoliosis Patients.

Stefano Negrini, MD, PhD; *Greta Jurenaite, MD;* Fabio Zaina, MD; Francesco Negrini, MD

Hypothesis
IS-GROWTH can accurately predict the risk of reaching clinically significant scoliosis thresholds by the end of growth: 30° for probable stability in adulthood; 45° and 50° for surgical indications.

Design
Secondary analysis of a retrospective study on prospectively collected data.

Introduction
IS-GROWTH has recently been developed to predict the progression of curves in patients with Idiopathic Scoliosis (IS) of all ages, with curves up to 70° at first observation. While it provides a graphical representation of the wide range of possible evolutions, IS-GROWTH does not offer a risk percentage or thresholds, unlike the previously developed BrAIST-Calc. The latter, however, applies only to adolescents with IS and curves between 20° and 40°, with Risser 0-2 at first observation.

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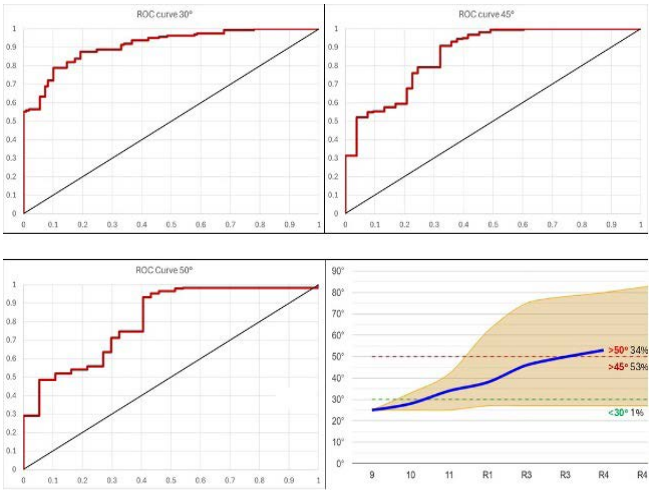
Methods
We analyzed the development and temporal validation groups from the previously published IS-GROWTH cohort, including all children with pre-treatment X-rays. Predicted curve ranges were examined in the validation group, and a square-root transformation was applied to approximate normality, assessed via Asymmetry and Kurtosis tests. Prediction models were developed for the 30°, 45°, and 50° thresholds, and temporal validation was performed on all radiograph pairs. Model performance was evaluated using discrimination (AUC), accuracy of risk estimates (Brier Scores with 95% CI), and calibration by comparing predicted probabilities with observed outcomes across risk deciles.

Results
We evaluated IS-GROWTH predictions for 552 patients (74% female, 12.4±2.0 to 14.7±1.7 years, 19±9° to 26±11°). A square-root transformation approximated normality (asymmetry 0.01, kurtosis 0.72). Temporal validation included 270 radiograph pairs (187 patients, 87% female). At growth end, 109 radiographs were <30°, 53>45°, and 37>50°. AUCs were 0.91, 0.86, and 0.81 for 30°, 45°, and 50° thresholds; Brier Scores 0.19, 0.15, and 0.14, respectively. Calibration showed strong agreement between predicted and observed risks across all thresholds, including extremes.

Conclusion
IS-GROWTH provides validated probabilities for reaching clinically significant scoliosis thresholds, complementing graphical trajectories with quantitative risk estimates. This enables personalized counselling and shared decision-making, allowing clinicians to quantify individual risk of progression or surgery and optimize treatment timing.



20. The Closing Triradiate Cartilage Stage Identifies Accelerated Curve Progression in Idiopathic Scoliosis

Hong Zhang, MD; Judy-Mae Lima, BS; Chan-Hee Jo, PhD; Daniel J. Sucato, MD, MS

Hypothesis
A distinct transitional phase exists between the open and closed triradiate cartilage (TRC) that represents a biologically critical window for accelerated curve progression.

Design
Retrospective cohort study

Introduction
TRC status is commonly used to assess skeletal maturity and progression risk in scoliosis, however, its traditional binary classification as open or closed may inadequately capture critical transitional growth periods. This study aimed to re-evaluate TRC maturation, with particular emphasis on this transitional period, and to investigate scoliosis progression and growth patterns during the transitional phases.

Methods
A retrospective longitudinal study was conducted of 179 patients with idiopathic scoliosis (126 girls, 53 boys, mean age 9.7±1.5 years) who were followed from childhood through early adolescence. Inclusion criteria were age >6 years with an open TRC at baseline, initial major Cobb angle between 10° and 45°, and documented curve progression to ≥50° requiring surgical treatment during adolescence. TRC status was classified as open, closing, initial-closed, or fully closed based on radiographic appearance. Cobb progression rate (CPR), total spine height increase rate (TSHIR), and patient standing height increase rate (PSHIR) were measured and calculated for each TRC stages.

Results
In both sexes, CPR peaked during the closing-TRC stage, increasing approximately fivefold in girls and more than thirtyfold in boys compared with the open-TRC stage ($p<0.0001$). Elevated CPR persisted into the initial-closed-TRC stage. TSHIR did not peak during closing-TRC and showed a significant inverse correlation with CPR in girls, whereas PSHIR remained relatively stable and did not correlate with CPR in either sex. The closing-TRC stage had a mean duration of 0.8±0.3 years, occurring between 11.1±0.9 and 12.0±0.9 years of age in girls. In boys, the closing-TRC lasted 1.0±0.5 years, occurring between 13.0±1.1 and 13.9±1.2 years, approximately 1.9 years later than in girls.

Conclusion
Redefining TRC maturation into four distinct stages identifies the closing-TRC stage as a critical window for accelerated scoliosis progression. This readily obtainable radiographic marker may enhance early risk stratification, inform surveillance timing, and support more proactive clinical decision-making in skeletally immature patients with idiopathic scoliosis.

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† Hibbs Award Nominee – Best Basic Science/Translational Paper
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PODIUM ABSTRACTS

21. Deep Learning of Apical Intervertebral Disc MRI Predicts Scoliosis Progression Independent of Radiographic Parameters

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Hypothesis
Apical intervertebral disc morphology on MRI independently predicts scoliosis progression to surgery in adolescents with idiopathic scoliosis.

Design
Retrospective cohort study with deep learning–based imaging analysis.

Introduction
Current models for predicting adolescent idiopathic scoliosis (AIS) progression rely largely on radiographic spinal geometry, despite growing evidence that intervertebral disc changes may precede structural deformity. This study evaluated whether deep learning (DL) applied to apical intervertebral disc slices on MRI can independently predict progression to surgery, and assessed the incremental value of additional clinical variables.

Methods
Axial MRI regions of interest of apical intervertebral discs were extracted from 477 AIS patients. Images were standardised and augmented prior to analysis. A custom convolutional neural network (CNN) was trained to predict progression to surgical intervention within 5 years using the morphological appearance of the disc images alone. Numerical clinical variables (Cobb angle, age at imaging, and apical disc level) were subsequently integrated with CNN-derived features using a boosting-based classifier. The model was internally validated and performance evaluated on held-out validation data using accuracy, area under the receiver operating characteristic curve (AUC), and binary cross-entropy.

Results
DL analysis of disc images alone demonstrated strong predictive performance, achieving 81.3% accuracy with an AUC of 0.81. Incorporation of numerical clinical variables produced a modest improvement, with the combined model reaching 83.3% accuracy and an AUC of 0.82, alongside improved probability calibration. This is compared to an accuracy of 77.1% (AUC 0.87) when using Cobb angle alone as a predictor.

Conclusion
Apical intervertebral disc deformation on MRI is a strong independent predictor of AIS progression, supporting a disc-centred driver of disease evolution. While additional numerical clinical variables provide incremental benefit, deep learning of disc images alone achieves robust discrimination. Additionally, this MRI-based approach aligns with a growing focus on radiation-free care, offering a safer framework for early risk stratification. These findings reinforce disc-level imaging biomarkers as efficacious, non-ionising alternatives and offer a scalable framework for predictive modelling in scoliosis.

22. Can Machine Learning Optimize Fusion Selection in Thoracic Adolescent Idiopathic Scoliosis? – a Dual-center Cohort Study with External Validation

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Hypothesis
Fusion shorter than the last touched vertebra (LTV) can be safely performed in selected patients with main thoracic adolescent idiopathic scoliosis (AIS)

Design
Retrospective dual-center cohort study.

Introduction
The optimal selection of the lowest instrumented vertebra (LIV) remains a critical challenge in the surgical management of AIS. Traditional strategies rely on the LTV, but this approach may not fully account for three-dimensional curve- and flexibility characteristics. We aimed to evaluate whether the use of a machine learning algorithm could improve patient-specific selection of the LIV and decrease the risk of distal adding-on in patients with thoracic AIS.

Methods
The derivation cohort included 177 AIS patients (Lenke type 1 or 2, lumbar modifier A/B) treated with selective posterior fusion. Radiographic analysis included a wide variety of parameters from coronal, sagittal and bending x-rays. After identifying the five most predictive preoperative parameters using random forest modeling and ROC analysis, the algorithm was externally validated in a cohort of 289 patients where LIV selection followed a standardized protocol. The primary outcome was distal adding-on at minimum two-year follow-up.

Results
Adding-on was observed in 33% and 21% of patients in the derivation and validation cohorts, respectively. Of the variables tested, only the S1-LIV angle - a measure of vertebral deviation from the midline - remained a significant predictor in multivariate analysis. An S1-LIV angle above 9.5° was associated with fourfold increased odds of adding-on. Machine learning-selected axial and sagittal parameters did not yield improvement over the S1-LIV angle alone when validated externally. Notably, selection of the LIV based on the S1-LIV angle saved lumbar motion segments in approximately 20% of patients without increasing the risk of adding-on.

Conclusion
The S1-LIV angle offers a quantitative tool for individualized LIV selection in AIS, and its use may facilitate lev-

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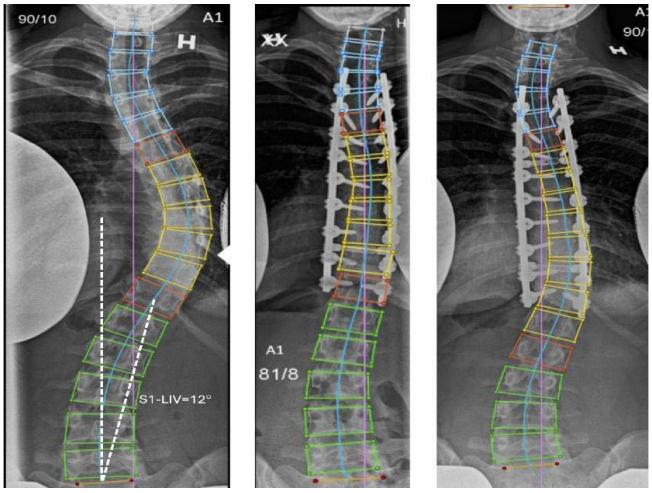
el-sparing strategies in surgical planning without compromising patient outcomes.



A 55-degree Lenke 1A curve with an S1-LIV angle of 12 degrees. The last touched vertebra was L1. The patient was operated with a Th4-Th12 fusion with good immediate correction (middle). Two-year postoperative x-ray (right) showed adding-on with progression of the main curve and distalisation of the end vertebra.

23. Updated Guidance on Lower Instrumented Vertebra Horizontalization in Lenke C Curves after Selective Thoracic Fusion: The Concept of Dynamic Lumbar Curve Behavior

Josephine R. Coury, MD; Ying Yu, MD; Eduardo C. Beauchamp, MD; Mehdi Elfilali, BA; Justin L. Reyes, MS; Nicholas Laskay, MD; Evan Joiner, MD; Lawal A. Labaran, MD; Matthew E. Simhon, MD; Zeeshan M. Sardar, MD; Benjamin D. Roye, MD; Lawrence G. Lenke, MD; Michael G. Vitale, MD, MPH

Hypothesis
In AIS, a dynamic lumbar C modifier (C to B on supine films) in structural lumbar curves is associated with tolerance of a more horizontal LIV and improved radiographic outcomes compared with a fixed Lenke C modifier.

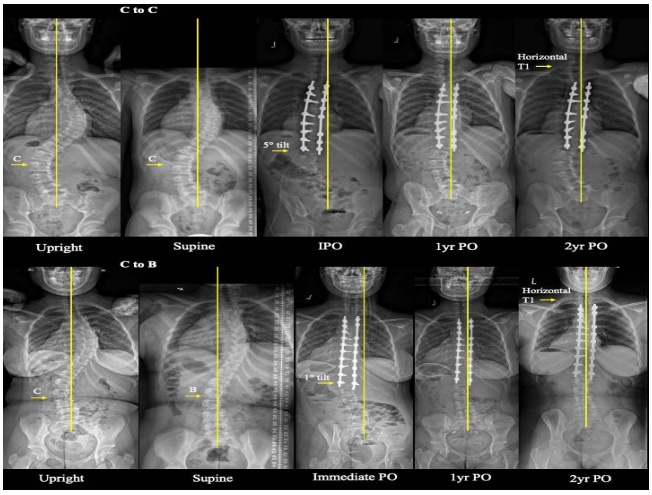
Design
Retrospective Review

Introduction
Selective thoracic fusion (STF) can be performed in select AIS pts with structural lumbar curves; however, optimal lower instrumented vertebra (LIV) alignment in Lenke C curves remains controversial. While a tilted LIV has traditionally been recommended to maintain coronal balance, LIV horizontalization may facilitate spontaneous lumbar curve correction at the risk of shoulder or coronal imbalance. "Dynamic alignment", defined as a Lenke C modifier on upright XRs but Lenke B on supine XR, is a means of reliably quantitating lumbar curve flexibility. We hypothesize that this concept will be useful in guiding treatment strategies in Type C curves.

Methods
Review of AIS pts with a Lenke C modifier on upright XRs who underwent STF (LIV T11–L2) with ≥2-year f/u. Pts were stratified by dynamic lumbar behavior (C to B vs C to C on supine XRs) and postop LIV orientation (horizontal vs tilted), yielding four groups (CBH, CBT, CCH, CCT). Outcomes included sagittal/coronal alignment (C7CSVL, C7SVA), LIV tilt, thoracolumbar (TL) cobb, and shoulder balance (T1 tilt).

Results
30 AIS pts were identified. In C to C curves, pts with a tilted LIV (CCT; mean immediate postop [IPO] LIV tilt 7°) had significantly better 2-year alignment than those with horizontal LIVs (CCH; IPO tilt 2°), including lower T1 tilt (0.6°vs11°,p<0.001), reduced C7CSVL (0.4 vs 6cm,p=0.003), lower CSVL–LIV distance (0.6 vs 2.1cm,p=0.03), and improved C7SVA (1.6 vs 5.8cm,p=0.01). In contrast, CCH pts had progressive LIV tilt to 13° with left shoulder imbalance. For C to B pts, CBH LIV tilt was 2° IPO and remained stable at 2yrs. Compared CBT, IPO tilt 9°, CBH pts had better shoulder balance (T1 tilt 0.8°vs5.8°,p<0.001), reduced C7CSVL (0.5 vs 3.8cm,p=0.007), and smaller CSVL–LIV (0.6 vs 1.3cm,p=0.01), with no difference in C7SVA (1.5 vs 2.1cm,p=0.10).

Conclusion
In AIS pts undergoing STF, LIV tilt should be guided by dynamic lumbar behavior. Curves that convert from Lenke C to B supine tolerate LIV horizontalization with favorable coronal and shoulder balance, whereas curves that remain C require a tilted LIV to maintain balance.



CCT vs CBH

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PODIUM ABSTRACTS

24. Long-Term Clinical and Radiographic Outcomes of Stopping Fusion at L3 in Structural Lumbar Curves Despite Standing and Bending X-rays Indicated to Stop at L4: A Minimum 20-Year Follow Up

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Hypothesis
Distal fusion can be safely stopped at L3 based on traction radiographs under general anesthesia (TrUGA), with durable and satisfactory long-term outcomes.

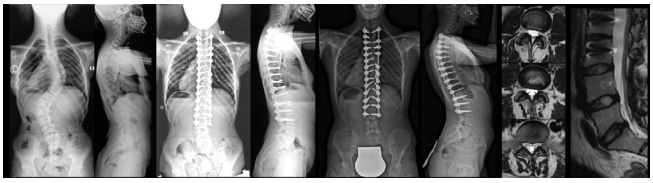
Design
Retrospective

Introduction
Selection of the LIV remains challenging in pts with structural lumbar curves particulary when choosing between L3 and L4. Stopping at L3 may help to maintain lumbar motion and limit degeneration in the unfused lomber spine. The long-term consequences of stopping at L3 instead of L4 remains unclear. The aim of this study was to assess the clinical and radiographic outcomes, and evaluate disc degeneration (DD) and facet joint degeneration (FJD) of unfused lumbar spine, at minimum 20-year f/up.

Methods
34 pts (28F/6M) with structural lumbar curves were included. In all pts, standing CSVL did not touch L3, and conventional standing and bending x-rays indicated L4 as LIV; however, fusion was stopped at L3 based on TrUGA. Radiographic assessment included coronal,sagital alignment, spinopelvic and vertebral pelvic angles (L1PA, T4PA, and T4–L1PA mismatch). Lumbar DD and FJD were evaluated on MRI using Pfirrmann and Fujiwara class. Clinical outcomes were assessed with SRS-22r.

Results
Mean f/up was 22.5 yrs (range, 20–30), mean age at final f/up was 34 yrs (32–43). Mean lumbar curve correction was 78%, with no significant loss of correction. Disc wedging below LIV (early: 0.4°±3.8°; final: 2.4°±3.2°) and residual curve below L3 (early: 3.1°±2.7°; final: 3.0°±2.2°) remained stable over f/up. Sagittal parameters showed no significant changes including L1PA, T4PA, and T4–L1PA mismatch. Mild degeneration was observed below L3, with mean DD grade of 3.12 (range,2–5) and FJD grade of 2.58 (range 1–4). Ten pts (33%) with sacral slanting >10° demonstrated one higher grade of DD and FJD at L5–S1 level compared with pts with <10°. SRS-22r total score at final f/up was 4.54 ± 0.23, and increased DD and FJD grades were not correlated with final SRS scores (all p>0.05).

Conclusion
According to our study with min 20-year f/up, distal fusion could be safely stopped at L3 based on TrUGA, even when conventional radiographs suggested L4. Coronal and sagittal alignment parameters remained stable, and degenerative changes below L3 didn't correlate with final SRS scores. However, sacral slanting >10° was associated with increased L5–S1 DD and FJD over 20-year f/up



25. Rate and Risk of Curve Progression in Moderate AIS following Skeletal Maturity

Firoz Miyanji, MD, FRCS(C); Abdullah AlDuwaisan, FRCS(C); Baron S. Lonner, MD; Paul D. Sponseller, MD; Tracey P. Bastrom, ; Burt Yaszay, MD; Stefan Parent, MD, PhD; Amer F. Samdani, MD; Harms Study Group; Peter O. Newton, MD

Hypothesis
Skeletally mature patients with moderate scoliosis do not have risk of curve progression into adulthood with no change in SRS outcome scores

Design
Multicenter,prospective

Introduction
Natural history of moderate AIS(≥30°) in skeletally mature patients is poorly defined.Studies reporting rates/risk factors for progression in AIS are predominantly of large curves in immature patients.Our aim was to determine the rate of curve progression in AIS following skeletal maturity and any associated changes in SRS-22 outcome scores;we also aimed to identify potential predictors of curve progression.

Methods
All patients had min 5yr f/u,AIS≥30°,and were skeletally mature(Risser≥4;females>14 and 2yrs post-menarche; boys>16 with no height change over 6mo).SRS-22 outcome scores and radiographic data were compared at baseline and 5yr f/u.Patients were divided into 2 grps based on curve size:Grp1=30-39° and Grp2≥40°.Curve progression was defined a priori as change in curve magnitude ≥5° at f/u.Univariate and multivariate regression explored the association between curve progression and variables of interest to identify predictors of progression.

Results
There were 116 patients with mean age of 16.6+/-1.5yrs;majority were females(91.4%).Mean major cobb at baseline was 39.9°+/-7.3°and 5yr f/u was 42.5°+/-8.6°.Mean change in Cobb was 2.6°+/-5.9°.Curve progression was noted in 27.6% of patients.24.7% of thoracic curves progressed compared to 32.6% thoracolumbar/lumbar curves.33.3% of Grp1 patients progressed compared to 22% in Grp2(p=0.3).Progressors had a

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significantly larger avg major Cobb at 5yr f/u compared to non-progressors (48.3°+/6.9°vs40.2°+/8.1°;p<0.001). Progressed curves on avg had a change in Cobb of 9.5°+/-4.6° with Grp1 trending to a greater rate of progression compared to Grp2(11.1°+/-5.4°vs7.2°+/-1.6°;p=0.015).SRS-22 scores on avg declined significantly over 5yrs(4.07 to 3.82;p<0.001).There was a significant decline in SRS general function(p<0.001),satisfaction(p=0.04),and total scores(p=0.02)in those that did not progressed.In progressed curves, there was a significant decline in all SRS domain scores.Univariate and multivariate analysis did not identify any predictors of curve progression.

Conclusion

Skeletally mature patients with moderate AIS(≥30°) may have a risk of progression at a mean rate of 1.9°/yr.Curve progression may lead to significant decline in SRS-22 outcome scores;in particular general function,pain and satisfaction.

Table

Patient Demographics	Baseline	5 yr f/u	
Mean age(yrs)	16.6+/-1.5	-	
Gender (%)	M=91.4 F=8.6	-	
Mean Major Cobb (°)	39.9°+/-7.3°	42.5°+/-8.6°	
% Curves progressed (>=5°)	-	27.6	
Mean Change of Progressed Curves(°)	-	9.5°+/-4.6°	
% Progressed curves - MT	-	24.7	
% Progressed curves – ThL/L	-	32.6	
Curve Size at Baseline	**Grp 1 (N=57)**	**Grp 2 (N=59)**	**P-value**
Mean Baseline Major Cobb (°)	33.9	45.6	<0.001*
% Curves Progressed	33.3	22	0.17
Mean Change of Progressed Curves (°)	11.1	7.2	0.02 *
SRS-22 Scores of Progressed curves (n=32)	**Baseline**	**5 year**	**P-value**
Pain	4.2	3.9	<0.001*
Self- Image	3.8	3.6	0.012 *
General Function	4.4	4.1	<0.001*
Mental Health	3.9	3.5	<0.001*
Satisfaction	4.0	3.7	0.02*
Total	4.1	3.8	<0.001*
SRS-22 Scores of Non-Progressed curves (n=84)	**Baseline**	**5 year**	**P-value**
Pain	4.2	4.1	0.2
Self- Image	3.9	3.8	0.43
General Function	4.6	4.2	<0.001*
Mental Health	4.0	3.7	0.09
Satisfaction	3.9	3.6	0.04*
Total	4.1	3.9	0.02*
Multivariate Regression Variables	**P-value**		
Age	0.72		
Major Cobb	0.32		
Thoracic T2 to T12	0.8		
Thoracic Translation	0.98		
Lumbar Translation	0.9		
Pelvic Incidence	0.83		
Pelvic Tilt	0.72		
Sacral Slope	0.64		

26. Later Menarche Tracks with AIS Curve Severity—Clinical Association and Genetic Causality in 5,891 Patients

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Hypothesis

Later age at menarche (AAM) and stronger family-history (FH) burden are positively associated with greater AIS curve severity. We hypothesized that AAM shows stronger genetic and causal links to curve severity than to AIS susceptibility.

Design

Retrospective cohort with integrative genetic analyses.

Introduction

AIS progression accelerates during puberty, making prediction of ultimate curve severity central to clinical management. Although later AAM and stronger FH burden correlate with curve severity, whether they relate specifically to severity rather than susceptibility and whether genetics supports causality remains unclear.

Methods

AIS patients (N=5,891) were analyzed. The outcome was Cobb angle at last follow-up. FH categorized by affected relative count (0, 1, ≥2). AAM analyzed continuously and ordinally (≤11, 12–15, ≥16 years). Associations were tested using linear regression adjusted for age and BMI. Using GWAS (genome-wide association study) summary statistics, bivariate LD (linkage disequilibrium) score regression assessed genetic correlation between AAM and AIS phenotypes (Cobb angle; susceptibility). Two-sample MR (Mendelian randomization) tested causal effects of AAM on Cobb angle severity and AIS susceptibility, and AIS susceptibility on Cobb angle severity.

Results

FH was associated with higher Cobb angle at last follow-up (β=1.26, P=0.02). Later AAM was associated with higher Cobb angle (β=1.95 degrees/year, $P=3.7\times10^{-23}$), with a monotonic trend across ordinal AAM categories (β=3.50 per category, $P=4.0\times10^{-11}$). Genetic correlation was significant between AAM and Cobb angle severity (rg=0.25, P=0.04) but not between AAM and AIS susceptibility (rg=0.04, P=0.33). MR supported a causal effect of genetically later AAM on Cobb angle severity (IVW=2.35, P=0.04) but not on AIS susceptibility (IVW=0.03, P=0.77). Genetically increased AIS susceptibility also causally increased Cobb angle severity (IVW=1.79, P=0.005).

Conclusion

Greater FH burden and later AAM track with higher Cobb angle, and genetic correlation plus MR support a biologic relationship between pubertal timing and ultimate Cobb angle rather than AIS susceptibility alone. While the absolute per-year AAM effect size is modest, the consistency across clinical and genetic analyses provides objective support for a widely held clinical impression and motivates further work on pubertal-timing pathways in AIS severity and progression.

27. Sacral Slanting Predicts Residual Disc Wedging After Fusion to L3 in AIS

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PODIUM ABSTRACTS

Hypothesis
Preoperative sacral slanting (SS) angle has the greatest impact on postoperative L3–4 disc wedging angle (DWA) in adolescent idiopathic scoliosis (AIS) patients whose fusion stops at L3.

Design
Retrospective cohort study.

Introduction
Previous studies have reported that fusion to L4 in patients with a high SS angle may lead to coronal decompensation, whereas stopping at L3 may increase residual DWA below the lowest instrumented vertebra (LIV); however, the relative contribution of SS compared with other coronal alignment parameters is unclear.

Methods
AIS patients with a structural thoracolumbar (TL) curve (Lenke types 3–6) who underwent posterior spinal fusion with L3 as the LIV and had ≥2-year follow-up were included. Patients with leg length discrepancy were excluded. SS was defined as the angle between the S1 superior endplate and the horizontal. DWA was measured at the L3–4 disc. Radiographic parameters measured on baseline, side-bending, and first-erect radiographs were used as candidate predictors, including TL Cobb angle, SS angle, LIV tilt, C7 plumb line to central sacral vertical line (C7-CSVL), LIV-CSVL, DWA, the angle between the construct axis and the LIV endplate, and the Cobb angle between the upper instrumented vertebra and LIV. The primary outcome was DWA at 2 years postoperatively. Candidate predictors were selected using least absolute shrinkage and selection operator (LASSO) regression to address potential collinearity, followed by multivariable linear regression.

Results
Forty-four patients were included (91% female; mean age 15.2 years; mean follow-up 2.7 years), with 61% Lenke type 5. Mean baseline TL Cobb angle, SS angle, and C7-CSVL were 50°, 3.4°, and 21 mm, improving to 15°, 2.7°, and 11 mm at 2 years, respectively. Mean DWA shifted from 2.7° toward TL convexity preoperatively to 5.0° toward concavity at 2 years. LASSO regression identified multiple candidate predictors; however, baseline SS angle was the only variable consistently selected across the overall cohort, Lenke type 5 subgroup, and non–type 5 subgroup. Greater baseline SS angle was independently associated with increased 2-year postoperative DWA ($\beta = 0.37$ per degree; 95% CI, 0.14–0.60; $P = 0.003$).

Conclusion
Preoperative SS angle was the most consistent predictor of residual DWA following fusion to L3 in AIS patients with structural TL curves and may aid patient counseling regarding a theoretically higher risk of future disc degeneration.

28. Is There a Cervical Alignment Threshold Warranting Cervical Inclusion in the Construct of Thoracolumbar ASD Patients?

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Hypothesis
Thoracolumbar (TL) adult spinal deformity (ASD) patients with poor preop cervical spine (CS) alignment have increased postop CS decompensation (D)

Design
Retrospective analysis of prospectively collected data

Introduction
Postop TL realignment in ASD patients may induce CS D. This study identifies CS D predictors after TL surgery and defines a BL CS alignment (C2PA) threshold for CS inclusion in the TL construct

Methods
ASD patients undergoing TL fusion to the sacrum with UIV at T2 or below and available BL and 2Y radiographs and PROMs were included. CS D was defined as CS surgery or >2SD above the mean in C2PA, cSVA, or TSCL at the studied postop timepoint. Radiographic parameters and PROMs were compared between D and non-D patients. Kaplan Meier (KM) analysis assessed BL C2PA impact on time to CS D. Cox regression identified predictors of CS D and BL C2PA thresholds, adjusting for preop CS and TL alignment (C2PA, TS-CL, PI-LL), prior CS surgery, age, sex, BMI, frailty, comorbidities, surgical invasiveness (SI), and UIV above vs below T8 (UT)

Results
Of 1,190 patients, 166 (13.9%) had CS D after TL surgery, including 24 (2.0%) requiring CS extension. CS D was identified in 81 patients (6.8%) at 6 weeks (4 (0.3%) extensions), 13 (1.2%) at 6 months (2 (0.2%)), 43 (3.9%) at 1Y (7 (0.6%)), and 29 (2.8%) at 2Y (11 (0.9%)). BL variables differed between patients with and without CS D and between those with and without CS extension (Fig1A). Patients with CS D at 6 months showed worse global and CS alignment at 6 weeks (LL: 53.6 vs 46.3; cSVA: 30.5 vs 38.5; $p<0.05$). CS D at 1 year was associated with worse PROMs at 1 year (PCS: 39.0 vs 35.4; SRS: 3.6 vs 3.3; $p<0.05$). CS D at 2 years was associated with worse CS alignment at 1 year (TS-CL: 20.8 vs 28.6; cSVA: 31.1 vs

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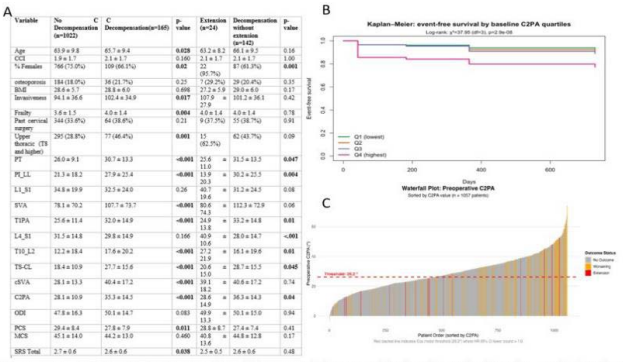
37.8) and worse PROMs at 2 years (ODI, PCS, SRS; p<0.05). KM analysis showed higher BL C2PA was associated with shorter time to CS D (Fig1B). Cox modeling identified BL C2PA (HR 1.05, 95% CI 1.03–1.06), TSCL (HR 1.05, 95% CI 1.03–1.06), SI (HR 0.99, 95% CI 0.98–0.99), and UT (HR 2.9, 95% CI 1.8–4.7) as predictors of CS D, with a C2PA threshold of 26.2° (Fig1C)

Conclusion

2Y after TL ASD surgery, 13.9% had CS D, with 14% requiring CS extension. After adjustment for patient factors and global alignment, BL CS alignment independently predicted CS D. Patients with preoperative C2PA >26.2° may benefit from CS inclusion in the TL construct



Variable	No Decompensation (n=1022)	C Decompensation(n=160)	p-value	Extension (n=24)	Decompensation without extension (n=142)	p-value
Age	63.9 ± 9.8	65.7 ± 9.4	**0.028**	63.2 ± 8.2	66.1 ± 9.5	0.16
CCI	1.9 ± 1.7	2.1 ± 1.7	0.160	2.1 ± 1.7	2.1 ± 1.7	1.00
% Females	766 (75.0%)	109 (66.1%)	**0.02**	22 (91.7%)	87 (61.3%)	**0.001**
osteoporosis	184 (18.0%)	36 (21.7%)	0.25	7 (29.2%)	29 (20.4%)	0.35
BMI	28.6 ± 5.7	28.8 ± 6.0	0.696	27.2 ± 5.8	28.9 ± 6.0	0.17
Invasiveness	94.1 ± 36.6	102.4 ± 34.9	**0.017**	107.9 ± 27.9	101.2 ± 36.1	0.42
Frailty	3.6 ± 1.5	4.0 ± 1.4	**0.004**	4.0 ± 1.4	4.0 ± 1.4	0.78
Part cervical surgery	344 (33.6%)	64 (38.6%)	0.21	9 (37.5%)	55 (38.7%)	0.91
Upper thoracic (T8 and higher)	295 (28.8%)	77 (46.4%)	**0.001**	15 (62.5%)	62 (43.7%)	0.09
PT	26.0 ± 9.1	30.7 ± 13.3	**<0.001**	25.6 ± 11.0	31.5 ± 13.5	**0.047**
PI_LL	51.3 ± 18.2	57.9 ± 23.4	**<0.001**	53.9 ± 20.3	59.2 ± 25.5	**0.004**
L1_S1	34.8 ± 19.9	32.5 ± 24.0	0.26	40.7 ± 19.6	31.2 ± 24.5	0.08
SVA	78.1 ± 70.2	107.7 ± 73.7	**<0.001**	80.6 ± 74.3	112.3 ± 72.9	0.06
TIPA	25.6 ± 11.4	32.0 ± 14.9	**<0.001**	24.9 ± 13.8	33.2 ± 14.8	**0.01**
L4_S1	31.5 ± 14.8	29.8 ± 14.9	0.166	40.9 ± 10.6	28.0 ± 14.7	**<.001**
T10_L2	12.2 ± 18.4	17.6 ± 20.2	**<0.001**	27.2 ± 21.9	16.1 ± 19.6	**0.01**
TS-CL	18.4 ± 10.9	27.7 ± 15.6	**<0.001**	20.6 ± 15.0	28.7 ± 15.5	**0.045**
cSVA	28.1 ± 13.3	40.4 ± 17.2	**<0.001**	39.1 ± 18.2	40.6 ± 17.2	0.74
C2PA	28.1 ± 10.9	35.3 ± 14.5	**<0.001**	28.6 ± 14.9	36.3 ± 14.3	**0.04**
ODI	47.8 ± 16.3	50.1 ± 14.7	0.083	49.9 ± 13.3	50.1 ± 15.0	0.94
PCS	29.4 ± 8.4	27.8 ± 7.9	**0.011**	28.8 ± 8.7	27.4 ± 7.4	0.41
MCS	45.1 ± 14.0	44.2 ± 13.0	0.460	40.8 ± 19.6	44.8 ± 12.8	0.17
SRS Total	2.7 ± 0.6	2.6 ± 0.6	**0.038**	2.3 ± 0.5	2.6 ± 0.6	0.48

Figure legend: (A): Table showing the differences between patients with and without a cervical spine decompensation and patients with both a decompensation and extension to the cervical spine and patients with only decompensation. **(B):** Kaplan-Meier curve showing how baseline C2PA affects time to cervical spine decompensation. **(C):** Waterfall plot reporting a threshold for baseline C2PA above which patients undergoing TL surgery are more prone to cervical spine decompensation while controlling for pre-operative CS and TL alignment (C2PA, TS-CL, PI-LL), previous CS surgery, age, gender, BMI, frailty, comorbidities, invasiveness, and whether or not patients had a UIV above or below T8.

29. Does Proximal Thoracic Rod Contour Influence PJK Risk in Adult Spinal Deformity?

Harsh Jain, MBBS; Advith Sarikonda, BS, BA; Ranbir Ahluwalia, MD; Tyler Zeoli, MD; Iyan Younus, MD; Omar Zakieh, MBBS; Hani Chanbour, MD; Bayard Wilson, MD; *Byron F. Stephens, MD;* Scott Zuckerman, MD

Hypothesis

A kyphotic proximal thoracic rod contour between upper instrumented vertebra and L1 (UIV–L1) reduces the risk of proximal junctional kyphosis/failure (PJK/F) in adult spinal deformity (ASD) patients.

Design

Retrospective Cohort

Introduction

In lower thoracic to pelvis fusions, we evaluated whether UIV–L1 rod contour was associated with PJK/F.

Methods

A retrospective cohort study (2009-23) was conducted of ASD surgery patients with lower thoracic UIV (T9-T12) and ≥2-year follow-up. Primary exposure was postoperative UIV-L1 rod contour, assessed by drawing a straight reference line connecting the points on the rod corresponding to the midpoint of the UIV and L1. Alignment of the rod with this reference line was classified as neutral, whereas anterior and posterior deviations from the line were classified as lordotic and kyphotic, respectively (Figure 1). The primary outcome was PJK/F, defined as UIV/UIV+2 angle ≥10° and ≥10° change from the preoperative measurement. Secondary outcomes were reoperation for mechanical complications and other mechanical complications (rod fracture, pseudarthrosis, implant failure). Sub analysis was performed in patients with high and low pelvic incidence (PI), binarized at 50°.

Results

Among 90 patients (age 69±11 years, 72% female), the UIV distribution was: T9 18%, T10 51%, T11 19%, T12 12%. Postoperatively, 37% patients had a kyphotic rod contour while 63% had a neutral contour. There was no significant difference in the rate of PJK/F between patients with kyphotic or neutral rod (39% vs. 37%, p=0.810). Similar non-significant differences were seen for reoperation for mechanical complications (24% vs. 23%, p=0.877) or other mechanical complications (30% vs. 28%, p=0.822). Patients with a kyphotic rod trended toward a higher proximal junctional angle (25±10° vs. 20±10°, p=0.371) at last clinical follow-up. Specifically, among low PI patients, PJK/F rates were higher in those with a kyphotic rod (67% vs. 31%, p=0.073).

Conclusion

In ASD patients undergoing lower thoracic to pelvis fusions, postoperative UIV–L1 rod contour was not associated with the risk of PJK/F or other mechanical complications. Specifically, a kyphotic rod contour at the proximal thoracic segment did not confer a protective effect compared with a neutral contour. Proximal rod contour alone may be insufficient to mitigate PJK/F risk, and other aspects of proximal alignment likely play a more dominant role.

	Neutral	Kyphotic	P-value
All Patients			
PJK/F	36.8%	39.4%	0.810
Reoperation for Mechanical Complications	22.8%	24.2%	0.877
Rod Fracture, Pseudarthrosis, Implant Failure	28.1%	30.3%	0.822
High Pelvic Incidence			
PJK/F	46.0%	25.0%	0.141
Reoperation for Mechanical Complications	20.0%	25.0%	0.717
Rod Fracture, Pseudarthrosis, Implant Failure	32.0%	43.8%	0.446
Low Pelvic Incidence			
PJK/F	30.8%	66.7%	0.073
Reoperation for Mechanical Complications	15.4%	25.0%	0.645
Rod Fracture, Pseudarthrosis, Implant Failure	23.1%	16.7%	0.260

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30. The Gradual Decay of the Proximal Junctional Angle following Thoracolumbar fusion of Adult Spine Deformity

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Hypothesis
The natural history of the proximal junction is one of gradual kyphosis, with a discernable annual average change.

Design
Retrospective cohort study

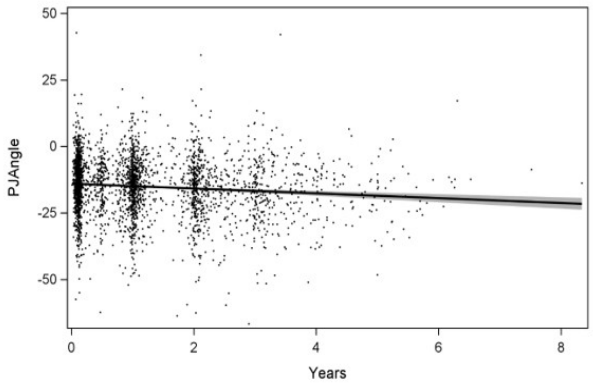
Introduction
Proximal junctional kyphosis (PJK) is a common complication after adult spinal deformity surgery, in many cases necessitating revision surgery. No studies have examined change in alignment of the proximal junction over time among patients who do not ultimately undergo revision surgery.

Methods
This study utilized a multi-center database of patients undergoing adult spinal deformity surgery. Inclusion criteria were those eligible for minimum 2-year follow-up, undergoing long-segment (i.e., >5 levels) instrumented arthrodesis with LIV at the sacropelvis.

Results
In total, 1,076 patients were included (mean age at surgery 64.0, SD 9.5; 74.3% female). The mean immediate post-operative proximal angle was 14.0 degrees kyphotic (SD 10.0). A total of 3,081 follow-up visits were recorded, with 17.9% (n=193) of patients with greater than 5-year terminal follow-up. Among all patients, PJK increased by 0.9 degrees annually (p<0.0001). This trend persisted upon multiple iterations of sub-analysis, including only patients who did not undergo revision surgery (1.0 degrees annually, p<0.0001), only patients with >5-year follow-up (0.8 degrees annually, p=0.0030), and patients meeting both criteria (0.9 degrees annually, p=0.0009). Importantly, the majority of patients tended to exhibit more PJK at each subsequent follow-up – 54.6% of patients had greater PJK at 6 months post-operatively than at 6 weeks post-operatively, 51.1% at 1 year vs. 6 months, 61.0% at 2 years vs. 1 year, and 61.1% at 3 years vs. 1 year.

Conclusion
In this study of adult spinal deformity patients undergoing long-segment instrumented fusion to the sacropelvis, the fate of the proximal junction was one of gradual kyphosis, at a rate of approximately 1 degree annually. This is directionally more rapid and focal than documented annual increases in thoracic kyphosis among the general population. Patients should be counseled that, even if they do not require revision surgery, they should expect gradual proximal junctional kyphosis as time passes post-operatively.

Figure 1: Proximal junctional angle measurements over time among all patients. Individual follow-up measurements are plotted as dots, with regression trendline indicated in black with 95% confidence interval in gray.



31. Does Postoperative UIV–L1 Alignment Predict Proximal Junctional Kyphosis After Adult Spinal Deformity Surgery?

Harsh Jain, MBBS; Advith Sarikonda, BS, BA; Ranbir Ahluwalia, MD; Tyler Zeoli, MD; Iyan Younus, MD; Hani Chanbour, MD; Bayard Wilson, MD; Byron F. Stephens, MD; Scott Zuckerman, MD

Hypothesis
Insufficient kyphosis at the proximal end of a lower thoracic to pelvis fusion, measured with the upper instrumented vertebra–L1 (UIV–L1) angle, increases the risk of proximal junctional kyphosis/failure (PJK/F).

Design
Retrospective Cohort

Introduction
In adult spinal deformity (ASD) patients undergoing lower thoracic to pelvis fusions, we evaluated whether postoperative UIV–L1 Cobb angle orientation predicted PJK/F.

Methods
A retrospective cohort study (2009-23) was performed of ASD patients with lower thoracic UIV (T9-T12) (≥2-year follow-up). Primary exposure was postoperative UIV-L1 sagittal Cobb angle, binarized as neutral (-3° to 3°) and non-neutral. Non-neutral group was further analyzed as kyphotic (>3°) and lordotic (<-3°). Primary outcome was PJK/F: UIV/UIV+2 angle ≥10° and ≥10° change from the preoperative measurement. Secondary outcomes were reoperation for mechanical complications and other mechanical complications. Sub-analysis was performed

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for high and low pelvic incidence (PI), binarized at 50°. Multivariable regression controlled for age, sex, body mass index and UIV level.

Results

Among 90 patients, (age 69±11 years, 72% female), UIV distribution was: T9 18%, T10 51%, T11 19%, T12 12%. Median postoperative UIV-L1 Cobb angle was 9° (IQR:4°-19°), with 3% lordotic, 20% neutral, 77% kyphotic. Neutral vs. Non-Neutral: Patients with a neutral alignment had a lower rate of PJK/F (17% vs. 43%, p=0.039), while no association was seen with reoperation for mechanical complications (28% vs. 22%, p=0.618) or other mechanical complications (17% vs. 32%, p=0.201). A non-neutral UIV-L1 independently increased the risk of PJK/F (OR=5.4, 95%CI:1.2-24.9, p=0.029). Similar trends were seen in patients with both high and low PI (Table). Kyphotic vs. Neutral vs. Lordotic: Patients with neutral alignment had the lowest rate of PJK/F, while lordotic patients had the highest (41% vs. 17% vs. 100%, p=0.014). No difference was seen in reoperation for mechanical complications (28% vs. 22%, p=0.618) or other mechanical complications (23% vs. 28% vs. 0%, p=0.573).

Conclusion

In lower thoracic to pelvis fusions, a neutral UIV–L1 alignment conferred lowest PJK/F rate, while deviation toward either lordosis/kyphosis significantly increased risk, with lordotic alignment demonstrating the highest risk. Achieving a neutral UIV–L1 alignment may represent a modifiable target to mitigate the risk of PJK/F.

	Neutral	Non-Neutral	P-value
All Patients			
PJK/F	16.7%	43.1%	0.039
Reoperation for Mechanical Complications	27.8%	22.2%	0.618
Rod Fracture, Pseudarthrosis, Implant Failure	16.7%	31.9%	0.201
High Pelvic Incidence			
PJK/F	16.7%	32.4%	0.648
Reoperation for Mechanical Complications	33.3%	26.5%	1.000
Rod Fracture, Pseudarthrosis, Implant Failure	16.7%	47.1%	0.216
Low Pelvic Incidence			
PJK/F	0.0%	52.6%	0.156
Reoperation for Mechanical Complications	50.0%	20.0%	0.334
Rod Fracture, Pseudarthrosis, Implant Failure	50.0%	10.0%	0.260

32. Development of a Novel Sagittal Segmental Phenotyping System for Mechanical Complication Risk Stratification in Degenerative Lumbar Scoliosis Surgery

Weipeng Qiu, MD; Zhuoran Sun, MD; Weishi Li, MD

Hypothesis

We hypothesize that integrating segmental inclination and curvature into degenerative lumbar scoliosis (DLS) sagittal evaluation may optimize current classification systems, and improve the prevention of mechanical complications following surgery.

Design

A retrospective cohort study.

Introduction

Sagittal alignment critically influences the management of degenerative lumbar scoliosis (DLS). As the concept of precision assessment evolves, ideal sagittal reconstruction has become increasingly refined, requiring attention not only to regional curvature and global balance but also to harmonious segmental distribution.

Methods

A total of 151 DLS patients undergoing posterior long-segment fusion from January 2010 to December 2022 with a minimum 2-year follow-up were included. Full-spine radiographs were obtained preoperatively, postoperatively, and at final follow-up. In addition to conventional sagittal parameters, two novel segmental inclination parameters were introduced: thoracic tilt (TT) and lumbar tilt (LT). Postoperative mechanical complications were recorded, and patient-reported outcomes were also assessed.

Results

A segmental sagittal phenotype based on distal lumbar lordosis (DLL) and thoracolumbar kyphosis (TLK) was defined as follows: Type 0 (normal): DLL >30°, TLK <20°; Type I (thoracolumbar kyphosis): DLL >30°, TLK >20°; Type II (loss of distal lordosis): DLL <30°, TLK <20°; Type III (global kyphosis): DLL <30°, TLK >20°. Significantly negative LT and positive TT were observed in Types I and III, whereas Type II showed markedly positive LT. The incidence of mechanical complications differed significantly across phenotypes: lowest in Type 0 (12.9%) and highest in Type III (65.0%). Multivariate regression identified the sagittal phenotype as an independent predictor of mechanical complications, with Type I (OR=6.073, P=0.007), Type II (OR=3.755, P=0.027), and Type III (OR=13.769, P<0.001) carrying significantly increased risk compared to Type 0.

Conclusion

The proposed DLL-TLK-based sagittal segmental phenotype effectively discriminates distinct sagittal profiles in DLS. This novel classification reliably predicts postoperative mechanical complications and can inform personalized strategies for sagittal alignment reconstruction.

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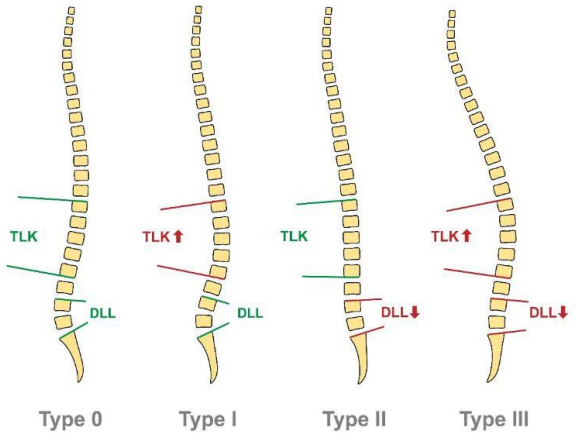


Schema of the DLL-TLK-based sagittal segmental phenotype

33. Lumbar Alignment Transitions: The Relationship of Lumbar Lordosis Distribution with Proximal Junctional Kyphosis and Pseudoarthrosis

Travis Kotzur, MD; Lane H. McCoy, BS; R. Adams Cowley II, MD; Neset Tang, MD; Munish C. Gupta, MD, MBA; Nicholas A. Pallotta, MD, MS; Brian J. Neuman, MD

Hypothesis
Distribution of lumbar lordosis predicts rates of mechanical complication.

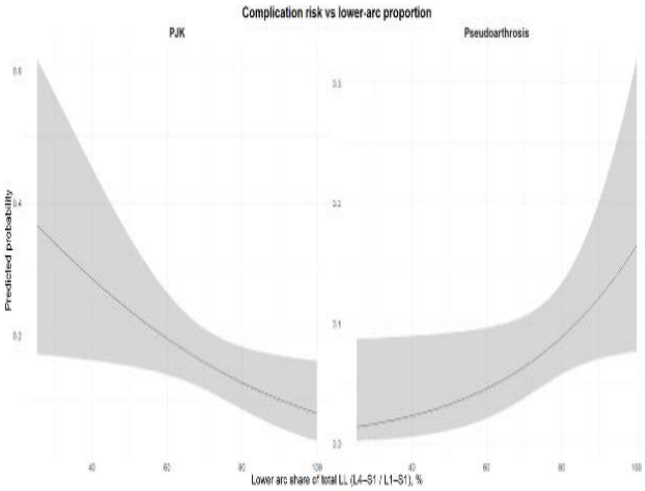
Design
Retrospective cohort study.

Introduction
Spinal deformity surgery requires careful restoration of sagittal alignment to optimize long-term outcomes. The distribution of lumbar lordosis, particularly across the lumbosacral transition zone, influences both proximal junctional mechanics and fusion integrity. While global lordosis targets are well established, the role of segmental lordosis remains poorly defined in predicting mechanical complications. Understanding how lower-segment lordosis mediates these opposing risks may guide surgical planning and improve outcomes in long-segment fusions.

Methods
Adult spinal deformity patients from a single tertiary-care center with ≥2-year follow-up or follow-up to proximal junctional kyphosis (PJK) or pseudoarthrosis were included. Patients with both outcomes were excluded. Lower lumbar lordosis (L4–S1) and its percent share of total lumbar lordosis were calculated. Logistic regression estimated odds ratios (OR) and 95% confidence intervals per 10% increase in lower-segment lordosis for PJK and pseudoarthrosis. Predicted risks across the observed lower lordosis range were evaluated using Pareto optimization with an equal-weight weighted-sum objective to identify the lordosis distribution minimizing combined complication risk.

Results
Among 258 patients, pseudoarthrosis occurred in 29 (11.2%) and PJK in 52 (20.1%). Each 10% increase in lower lumbar lordosis share was associated with decreased odds of PJK (OR 0.78, 95% CI 0.62–0.97; p=0.027) and increased odds of pseudoarthrosis (OR 1.42, 95% CI 1.01–2.01; p=0.046). Pareto analysis identified an optimal lower-segment lordosis share of 79.5%, corresponding to predicted risks of 12.9% for PJK and 8.7% for pseudoarthrosis, representing the lowest combined junctional complication burden.

Conclusion
Lower lumbar lordosis percentage of total lumbar lordosis demonstrates opposing associations with junctional outcomes: greater lower-segment lordosis reduces the risk of PJK but increases the risk of pseudoarthrosis. These findings highlight the importance of balancing lower lordosis to optimize fusion integrity while minimizing junctional complications. Future studies should seek to determine optimal lower segment lordosis cutoffs to reduce risks of all junctional adverse events.



Complication risk v lower arc proportion.

34. Dynamic Gait-Related Sagittal Decompensation After a 10-Minute Walking Test Predicts Revision-Requiring Proximal Junctional Kyphosis

Junseok Bae, MD; SangHo Lee, MD, PhD

Hypothesis
Fatigue-related sagittal decompensation after a standardized 10-minute walking test is more strongly associated with revision-requiring proximal junctional kyphosis (PJK) and mechanical failure than static preoperative alignment parameters.

Design
Retrospective review of prospectively collected data

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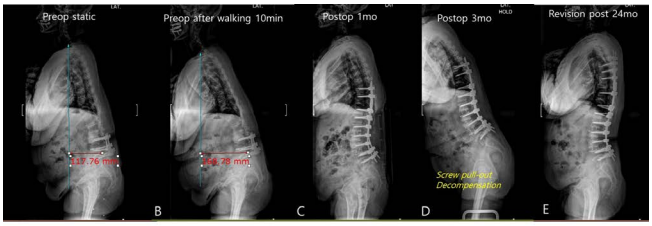
Introduction
In adult spinal deformity (ASD), static radiographs may not reflect functional deterioration caused by fatigue of compensatory mechanisms during daily activities. Although proximal junctional kyphosis is common after surgery, only a subset progresses to clinically significant failure requiring revision. Dynamic assessment under physiological stress may better identify patients at risk for meaningful mechanical complications.

Methods
Adult patients who underwent thoracolumbar deformity correction with sacropelvic fixation (upper instrumented vertebra ≥ L1) and had a minimum 24-month follow-up were reviewed. All patients underwent full-length standing lateral radiographs, followed by a standardized 10-minute walking test without rest and immediate repeat radiographs. Sagittal parameters including sagittal vertical axis (SVA), pelvic tilt, lumbar lordosis, PI–LL mismatch, thoracic kyphosis, and T1 pelvic angle were measured before and after walking. Outcomes included radiographic PJK, revision surgery for symptomatic PJK, and mechanical failure such as screw pull-out, vertebral fracture, or rod failure. Associations between dynamic sagittal changes and outcomes were analyzed.

Results
Radiographic PJK developed in 16% of patients, with half requiring revision surgery. Mechanical failure occurred in a separate subset, all of whom underwent revision surgery. Mean SVA increased significantly after walking compared with pre-walk measurements. Post-walk SVA correlated significantly with revision surgery for PJK and mechanical failure, whereas static preoperative SVA and PI–LL mismatch showed weaker associations. Dynamic sagittal deterioration after walking was not associated with radiographic PJK alone but was strongly associated with revision-requiring PJK.

Conclusion
Fatigue-related sagittal decompensation following a 10-minute walking test predicts revision-requiring PJK and mechanical failure after ASD surgery. Dynamic functional assessment under physiological stress may improve risk stratification beyond static alignment parameters.



35. Predicting Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery in the Early Postoperative Period with High Accuracy Using a Machine Learning-Based Scoring Model

Ted Shi, BS; Justin L. Reyes, MS; Varun Arvind, MD, PhD; Cole Morrissette, MD, MS; Mark Herbert, MD; Roy Miller, MD; Gabriella Greisberg, BS; Fthimnir Hassan, MPH; Eduardo C. Beauchamp, MD; Zeeshan M. Sardar, MD; Ronald Lehman Jr, MD; Lawrence G. Lenke, MD; Joseph M. Lombardi, MD

Hypothesis
A machine learning (ML)-derived scoring model can accurately detect proximal junctional kyphosis (PJK) in the early postoperative period.

Design
Retrospective Review

Introduction
Early detection of PJK is critical for risk stratification and postoperative management following adult spinal deformity. However, no clinically practical and validated tool currently exists for early postoperative risk assessment.

Methods
530 adult spinal deformity (ASD) patients undergoing surgery with ≥4 instrumented levels from a single-institution, multi-surgeon cohort were reviewed, all with ≥2-year follow-up. Over 100 clinical variables were analyzed. A stepwise machine learning (ML) framework incorporating random forest modeling, Boruta feature selection, and multivariate logistic regression was used to develop a scoring model for early detection of symptomatic PJK (proximal junctional angle (PJA) ≥ 10˚ and ΔPJA≥10˚ with pain at the proximal junction during time of diagnosis). Features selected by Boruta were thresholded by random forest and weighted based on logistic regression beta coefficients. The cohort was randomly split into training (50%) and testing (50%) sets. Model performance was evaluated using accuracy, sensitivity, specificity, and area under the receiver operating characteristic curve (AUC).

Results
4.7% of patients (n=25) progressed to symptomatic PJK. The model included seven features: pain at/near the upper instrumented vertebrae (UIV) at the first postop visit (score=3); lower thoracic (T7-T12) UIV (score=2); upper thoracic (T1-T6) UIV; BMI<20, osteopenia/osteoporosis; fixation to pelvis/sacrum; and ΔPJA≥5° from preop to first postop visit (each score=1). On the test cohort, the model achieved an accuracy of 91.3%, sensitivity of 85.7%, specificity of 91.6%, and AUC of 0.93. Higher cumulative scores were associated with increased rates of PJK. Patients were stratified into low (0–4), moderate (5–6), and high (7–9) risk groups, with corresponding PJK rates of 0.2%, 14.0%, and 53.8%, respectively.

Conclusion
This ML-derived scoring model enables highly accurate early postoperative detection of symptomatic PJK follow-

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ing ASD surgery. By integrating modifiable preoperative risk factors, surgical characteristics, and early postoperative clinical and radiographic changes, the model provides a practical tool for early risk stratification.

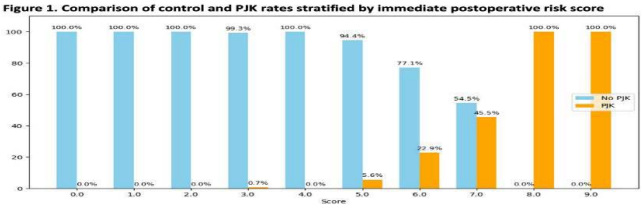
Table 1. Selected features and corresponding scores for immediate postoperative scoring system

Variable	Score
Pain/Symptoms Near UIV	3
UIV Lower Thoracic (T7-T12)	2
UIV Upper Thoracic (T1-T6)	1
BMI < 20	1
Osteopenia/Osteoporosis	1
Fixation to Pelvis/Sacrum	1
Δ PJA > 5°	1

Table 2. PJK rates in cohort stratified by immediate postoperative risk score

	Cumulative Score	PJK (n)	No PJK (n)	Rate
Low Risk	0	0	7	0%
	1	0	80	0%
	2	0	145	0%
	3	1	133	0.7%
	4	0	67	0%
Moderate Risk	5	2	34	5.6%
	6	8	27	22.9%
High Risk	7	10	12	45.5%
	8	3	0	100%
	9	1	0	100%

Figure 1. Comparison of control and PJK rates stratified by immediate postoperative risk score



36. Do Supplementary Rod Constructs Influence the Rate of Proximal Junctional Kyphosis? A Multicenter Study

Ahmed Sulieman, MD; Tej Azad, MD; Harsh Jain, MBBS; Advith Sarikonda, BS, BA; Virginie Lafage, PhD; Renaud Lafage, MS; Breton Line; Richard Hostin, MD; Peter G. Passias, MD; Bassel G. Diebo, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Alan H. Daniels, MD; Gregory M. Mundis Jr, MD; Themistocles S. Protopsaltis, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Munish C. Gupta, MD, MBA; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Christopher P. Ames, MD; Lawrence G. Lenke, MD; Shay Bess, MD; Sang Hun Lee, MD, PhD; Byron F. Stephens, MD; Scott Zuckerman, MD; *Khaled M. Kebaish, MD;* International Spine Study Group

Hypothesis
Supplementary rod constructs are associated with increased proximal junctional pathology due to increased construct stiffness

Design
Retrospective analysis of prospective multi-center adult spine deformity (ASD) database

Introduction
Supplemental rod constructs are frequently used in ASD surgery to reduce rod-related mechanical complications. However, their effect on proximal junctional kyphosis (PJK) and junctional alignment remains unclear

Methods
ASD patients undergoing fusion from T8–T11 to the pelvis with ≥ 2-year follow-up were included. Patients were grouped into dual-rod constructs and supplemental-rod constructs (supplemental rod with distal fixation at S1 or below). Primary outcome was PJK; secondary outcomes were 2-year proximal junctional angle (PJA) and mechanical complications. Multivariable regression models evaluated associations adjusting for age, osteoporosis, postoperative T1 Pelvic Angle (PA) and T4PA-L1PA mismatch

Results
A total of 284 patients were analyzed (dual-rod n=219, supplemental-rod n=65). 60% (n=39) had a 3-rod construct, and 40% (n=26) had a 4-rod construct. Demographics were comparable between the groups. The supplemental rod group had a higher rate of three column osteotomies (25% vs 12%, p=0.01) but similar number of levels fused. Both groups had similar baseline and postoperative radiographic measurements with exception of the PJA which was higher in the supplemental rod group at 6 weeks (14.8 vs 17.6, p=0.03) and 2 years postoperatively (16.8 vs 20.1, p=0.03). Rod fractures and revisions were significantly higher in the dual rod group compared to the supplemental rod group (17% vs 6%, 27% vs 14% respectively, both p=0.03). PJK rate was similar between constructs (54.8% vs. 52.3%, p=0.72) and supplemental rods were not associated with PJK on multivariate analysis (OR 0.87, p=0.8). With respect to the PJA, 4-rod constructs had greater 2-year PJA compared to dual-rod constructs (β −4.7, p=0.03).

Conclusion
In long fusions from the lower thoracic spine to the pelvis, supplemental rods were associated with a lower rate of rod fractures and revision surgeries without an increased rate of PJK/F. Supplemental rod constructs may modestly increase the proximal junctional angle at 2 years postoperatively

Table 1: Complication rates between the dual rod constructs cohort and the supplementary rods constructs cohort.

Complications	Double Rod (n=219)	Supplementary Rod (n=65)	P value
Revision Surgery	59 (26.94%)	9 (13.85%)	**0.03**
Rod Fracture	37 (16.89%)	4 (6.15%)	**0.028**
Rod dislodgement	1 (0.46%)	0 (0.00%)	>0.99
Adjacent segment disease	8 (3.65%)	3 (4.62%)	0.718
PJK	120 (54.79%)	34 (52.31%)	0.724
Pseudoarthrosis	7 (3.20%)	1 (1.54%)	0.687
Reoperation for rod fracture	14 (6.39%)	1 (1.54%)	0.204
Reoperation for rod dislodgement	1 (0.46%)	0 (0.00%)	>0.99
Reoperation for adjacent segment disease	3 (1.37%)	1 (1.54%)	>0.99
Reoperation for PJK	24 (10.96%)	6 (9.23%)	0.691
Reoperation for Pseudoarthrosis	7 (3.20%)	0 (0.00%)	0.357

Values represent n (%). PJK: Proximal Junctional Kyphosis.

Table 2: Multivariate logistic regression comparing proximal junctional kyphosis between 3-rods & 4-rods constructs to dual rod constructs. Multivariate linear regression comparing 2-year proximal junctional angle comparing 3-rods & 4-rods constructs to dual rod constructs.

PJK	OR	95% CI	P value	2 Year PJA	Coefficient	95% CI	P value
3 Rods	0.6208	0.1654 to 2.3291	0.48	3 Rods	-0.9533	-4.4640 to 2.5573	0.593
4 Rods	1.228	0.3599 to 4.1903	0.743	4 Rods	-4.7426	-8.9139 to -0.5713	**0.026**
Age	1.0117	0.9578 to 1.0685	0.678	Age	-0.1601	-0.3004 to -0.0198	**0.025**
Osteoporosis	1.1531	0.4179 to 3.1822	0.783	Osteoporosis	3.8976	0.7099 to 7.0853	**0.017**
Postoperative T1PA	0.9668	0.9109 to 1.0261	0.266	Postoperative T4PA-L1PA mismatch	-0.7493	-1.0931 to -0.4054	**<0.001**
Postoperative T4PA-L1PA mismatch	1.3079	1.1401 to 1.5004	**<0.001**	Postoperative T1PA	0.1032	-0.0593 to 0.2657	0.212

PJK: Proximal Junctional Kyphosis; PJA: Proximal Junctional Angle.T1PA: T1 Pelvic Angle; T4PA: T4 Pelvic Angle; L1PA: L1 Pelvic Angle

37. The Breakdown on Breakage: Why Pre-bent Rods Outperform Manual Contouring in ASD Surgery

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§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

Hypothesis
Pre-bent (PB) rod constructs in long-segment posterior spinal fusions (PSF) will have lower rates of hardware complications and greater construct complexity than manually bent (MB).

Design
Retrospective single-center cohort study comparing pre-bent and manually bent long fusions constructs in ASD patients.

Introduction
Optimal surgical outcomes in Adult Spinal Deformity (ASD) surgery are heavily contingent upon structural integrity and configuration of the spinal construct. The specific makeup of the construct—rod number, diameter, contouring method—is crucial in determining the distribution of mechanical loads and the subsequent risk of hardware failure and complications.

Methods
357 patients (192 PB, 165 MB) undergoing PSF for ASD (≥4 levels) were included. Radiographic and clinical variables included: rod fracture (RF), proximal junctional kyphosis (PJK), use of accessory bridging rods, and reoperation rates. These were assessed via radiographs and chart review. Satellite rods were defined as independent rods secured by pedicle screws without side-to-side connectors; accessory rods used connectors to the main rod without independent screw fixation.

Results
PB patients utilized more robust constructs, including 4-5 rod configurations (52.6% vs. 21.2%, $p < .001$) and 3-4 pelvic screw fixations (44.2% vs. 9.7%, $p < .001$). PB constructs more frequently employed S2-alar-iliac (S2AI) screws (59.4% vs. 23.0%, $p < .001$) and titanium rods (43.2% vs. 32.7%, $p = .042$), whereas MB constructs relied more on iliac screws (77.0% vs. 45.3%, $p < .001$). PB had a larger proportion of greater than 2 rods crossing over the thoracolumbar, lumbosacral junctions, and osteotomy sites.($p<.001$). Despite PB cases having higher surgical complexity—including more Ponte osteotomies (66.1% vs. 51.5%, $p = .005$) and corpectomies (4.2% vs. 0.6%, $p = .001$) — the rate of RF was significantly lower in the PB group (8.3% vs. 21.8%, $p < .001$) with breakages most commonly at L1-L2 and L2-L3.. Rod loosening, screw fracture, and screw loosening rates were not significantly different amongst groups. Rates of pseudoarthrosis, ASD, PJK, and revisions were comparable.

Conclusion
By facilitating multi-rod configurations and reinforcing high-stress junctions, pre-bent systems offer superior mechanical stability. Notably, this increased construct rigidity reduces hardware failure without a concomitant increase in PJK, pseudarthrosis, or overall revision rates.

38. The Over-Widening Phenomenon as a Risk Factor for Rod Fracture after Deformity Corrective Surgery using Anterior Column Realignment in Patients with Degenerative Sagittal Imbalance

SungMin Kim, MD, PhD; Yong-Chan Kim, MD, PhD; Inseok Son, MD; XiongJie Li, MD; LinJin Mao, MD

Hypothesis
Suboptimal lordosis distribution index (LDI) causes over-widening phenomenon (OWP), which is a significant risk factor for rod fracture (RF).

Design
A retrospective cohort study

Introduction
RF is one of the most common postoperative mechanical complications (MCs) after long-segment fusion using ACR in deformity corrective surgery for patients with DSI, yet the relationship between cage–endplate mismatch—referred to as the OWP—and RF has not been clarified. Therefore, this study aimed to demonstrate OWP as a potential risk factor for RF in patients with DSI undergoing deformity corrective surgery using ACR.

Methods
A total of 199 patients diagnosed with DSI who underwent deformity corrective surgery using ACR at a single institution between March 2020 and December 2023 were retrospectively analyzed. Finally, 35 patients with OWP (Group I) and 63 patients without OWP (Group II) were enrolled and compared. OWP was defined on immediate postoperative lateral radiographs as incomplete contact between the upper or lower cage endplate and the adjacent vertebral endplate (Figure 1). Demographic data, radiographic sagittal spinopelvic parameters, and perioperative factors were compared and analyzed. Multivariable logistic regression analyses were performed to identify risk factors for RF.

Results
The incidence of RF [Group I, 23/35 (65.7%) vs Group II, 24/63 (38.1%), $p= 0.032$] and subsequent revision surgery [Group I, 13/23 (56.5%) vs Group II, 3/24 (14.3%), $p= 0.019$] was significantly higher in Group I than in Group II. In Group I, the concordance rate between the level of OWP and the level of RF was 73.9%. Postoperative L4-S1 lordosis and changes in L4-S1 lordosis from pre- to postoperative were significantly greater in Group II than in Group I. Postoperative lordosis distribution index (LDI) was significantly lower in Group I (43.5%) than in Group II (57.7%) and was below the ideal range of 50-80%. On multivariable logistic regression, OWP was independently associated with RF as a risk factor (odds ratio 1.097, 95% confidence interval 1.011-1.189, $p= 0.028$).

Conclusion
Suboptimal postoperative LDI was associated with OWP, and OWP, in turn, was a significant risk factor for RF.

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

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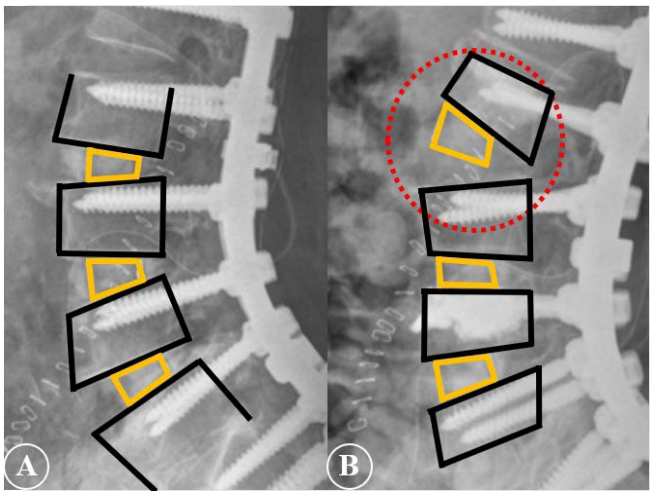

Figure 1. Unlike proper cage insertion (A) after the ACR procedure, OWP (B) results in a mismatch between the cage and the adjacent vertebral endplate.

39. Rod Fractures After Adult Spinal Deformity Surgery: What Happens After 2-years?

Harsh Jain, MBBS; Albert Cordoves, BS; Emma Ye, BA; Advith Sarikonda, BS, BA; Hani Chanbour, MD; Tyler Zeoli, MD; Ranbir Ahluwalia, MD; *Iyan Younus, MD;* Soren Jonzzon, MD; Byron F. Stephens, MD; Bayard Wilson, MD; Scott Zuckerman, MD

Hypothesis
Rod fractures (RF) after adult spinal deformity (ASD) surgery occur frequently beyond 2 years and can be associated with neurological deficits and reoperation.

Design
Retrospective Cohort Study

Introduction
In patients with ≥5-year follow-up after ASD surgery, we sought to report:1) incidence and timing of RF at 2-years and 2-5 years, and 2) associated clinical/surgical consequences.

Methods
A retrospective cohort study evaluated patients undergoing ASD surgery (2009-23) with ≥5-level fusion, sagittal/coronal deformity, and ≥5-year follow-up. Primary outcome was incidence of RF postoperatively. RF were described regarding timing, rod characteristics, location, unilateral/bilateral involvement, rod displacement, neurological deficits, and need for reoperation. Descriptive statistics were reported.

Results
Of 227 patients (mean age 63.8±17.2 years; 24.2% male), 67 (29.5%) experienced RF: 9/67 (13.4%) had ≥2 RFs, 7 (10.5%) had repeat RFs after reoperation, and 2 (3.0%) had multiple recurrent RFs. A total of 92 RFs occurred in 67 patients: 1-year 25 (27.2%), 2-years 49 (53.3%), 3-years 62 (67.4%), 4-years 68 (73.9%), 5-years 78 (84.8%), >5-years 14 (15.2%). Most patients had 1 reoperation (43.3%), 12 (17.9%) had 2, and 1 (1.5%) each had 3 and 5 reoperations, all for RF/pseudarthrosis. Median time to first RF was 1.4 years (IQR 0.8–2.7). RF most frequently occurred at L3/4 (29.9%), L5/S1 (28.4%), and L4/5 (25.4%), with fewer events at L2/3 (10.5%), thoracic levels (6.0%), L1/2 (1.5%), and cervical levels (1.5%). Initial RF was unilateral in 74.6% and bilateral in 25.4%, and rod displacement occurred in 23.9%. New neurological deficits occurred in 8 (11.9%), due to kyphosis (50.0%), severe pain (25.0%), misplaced screw (12.5%), or pseudarthrosis (12.5%). Reoperation was required in 39 (58.2%), median 119 days from RF diagnosis (IQR 66–302).

Conclusion
Rod fractures are a common long-term complication after ASD surgery, affecting ~30% of patients over the 3 to ≥5 year period. Of these, 47% occurred after 2 years and 15% after 5 years. Most occurred in the lower thoracic/lumbar spine within the first 3 years and were usually unilateral. Neurological deficits occurred in 12%, mostly from kyphosis, and over half required reoperation. These results underscore the need for long-term monitoring of ASD patients and to follow rod fractures closely.

40. Rethinking ASD in 3D: How Scoliosis Correction Interacts with Sagittal Alignment and PJK

Ahmed Sulieman, MD; Goutham Yalla, MD; Tej Azad, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Breton Line; Richard Hostin, MD; Peter G. Passias, MD; Bassel G. Diebo, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Alan H. Daniels, MD; Gregory M. Mundis Jr, MD; Themistocles S. Protopsaltis, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Munish C. Gupta, MD, MBA; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Christopher P. Ames, MD; Lawrence G. Lenke, MD; Shay Bess, MD; Sang Hun Lee, MD, PhD; *Khaled M. Kebaish, MD;* International Spine Study Group

Hypothesis
Scoliosis correction is associated with sagittal alignment changes and increased proximal junctional kyphosis (PJK) risk

Design
Retrospective analysis of a prospective multicenter adult spine deformity (ASD) database

Introduction
Some ASD patients are sagittaly balanced yet exhibit substantial coronal deformity. The degree of scoliosis correction may influence sagittal alignment and PJK risk, but these relationships are not well defined

Methods
Patients were included if they had a scoliotic curve ≥30°, T1 Pelvic Angle (PA) <30°, sagittal vertical axis (SVA) <4 cm, and underwent fusion to the pelvis with upper instrumented vertebra (UIV) in the upper thoracic (UT; T2–T5) or lower thoracic (LT; T8–T11) spine, with ≥2-year

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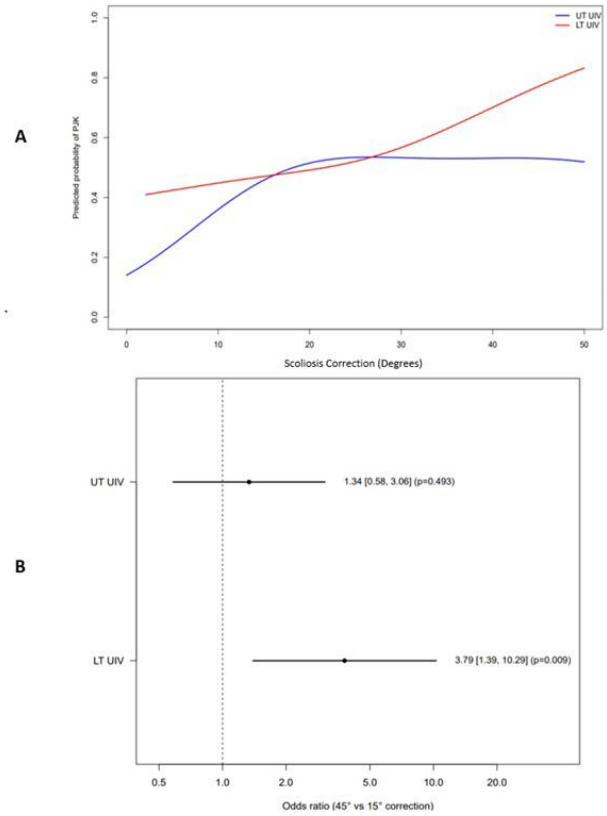
follow-up. Correlations were assessed between baseline scoliosis and scoliosis correction with postoperative sagittal parameters. PJK risk was evaluated using a generalized additive logistic regression model with a smooth term for scoliosis correction, adjusting for age, osteoporosis, postoperative T1PA and T4PA–L1PA mismatch

Results
183 patients were included. At baseline, median scoliotic curve was 52°, median SVA was 1 cm and median T1PA was 15°. UT UIV was used in 89 patients (49%) and LT UIV in 94 (51%) patients. Most LT patients had lumbar curves (71%) versus 31% in UT, while UT patients were predominantly double thoracic lumbar curves (62%) versus 26% in LT. Baseline scoliosis negatively correlated with postoperative T1PA in both constructs (UT ρ=−0.26, p=0.02; LT ρ=−0.26, p=0.02) and SVA in UT constructs (UT ρ=−0.26, p=0.02; LT ρ=−0.03, p=0.79). Likewise, scoliosis correction negatively correlated with postoperative sagittal measures exclusively in UT constructs: T1PA (UT ρ=−0.3, p=0.02; LT ρ=−0.20, p=0.10) and SVA (UT ρ=−0.3, p=0.01; LT ρ=−0.10, p=0.70). In the adjusted model, scoliosis correction was a significant non-linear predictor of PJK in LT (p=0.03) but not UT constructs (p=0.21). Comparing a 45° vs 15° correction, PJK odds were higher in LT constructs (OR 3.79, p<0.01) but not UT (OR 1.34, p=0.49)

Conclusion
In ASD patients with primary coronal deformity, the magnitude of scoliosis correction is associated with unintended postoperative sagittal alignment changes and is associated with increased PJK risk in LT constructs. These findings support a 3D alignment strategy that calibrates scoliosis correction to UIV selection and postoperative sagittal targets to mitigate the risk of PJK

Figure 1. Effect of scoliosis correction on the risk of proximal junctional kyphosis (PJK), stratified by upper instrumented vertebra (UIV). **(A)** Predicted probability of PJK across the range of scoliosis correction, shown separately for each UIV stratum. **(B)** Forest plot comparing the odds of PJK at 45° versus 15° of scoliosis correction within each UIV stratum.



41. Evolution of Surgical Strategy in Adult Spinal Deformity: A Longitudinal Analysis of Sagittal Alignment and 2-Year Outcomes Across 18 Years

Emil Haikal, MD; Renaud Lafage, MS; Jonathan Elysee, MS; Bassel G. Diebo, MD; Christopher P. Ames, MD; Shay Bess, MD; Alan H. Daniels, MD; Robert K. Eastlack, MD; Munish C. Gupta, MD, MBA; Jeffrey Gum, MD; Richard Hostin, MD; Khaled M. Kebaish, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Lawrence G. Lenke, MD; Gregory M. Mundis Jr, MD; David O. Okonkwo, MD, PhD; Pierce D. Nunley, MD; Peter G. Passias, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; International Spine Study Group

Hypothesis
Alignment targets for adult spinal deformity have evolved over time, leading to improved sagittal alignment and outcomes.

Design
Retrospective multicenter registry (2008–2025)

Introduction
Despite advances in surgical techniques and the development of novel sagittal alignment targets, temporal trends of surgically achieved alignment goals have not been

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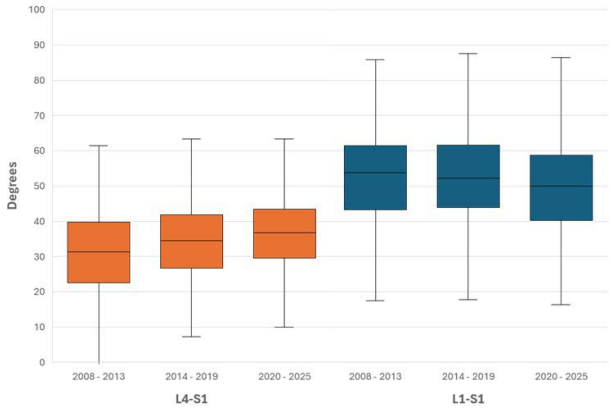
examined. The aim of this study was to evaluate the evolution of achieved alignment following ASD surgeries.

Methods
ASD patients from two large multicenter registries were included if they had pre-operative SRS-Schwab type N or L and underwent posterior fusion from thoracic (T1–12) to the ilium. Patients were grouped by surgery year: Epoch1 (2008–2013), Epoch2 (2014–2019), Epoch3 (2020–2025). Alignment parameters and outcomes were compared using ANOVA/Kruskal–Wallis. Variance was assessed via Levene testing.

Results
1,166 patients were included (mean age: 68.1 ± 8.4; 67% F): 182 in Epoch1, 472 in Epoch2, and 512 in Epoch3. Over time, age increased (66±11 vs. 69±8, p<0.001), female proportion decreased (61% vs. 75%, p<0.001), and patients had lower comorbidity burden (p<0.001), ODI (p=0.003), and higher baseline SRS-22 scores (p<0.001). Baseline alignment was stable (PT, PI-LL, regional lordosis, or pelvic angles), except SVA, which decreased across epochs (11 vs 9.2cm, p=0.004). At 6 weeks, L4–S1 lordosis was larger in recent Epochs (p<0.001), while L1PA and its offset from norm were smaller (all p<0.01). Alignment variance (PI–LL, SVA, L1PA) declined significantly In terms of correction, later epochs showed less change in PT, PI–LL, SVA, and T4L1PA (all p<0.05) but more changes in L4–S1, resulting in an overall better lordosis distribution. Severe radiographic PJK at 6 weeks progressively decreased across the epochs (10.5% vs. 3.9%, p = 0.001), while satisfaction and revision rates did not. Subgroup analysis showed similar evolution of sagittal alignment in Upper thoracic and Lower Thoracic constructs, with the latter showing more focus on segmental lumbar lordosis in later epochs.

Conclusion
ASD alignment strategies have evolved, emphasizing distal LL restoration and reducing variability. While radiographic improvements are evident, satisfaction and revision rates have not significantly improved, highlighting a gap between radiographic and clinical outcomes.



42. Fate of the Unfused Distal Lumbar Coronal Curve After Scoliosis Correction in Children versus Adults: A Collaborative Study Group Analysis

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Hypothesis
The unfused distal lumbar coronal curve (DLCC) in children will improve more rapidly compared to adults after scoliosis correction.

Design
Retrospective cohort study of pediatric and adult patients with idiopathic scoliosis.

Introduction
Fractional curve and DLCC behavior after scoliosis correction has been studied in children and adults, but no prior study has compared matched pediatric and adult cohorts to define age-related differences in DLCC behavior.

Methods
Patients undergoing thoracolumbar fusion for idiopathic scoliosis were included—Pediatric (ages 8–17; n=140): Lenke 5/6 (n=103) with LIV L1/2/3/4 = 0/2/74/27, or Lenke 3/4 with LIV L3/4 = 23/14; Adults (age ≥18; n=105): LIV L1/2/3/4 = 16/15/33/41, UIV > T12. Radiographic parameters and outcomes (SRS-22, mechanical complications) were assessed preop, 6 weeks, and 2 years. Pediatric (pDLCC) and adult (aDLCC) DLCCs were defined as the coronal Cobb angle between LIV and S1 >10°. Global coronal malalignment (GCM) was defined as C7PL–CSVL distance, with <3 cm considered balanced.

Results
Pediatric (14.9yo±2.2) and adult (34.5yo±15.1) patients had similar major curve magnitude and correction (57.6°±14.3 to 23.6°±8.6 vs 55.0°±17.3 to 21.8°±13.4; p>0.2). pDLCCs were larger preop vs aDLCCs (25.9°±6.5 vs 20.0°±7.4; p<0.001) and experienced greater correction at 6 weeks (Δ20.2° vs Δ12.9°; p<0.0001). pDLCC and GCM changed rapidly at 6 weeks and remained stable at 2 years, whereas adult GCM changed over 2 years (p<0.0001). pDLCC changed to improve GCM between preop->6w (p =0.04), while aDLCCs changd to improve GCM 6w -> 2y (p=0.049). More pediatric than adult patients had GCM<3 cm at 2yr fu (94.4% vs 80.4%; p<0.01). On multivariate linear regression, older age was associated with lower DLCC correction (β=-0.12, p=0.005). Residual pDLCC or aDLCC magnitude was not associated with SRS-22 subdomains (p>0.50), mechanical complications (p=0.25), or re-op (p=0.30).

Conclusion
Pediatric patients experience more rapid and greater magnitude correction of the unfused lumbar coronal

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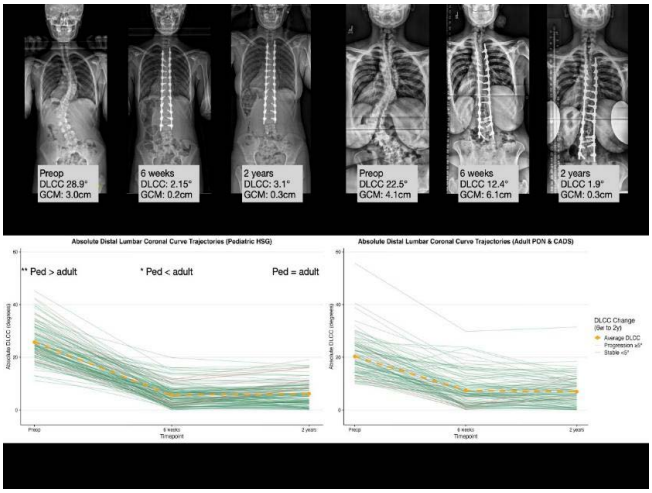
curve after TL fusion compared to adults. Pediatric DLCC improved over the first 6 weeks postoperatively, whereas adult DLCC improved more gradually over 2 years. In both groups, DLCC changed correlated with improved GCM, with higher rates of coronal balance at 2yrs in children. Residual DLCC magnitude was not associated with revision surgery or SRS-22.



43. Thoracic Kyphosis Restoration Is Associated with Improvement of the L1 Pelvic Angle in Thoracic Adolescent Idiopathic Scoliosis

Yusuke Hori, MD, PhD; Takashi Namikawa, MD, PhD; Masaki Kawamura, MD; Masahiro Ohno, MD; Kazuki Ohki, MD; Akira Matsumura, MD, PhD

Hypothesis
In thoracic adolescent idiopathic scoliosis (AIS), restoring thoracic kyphosis (TK) helps normalize the L1 pelvic angle (LPA) with minimal impact on global alignment.

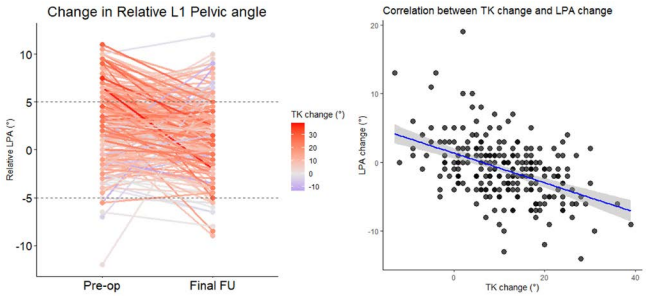
Design
Retrospective cohort study.

Introduction
Thoracic AIS is commonly associated with hypokyphosis, which may induce compensatory changes in lumbar and pelvic alignment. LPA integrates lumbar alignment relative to pelvic morphology and may serve as a sensitive marker of lumbopelvic compensation. However, the impact of TK restoration on LPA in thoracic AIS remains uncertain.

Methods
This study included 239 patients (mean age, 16±4 years; 88% female; Lenke type 1, 51%; type 2, 49%; sagittal modifier −, 49%) with AIS who underwent posterior spinal fusion and had a minimum two-year follow-up. Radiographic sagittal parameters, including LPA and T4 pelvic angle (T4PA), were measured preoperatively and at final follow-up. Ideal LPA was defined as 0.5×PI−21, and relative LPA was defined as the difference between measured and ideal LPA. Associations between ΔT-K(T5-12) and changes in sagittal parameters were evaluated using Pearson correlation.

Results
TK increased from 10.8° preoperatively to 21.7° at final follow-up (p<0.001). Relative LPA improved from 4.7° to 3.7° (p<0.001), and the proportion within the normal range (±5°) increased from 52% to 63%. In sagittal modifier− patients, relative LPA improved from 6.4° to 4.0°, with the normal-range proportion increasing from 34% to 61%. ΔTK correlated with ΔLPA (r=−0.46, p<0.001), corresponding to LPA normalization (see image). ΔTK also correlated with ΔC2-7 (r=-0.45) and ΔL1-S1 (r=-0.41) kyphosis, showed a weak correlation with ΔT4PA (r=0.30), and no correlation with ΔTPA. Mean T4PA−LPA was −2.1° preoperatively and −2.0° at final follow-up, and the proportion within the normal range (±4°) showed no significant change (71.1% vs 73.6%).

Conclusion
In thoracic AIS, particularly in patients with hypokyphosis, LPA was increased, suggesting compensation for reduced TK through decreased LL and pelvic retroversion. Surgical restoration of TK facilitated normalization of lumbopelvic alignment; however, its impact on global sagittal alignment was limited.



Individual changes in relative LPA from preoperative to final follow-up (left), with dashed lines indicating the normal range (±5°). Changes in TK showed a significant negative correlation with changes in LPA (right; r=−0.46, p<0.001).

44. Global Sagittal Equilibrium in Pediatric Scoliosis is Maintained Postoperatively via Compensations Rather than Construct Optimization

Deniz Kara, MD; Bryan Menapace, MD, MBA; Daniel Bouton, MD; Robert Bernstein, MD; Joseph Ivan Krajbich, MD; Jeffrey M. Hills, MD; Michelle C. Welborn, MD; Rebecca GraceTracey, RN; Cindy Nguyen, PA-C; Michael P. Kelly, MD; *Chinmay Paranjape, MD, MHSc*

Hypothesis
We posit that the C2 tilt = 0 relationship is maintained pre- and postoperatively regardless of achievement of regional PI-based anatomic targets, reflecting the immense compensatory ability of pediatric patients

Design
Retrospective review

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

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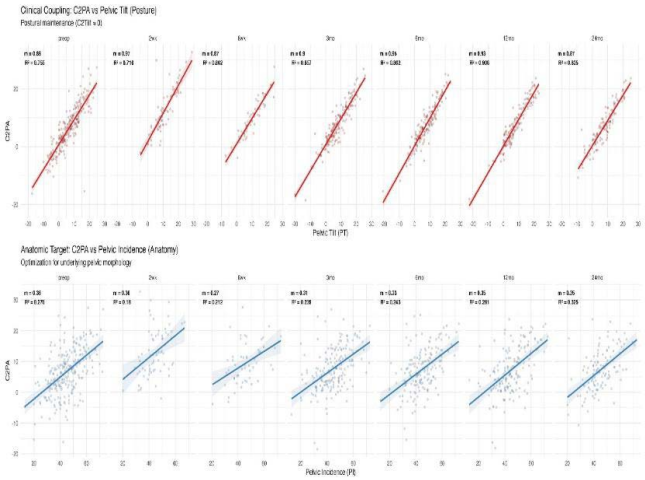
Introduction
Maintaining global sagittal balance is paramount. C2-Pelvic Angle (C2PA) reflects global balance with a goal of C2 tilt = 0. Since C2 tilt = C2PA - PT, C2PA ≈ pelvic tilt (PT) . In typical anatomy, C2PA and PT are both functions of pelvic incidence (PI). However, longitudinal postoperative changes to PT and PI in Juvenile and Adolescent Idiopathic Scoliosis (J/AIS) requires quantification.

Methods
We retrospectively analyzed 251 JIS and AIS patients after instrumented spinal fusion. Standing full-spine lateral radiographs were evaluated pre- and post-operatively at 2 weeks, 6 weeks, 3 months, 6 months, 12 months, and 24 months. Linear regression was utilized to assess global postural coupling (C2PA vs. PT) and the regional anatomic target (C2PA vs. PI) across time.

Results
The C2PA ≈ PT relationship demonstrated clear postural coupling from preoperative baseline through 24 months. Across all intervals, correlation remained high (mean R2 = 0.83; range 0.71–0.90) with slopes consistently approaching 1.0 (range 0.86–0.97). In stark contrast, the relationship between global balance and regional balance (C2PA vs. PI) was consistently weak (mean R2 = 0.25; range 0.18–0.32), with significantly lower slopes (≈ 0.35). While global parameters stabilized into a final compensated state by 3 months postoperatively (p > 0.05), this balance was driven by postural maintenance (C2 tilt ≈ 0) rather than optimization for the patient's underlying pelvic morphology.

Conclusion
In patients with JIS and AIS, global sagittal balance is maintained via a constant, invariant postural equivalence where C2PA ≈ PT (C2 tilt ≈ 0). While the pediatric spine and pelvis demonstrate an immense capacity to preserve global equilibrium, the high correlation in postural coupling versus the profound discrepancy in anatomic alignment suggest that the system prioritizes global balance over PI-based regional optimization. While patients may appear balanced in the short-term, their global position is often uncoupled from their individual regional anatomic requirements.



Global compensation (C2 tilt = 0, R^2 > 0.7) despite poor PI-driven C2PA correlation (R^2 < 0.35)

45. Impact of Three-Dimensional Thoracic Hypokyphosis on Lower Cervical Degeneration and Cervical Alignment After Deformity Correction in Adolescent Idiopathic Scoliosis

Hong Jin Kim, MD, PhD; *Chang Hwa Ham, MD;* Subin Lim, MD; Hyung Rae Lee, MD; Jae Hyuk Yang, MD, PhD; Seung Woo Suh, MD, PhD

Hypothesis
Thoracic hypokyphosis in adolescent idiopathic scoliosis (AIS) is associated with cervical disc degeneration, and restoration of three-dimensional (3D) thoracic kyphosis (TK) improves postoperative cervical alignment.

Design
Retrospective study

Introduction
Thoracic hypokyphosis is common in AIS and may adversely affect cervical alignment; however, its relationship with cervical degeneration and sagittal alignment in a three-dimensional context remains unclear. This study evaluated the association between 3D hypo-TK, cervical degeneration, and cervical alignment, and assessed the impact of kyphosis restoration after deformity correction.

Methods
A total of 195 patients with AIS who underwent posterior deformity correction were retrospectively reviewed. Following calculation of 3D TK using a formula 18.1 + 0.81 * (2D TK) – 0.54*(2D coronal Cobb), the patients were categorized into hypo-TK and control groups. The DSI2 score and sagittal grade of herniation on preoperative magnetic resonance imaging were measured to evaluate disc degeneration and herniation. Cervical alignment parameters, including cervical lordosis (CL), T1 slope (T1S), and cervical sagittal vertical axis (cSVA), were evaluated preoperatively, postoperatively, and at 2-year follow-up.

Results
The hypo-TK group demonstrated a higher prevalence of lower cervical disc degeneration, predominantly at C6-7 level (P = 0.010), compared with control group. Preoperative 3D TK showed significant correlations with cervical lordosis (r = 0.34, P < 0.001), T1 slope (r = 0.45, P < 0.001), and the lowest DSI-2 level (r = -0.27, P = 0.016). Restoration of 3D TK correlated with improvements in cervical alignment parameters; however, 2-year follow-up CL was significantly correlated with the 2-year follow-up 3D TK, rather than the extent of kyphosis correction. Multiple linear regression model revealed that 2-year follow-up CL was significantly associated with 2-year follow-up 3D TK (B = 0.30; P = 0.045) and preoperative CL (B = 0.42, P < 0.001).

Conclusion
3D TK is associated with lower cervical disc degeneration

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and cervical kyphosis in AIS. Adequate restoration of 3D TK through deformity correction appears to mitigate cervical malalignment, suggesting that thoracic sagittal correction plays a key role in optimizing cervical alignment and reducing lower cervical stress.

46. Preoperative Thoracic Kyphosis, Not Implant Choice or Navigation, Predicts Proximal Junctional Kyphosis in Adolescent Idiopathic Scoliosis

Eddie Geagea, MD; Manas Peddiboyina, MS; *John Lovejoy, MD*

Hypothesis
Increased preoperative thoracic hyperkyphosis would be independently associated with PJK, whereas UIV instrumentation type and navigation would not independently mitigate this risk.

Design
Retrospective cohort study

Introduction
Proximal Junctional Kyphosis (PJK) remains a common sagittal complication following posterior spinal fusion (PSF) for Adolescent Idiopathic Scoliosis (AIS). While various surgical techniques have been proposed to mitigate this risk, including the use of hooks at the Upper Instrumented Vertebra (UIV) or CT-guided navigation, their efficacy remains controversial.

Methods
A retrospective review of 543 AIS patients who underwent PSF between 2016 and 2024 was conducted. All patients had a minimum of 2-year clinical and radiographic follow-up (mean 3.3 years). PJK was defined as a proximal junctional sagittal Cobb angle (UIV to UIV+2) ≥10° greater than the preoperative measurement. Variables analyzed included age, BMI, preoperative thoracic kyphosis (TK), UIV instrumentation type (Hook vs. Screw), and surgical technique (Navigation vs. Freehand). Statistical analysis included Fisher's exact tests for categorical variables, Mann-Whitney U tests for continuous variables, and a multivariate logistic regression model.

Results
The overall incidence of PJK was 21.7% (118/543). Patients who developed PJK had significantly higher preoperative TK (40.8° ±12.1°) compared to those who did not (27.3° ±10.4°; $p < 0.001$). Multivariate logistic regression confirmed that preoperative TK was a significant independent predictor of PJK (OR 1.08 per degree increase; 95% CI 1.05-1.11; $p < 0.001$). No statistically significant difference in PJK rates was found between UIV hooks (21.0%) and UIV screws (21.9%; $p = 0.81$), nor between the use of Navigation (22.8%) and Freehand techniques (20.8%; $p = 0.65$). Age and BMI were not significant predictors in the multivariate model ($p > 0.05$).

Conclusion
In this large cohort of AIS patients, preoperative thoracic kyphosis was the primary driver of PJK development. Notably, the selection of UIV instrumentation (hooks vs. screws) and the use of navigation did not significantly reduce the incidence of PJK. These findings suggest that PJK risk is dominated by preoperative sagittal alignment rather than specific hardware choices or placement techniques, highlighting the need for patient-specific surgical planning in high-kyphosis cohorts.

47. Sagittal Profiles and their Reciprocal Changes Manifesting in Proximal Junctional Kyphosis in Adolescent Idiopathic Scoliosis

Hong Jin Kim, MD, PhD; *Hyung Rae Lee, MD;* Subin Lim, MD; Jae Hyuk Yang, MD, PhD; Seung Woo Suh, MD, PhD

Hypothesis
The sagittal profiles, including sagittal shape and alignment in adolescent idiopathic scoliosis (AIS), are significantly associated with the development of proximal junctional kyphosis (PJK) as a reciprocal change after deformity correction

Design
A retrospective cohort study

Introduction
Unlike adult spinal deformity (ASD), sagittal alignment in AIS is characterized by alteration of thoracic kyphosis (TK) resulting from relative anterior spinal overgrowth. While recent studies on PJK in ASD have focused on spinal shape and alignment, little information is available in AIS.

Methods
A total of 282 AIS patients who underwent deformity correction were retrospectively reviewed. Patients were categorized into two groups according to the presence of PJK at the 2-year follow-up: the PJK group (n = 48) and the non-PJK group (n = 234). Sagittal shape was classified as normal TK, hypo-TK with/without thoracolumbar kyphosis (TLK), and cervico-thoracic kyphosis. Coronal, sagittal, and spinopelvic radiographic parameters were measured. Changes in Roussouly classification and correction relative to the functional T10 pelvic angle target were assessed to evaluate sagittal restoration and its association with PJK.

Results
At the 2-year follow-up, the incidence of PJK was 17.0% (48 of 282). The upper instrumented vertebra (UIV) level differed significantly between the two groups ($P = 0.002$). The mean absolute Δ sagittal vertical axis (SVA) between the postoperative and the 2-year follow-up was also greater in the PJK group (28.9 mm vs 17.3 mm, $P = 0.008$). Regarding sagittal shape, the PJK group was most prevalent in normal TK (43.8%) and cervico-thoracic kyphosis (31.3%), whereas the non-PJK group was most prevalent in hypo-TK without TLK (40.2%), followed by normal TK (35.0%) ($P < 0.001$). Multivariate logistic regression showed that lower UIV level, cervico-thoracic kyphosis, and greater ΔSVA were significantly associated with PJK.

Conclusion
Our findings indicated that UIV level, cervicothoracic

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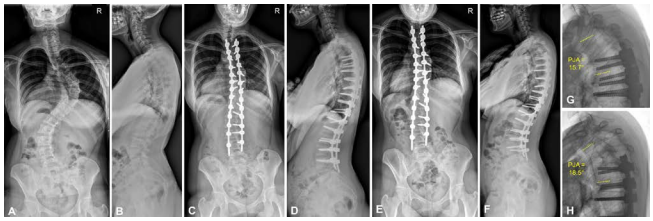
kyphotic profile, and greater changes in the SVA were the main factors associated with PJK. In contrast to ASD, PJK in AIS rarely causes serious clinical sequelae but instead represents reciprocal changes driven by the original sagittal shape and subsequent alterations in sagittal alignment.



Case presentation of AIS with PJK associated with sagittal spinal shape

48. Does T4PA–L1PA Mismatch Matter? Patient-Reported Outcomes After Posterior Fusion for Adolescent Idiopathic Scoliosis: Min 20 years follow-up

Ibrahim Dag, MD; Hamisi M. Mraja, MD; Mustafa Buğra Ayaz, MD; Ahmet Hamdi Olcar, MD; Ilyas Dolas, MD; *Sinan Kahraman, MD;* Meric Enercan, MD; Selhan Karadereler, MD; Azmi Hamzaoglu, MD

Hypothesis
T4-L1PA mismatch in AIS correlates with clinical outcomes at long term f/up

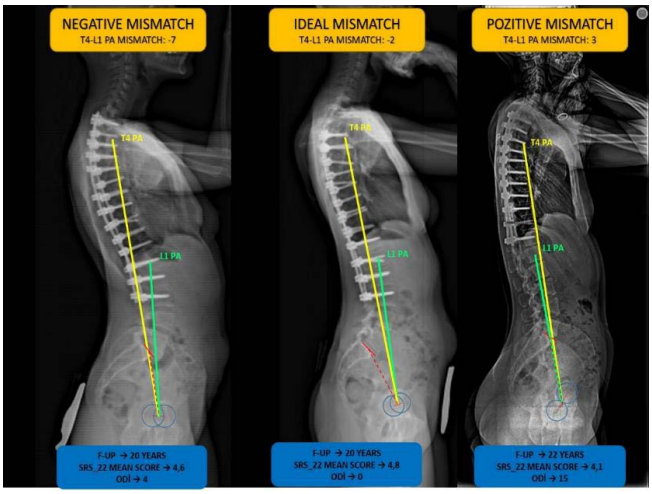
Design
Retrospective case series

Introduction
Many studies focused on T4-L1PA mismatch for adult deformity pts,but there is gap in the literature for AIS pts in terms of T4-L1 mismatch in longterm f/up.This is the first study that evaluates longterm PROs and their relation with T4L1PA mismatch and other sagittal parameters in AIS pts with a min 20yrs f/up

Methods
30 AIS pts (28f,2m) who underwent PSF and had min 20 yrs f/up(20-30)duration were included.Standing full-spine x-rays were analyzed preop and final f/up.Coronal cobb and sagittal parameters were assessed, including pelvic parameters,LL, TK, T4PA–L1PA mismatch, PI–LL mismatch, T4PA, L1PA,C2PA. T4PA–L1PA mismatch was defined as the angular difference between T4PA and L1PA and categorized as ideal (between-3°+1°),negative(<-3°),positive (>+1°).Clinical outcomes at final f/up were evaluated using the SRS-22 and ODI

Results
PT, MT and TL curves demonstrated significant correction from preop to f/up($p< 0.001$).At f/up, mean T4PA was 2.53±6.76,mean L1PA was 5.60±7.54,mean T4PA–L1PA mismatch was −3.80±4.11.Comparison between preop and f/up measurements revealed no significant changes in pelvic p, LL, PI–LL mismatch,T4PA, L1PA, or T4PA–L1PA mismatch($p>0.05$).T4PA–L1PA mismatch distribution showed a trend toward improvement from preop to last f/up. Pts classified as ideal mismatch increasing from 26.7% preop to 46.7% at f/up.Clinical outcomes at f/up were satisfactory, with a mean SRS-22 total score of 4.24(pain of 4.29, function of 4.55). Significant positive correlation found between the SRS-22 total score with T4PA–L1PA mismatch at the f/up($r =0.96$,$p<0.05$).Mean ODI was 7.2, only 2 patients(6%) had ODI>20 with positive T4-L1 mismatch

Conclusion
This long-term (>20 yrs)f/up study showed that the ideal(47%) and negative(47%) T4PA–L1PA mismatch pts demonstrate improved coronal cobb corrections and sagittal plane restorations with higher pts reported outcomes in AIS. However,6% of the pts who were in the positive T4PA–L1PA mismatch resulted in lower clinical satisfactory results with improved coronal corrections. Our study showed that T4PA-L1PA mismatch is significantly correlated with HRQoL scores at the end of 20 yrs f/up.Maintaining T4PA–L1PA mismatch within ideal or negative ranges over the long term will provide satisfactory clinical outcomes



49. How Can We Minimize Disc Wedging and Trunk Shift After Selective Thoracic Fusions in AIS?

Joshua M. Pahys, MD; Tej Azad, MD; Alexander J. Schupper, MD; Amer F. Samdani, MD; Terrence G. Ishmael, MBBS; Firoz Miyanji, MD, FRCS(C); Suken A. Shah, MD; Peter O. Newton, MD; Harms Study Group; Steven W. Hwang, MD

Hypothesis
Early postop correction imbalance predicts trunk shift and can guide goal thoracic correction to reduce trunk shift

Design
Retrospective multicenter study

Introduction
Selective thoracic fusions (STF) have problematic residual trunk shift and disc wedging

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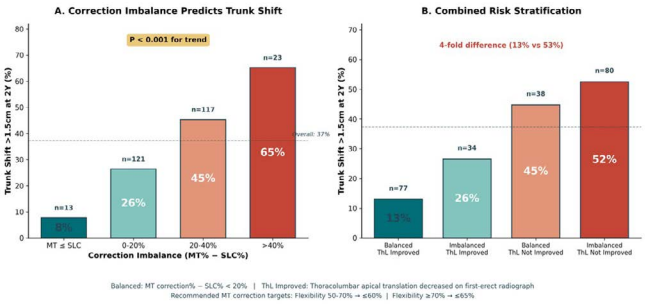
‡ SRS Funded Research Grant

Methods
Lenke 1–4C pediatric AIS patients undergoing STF with ≥2-year follow-up were analyzed. Main thoracic (MT) correction% and SLCC% were calculated on first-erect (FE) radiographs. Primary outcome was trunk shift >1.5 cm at 2 years. Disc wedging was defined as the angle of the disc below LIV opening contralaterally

Results
Among 385 patients, mean MT correction was 64% and mean SLCC was 43% (imbalance 22%); trunk shift >1.5 cm occurred in 37% (103/276) at 2 years and 32% (35/110) by 5 years. Preop predictors were modest: lumbar bending flexibility was associated with 2-year trunk shift (p<0.05), while LIV position relative to the lumbar apex was not predictive (p=0.72); lumbar flexibility (LF) remained the strongest preop predictor at 5 years (p<0.01). Greater LF was associated with slightly higher SLCC (45% SLCC with LF≥70% vs 42% SLCC with LF 50–60%), supporting goal correction of MT up to 60% for LF 50–70% and MT correction up to 65% for LF ≥70% to maintain balance. Combining correction balance with early ThL translation improvement stratified risk four-fold (13% of patients had a trunk shift in the setting of balanced correction + initial ThL improvement vs 53% rate of trunk shift with imbalanced correction and no initial ThL improvement). Early ThL improvement was also associated with better SRS-22 self-image scores (4.4 vs 4.2, p=0.02). The W group did have shorter construct lengths (9.2±0.99 vs. 9.7±1.2 levels, p=0.027), and the LIV was more rostral (T11 vs. T12, p<0.001). The W group had LIV further from the lumbar apex (2.5 vs. 2.1 levels, p=0.005). Multivariate analysis demonstrated that number of levels was the strongest predictor of post-op wedging (p<0.001, 95% CI: 0.341-0.637).

Conclusion
1/3 of patients undergoing STF will have significant trunk shift at 2 years with improvement at 5 years. Maintaining MT correction within 20% of expected SLCC and assessing early ThL translation on FE radiographs may help identify and mitigate risk for persistent trunk shift. Post-op DW occurred in 13% of patients; LIV selection and number of fusion levels was most predictive of post-op wedging, highlighting the importance of level selection in STF.



50. The Role of Vertebral Rotation Discrepancy for Add-on Phenomenon in Thoracic Curves of Adolescent Idiopathic Scoliosis

Hong Jin Kim, MD, PhD; Hyung Rae Lee, MD; *Subin Lim, MD;* Jae Hyuk Yang, MD, PhD; Seung Woo Suh, MD, PhD

Hypothesis
Considering the SRS-Lenke-Aubin 3D classification, vertebral rotation in the remnant lumbar curve may be contributed to the distal add-on when the lowest instrumented vertebra (LIV) is set at the touched vertebra (TV) in adolescent idiopathic scoliosis (AIS).

Design
Retrospective study

Introduction
There is little doubt that selecting the LIV at the TV represents the most balanced landmark between the risk of the add-on phenomenon and the preservation of motion segments. Given that the add-on is not uncommon when the LIV is set at the TV, the role of vertebral rotation in the determination of the LIV remains unclear.

Methods
A total of 96 thoracic AIS patients who underwent deformity correction with LIV = TV were retrospectively analyzed to evaluate the distal add-on. Patients were divided into the DA group (distal add-on) and the non-DA group (non-distal add-on). Radiological variables included coronal parameters (Cobb's angle, coronal balance, sacral slanting angle, and L4 vertebral tilt), sagittal parameters (sagittal vertical axis, thoracic kyphosis, and lumbar lordosis), and axial parameters (vertebral rotation angle).

Results
When selecting the TV as the LIV, the occurrence of distal add-on was 20.8% at a mean follow-up of 3 years. The mean number of remnant motion segments was significantly higher in the DA group (4.7) compared to the non-DA group (3.8) (P < 0.001). Furthermore, the difference in the vertebral rotation angle between the lumbar apex and the TV level was significantly higher in the DA group (6.6°) than in the non-DA group (1.3°) (P < 0.001). Multivariate logistic regression analysis demonstrated that the occurrence of distal add-on was significantly associated with remnant motion segments (OR = 3.69, 95% CI: 1.03–13.18) and the vertebral rotation discrepancy (OR = 4.09, 95% CI: 1.98–8.43). In this model, the boundary of the high predictive probability was located at vertebral rotation discrepancy = 3.15°, 4.08°, 5.01°, and 5.93° when LIV = T12, L1, L2, and L3

Conclusion
The distal add-on was influenced by the number of remnant motion segments and the vertebral rotation discrepancy between the LIV and the lumbar apex. In light of the rotation parameter in the SRS-Lenke-Aubin 3D classification, surgeons may need to select an LIV caudal to the TV in cases with significant rotational discrepancy.

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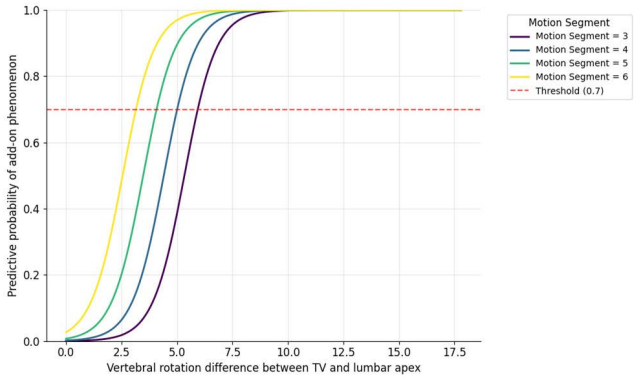

Predictive probability of distal add-on phenomenon

51. ΔUIV Tilt Correction ≥10° Is an Independent Risk Factor for Left PSI at 2 Years in Lenke 1 AIS

Ryutaro Tanaka, MD; *Kazuki Takeda, MD, PhD;* Takahito Iga, MD, PhD; Toshiki Okubo, MD, PhD; Masahiro Ozaki, MD, PhD; Satoshi Suzuki, MD, PhD; Narihito Nagoshi, MD, PhD; Morio Matsumoto, MD, PhD; Masaya Nakamura, MD, PhD; Kota Watanabe, MD, PhD

Hypothesis
Greater correction of upper instrumented vertebra (UIV) tilt increases the risk of postoperative shoulder imbalance (PSI) in Lenke 1 adolescent idiopathic scoliosis (AIS).

Design
Single-center retrospective cohort study.

Introduction
PSI remains a concern in Lenke 1 AIS when the proximal thoracic (PT) curve is left unfused. We tested whether larger ΔUIV tilt correction is associated with PSI and compared outcomes between proximal thoracic side-bending (PTSB) groups.

Methods
Female Lenke 1 AIS pts undergoing posterior spinal fusion were reviewed (n=120). ΔUIV tilt was defined as UIV tilt at 2 years minus preoperative UIV tilt. Pts were categorized by ΔUIV tilt (≥10° vs <10°; prespecified) and grouped by PTSB angle: F (<15°) vs R (15–25°). PSI was defined as left shoulder elevation by signed radiographic shoulder height (RSH ≥10 mm) at 2 years (absolute value not used). Multivariable logistic regression adjusted for Risser ≥3, preop RSH >0 mm, preop T1 tilt, and PT flexibility.

Results
PSI occurred in 34/120 pts (28.2%) and did not differ between PTSB groups (26.3% vs 29.1%, p=0.80). ΔUIV tilt ≥10° was independently associated with PSI (OR 2.78, 95% CI 1.07–7.24; p=0.02), along with Risser ≥3 (OR 10.32, 95% CI 1.27–87.78; p=0.03) and preop RSH >0 mm (OR 2.90, 95% CI 1.13–9.31; p=0.04). In Risser ≥3 pts, PSI tended to be higher with ΔUIV tilt ≥10° (42% vs 23%, p=0.06).

Conclusion
ΔUIV tilt correction ≥10° was an independent risk factor for left PSI at 2 years in Lenke 1 AIS with the PT curve left unfused. PTSB 15–25° alone was not associated with higher PSI.

52. Distal Instrumentation Failure After Posterior Spinal Fusion in Adolescent Idiopathic Scoliosis: Incidence, Risk Factors, and Radiographic Impact

Myeong Geun Song, MD; *Chang Ju Hwang, MD, PhD;* Dong-Ho Lee, MD, PhD; Jae Hwan Cho, MD, PhD; Sehan Park, MD, PhD; Wan Soo Park, MD

Hypothesis
We hypothesized that distal instrumentation failure is associated with distal construct and curve characteristics and results in loss of correction and distal curve deterioration after posterior spinal fusion in adolescent idiopathic scoliosis (AIS).

Design
Retrospective cohort study.

Introduction
Distal instrumentation failure, including axial rod slip (ARS) and distal screw fixation failure, may compromise maintenance of correction after posterior spinal fusion for AIS. This study evaluated its incidence and associated factors.

Methods
We retrospectively reviewed 302 AIS patients who underwent posterior spinal fusion with all pedicle screw constructs and had at least 2 years of radiographic follow-up. Distal instrumentation failure was defined as ARS (≥2 mm rod shortening at the LIV) or screw fixation failure (pull-out) on follow-up radiographs. Patients were classified into failure (n=35) and non-failure (n=267) groups, and distal construct–related clinical and radiographic parameters were analyzed.

Results
Distal instrumentation failure occurred in 35 of 302 patients (11.6%), predominantly ARS (28/302, 9.3%). ARS developed within 3 months in 50.0% of cases and was more frequent on the convex side (64.3%). Failure was associated with larger preoperative lumbar curves, higher lumbar modifiers, distal LIV selection (L3 or L4), and inferior LIV screw trajectory. The failure group showed greater correction loss (7.0% vs. 1.1%, p = 0.007) and higher distal curve progression >5° (69.2% vs. 3.0%, p < 0.001). Torque-limiting locking mechanisms showed a lower failure incidence than break-off systems.

Conclusion
Distal instrumentation failure after AIS fusion was not uncommon and was mainly attributable to ARS. Larger preoperative lumbar curves, distal LIV selection (L3/L4), inferior screw angulation, and high lumbar modifiers were associated risk factors. Awareness of these distal construct–related risk factors may help surgeons adopt preventive strategies during instrumentation. In particu-

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lar, transverse traction at the LIV may help maintain correction in AIS surgery.

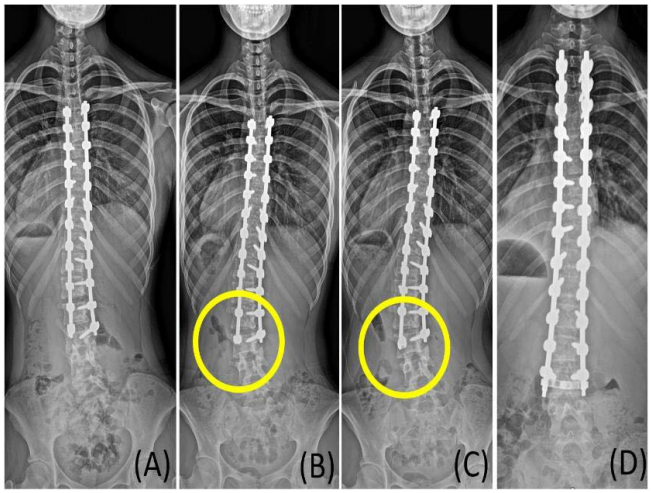


Figure 1. Representative case of distal instrumentation failure and preventive transverse traction. (A) Immediate postoperative radiograph. (B) Axial rod slip at 1yr follow-up. (C) Distal screw dislodgement at 2yr follow-up. (D) Transverse traction applied at the distal end of the construct.

53. What Factors Allow Us to Predict Ideal Radiographic Outcomes at 2 and 5 Years in Selective Thoracic Fusion in Lenke C AIS?

Tej Azad, MD; Michael Rothbaum, MD; Joshua M. Pahys, MD; Amer F. Samdani, MD; Terrence G. Ishmael, MBBS; Todd F. Ritzman, MD; Firoz Miyanji, MD, FRCS(C); Suken A. Shah, MD; Peter O. Newton, MD; Harms Study Group; *Steven W. Hwang, MD*

Hypothesis
Lumbar curve size and flexibility predict achievement of radiographic success (RS) following selective thoracic fusion (STF) in Lenke C AIS curves.

Design
Retrospective multicenter database

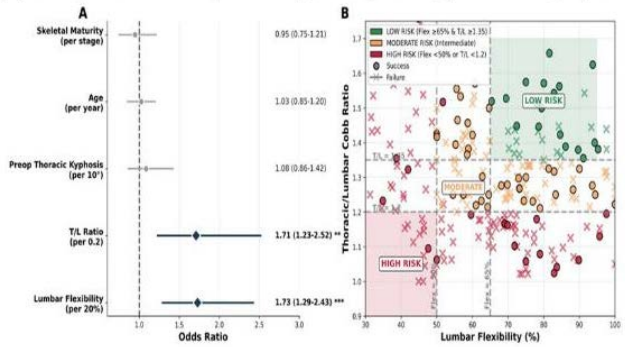
Introduction
STF is increasingly performed in AIS to preserve lumbar motion, yet ideal selection criteria remain elusive.

Methods
We included Lenke type 1-4 C AIS patients who underwent STF (LIV <L1) with a minimum of 2Y follow-up. Primary outcome was composite RS, defined as meeting all 5 RS criteria (Schulz 2014): lumbar Cobb<26°, C7-CSVL ≤2 cm, trunk shift <1.5 cm, lumbar correction >37%, and deformity-flexibility quotient (DFQ, residual lumbar Cobb/# unfused levels) <4. Multivariable regression evaluated pre-op predictors of RS. Risk groups were stratified by predictive thresholds, and SRS-22r patient-reported outcomes at 2Y were compared between RS/no-RS groups within each risk stratum. 5Y RS was also assessed.

Results
268 patients with mean age of 14.6±2.1 yrs were included; curve types included Lenke 1 (60%), 2 (19%), 3 (12%), and 4 (6%). Mean pre-op thoracic and lumbar curves were 55±10° and 43±8°, respectively. Composite RS was achieved in 29% at 2Y (78/268) and increased to 34% at 5Y (36/107), with older age and Lenke 1 curve type associated with success. LIV selection and achieved thoracic correction magnitude did not differ between RS/no RS groups (p>0.3). L1 LIV was associated with lumbar correction >37% (p<0.001), T11/12 vs L1 LIV was associated with achieving DFQ <4 (p=0.04), while greater thoracic curve correction was associated with worse trunk shift (p=0.02). On multivariable analysis, greater pre-op lumbar flexibility (OR 1.8/20% increase, p<0.001) and higher pre-op thoracic:lumbar (T/L) curve ratio (OR 1.6/0.2 increase, p=0.002) independently predicted RS (AUC=0.70). Risk stratification using both predictors identified high (flexibility <50% or T/L ratio <1.2), moderate, and low-risk (flexibility ≥65% and T/L ratio ≥1.35) groups with 2Y RS rates of 16% (N=121), 37% (N=102), and 53% (N=36), respectively (p<0.001). Within risk groups, RS was associated with better SRS-22r self-image (high-risk: 4.6±0.4 vs 4.3±0.6, p=0.03) and satisfaction scores (low-risk: 4.9±0.3 vs 4.4±0.8, p=0.03).

Conclusion
Greater lumbar flexibility (≥65%) and higher preoperative T/L ratio (≥1.35) predicted RS in 53% of patients undergoing STF.

(A) Forest plot of multivariable predictors. (B) Scatterplot of key predictors/risk groups.



54. Lumbar Curve Correction is Durable at 5 Years After Thoracic Fusion in Patients with Open Triradiate Cartilage

Scott Yang, MD; Bailey Ingalls, MD; Tracey Bryan, MS; Jennifer M. Bauer, MD, MS; Paul D. Sponseller, MD; Suken A. Shah, MD; Peter O. Newton, MD; Burt Yaszay, MD; Harms Study Group

Hypothesis
The lumbar spine responds differently in patients with open triradiate cartilage (OTRC) versus those with closed triradiate cartilage (CTRC) after thoracic fusion (TF) in adolescent idiopathic scoliosis (AIS).

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

PODIUM ABSTRACTS

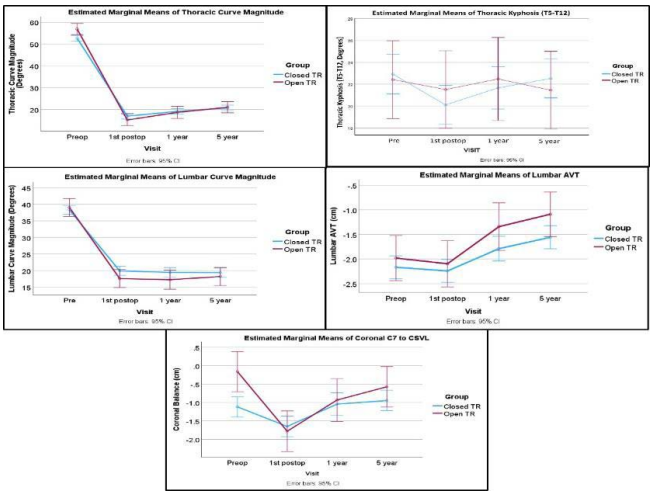
Design
Retrospective Cohort Study

Introduction
TF in AIS maintains mobile lumbar segments in patients with primary thoracic and compensatory lumbar curves. In AIS patients with substantial growth remaining, little is known about the behavior of the unfused spine and coronal balance after TF. This study aims to assess the behavior of the unfused lumbar spine 5 years after TF in AIS patients with OTRC.

Methods
A multicenter AIS database was queried for patients who underwent TF with the lowest instrumented vertebra L1 or cephalad. Patients were grouped based on 1) OTRC, or 2) CTRC and Risser 4/5. Radiographic measures at preop, 1st postop, 1 year, and 5 years included lumbar curve magnitude (LCM), lumbar apical vertebral translation (LAVT), coronal balance, adding on, thoracic curve magnitude (TCM), and thoracic kyphosis (TK). A generalized linear model was utilized to estimate and evaluate differences in means of variables.

Results
The OTRC group included 33 patients (mean 11.9 years). The CTRC group included 131 patients (mean 15.3 years). Both groups had comparable curve types and magnitudes, with >85% Lenke 1 or 2, B or C curves. LCM and TCM decreased significantly from preop to the 1st postop visit in both CTRC and OTRC groups (Figure 1), with no change at 1 year and 5 years postop in both groups. In both groups, there was significant coronal balance decompensation at 1st postop with significant improvement at 1 year and 5 years compared to 1st postop. In both groups, LAVT did not change from preop to 1st postop, though improved significantly at 1 year and 5 years compared to preop. In all postoperative periods, there was no significant difference between OTRC and CTRC groups in LCM, LAVT, coronal balance, and TK. Although there was significantly higher rate of adding on at 5 years in the OTRC versus CTRC group (OTRC 48%, CTRC 24%, p=0.003), this drove improvement in balance in the OTRC group.

Conclusion
TF alone in young patients with OTRC results in similar balanced spine with maintained lumbar correction at 5 years follow up compared to more skeletally mature patients and remains a reasonable surgical option for compensatory lumbar modifier B and C curves.



Radiographic Measures

55. Health Related Quality of Life Assessment Using the Srs-22 Questionnaire Comparing Adolescent Idiopathic Scoliosis (AIS) versus Adult Idiopathic Scoliosis (AdIS) who had undergone Posterior Spinal Fusion (PSF): A Propensity Score Matched Study

Chris Yin Wei Chan, MD, MSOrth; Amanda W. Leong, MBBS; Van Jet Leong, MBBS; Hui Chin Ting, MBBS; Zhi Sean Teng, MBBS; Chee Kidd Chiu, MBBS, MSOrth; Mun Keong Kwan, MBBS, MSOrth

Hypothesis
AIS and AdIS patients demonstrate different health-related quality-of-life outcomes and rates of MCID achievement following surgical treatment, as measured by the SRS-22r.

Design
Retrospective study

Introduction
Adolescent Idiopathic Scoliosis (AIS) and Adult Idiopathic Scoliosis (AdIS) differ in clinical characteristics and treatment challenges, yet comparative data on surgical outcomes and patient-reported quality of life are limited. This study evaluates health-related quality of life and the achievement of the Minimum Clinically Important Difference (MCID) using the SRS-22r in AIS and AdIS patients.

Methods
388 patients (316 AIS, 72 AdIS) were recruited. Following propensity score matching (PSM), there were 46 pairs in each group. Matching was based on gender, Lenke classification, major Cobb angle, and number of fusion levels with match tolerance 0.005. The SRS-22r questionnaire was assessed preoperatively and at a minimum of two years postoperatively.

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

Results
AIS patients (mean age14.1 ± 2.0 years) and AdIS patients (mean age 25.2 ± 4.9 years) were comparable in terms of BMI and average follow-up duration. There was also no significant difference in terms of mean operative times (136.5 ± 47.2 vs. 138.5 ± 47.9 min, p=0.839), blood loss (833.4 ± 405.6 vs. 785.0 ± 435.5 mL, p=0.584), and screw density (1.2 ± 0.2 vs. 1.2 ± 0.1, p=0.606). The odds of AIS patients achieving MCID compared to AdIS is 11.6 times (95% CI 3.891-34.483, p<0.001) for function domain and 6.3 times (95% CI 2.110-18.868 p<0.001) for the pain domain, while the odds of AdIS patients achieving MCID for self-image is 2.1 times (95% CI 0.892-4.921, p=0.087). 1 AIS patient was recorded to have superficial surgical site infection and 1 AdIS patient had T10 radiculitis postoperatively.

Conclusion
AIS patients had higher odds of achieving MCID in function (11.6 times) and pain domain (6.3 time) compared to AdIS patients.

56. Age Matters: Increased Perioperative Morbidity in Young Adults Compared to Adolescents Undergoing Posterior Spinal Fusion for Idiopathic Scoliosis

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Hypothesis
We hypothesized that young adults undergoing posterior spinal fusion for idiopathic scoliosis have higher risk of perioperative morbidity than adolescents.

Design
This was a retrospective cohort study using data from NSQIP databases from 2016 to 2024.

Introduction
The purpose of this study was to compare perioperative outcomes between adolescents and young adults undergoing posterior spinal fusion for idiopathic scoliosis using a large clinical registry.

Methods
Patients aged 10–40 years who underwent posterior spinal fusion for idiopathic scoliosis were included. Two study cohorts were defined: (1) adolescent idiopathic scoliosis (AIS) (10–17 years) and (2) young adult idiopathic scoliosis (YADIS) (18–40 years). Outcomes included operative time, length of stay (LOS), allogeneic transfusion, any adverse event, 30-day readmission, 30-day reoperation, and non-home discharge. Groups were compared using chi-square test and Student's t-test. Multivariable regression analyses were performed controlling for sex, ASA, and number of fusion levels.

Results
There were 31,120 AIS patients (mean age 14.5 years) and 439 YADIS patients (mean age 21.9 years). Compared with the AIS cohort, YADIS had significantly longer operative times (AIS: 276.4 minutes vs YADIS: 353.7 minutes; p<0.001) and longer LOS (AIS: 3.4 days vs YADIS: 5.1 days; p<0.001). The YADIS cohort had higher rates of allogeneic transfusion (AIS: 10.9% vs YADIS: 33.3%; p<0.001), any adverse event (AIS: 1.6% vs YADIS: 3.0%; p=0.03), reoperation (AIS: 1.3% vs YADIS: 2.5%; p=0.03), and non-home discharge (AIS: 0.4% vs YADIS: 2.7%; p<0.001). There was no significant difference in readmission (AIS: 1.7% vs YADIS: 2.7%; p=0.10). In multivariable logistic regression analyses, the YADIS cohort had higher odds of allogeneic transfusion (OR 4.8, p < 0.001), reoperation (OR 1.9, p = 0.04), any adverse event (OR 1.8, p = 0.04), and non-home discharge (OR 7.19, p < 0.001). In multivariable linear regression analyses, YADIS was associated with longer operative time (+78.9 minutes, p<0.001) and length of stay (+1.7 days, p<0.001).

Conclusion
Compared with adolescents, young adults undergoing posterior spinal fusion for idiopathic scoliosis experience greater perioperative morbidity and resource utilization.

	Adolescent Idiopathic Scoliosis (n=31,120)	Young Adult Idiopathic Scoliosis (n=429)	
Operative time (minutes)	276.4 ± 94.6	353.7 ± 124.7	t=16.92, p<0.001 mean difference 77.3
Length of stay (days)	3.4 ± 4.1	5.1 ± 3.1	t=8.5, p<0.001 mean difference 1.7
Allogeneic transfusion	10.9%	33.3%	X^2= 215.7, p<0.001
Any adverse event	1.6%	3.0%	X^2=46.7, p=0.03
Unplanned readmission	1.7%	2.7%	X^2=2.7, p=0.10
Unplanned reoperation	1.3%	2.5%	X^2=4.5, p=0.03
Non-home Discharge	0.4%	2.7%	X^2=59.1, p<0.001

Comparison of perioperative measures

57. Longitudinal Patient-Reported Outcomes Following Spinal Fusion for Adolescent Idiopathic Scoliosis: Recovery Trajectories and Implications for Surgical Timing

Wai Wang Chau, MS; Alec Lik Hang Hung, FRCS; *Adam Yiu Chung Lau, FRCS*

Hypothesis
Beyond skeletal maturity and curve severity, incorporating patient-reported outcome measures (PROMs), such as the SRS-22r and the Spinal Appearance Questionnaire (SAQ), which reflect perceptions of function, pain, and quality of life, may help determine the optimal surgical timing in otherwise asymptomatic AIS patients.

Design
Retrospective cohort study

Introduction
Current guidelines recommend surgery for AIS at Cobb angles ≥45-50°, but patient centered criteria are lacking. This study aims to determine the optimal surgical age for spinal fusion surgery in adolescents with idiopathic Scoliosis (AIS) by incorporating PROMs to assess recovery trajectories.

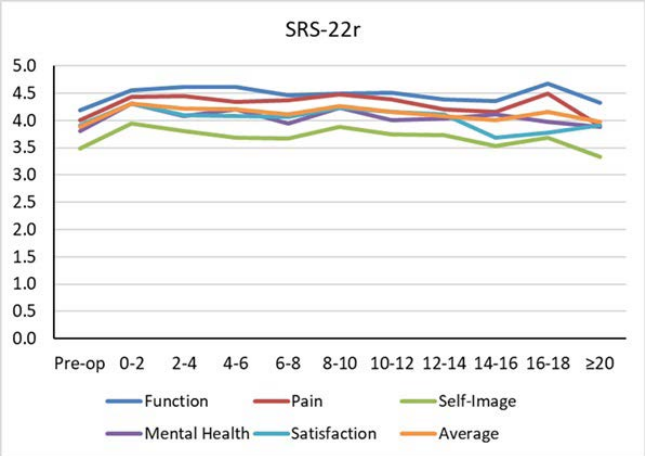
§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

PODIUM ABSTRACTS

Methods
Patients with severe AIS (Cobb ≥45°) who underwent spinal fusion surgery at a single tertiary center were included. Longitudinal SRS-22r and SAQ data were collected from preoperative assessment to more than 20 years postoperatively. Age at surgery was analyzed as a predictor of "good recovery" using receiver operating characteristics (ROC) curves, linear mixed models, and AI-assisted trajectory segmentation.

Results
A total of 388 AIS patients (1539 records; mean surgical age 15.3±2.1 years; mean Cobb angle 59°±12°) were included. ROC analysis identified 14.5 years (area under curve (AUC)=0.72, 95%CI:0.65-0.79) and 15.2 years (AUC=0.70) as optimal cut-offs for SRS-22r and SAQ recovery, respectively. Patients operated at 12-16 years showed faster HRQOL improvement (slope:0.45vs.0.28/year, p=0.021) and reached maximum improvement earlier (4 years for SRS-22r; 6 years for SAQ). Age≥14.5 years predicted good recovery (OR=2.45, 95%CI:1.67–3.60, p<0.001). Long-term HRQOL remained stable at normative levels (>20 years:SRS-22r:4.10±0.40), with no significant decline.

Conclusion
Our finding indicates that surgery between 14.5 and 15.2 years optimizes the HRQOL recovery trajectory in severe AIS. Scheduling surgery at approximately age 14.5, guided by SRS-22r data and accounting for a 6-month lag in body image improvement, yields the most favorable recovery trajectory. AI-based modeling provides actionable age thresholds, supporting the integration of age-HRQOL data into shared decision-making for optimal surgical timing.



Longitudinal mean SRS-22r domain scores

58. The Evolution of Sagittal Alignment in Pediatric Population: A Study of 500 Typically Developing Children

Anuj Gupta, MD; Alexander Aretakis, MD; Satoshi Takada, MD; Peter G. Gabos, MD; Petya Yorgova, MS; Andrea Elsby, BS; *Suken A. Shah, MD*

Hypothesis
The T4-L1-Hip Axis represent a normal sagittal alignment in pediatric population

Design
Cross-sectional

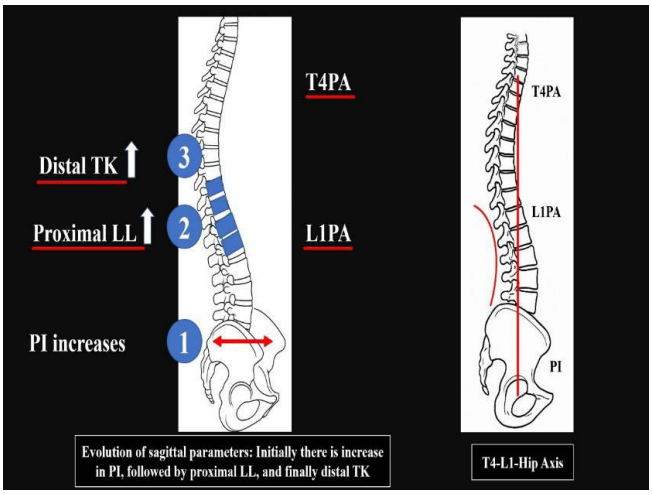
Introduction
Restoring sagittal parameters is essential to improve functional outcomes in deformity correction. The VPA, especially for L1 (L1PA), correlates well with global sagittal alignment, & T4-L1-hip forms a straight axis in normal adults. However, there is no data for the pediatric population.

Methods
Patients from a single institution's database were recruited. These (up to 18 years) had whole spine radiographs for screening of scoliosis. Patients with curves >10°, spondylolisthesis, pelvis or lower limb pathology, or significant back pain were excluded. Sagittal measurements recorded were pelvic parameters (PI, SS, PT), L1PA, T4PA, lumbar lordosis (LL: L1-S1, proximal LL: L1-L4, distal LL: L4-S1), and thoracic kyphosis (TK: T1-T12, upper TK: T1-T5, middle TK: T5-T9, lower TK: T9-L1). Change was assessed between the groups divided based on skeletal maturation (pre-pubertal, early puberty, pubertal peak, and late/post-puberty).

Results
500 children (293F) with mean age 12.9 years (pre-pubertal= 134, early puberty= 67, pubertal peak= 47, post-puberty= 252) were included. PI (44°± 10°) & PT (6°± 8°) increased significantly with age (p<0.001). On post-hoc analysis, increase was significant at early puberty. SS (38.1°± 8.8°) was consistent at all age groups (p=0.07). LL (55.4°± 11.4°) increased significantly with age (p=0.003), particularly in early puberty &, increase was due to proximal LL (p<0.001), not distal LL (p=0.59). Similarly, there was an increase in TK (p<0.001) at post-puberty, significantly contributed by distal TK (p=0.001). The change in L1PA (median 0.7°, IQR 8.6°) and T4PA (median -1.4°, IQR 9.8°) corresponds with LL and TK, respectively. On multivariable regression analysis, PI & L1PA combined have a strong correlation with LL, especially in the post-puberty group (R2=0.7). T4PA values have a strong correlation with L1PA & are within 5° of L1PA, for 80% prediction.

Conclusion
This study reports the normal values of various sagittal parameters in pediatric population. PI exhibits a significant correlation with lumbar alignment; &, this correlation improves when combined with L1PA across all age groups. Sagittal alignment evolves during growth: an increase in proximal LL followed by distal TK. The T4-L1-hip axis holds true for the pediatric population, especially older children.

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant



59. Defining Whole Spine Sagittal Alignment Parameters in Normal Population: Prospective Analysis of 50000 Patients

Sung Hyeon Noh, MD, PhD

Hypothesis
The purpose of this study is to present the normal whole spine sagittal alignment parameters in normal population

Design
Retrospective study

Introduction
Defining normative values of these clinically relevant sagittal parameters are essential as they provide objective surgical indications when planning treatment and serve as optimal target values for surgical correction. Insufficient incorporation of spino-pelvic parameters can result in detrimental outcomes such as spinal misalignment, decompensation, and failure of treatment.

Methods
Fifty thousand patients aged more than 20 years old who had mild disability (MD, ODI of ≤ 20 score) and who met the inclusion criteria were included in this study. Patients were stratified into age cohorts: 20s, 30s, 40s, 50s, 60s, 70s or older. Radiographic evaluation, including C0C2 angle, C0C7 angle, C27 angle, odontoid hip axis (OH), SVA, TK, LL, L4S1 angle, PT, TPA, PI−LL, sacral slope (SS), spino-sacral angle (SSA) were conducted on the whole spine standing radiographs. Clinical scales (ODI, 36-item Short Form Health Survey [SF-36], and visual analogue scale [VAS] for back pain) were completed.

Results
Among 50000 patients, there were 5805 people in their 20s, 5845 people in their 30s, 7875 people in their 40s, 10625 people in their 50s, 10750 people in their 60s, and 9100 people in their 70s or older. The average C0C2 angle, C0C7 angle, C2C7 angle, OH, SVA, TK, LL, L4S1 angle. PT, TPA, PI−LL, SS and SSA for 20s were 23.5±12.42, 34.72±17.41, 14.05±12.29, 9.22±14.98 degrees, 25.22±24.25 mm, 28.31±15.07, 54.22±17.21, 34.31±16.66, 41.49±33.58, 26.63±39.97, -12.35±36.74, 41.03±9.75, 132.71±9.75 degrees.

Conclusion
Through this study, whole spine sagittal alignment parameters according to age in a normal population were presented. C0C7 angle, C2C7 angle, SVA, TK, PT, and PI-LL increased statistically significantly with age. OH, LL, L4S1 angle, TPA, SS, and SSA decreased statistically significantly with age. These parameters will be very helpful to doctors and patients performing spinal surgery.

60. Does everyone with a given PI have the same L1PA? The importance of L4S1 in Sagittal Alignment

Stephen J. Lewis, MD, FRCS(C); Fatemeh Alavi, PhD; Christopher J. Nielsen, MD; Fred H. Nicholls, MD

Hypothesis
Individuals with similar pelvic incidence (PI) do not necessarily exhibit the same L1–pelvic angle (L1PA). We hypothesize that L4S1 better impacts variability in sagittal alignment than PI alone.

Design
Cross-sectional analysis

Introduction
The L1PA as a critical measure for describing lumbar sagittal alignment has been proposed to be a function of PI: L1PA = 0.5 × PI -21°. The T4 pelvic angle also reported to be nearly equivalent (within 4o) to the L1PA. However, patients with similar PI often demonstrate different L1PAs. This suggests that segmental lumbar distribution may play a critical role. This study evaluates the magnitude of L4S1 and variability in L1PA in individuals with comparable PI.

Methods
A retrospective analysis was conducted on standing full-spine EOS radiographs of 410 asymptomatic adult volunteers (55.8% female; age 20–39 years). Spinopelvic parameters including PI, SS, L1PA, L1S1, and L4S1 were measured. Three groups with low (<45o), moderate (45o-55o), and high (>55o) PIs were considered. Each group was then divided into two groups with high and low L4S1 ($p<0.0001$) and non-significant difference between PI, PT, L1S1 from 242 individuals in total. The variability in L1PA and T4L1PA within same PI subgroups were assessed. Multivariable regression analyses on whole cohort determined the contribution of L4S1 versus PI to L1PA variability.

Results
The groups with similar PI, PT, and L1S1, but different L4S1 ($p<0.0001$) demonstrated substantial inter-individual variability in L1PA ($p<0.0001$) and T4L1PA ($p<0.001$). L1PA was strongly associated with PI ($\beta=0.59$; $P<0.001$) and L4S1 ($\beta=-0.49$; $P<0.001$). Predicted L1PA based on PI alone was compared with actual L1PA and contrasted with predictions derived from L1PA=0.5 × (PI-L4S1) model. The magnitude of L4S1 lordosis plays a critical role in shaping global sagittal alignment.

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

PODIUM ABSTRACTS

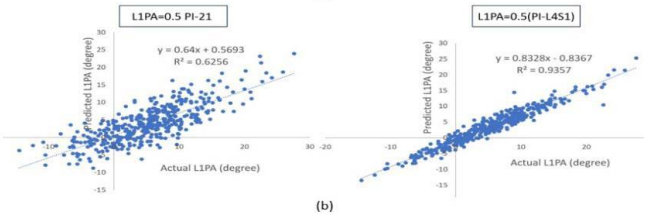
Conclusion
Patients with the same PI do not necessarily share the same L1PA. While L1PA approximates the distribution of the lumbar lordosis, L4S1 lordosis is a critical driver of the L1PA variability and may provide more clinically meaningful guidance than PI alone. Incorporating the distal lordosis as measured by the L4S1 provides a more reliable measure of the L1PA (R2=0.94). These results support incorporating distal lumbar distribution into alignment assessment and planning rather than relying solely on PI.

		N	PI	PT	SS	L4S1	L1S1	L1PA	T4PA	T4L1PA
Group 1	mean	24	39.96	7.77	32.20	31.09	46.81	4.39	2.88	-1.50
	mean	50	39.41	6.28	33.13	42.10	49.23	-0.64	0.08	0.72
	T-test	74	0.55	0.07	0.20	1.16E-21	0.09	8.44E-11	0.0005	0.0004

		N	PI	PT	SS	L4S1	L1S1	L1PA	T4PA	T4L1PA
Group 2	mean	52	50.04	13.13	36.91	35.49	53.26	8.87	6.82	-2.05
	mean	43	49.52	12.04	37.48	44.13	54.69	5.07	5.26	0.19
	T-test	95	0.34	0.07	0.37	1.51E-21	0.332	3.81E-11	0.01	1.1E-05

		N	PI	PT	SS	L4S1	L1S1	L1PA	T4PA	T4L1PA
Group 3	mean	36	61.81	17.59	44.22	39.30	60.79	13.99	11.11	-2.88
	mean	37	61.68	15.72	45.96	49.74	63.12	9.07	8.49	-0.58
	T-test	73	0.929	0.10	0.13	3.66E-16	0.17	9.97E-07	0.012	0.00024

(a)



(b)

(a) Spinopelvic parameters of groups (b) Predicted versus actual L1PA

61. Establishing Lumbar Apex Pelvic Angle (LaPA) as the Rosetta Stone of Spinal Shape

Sleiman Haddad, MD, PhD, FRCS; Lluis Vila Castillo, MD; Susana Nunez Pereira, MD, PhD; Anika Pupak, PhD, BS; Javier Pizones, MD, PhD; Michael P. Kelly, MD; Jeffrey M. Hills, MD; Frank Kleinstuck, MD; Ahmet Alanay, MD; Ibrahim Obeid, MD; Ferran Pellise, MD, PhD; Yann Phillippe Charles, MD, PhD; European Spine Study Group ESSG

Hypothesis
Dynamic regional landmarks especially lumbar apex predict PI-concordant sagittal shape more reliably than fixed vertebrae, acting as a "Rosetta Stone" to translate pelvic morphology into global sagittal shape

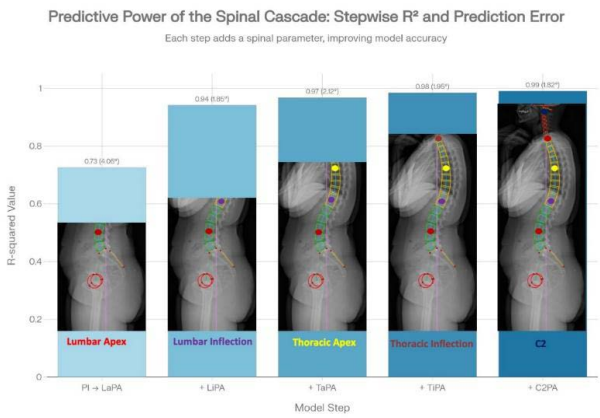
Design
Multicenter radiographic analysis of normative volunteers

Introduction
Pelvic incidence (PI) governs sagittal morphology, yet translating this constant into patient-specific targets remains difficult. Models anchored to fixed vertebrae (e.g. L1, T4) do not capture inter-individual variation in curve apices and inflection points. We tested whether the lumbar apex pelvic angle (LaPA) is the key PI-dependent landmark linking pelvic morphology to global spinal shape, while separating PI-driven variables from PI-independent geometric constraints

Methods
We analyzed 236 asymptomatic volunteers (age 20–50; PI 21.8–103.2°) with standardized standing full-spine xrays. Pelvic Angles (PA) of regional landmarks were measured: LaPA, LiPA (thoracolumbar inflection), TaPA (thoracic apex) and TiPA (cervicothoracic inflection) contrasting them with fixed parameters (L1PA, T4PA, C2PA). PI dependency was assessed via Pearson correlation(r) and effect size(η^2). Heteroscedasticity was evaluated to quantify variability across the PI spectrum. Inter-parameter relationships mapped a stepwise predictive chain from pelvis to regional landmarks

Results
LaPA showed the strongest dependency on PI and enabled continuous prediction (LaPA = -10.26 + 0.39 x PI; r=0.852, η^2=0.59, p<0.001), outperforming L1PA (r=0.784; η^2=0.47). Mean LaPA increased from 5.0 degrees (low PI) to 17.4 degrees (high PI) with stable correlation across the full PI spectrum, including distribution extremes where fixed-vertebra angles were less reliable. A robust cascade was identified: LaPA predicted LiPA(r2=0.94), which sequentially predicted TaPA (r2=0.97), TiPA (r2=0.98), and C2PA (r2=0.99). Composite indices (TiLiPA & TaLaPA) were PI-independent (r<0.10, η^2<0.001) suggesting universal alignment "rules". Variability increased with PI magnitude, supporting wider acceptable ranges for high PI individuals

Conclusion
LaPA functions as the optimal Rosetta Stone for PI-concordant shape reconstruction offering greater accuracy than fixed points. Calculating target LaPA from PI allows reliable sequential derivation of ideal regional landmarks via a strong correlation chain - while PI-independent parameters (TiLiPa & TaLaPa) provide universal bounds. Surgical validation is needed



§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

62. Using Artificial Intelligence to Capture CT Films with Smartphones for Automatic Recognition of Osteoporosis

Junyu Li, MD; Da Zou, MD; Liangyuan Wang; Yongqiang Wang, MD; Zhuoran Sun, MD; *Miao Yu, MD;* Weishi Li, MD

Hypothesis
A deep learning model (AIPOS) using smartphone-captured CT film or screen images can accurately screen for osteoporosis, offering a portable and accessible alternative to traditional methods.

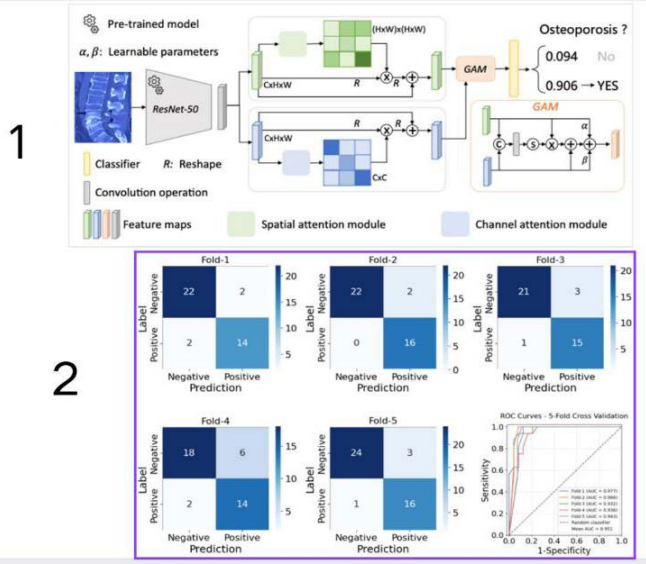
Design
Retrospective diagnostic study developing and validating an AI model. Included 204 patients (149 with CT film photos, 55 with screen-captured images) for osteoporosis classification.

Introduction
Osteoporosis is a major public health challenge with high rates of missed diagnosis. Current gold-standard screening (DXA, QCT) is limited by cost and accessibility. While AI models show promise, they typically rely on original DICOM data within hospital networks, hindering point-of-care use. This study aims to develop a portable system using smartphone photos of CT images for accessible screening.

Methods
CT images from 204 inpatients were captured via smartphone (films or computer screens). Two orthopedic physicians provided reference diagnoses based on bone density. The AIPOS model was built on ResNet-50 with a triple-attention mechanism. Performance was evaluated using 5-fold cross-validation, assessing accuracy, sensitivity, specificity, F1-score, and AUC.

Results
In 5-fold cross-validation, AIPOS achieved an average accuracy of 89.2%, sensitivity 92.6%, specificity 86.9%, F1-score 87.4, and AUC 0.951. Performance was better on CT film images than on screen-captured images (F1: 0.891 vs. 0.753). Cross-testing showed better generalization from film-trained to screen-test data (AUC 0.963) than the reverse (AUC 0.880). Window settings and scan orientation affected model performance

Conclusion
The AIPOS system enables accurate, portable osteoporosis screening using smartphone-captured CT images, potentially increasing accessibility in community and home settings and reducing missed diagnoses



AIPOS Model Structure Diagram and Confusion matrix and ROC curve of the model in five-fold cross-validation on the mixed dataset.

63. Utilizing a Supervised Machine Learning Strategy to Automate Detection of Bony Fusion Using X-Rays in Lumbar Fusion Surgery ‡

Rushikesh S. Joshi, MD; Edward S. Harake, BS; Todd C. Hollon, MD; Paul Park, MD

Hypothesis
With a combination of self-supervised and supervised learning strategies, we aim to develop a computational tool that can learn radiographic features inherent to X-rays to predict bony fusion comparable to CTs, and outperform our ability as humans to predict fusion on spine X-rays.

Design
1,403 patients who underwent one- or two-level lumbar fusion surgery at a single institution between 2005-2023 were identified, yielding a total of 1,395 associated CT scans. CT scans were provided to fellowship-trained spine surgeons and a neuroradiologist for annotation. Every lumbar segment containing instrumentation was labeled as "fused" or "not fused" at three distinct anatomic sites. A total of 3,140 lumbar and scoliosis X-rays taken at various postoperative time points were paired with the extracted CTs and their level-specific labels.

Introduction
Bony fusion is one of the primary outcomes of spinal fusion surgery. CT scans remain the gold-standard for assessing bony fusion postoperatively, and can be difficult to obtain, are costly, and subject to surgeon bias. In this study, we sought to build an artificial intelligence (AI) tool to accurately predict bony fusion on X-rays.

Methods
A convolutional neural network (CNN) was developed to

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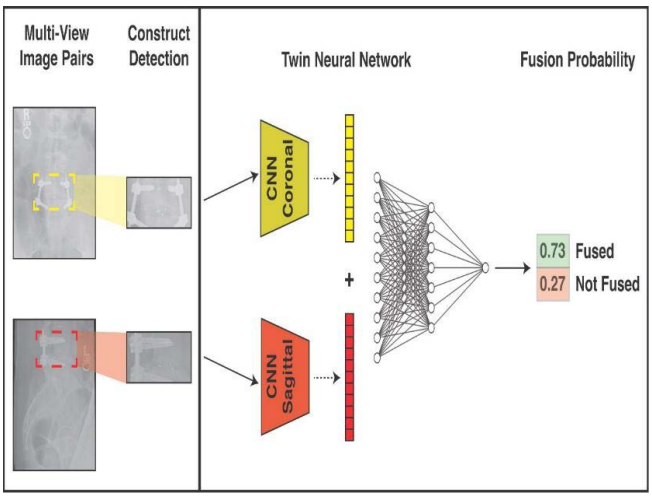
isolated instrumented segments from X-rays, and a twin neural network architecture was built to simultaneously evaluate individual cropped segments in both coronal and sagittal planes to predict bony fusion.

Results
Approximately 180 CTs were carefully annotated by our expert spine surgeons, corresponding to 367 unique x-ray studies. Individual instrumented levels were isolated from these studies using our CNN-based object detector and fed into our twin neural network model for training, with the dataset being split 85% training/15% testing. On an independent validation set, our model was able to predict bony fusion in relation to ground truth CT labels with 88% accuracy. This was compared to human performance of a board-certified neurosurgeon, who was able to predict bony fusion on x-rays in only 64% of cases by eye.

Conclusion
Using a combination of machine learning techniques, we were able to develop an AI-based model that could accurately predict bony fusion on X-rays. Future studies will continue to incorporate larger datasets to further train our model and enhance predictive capabilities to assist surgeons.



Twin neural network architecture

64. Development and Validation of the Three-dimensional Depth Sensor Imaging System for Non-invasive Scoliosis Screening

Chen Liu, MD; *Yingsen Pan, MD;* Shao Chen, MD; Xiao-min Chen, MD; Yin-ling Sun, MD; Kai-qi Wang, MD; Honggen Du, MD

Hypothesis
We hypothesize that the developed three-dimensional depth sensor imaging system, integrated with adaptive correction and deep learning-based feature fusion, will demonstrate non-inferiority and potentially superiority in accuracy, sensitivity, and specificity compared to manual Angle of Trunk Rotation (ATR) assessment for the non-invasive screening of adolescent idiopathic scoliosis (AIS).

Design
Multicenter cross-sectional study

Introduction
To mitigate the high costs and radiation risks associated with X-ray examinations, numerous countries have implemented School Scoliosis Screening programs that utilize measurements of the ATR to screen large adolescent populations, despite the methods being time-consuming and subject to interpretative variability. We developed and validated a novel AIS screening system using a three-imensional depth sensor, which incorporates adaptive correction techniques, deep learning algorithms and feature fusion method for objective, non-invasive, and automated detection of scoliosis.

Methods
Participants were based on suspected cases of adolescent idiopathic scoliosis. Utilizes a consumer-grade 3D depth sensor and a laptop, both integrated into the ROS framework. To identify whether patients with suspected adolescent idiopathic scoliosis were scoliosis by scanning the anterior flexion position. The data analysis framework presented in this article is methodically divided into two principal phases: the collection and preprocessing of human back point cloud data, and the development of deep learning classification models.And utilizing the Swin-Transformer model and the Feature-level feature fusion method. Accuracy, sensitivity and specificity were used to evaluate the system.

Results
This study included 869 subjects with documented ATR data across multiple centers. The system remarkably demonstrated an accuracy, sensitivity, and specificity of 93.0%, 96.4%, and 88.7% for predicting ATR equal to or greater than 5°, and 90.4%, 94.5%, and 85.2% for ATR equal to or greater than 7°, respectively. The introduction of the adaptive correction method enhanced accuracy by at least 1% (all $P<0.001$).

Conclusion
Our system exhibits great promise for highly accurate and readily accessible scoliosis screening, presenting a potential alternative to manual ATR measurements in large-scale screening initiatives.

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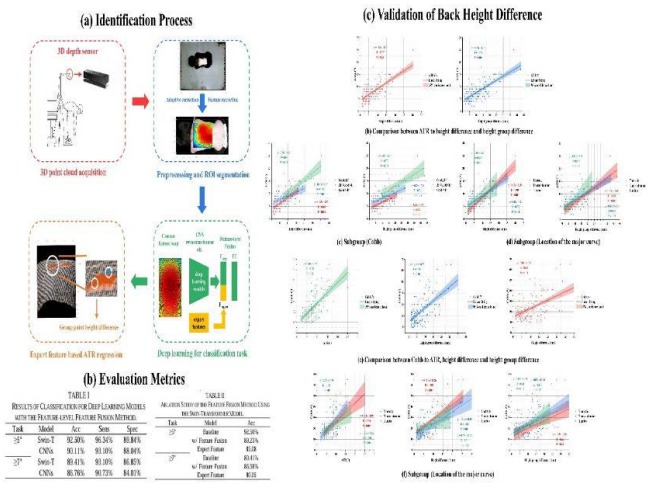

Methods and Results

65. Machine Learning Prediction of Cobb Angle from 3D Surface Topography in Adolescent Idiopathic Scoliosis: A Radiation-Free Alternative

Jose Maria Gonzalez Ruiz, PhD; Stephan Rothstock, PhD; Javier Pizones, MD, PhD

Hypothesis
A machine learning model applied to 3D surface topography (3D-ST) data predicts the Cobb angle with a mean absolute error (MAE) <5°, meeting clinical accuracy for detecting significant scoliotic changes.

Design
Retrospective, observational, and analytical study.

Introduction
Diagnosis, classification, and evaluation of adolescent idiopathic scoliosis (AIS) rely on the Cobb angle measured on radiographs with radiation risks. Tools combining 3D-ST and artificial intelligence have been developed, but most fail to meet the 5° clinical threshold for minimal significant change. Unlike conventional marker-less approaches, our model uses precise landmark-based extraction of 3D-ST coordinates for superior feature engineering that captures spinal curvature geometry.

Methods
174 AIS patients (10-18 years, Cobb 10°-60°) had their trunk surfaces analyzed by geometric morphometry, and the first 10 principal components of shape were extracted for Cobb prediction. These components were used to train and test the Cobb angle estimation model. The cohort was stratified by severity (mild <25°, moderate 25-40°, and severe >40°) to ensure equal representation of classes in the training and test sets. 140 patients were used for training and 34 for testing. Root Mean square error (RMSE), mean absolute error (MAE), and R2 were calculated comparing predictions and radiographic Cobb. The percentage of predictions below clinical threshold was calculated for the test set.

Results
In the training set, the RMSE, MAE, and R2 were 3.93°, 3.15°, and 0.86, respectively. In the test set, the RMSE was 5.39° [CI95%:4.15-6.74], the MAE was 4.33° [CI95%:3.29-5.50], and the R2 was 0.81 [CI95%:0.72-0.87]. 70.6% of patients were predicted below the clinical threshold (5°). Figure 1 shows the plot of predicted versus radiographic Cobb.

Conclusion
Our model predicts Cobb angle from 3D-ST with an MAE below the clinical threshold of 5°, allowing detection of relevant curve changes while reducing reliance on radiographs. This radiation-free tool supports follow-up by flagging progression and quantifying changes in trunk asymmetry associated with radiographic progression.

66. XR-GAN Enables Radiation-Free Radiograph Synthesis After Posterior Spinal Fusion in Adolescent Idiopathic Scoliosis: Toward Remote Follow-Up

Nan Wu, MD; *Jingxi Su, ME;* Aoran Maheshati, MD; Baitao Liu, MD; Kexin Xu, MS; Xiangjie Yin, MD; Jianguo T. Zhang, MD

Hypothesis
A generative adversarial network (GAN) framework can accurately synthesize high-fidelity postoperative spinal radiographs from standardized 2D-RGB back photographs, providing a radiation-free alternative for monitoring spinal alignment and instrumentation.

Design
This was a multi-center retrospective diagnostic study utilizing a large cohort of clinical and imaging data for model development and external validation.

Introduction
Adolescent idiopathic scoliosis (AIS) management requires frequent postoperative radiographic follow-up to monitor spinal alignment and implant integrity. However, repeated ionizing radiation exposure and limited access to full-spine imaging in primary care or resource-limited settings complicate long-term care. While artificial intelligence has advanced scoliosis screening, high-fidelity generative solutions for postoperative assessment, which must account for complex surgical hardware, remain scarce. We proposed a radiation-free, deep-learning framework to bridge this gap.

Methods
A total of 1,229 paired postoperative back photographs and radiographs from 1,059 AIS patients who underwent posterior spinal fusion were collected. A GAN-based model, XR-GAN, was trained on 992 image pairs. The model was evaluated on 110 internal and 127 external test pairs from three independent centers. Performance was measured by Cobb angle prediction accuracy (R2, MAE), scoliosis severity grading, and image quality metrics, including Fréchet Inception Distance (FID) and Structural Similarity Index (SSIM).

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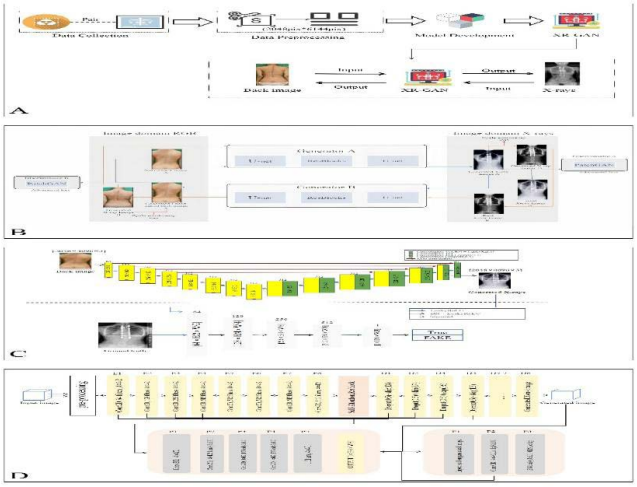
Results
XR-GAN achieved superior Cobb angle prediction in the internal test set (R2=0.964, MAE=1.54°) and maintained robustness in external validation (R2=0.873, MAE=2.16°). Compared to baseline models, XR-GAN demonstrated significantly higher image quality (FID=12.275, SSIM=0.920) and expert ratings (90.3/100). The model accurately preserved anatomical fidelity in fusion segments and successfully reconstructed pedicle screw-rod instrumentation at both immediate postoperative and one-year follow-up stages.

Conclusion
XR-GAN enables the accurate synthesis of postoperative radiographs from simple back photographs. This low-cost, radiation-free methodology provides a practical solution for remote AIS monitoring, potentially reducing the need for clinical visits and radiation exposure while improving access to care in underserved regions.



XRGAN framework

67. Impaired Laminin-Dystroglycan/ Integrin Signaling from Fibro-Adipogenic Progenitor Drives Deep Paravertebral Muscle Strength Imbalance in Adolescent Idiopathic Scoliosis

Xuan Huang, MD; Jiafeng Dai, MD; Zhen Wang, MD; Junduo Zhao, MD; Haoyu Cai, MD; Hongyi Zhou, MD; Yutian Niu, MD; Yizhen Huang, MD; Heng Sun, MD; Yong Zhang, PhD; Jianxiong Shen, MD

Hypothesis
Deep paravertebral muscle strength imbalance induces adolescent idiopathic scoliosis. Impaired Laminin-Dystroglycan/Integrin signaling contributes to deep paravertebral muscle strength imbalance in AIS.

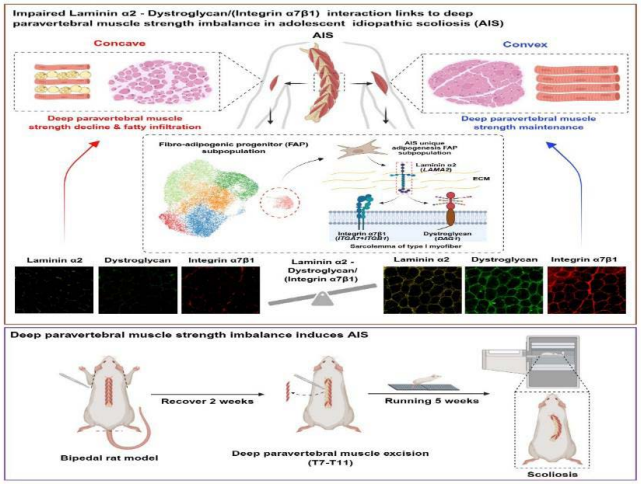
Design
Basic research

Introduction
Adolescent idiopathic scoliosis (AIS) is a prevalent spinal deformity with a largely elusive etiology. While genetic, hormonal, and neurological factors have been implicated, the precise pathogenesis remains unclear. Deep paravertebral muscle (DPM) includes multifidus, rotatores, and semispinalis. This study investigates the role of DPM strength imbalance and its underlying cellular and molecular mechanisms in AIS development.

Methods
A bipedal rat model was established, comprising a control (CON) group and a group with unilateral DPM excision (EX) to induce scoliosis. Spinal morphology was assessed via CT and MRI. Human DPM samples from controls and AIS patients were analyzed using histological staining (H.E., Oil Red O, NADH, myofiber typing) and MRI-based fat quantification. Single-cell (sc) and single-nucleus (sn) RNA sequencing of DPM were performed to characterize cellular heterogeneity and interactions. Immunofluorescence was performed to validate the result.

Results
All EX rats (16/16) developed scoliosis with right-sided spinal curvature, whereas no deformity occurred in CON rats (0/10). In human AIS samples, the concave-side DPM exhibited a lower proportion of type I myofibers, a higher proportion of type IIx myofibers, and greater fatty infiltration compared to the convex side. snRNA-seq confirmed myofiber type imbalance and adipogenic changes in AIS. scRNA-seq identified a unique, imbalanced Fibro-Adipogenic Progenitor (FAP) subpopulation in AIS with an aberrant differentiation trajectory. Cell-cell communication analysis revealed a significantly weaker Laminin α2-Dystroglycan/Integrin α7β1 interaction from this AIS-specific FAP subpopulation to type I myofibers on the concave side than on the convex side. This result was further validated by immunofluorescence of AIS DPM.

Conclusion
Imbalanced DPM strength is a causative factor in AIS. This imbalance is associated with a pathological FAP subpopulation in AIS, whose impaired signaling via Laminin α2-Dystroglycan/Integrin α7β1 pathway to type I myofibers contributes to the asymmetric muscle properties and the pathogenesis of AIS.



Graphical abstract

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68. Unilateral Intradiscal Injection of Vosoritide-Loaded PLGA Microspheres Induces Asymmetric Spinal Growth in Juvenile Rabbits

Xiaochen Yang, MD; Yingsong Wang, MD; Zhi Zhao, MD; Jingming Xie; Ying Zhang, MD; Tao Li, MD; Ni Bi, MD; Zhiyue Shi, MD; Li Zhang, MD; Zhibo Song, MD; Zhaoquan Zhang, MD; Quan Li, MD; Yingliang Liu, MD

Hypothesis
Asymmetric growth plate chondrocyte activity contributes to scoliosis progression. Locally promoting unilateral vertebral growth via sustained release could modulate spinal alignment.

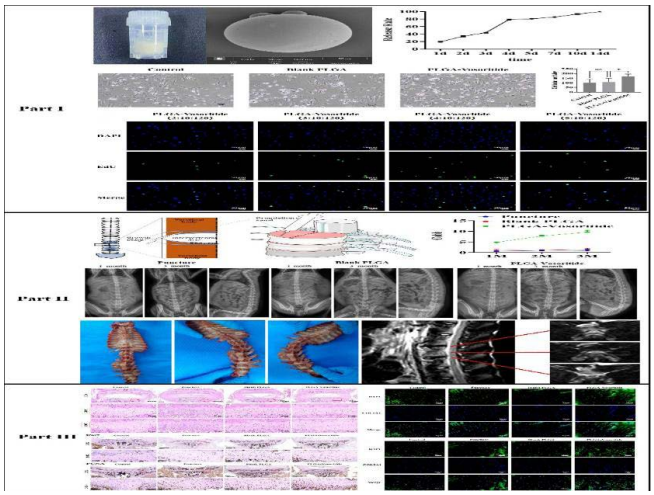
Design
Experimental study

Introduction
Spinal growth imbalance drives scoliosis. While our team previously proved locally inhibiting growth through chondrocyte apoptosis could induce spinal curvature, a strategy to actively promote growth via sustained local drug delivery remains unexplored.

Methods
We fabricated vosoritide-loaded PLGA microspheres via S/O/W emulsification. After optimization in vitro, juvenile rabbits received unilateral intradiscal injections at two lumbar levels. Groups: control, puncture, blank PLGA, and PLGA-vosoritide. Cobb angles were tracked radiographically at 1, 2, and 3 months. Growth plate responses were evaluated via histology and immunofluorescence.

Results
Part I: PLGA-vosoritide microspheres (optimal formulation: vosoritide:DEX:PLGA=4:10:120) demonstrated sustained release over 14 days with no cytotoxicity. Part II: Unilateral injection induced progressive spinal curvature, with Cobb angles measuring 4.76°±0.27°, 7.79°±0.49°, and 9.58°±0.95° at 1, 2, and 3 months respectively, with no neurological impairment observed. Part III: The injected side exhibited thickened growth plates, increased chondrocyte proliferation, and enhanced collagen synthesis, as confirmed by histology and immunofluorescence showing upregulated expression of proliferation markers and extracellular matrix components. No such changes or spinal deformity were observed in the control, puncture, or blank microsphere groups.

Conclusion
Local sustained release of vosoritide via PLGA microspheres effectively promotes unilateral vertebral growth and induces rigid asymmetric spinal curvature, introducing a novel biological approach with therapeutic potential for growth-related spine disorders.



Part I: PLGA-vosoritide microspheres demonstrated sustained release over 14 days. Part II: Unilateral injection induced progressive spinal curvature. Part III: The injected side showed enhanced growth plate thickness, chondrocyte proliferation, and collagen synthesis.

69. Increasing Opioid Dose Impairs Spinal Fusion in a Rat Model ‡

Dillon Stone, MD; Garrison Bentz, BS; Jonathan Dalton, MD; Lane H. McCoy, BS; Simon Y. Tang, PhD; Dessislava Markova, PhD; Munish C. Gupta, MD, MBA; *Mark Lambrechts, MD*

Hypothesis
Increasing postoperative opioid dose is associated with impaired spinal fusion and fusion bone mass quality in a rat lumbar fusion model.

Design
Controlled animal study.

Introduction
Opioids are commonly administered postoperatively for spinal surgery and have been implicated as a potential cause for impaired bone formation. However, the outcomes of prolonged opioid exposure on spinal fusion outcomes remains poorly defined. This study evaluated the dose-dependent impact of morphine on spinal fusion using a rat model.

Methods
One hundred twenty rats underwent bilateral posterolateral lumbar fusion at L4-5 and were randomized to receive postoperative subcutaneous morphine at 4 doses (control, 1mg, 2mg, 4mg) for 6 weeks. Fusion was assessed using manual palpation with 2 graders (MP), plain radiographs (XR), and micro computed tomography (CT). Bone mineral density (BMD), tissue mineral density (TMD), bone volume (BV), total volume (TV), and bone volume fraction (BV/TV) was assessed on an 80-rat subset. Comparisons were performed using one-way ANOVA or chi square testing, with post-hoc analysis as needed. Significance was $p<0.05$.

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Results
XR and CT demonstrated decreased fusion rates with increasing opioid dose, with CT bilateral fusion rates declining from 83.3% in controls to 56.7% in the 1mg, 53.3% in the 2mg, and 40% in the 4mg morphine groups (p=0.007). MP demonstrated a similar dose-dependent reduction in mechanical fusion rates for both graders (p=0.007, p<0.001). Imaging analysis revealed a reduction in fusion mass area with 307.6mm2 for controls, 268.1mm2 for 1mg, 257.6mm2 for 2mg, and 213.7mm2 for 4mg (p<0.001). BV (p=0.109) and TV (p<0.001) also demonstrated a reduction in increasing opioid dose groups. TMD differed between groups, with a lower TMD observed at 1mg and 2mg than control, but without further dose-response at 4mg (p=0.019). BMD (Control: 236.8 mgHA/cm3, 1mg: 248.7, 2mg: 255.9, 4mg: 249.1, p=0.508) and BV/TV (p=0.323) were similar across groups.

Conclusion
Prolonged postoperative opioid administration is associated with impaired spinal fusion in a rat model, driven primarily by reduced fusion mass size as opposed to impaired bone mineralization. These findings suggest that postoperative opioid exposure may adversely affect fusion mass formation in a dose-dependent manner, with a greater effect on the quantity of bone formation rather than the quality. Further research is needed to quantify this effect in humans.

Imaging Analysis of Fusion					
	Control (n=30)	1mg (n=30)	2mg (n=30)	4mg (n=30)	P-value
Plain Radiograph Bilateral Fusion (%)	26 (86.7)	19 (63.3)	20 (66.7)	14 (46.7)	0.013
Computed Tomography Bilateral Fusion (%)	25 (83.3)	17 (56.7)	16 (53.3)	12 (40)	0.007
Manual Palpation of Fusion					
Grader 1 (%)					0.007
Unrestricted	0	2 (6.7)	2 (6.7)	2 (6.7)	
Restricted	1 (3.3)	9 (30)	7 (23.3)	11 (36.7)	
Fused	29 (96.7)	19 (63.3)	21 (70)	17 (56.7)	
Grader 2 (%)					<0.001
Unrestricted	0	4 (13.3)	0	3 (10)	
Restricted	2 (6.7)	6 (20)	13 (43.3)	25 (83.3)	
Fused	28 (93.3)	20 (66.7)	17 (56.7)	2 (6.7)	
Imaging Results					
	Control (n=20)	1mg (n=20)	2mg (n=20)	4mg (n=20)	P-value
Fusion mass (mm^2)	307.6	268.1	257.6	213.7	<0.001
Bone Mineral Density (mg HA/cm^3)	236.8	248.7	255.9	249.1	0.508
Tissue Mineral Density (mg HA/cm^3)	861.3	844.1	841.3	850.1	0.019
Bone Volume (mm^3)	30.3	26.5	25.8	23.9	0.109
Total Volume (mm^3)	204.1	155.1	151	146.4	<0.001
Bone Volume /Total Volume (%)	15.3	17.1	17.3	16.3	0.323

Table 1

70. Consensus-Based Guidelines for Research in Bracing in Idiopathic Scoliosis by the SRS Comprehensive Care Committee in Collaboration with SOSORT

Alexander Park, BS; Michael W. Brown, BS; Mehdi Elfilali, BA; Caglar Yilgor, MD; Tom P. Schlosser, MD, PhD; Stefano Negrini, MD, PhD; Sabrina Donzelli, MD; Brian Smith, MD; *Benjamin D. Roye, MD*

Hypothesis
We hypothesize that a multidisciplinary panel of experts will achieve consensus using a structured Delphi process on recommendations for research in bracing for idiopathic scoliosis (IS).

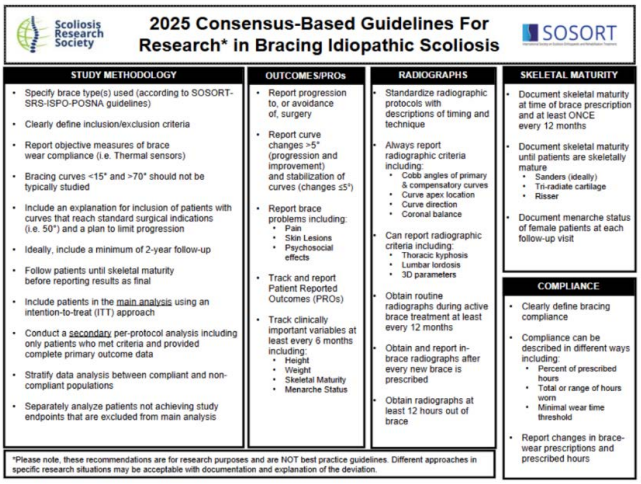
Design
Hybrid consensus study using a Delphi process followed by an in-person nominal group technique.

Introduction
Significant variability exists in the current literature of bracing research and outcome reporting, highlighting the need to standardize study design and reporting practices to ensure cross-study consistency and comparability. Previous efforts by Scoliosis Research Society (SRS) and Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) have been proposed. However, these recommendations were created over 10 years ago, and the evolving demands of current bracing practices require updated guidelines.

Methods
Three consecutive, anonymous Delphi rounds were administered to 30 multidisciplinary bracing experts invited to participate in this study by the SRS Complementary Care Committee based on their relevant clinical expertise, scholarly productivity, and leadership in the field. Participants completed anonymous, online questionnaires with controlled feedback by a core group of six facilitators. Results from the Delphi process were presented at a final in-person meeting during the 60th Annual SRS Meeting (September 2025). Consensus was defined as ≥80% agreement, with non-consensus items refined and redistributed in subsequent rounds.

Results
Of the 30 invited experts, response rates across Delphi rounds were 80%, 83%, and 77%, with 21 experts in attendance at the final, in-person meeting. Consensus was reached on 121 items across 6 domains (38 study methodology, 15 brace prescription and compliance, 25 study outcomes, 6 patient-reported outcomes, 12 skeletal maturity, and 25 radiographs) which were refined and consolidated into a final 28-item summary of consensus-based guidelines for research in bracing IS (Figure 1).

Conclusion
Consensus-based research guidelines for bracing treatment in patients with IS were successfully developed. These recommendations will serve to strengthen methodological rigor and promote consistency across published bracing research and lead to the broader improvement of patient care through higher quality evidence and more effective bracing practices.



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‡ SRS Funded Research Grant

2025 Consensus-based guidelines for research in bracing idiopathic scoliosis

71. Doomed to fail? Early Brace Adherence Predicts Long Term Brace Wear Behavior

Erica Olfson, BS; Anne Boeckmann, BS; David C. Thornberg, BS; Daniel J. Sucato, MD, MS; Amy L. McIntosh, MD; Brandon A. Ramo, MD; Jaysson T. Brooks, MD; *Megan Johnson, MD*

Hypothesis
Physicians are able to predict long term brace adherence in idiopathic scoliosis patients at the three-month bracing check-point.

Design
Retrospective chart review

Introduction
As bracing has become the primary non-operative treatment for idiopathic scoliosis (IS), consistent adherence to prescribed brace wear remains essential for achieving optimal clinical outcomes. Early patterns of brace use may provide important insight into long-term compliance, yet the predictive value of short-term adherence has not been fully characterized. This study evaluated whether brace adherence at three months predicts long-term brace adherence in patients treated for IS.

Methods
292 children (65 M, 227 F) with IS ages 7-16 yrs, curves 16°-50°, treated with either anterior or posterior opening thoracic-lumbar-sacral orthoses (TLSO) between 2017 and 2023 were reviewed. Brace adherence was measured using iButton temperature sensors. Patient demographic data and radiographic data was also collected.

Results
292 TLSO braces were prescribed during the study period (49 anterior opening; 243 posterior opening). Average age at brace prescription was 12.5yrs ±1.46. Average pre brace major curve cobb angle was 30.3°± 6.9. Overall brace adherence for the cohort was 68.9%, with an average wear time of 12.6 hrs. Using 80% of prescribed hours as a cut off for brace adherence, there was a significant difference in patients' 3-month brace adherence between brace adherent (n= 121, 97.9%) and non-adherent (n=171, 65.1%) subgroups (p=0.000). Additionally, 3-month average brace usage strongly correlated to overall brace compliance (r=0.824, p<0.01). Using a linear regression controlling for brace type, Risser score, age, Cobb angle, and sex, each 1%-point increase in 3-month brace adherence was associated with a 0.8%-point increase in overall, final brace compliance (p=0.000).

Conclusion
Three-month brace adherence was strongly associated with long-term brace adherence in patients with IS. Early compliance with brace wear appears to be a meaningful predictor of sustained adherence throughout treatment. These findings suggest that the three-month bracing checkpoint may serve as a critical window for identifying patients at risk for long-term non-adherence and for implementing targeted interventions to improve brace wear behavior.

72. A Step Closer To Bringing Idiopathic Scoliosis Monitoring At Home: A Smartphone App Accurately Generates Digital Twins in 624 Pediatric Patients

Paolo Brigato, MD; Gianmario Sangiovanni, PhD; Sabina Fehric, MSc; Kevin Smit, MD; Andrew Tice, MD; Firoz Miyanji, MD, FRCS(C); Stefan Parent, MD, PhD; Neil Saran, FRCS(C); Thierry A. Odent, MD, PhD; Anne TabardFougere, PhD; Natahly Gavira, MD; Romain Dayer, MD; *Jean A. Ouellet, MD, FRCS(C)*

Hypothesis
A smartphone-based, AI-powered 3D surface topography application can estimate Cobb angles and detect clinically significant scoliosis compared with radiography.

Design
Diagnostic accuracy study comparing smartphone-based 3D Cobb angle estimates with radiographic measurements for detection of scoliosis ≥20°.

Introduction
Idiopathic scoliosis is the most common pediatric spinal deformity, affecting 1–4% of adolescents. Despite most patients not requiring treatment, screening and follow-up rely on repeated radiographs with cumulative radiation exposure. Surface topography offers a non-invasive, radiation-free alternative by linking torso asymmetry to spinal curvature.

Methods
In this prospective cohort study (November 2022–March 2025), pediatric patients (aged 5–21 years) with suspected or confirmed IS were enrolled at five centers across three countries. Each underwent biplanar radiographs and smartphone-based surface scans at the same visit. Agreement was evaluated using Spearman's correlation and Bland–Altman analysis. Factors associated with discrepancies were assessed using Kruskal–Wallis and correlation tests. Diagnostic performance for detecting scoliosis ≥20° was summarized with accuracy, precision, recall, and confusion matrix analysis ($\alpha = 0.05$).

Results
A total of 624 radiograph–scan pairs were analyzed (76.7% female; mean age 13.6 ± 2.4 years). Surface scan–derived Cobb angles correlated strongly with radiographic measurements ($r = 0.775$, $p < 0.001$), with a mean bias of –3.6° and limits of agreement from –16.9° to 24.0°. Prediction errors were significantly influenced by brace status, scan quality, site, Cobb class and skin type. When the analysis was limited to high-quality scans (n = 382), the correlation improved ($\rho = 0.861$), with a mean bias of 2.4°, limits of agreement ranging from –14.4° to 19.2°, and 42% and 74% of predictions falling within ±5° and ±10° of the reference values, respectively. For

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detecting scoliosis ≥20° using all scans, the model achieved an accuracy of 84%, precision of 90%, and recall of 89%.

Conclusion
The smartphone-based 3D imaging system showed moderate agreement with radiographic Cobb angles and was adequate for detecting clinically significant scoliosis, though accuracy was influenced by curve and patient factors. Further longitudinal, real-world studies are needed to define its role as a complementary radiation-free tool.

73. Casting and Bracing are Associated with Worsening Quality of Life (QOL) in Early Onset Scoliosis (EOS) Patients – Does QoL Improve with Surgery?

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Hypothesis
Casting and bracing can lead to decreases in QoL that may improve after surgery.

Design
Multicenter retrospective review.

Introduction
QoL changes in EOS patients undergoing nonoperative management have been less well-studied than in surgically-treated patients. Our purpose was to 1) assess whether QoL changes in EOS patients undergoing nonoperative treatment, and 2) compare QoL changes when these patients undergo surgery.

Methods
Idiopathic EOS patients ages 0-18 years undergoing observation (OBS), bracing (BRACE), or casting (CAST) who completed ≥2 EOSQ-24s were included. Patients who later underwent surgery had to have ≥1 preoperative and ≥1 postoperative EOSQ-24. Univariate and multivariate linear regression analyses were conducted. Age was considered in the multivariate model both continuously and as tertiles (≤2, 3-5, ≥6 years).

Results
612 patients (260 OBS, 159 BRACE, 193 CAST) were analyzed. Compared to OBS, CAST had significantly greater decreases in Daily Living (-7.1 ± 2.3, p<0.01, uni), Parental Impact (-4.8 ± 1.9, p<0.05, multi age continuous), and Physical Function (-5.5 ± 2.7, p<0.05, multi age tertile). CAST also had greater decreases in Transfer in all models (-6.3 ± 2.1, p<0.01, uni; -7.6 ± 2.6, p<0.01, multi age continuous; -8.3 ± 2.7, p<0.01, multi age tertiles). BRACE had a significantly greater decrease in Emotion (-4.3 ± 2.2, p<0.05, multi age tertile). There were no group differences in the remaining domains, including General Health, Pain, and Child Satisfaction (Table). 88 patients (2 OBS, 47 BRACE, 39 CAST) transitioned to surgery. Compared to BRACE, CAST had a significantly greater increase in Parent Satisfaction (12.5 ± 5.5, p<0.05, uni) after surgery.

Conclusion
Children treated with casting experienced worsening QoL over time, as demonstrated by greater decreases in Daily Living, Parental Impact, Physical Function, and Transfer scores, compared to children who were observed. Children who were braced had a greater decrease in Emotion score. Compared to bracing, parents of casting patients had a greater increase in Satisfaction after surgery, suggesting a greater parental burden with casting that was partially alleviated postoperatively. Although nonoperative treatment is generally considered to be more benign than surgery, the potential long-term impact on QoL should be discussed with families.

74. Boys with Adolescent Idiopathic Scoliosis Treated with Nighttime Bracing Have Similar Outcomes to Girls

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Hypothesis
Boys with adolescent idiopathic scoliosis (AIS) treated with nighttime bracing have worse outcomes than girls.

Design
Retrospective review

Introduction
The few studies evaluating brace treatment outcomes specific to boys with AIS have found inferior results. We evaluated brace adherence and curve progression in boys with AIS treated with nighttime bracing compared to girls.

Methods
All children with AIS Risser stages 0 to 2, major curves 15° to 40° with predominantly thoracolumbar/lumbar curves treated with Providence nighttime braces prescribed ≥8 hours per night from 2015 to 2019 were retrospectively reviewed until either skeletal maturity or surgery. Brace adherence was measured using iButton temperature sensors at brace discharge. Brace outcomes included curve progression ≥6° and progression to surgical threshold of ≥45° among boys versus girls and boys with curves <25°, and the traditional SRS bracing guidelines of curves 25-40°.

Results
66 boys and 241 girls were included. At brace prescription, boys were older and had similar curve magnitudes (24° vs. 24°), triradiate cartilage status, body mass index, and years braced (Table). In-brace correction was similar (103% vs. 103%). From brace prescription to skeletal maturity or surgery, boys grew more (12cm vs. 9cm, p=0.007). Boys had similar brace wear adherence throughout bracing (6.4hrs vs. 7.0hrs, p=0.09). Boys also had similar amounts of curve progression (4° vs. 2°, p=0.56) and similar rates of curve improvement ≥6º (17% vs. 20%, p=0.60), curve progression ≥6º (32% vs. 29%,

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p=0.66), and progression to surgical magnitude (8% vs. 4%, p=0.19). Boys with curves <25° (n=40) had similar amounts of curve progression (4° vs. 2°, p=0.42) and similar rates of progression to surgical magnitude (10% vs. 4%, p=0.13) as girls (n=151). Boys with curves ≥25° (n=26) also had similar progression (5° vs. 3°, p=0.49) and similar rates of surgery (8% vs. 3%, p=0.37) as girls (n=116).

Conclusion

Contrary to the literature from full-time bracing, boys with predominantly thoracolumbar/lumbar AIS treated in Providence nighttime braces have similar brace wear adherence and treatment outcomes to girls. Nighttime bracing for boys should be offered more frequently as a highly effective non-operative treatment approach.

	Boys (n=66)	Girls (n=241)	p-value
Race/Ethnicity			
White	67% (n=44)	71% (n=171)	0.65
Hispanic	11% (n=7)	11% (n=26)	
Black	8% (n=5)	6% (n=15)	
Other	9% (n=6)	5% (n=11)	
Asian	6% (n=4)	7% (n=18)	
Initial age (years)	13.8±1.5 (n=66)	12.3±1.2 (n=241)	<0.001*
Initial body mass index (kg/m^2)	18.5±2.8 (n=66)	18.1±2.7 (n=238)	0.27
Initial primary curve			
Thoracic	6% (n=4)	16% (n=38)	0.042*
Thoracolumbar/Lumbar	94% (n=62)	84% (n=116)	
Brace design			
Double	20% (n=11)	34% (n=78)	0.08
Thoracolumbar	66% (n=37)	50% (n=116)	
Lumbar	14% (n=8)	15% (n=35)	
Initial Risser stage			
0	64% (n=42)	76% (n=184)	0.005*
1	9% (n=6)	12% (n=30)	
2	27% (n=17)	11% (n=27)	
Initial triradiate cartilage			
Open	47% (n=31)	46% (n=110)	0.91
Closed	54% (n=35)	54% (n=131)	
Initial curve magnitude (°)	24±4 (n=66)	24±4 (n=241)	0.66
In-brace correction (%)	103±29 (n=55)	103±29 (n=227)	0.93
Years braced	2.4±0.9 (n=64)	2.2±0.9 (n=235)	0.29
Total brace wear (hr/day), according to sensor data	6.4±2.5 (n=51)	7.0±2.4 (n=191)	0.09
Growth (cm)	11.9±7.5 (n=66)	9.2±5.6 (n=237)	0.007*
Total curve progression (°)	4±12 (n=66)	2±9 (n=241)	0.56
Improvement ≥6°	17% (n=11)	20% (n=47)	0.60
Stable, between -5° and 5°	52% (n=34)	51% (n=124)	0.99
Progression ≥6°	32% (n=21)	29% (n=70)	0.66
Progression to full-time brace	8% (n=5)	11% (n=27)	0.39
Progression to 45°	9% (n=6)	5% (n=13)	0.26

*p<0.05. Initial=time of brace prescription

Characteristics, anthropometrics, and outcomes in boys versus girls

75. Nighttime Bracing is Equivalent to Full-time Bracing in Avoiding Curve Progression to Surgery in AIS Curves 20-35°

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Hypothesis

Nighttime bracing (NTB, 8 h/night) has similar radiographic outcomes as full-time bracing (FTB, ≥18 h/day) in adolescent idiopathic scoliosis (AIS).

Design

Retrospective cohort

Introduction

Studies comparing NTB to FTB lack adherence data and do not control curve type, curve magnitude, and skeletal maturity. This study compares radiographic outcomes between NTB and FTB in AIS.

Methods

Patients braced at Risser 0-2 with AIS curves 20°–35° between 2015–2019 were followed until skeletal maturity or progression to a surgical threshold (≥45°). Temperature sensors determined brace wear. First, NTB versus FTB cohorts were compared. Next, patients were propensity score-matched for curve magnitude and triradiate cartilage (TRC) status at brace initiation to compare NTB versus FTB within 1) thoracic and 2) thoracolumbar/lumbar curve subgroups. Primary outcomes were curve progression ≥6° and progression to surgery.

Results

520 (265 NTB, 255 FTB) patients were 12.5±1.3 yrs at brace initiation. The NTB group had more thoracolumbar/lumbar curve types (86% vs 14%, p<.001), smaller curves (24° vs 27°, p<.001), and lower rates of open TRC (47% vs 56%, p=.027). Brace wear averaged 7.0±2.3 h for NTB (86% adherence) and 12.1±5.8 h for FTB (66% adherence). NTB demonstrated greater curve improvement ≥6° (21% vs 11%, p=.002), less curve progression ≥6° (31% vs 45%, p<.001), and less progression to surgery (6% vs 20%, p<.001). Multivariable linear regression analysis including sex, BMI, TRC status, brace type, curve type, and curve magnitude identified open TRC and larger curves as predictors of progression to surgery, not brace type. In matched thoracic pairs (n=37), NTB and FTB curves averaged 27° with 51% open TRC, and had similar progression ≥6° (24% vs 32%, p=.44) and progression to surgery (5% vs 11%, p=.67). In matched thoracolumbar/lumbar pairs (n=32), NTB and FTB curves averaged 24°, 59% open TRC, and also had similar progression ≥6° (31% vs 28%, p=.78) and progression to surgery (13% vs 9%, p=1.00).

Conclusion

Nighttime bracing is equivalent to full-time bracing in stopping curve progression in skeletally immature AIS curves ≤35°. When matched by curve type, magnitude, and skeletal maturity, radiographic outcomes remained similar between NTB and FTB, supporting NTB as a viable, lower-burden treatment option for appropriately selected patients.

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	Nighttime brace	Full-time brace	p-value
Total Sample	n=265	n=255	
Female Sex	78% (n=208)	84% (n=215)	0.088
Initial age (yrs)	12.6±1.3	12.3±1.2	**0.023**
Initial curve type			**<0.001**
Thoracic	14%	86%	
Thoracolumbar/Lumbar	86%	14%	
Initial curve magnitude (°)	24.4±3.3	26.9±4.0	**<0.001**
Initial Risser grade			0.210
0	75%	75%	
1	11%	15%	
2	14%	10%	
Open TRC status	47%	56%	**0.027**
Initial BMI	18.3±2.9	19.2±3.5	**0.003**
Years braced	2.2±0.9	2.0±1.0	**<0.001**
Avg brace wear (h)	7.0±2.3	12.1±5.8	**<0.001**
Growth (cm)	9.7±6.0	9.0±5.8	0.166
Final curve magnitude (°)	26.7±10.8	33.5±12.7	**<0.001**
Total curve progression (°)	2.3±10.1	6.6±11.7	**<0.001**
Curve improvement ≥6°	21%	11%	**0.002**
Curves stable (-5° to 5°)	48%	44%	0.317
Curve progression ≥6°	31%	45%	**<0.001**
Progression to surgery	6%	20%	**<0.001**
Matched thoracic pairs	n=37	n=37	
Open TRC status	51%	51%	1.00
Initial curve magnitude (°)	23.5±2.6	23.5±2.6	0.969
Final curve magnitude (°)	26.2±10.5	27.9±11.9	0.581
Curve improvement ≥6°	17%	13%	0.562
Curve progression ≥6°	24%	32%	0.439
Progression to surgery	5%	11%	0.674
Matched thoracolumbar/lumbar pairs	n=32	n=32	
Open TRC status	59%	59%	1.00
Initial curve magnitude (°)	26.7±3.9	26.7±3.9	1.00
Final curve magnitude (°)	30.5±12.6	31.0±10.3	0.925
Curve improvement ≥6°	14%	7%	0.670
Curve progression ≥6°	31%	28%	0.784
Progression to surgery	13%	9%	1.00

*Bold indicates p<0.05. TRC=triradiate cartilage. Initial=time of brace prescription; Final=skeletal maturity or progression to surgery.

76. Impact of Skeletal Maturity in Vertebral Body Tethering: Early Outcomes from a Prospective, Multicenter Study

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Hypothesis
Risser and Sanders stages do not significantly affect most vertebral body tethering (VBT) outcomes at 2 year follow-up.

Design
Multicenter prospective cohort

Introduction
VBT in older patients is seen as controversial with less potential for permanent correction due to growth modulation. This study compares early (2 year) VBT outcomes in Risser 0-2 vs. 3-5 and Sanders 1-4 vs. 5-8 patients as this is a threshold for treatment in published POSNA/SRS guidelines.

Methods
All qualifying patients with adolescent idiopathic scoliosis (AIS) who underwent thoracic and lumbar VBT between 2019 and 2023 were prospectively enrolled from 9 institutions with minimum 2-year follow-up. Patients were grouped by preop Risser and Sanders stages. Fisher's exact tests, independent, and paired t-tests were used for analysis of outcomes.

Results
164 patients met inclusion and exclusion criteria and were prospectively enrolled. No significant differences were observed in the preoperative demographics, reoperation rates, complication rates, or fusion rates between the skeletally maturity groups. Over the 2-year follow-up, patients demonstrated improvements in thoracic (48±11 vs. 24±11°, p<0.001) and lumbar (38±13vs20±9°, p<0.001) curve magnitudes, with no significant differences in sagittal plane parameters or shoulder alignment.

Conclusion
Curve correction, reoperation, fusion, and complication rates were similar at 2-years in Risser 3-5 and Sanders 5-8 patients compared to Risser 0-2 and Sanders 1-4 patients. Given the known incidence of cord breakage after 2 years, this should not be interpreted as an endorsement for VBT in older patients with little potential for growth modulation, but as an important early time point of which longer-term follow-up is required.

	Risser 0-2 (n=135)	**Risser 3-5 (n=29)**	**p-value**
Age at surgery (years)	12.9 ± 1.4	14.1 ± 1.3	**<0.001***
% Female	80.7%	65.5%	0.085
Height (cm)	156.7 ± 9.6	163.6 ± 9.8	**<0.001***
Weight (kg)	47.4 ± 10.7	52.9 ± 11.2	**0.014***
BMI	19.2 ± 3.4	19.7 ± 3.4	0.450
Preop Major Curve Magnitude (°)	51 ± 10	50 ± 9	0.587
Preop Thoracic Curve (°)	48 ± 11	46 ± 12	0.355
Preop Lumbar Curve (°)	39 ± 13	36 ± 15	0.381
Preop T2-T12 (°)	24 ± 12	26 ± 15	0.443
Preop Lumbar Lordosis (°)	−55 ± 11	−58 ± 12	0.176
Preop Shoulder Height	1.2 ± 1.5	0.5 ± 0.5	0.055
First Erect Major Curve Magnitude (°)	27 ± 8	28 ± 9	0.668
	Sanders 1-4 (n=123)	**Sanders 5-8 (n=41)**	**p-value**
Age at surgery (years)	12.8 ± 1.4	13.9 ± 1.3	**<0.001***
% Female	76.4%	82.9%	0.514
Height (cm)	156.9 ± 10.2	161.1 ± 8.4	**0.019***
Weight (kg)	47.4 ± 11.5	51.1 ± 8.7	0.059
BMI	19.1 ± 3.5	19.7 ± 3.2	0.309
Preop Major Curve Magnitude (°)	51.5 ± 10.3	47.1 ± 7.7	**0.013***
Preop Thoracic Curve (°)	49 ± 11	43 ± 11	**0.002***
Preop Lumbar Curve (°)	39 ± 13	36 ± 13	0.143
Preop T2-T12 (°)	24 ± 12	22 ± 13	0.434
Preop Lumbar Lordosis (°)	−56 ± 11	−54 ± 11	0.507
Preop Shoulder Height	1.2 ± 1.5	0.8 ± 0.8	0.230
First Erect Major Curve Magnitude (°)	28 ± 8	25 ± 8	**0.049***
	Preoperative	**2-year**	**p-value**
Height (cm)	157.4 ± 10.2	163.6 ± 9.2	**<0.001***
Risser 0-2	156.3 ± 9.9	163.0 ± 9.0	<0.001*
Risser 3-5	162.8 ± 10.4	166.4 ± 9.5	<0.001*
Sanders 1-4	156.5 ± 10.6	163.6 ± 9.6	<0.001*
Sanders 5-8	160.2 ± 8.2	163.4 ± 7.9	<0.001*
Major Curve Magnitude (°)	51 ± 9	25 ± 11	**<0.001***
Risser 0-2	51 ± 9	26 ± 11	<0.001*
Risser 3-5	49 ± 8	24 ± 10	<0.001*
Sanders 1-4	52 ± 9	27 ± 11	<0.001*
Sanders 5-8	47 ± 8	22 ± 10	<0.001*
Thoracic Curve (°)	48 ± 11	24 ± 11	**<0.001***
Lumbar Curve (°)	38 ± 13	20 ± 9	**<0.001***
T2–T12 (°)	24 ± 13	25 ± 15	0.338
Lumbar Lordosis (°)	−55 ± 12	−53 ± 11	0.272
Shoulder Height Difference (cm)	1.0 ± 1.4	1.0 ± 0.8	0.997
	Risser 0-2 (n=135)	**Risser 3-5 (n=29)**	**p-value**
Reoperation	16	1	0.312
Fusion	3	1	0.545
Major Complication	6	0	0.592
	Sanders 1-4 (n=123)	**Sanders 5-8 (n=41)**	**p-value**
Reoperation	16	1	0.074
Fusion	4	0	0.573
Major Complication	5	1	0.532

77. Prospective, Multicenter Comparison of Hybrid and Bilateral VBT in the Treatment of Idiopathic Scoliosis

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Hypothesis
Bilateral VBT and hybrid procedures have similar radiographic and clinical outcomes at min 2-yr f/u

Design
Prospective,multicentre

Introduction
Vertebral body tethering(VBT) has shown to be safe and effective with motion-preservation being the advantage over fusion.For double major curves(Lenke 1C,3C,6C) two procedures have recently emerged:bilateral double VBT(both curves tethered) and hybrid procedure(thoracic posterior fusion and lumbar VBT).Our aim was to compare outcomes between these two methods at min 2 yr f/u to gain insight around treatment decisions and patient selection.

Methods
A prospective,multicentre non-fusion database identified consecutive patients that underwent either a bilateral single row,single tether VBT procedure(BSTG) or hybrid construct(HG) with min 2yr f/u.Preop,periop,and postop clinical, radiographic and complication data were compared between groups.Linear mixed-effects models were used,adjusted for baseline values.

Results
49 BSTG patients were compared to 45 HG patients.Mean age for BSTG was 12.7+/-1.4yrs and HG was 12.7+/-1.5yrs. Avg preop thoracic curve was 49.6+/-8.7° in BSTG and 57.6+/-12.7° in HG(p=0.001) and mean preop lumbar curve was 45.1+/-12.2°(BSTG) compared to 54.2+/-10.3°(HG)(p=0.004).Mean ORT,EBL,and LOS was significantly less in BSGT compared to HG(p=0.009,p<0.001,p<0.001,respectively).Adjusted mean post-op pain scores were significantly lower at 2yrs in BSTG compared to HG(VAS:0.7[95%CI:0.3,1.1] vs1.6[95%CI:1.2,2];p=0.002).Adjusted mean thoracic coronal Cobb was significantly improved in HG compared to BSTG(13.4[95%CI:10.7,16.1]vs25.4°[95%CI:22.9,27.9] ;p<0.0001) at 2yrs as well adjusted mean lumbar coronal Cobb(HG:14.2°vs21.4°;p<0.0001).No significant difference in thoracic or lumbar prominence was noted between groups(p=0.08,p=0.19,respectively).BSTG showed significantly better range of motion at 2yrs in forward flexion(p<0.001)and left/right lateral flexion compared to HG(p=0.0003/p=0.04).Despite 24% reported complications in BSTG compared to 44% in HG(p=0.3),there was no difference in adjusted mean SRS outcome scores in all domains across all f/u time-points between groups(p>0.05).

Conclusion
HG provides better coronal Cobb correction compared to BSTG.However,BSTG appears to preserve better spinal motion,is associated with decreased periop morbidity and lower pain scores at 2yrs post-op.The choice between these procedures will depend on patient priorities.

Table

Patient Demographics	BSTG	HG	P-value
Mean age(yrs)	12.7+/-1.4	12.7+/-1.5	
Gender (%)	M=18 F=82	M=24 F=76	
Mean Baseline Thoracic Cobb (°)	49.6+/-8.7	57.6+/-12.7	0.001*
Mean Baseline Lumbar Cobb (°)	45.1+/-12.2	54.2+/-10.3	0.004*
PeriOp Outcomes	**BSTG**	**HG**	**P-value**
Mean ORT (minutes)	335.4+/-100	410.8+/-154	0.009*
Mean EBL (cc)	184.7+/-155	433.4+/-315.7	<0.001*
Mean LOS (d)	3.9+/-1.7	6.0+/-2.1	<0.001*
Post-op Outcomes (2 yr Adjusted Means)	**BSTG**	**HG**	**P-value**
Pain VAS Score	0.7	1.6	0.002*
Thoracic Cobb (°)	25.4	13.4	<0.0001*
Lumbar Cobb (°)	21.4	14.2	<0.0001*
Thoracic Rib Prominence (°)	6.6	8.4	0.08
Lumbar Prominence (°)	4.4	3.3	0.19
Forward Flexion (cm)	14.0	11.1	<0.001*
Left Lateral Flexion (cm)	16.3	12.5	0.0003*
Right Lateral Flexion (cm)	15	12.8	0.04*
SRS Outcome Scores (2 yr Adjusted Means)	**BSTG [95% CI]**	**HG [95% CI]**	**P-value**
Pain	4.2[4,4.4]	4.3[3.9,4.5]	0.84
Self-Image	4.2[3.9,4.6]	4.3[3.9,4.6]	0.57
General	4.5[4.3,4.7]	4.4[4.1,4.6]	0.58
Mental	4[3.8,4.3]	3.9[3.6,4.2]	0.34
Satisfaction	4.5[4.3,4.7]	4.4[4,4.7]	0.48
Total	4.3[4.1,4.4]	4.2[4,4.4]	0.64
Complications	**BSTG**	**HG**	**P-value**
Neurologic	0	2	
Pain	5	11	
Radiographic	2	2	
Reoperations	1	2	
SSI	0	3	
GI	1	0	
Medical	2	0	
Pulmonary	1	0	
Total	12	20	0.3

78. Defining Multidomain "Success" After Vertebral Body Tethering for Adolescent Idiopathic Scoliosis

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Hypothesis
VBT will significantly improve major Cobb angle and SRS-22 Total, with most patients achieving composite success (VBT-SS ≥6) at follow-up.

Design
Single-site, retrospective cohort study with prospective follow-up when available.

Introduction
Outcomes after vertebral body tethering (VBT), which aims to correct coronal deformity while preserving motion through growth modulation for adolescent idiopathic scoliosis (AIS), are inconsistently reported. We applied a pragmatic multidomain success framework to evaluate VBT performance at midterm follow-up.

Methods
AIS patients aged 8–18 years undergoing primary VBT with approximately 2-year follow-up were included. Six pre-specified success domains were assessed: (1) safety and durability (no conversion to fusion and no unplanned reoperation), (2) coronal correction (final major Cobb ≤30° or ≥50% correction), (3) spinal balance (coronal balance ≤20 mm and sagittal vertical axis ≤50 mm), (4) function (clinically meaningful SRS-22 Total improvement, Δ≥0.23), (5) satisfaction/cosmesis, and (6) composite success defined by a VBT Success Score (VBT-SS ≥6).

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Paired analyses compared pre- and postoperative radiographic and SRS-22 outcomes.

Results
A total of 148 patients (mean age 14.4 ± 1.7 years; 85.6% female) were included. Major Cobb angle improved from 54.1 ± 10.3° to 28.9 ± 10.9° (Δ −25.2 ± 11.2°, p<0.001), with mean correction of 46.3 ± 17.8%. Secondary curves improved from 45.6 ± 10.9° to 24.9 ± 9.6° (Δ −20.7 ± 11.7°, p<0.001). Mean SRS-22 Total score improved from 3.49 to 4.29 (Δ +0.80, p<0.001). Domain-level and composite success outcomes are summarized in Table 1, with composite success achieved in 85.1%.

Conclusion
A multidomain definition of success provides a clinically meaningful assessment of VBT outcomes beyond isolated radiographic metrics. Within this framework, avoidance of fusion, together with maintenance of balance and functional improvement, emerged as a central determinant of composite success. This framework enables transparent benchmarking and improves patient counseling.

Table 1. Multidomain Success Framework and Outcomes After Vertebral Body Tethering.

Domain	Operational Definition	Outcome
Safety & Durability	No fusion conversion or unplanned reoperation	127 / 148 (85.8%)
Coronal Correction	Final major Cobb ≤30° or ≥50% correction	85 / 148 (57.4%)
Spinal Balance	Coronal ≤20 mm and SVA ≤50 mm	86 / 105 (81.9%)
Function (PROs)	SRS-22 MCID (Δ≥0.23)	40 / 60 (66.7%)
Satisfaction / Cosmesis	Patient/parent-reported satisfaction	39 / 53 (73.6%)
Composite Success (VBT-SS ≥6)	≥6 weighted domains met	126 / 148 (85.1%)

Success rates are reported among patients with available data for each domain.

Figure 1. Conceptual multidomain framework for defining success after vertebral body tethering, integrating safety, deformity correction, spinal balance, patient-reported function, and satisfaction into a composite success score (VBT-SS).

Figure 1. Conceptual multidomain framework for defining success after vertebral body tethering, integrating safety, deformity correction, spinal balance, patient-reported function, and satisfaction into a composite success score (VBT-SS).

79. Double Major Curves in AIS: Results of a Novel Hybrid Approach Combining Thoracic Fusion with Lumbar Vertebral Body Tethering

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Hypothesis
Patients undergoing hybrid fixation will demonstrate adequate clinical and radiographic outcomes.

Design
Retrospective review of prospective single institution study

Introduction
Currently, AIS patients with double major curves are offered fusion for both curves which provides excellent radiographic outcomes, but fusion of the lumbar segment limits motion and may predispose to degenerative disease. The hybrid approach combines thoracic fusion with lumbar VBT with the hope of minimizing these potential downsides, but this approach is limited by paucity of data.

Methods
78 patients were identified who underwent the hybrid approach with 15 being treated for double major curves with minimum 2 yr f/u (mean 2.6yrs). Clinical and radiographic variables were collected and compared from pre-op, first erect (FE), and last visit (LV) utilizing Students t-test.

Results
Patients were skeletally immature with a mean age of 13.3±1.6 years (female=60%) and a mean Sanders score of 3.9±1.7. 9 patients had a Lenke 6 curve type, and 6 Lenke 3. PSF procedures took a mean of 356±79 minutes, and VBT procedures had a duration of 370±64 minutes. Estimated blood loss (EBL) was 141±115.4 mL for VBT and 387±236.9 mL for PSF. Thoracic curves improved from 63.9±10.3° pre-op to 14.9±5.7° at FE (p<0.001), which was unchanged at LV (13.8±7.1°, p=0.474). Lumbar curves improved from 62.0±10.6° pre-op to 23.9±8.1° at FE (p<0.01) and continued to improve at LV (13.3±7.8, p<0.01). Both thoracic kyphosis (pre-op=24.0±12.2°, post-op=26.5±7.7°, p=0.55) and lumbar lordosis (pre-op=59.5±9.8, post-op=53.8±12.7, p=0.54) did not change. Thoracic scoliometer improved from 14.8±4.3° to 4.3±4.6°. 5 patients (33%) required revision surgery: 4 underwent tether release for overcorrection 1 one had removal of a prominent tether screw. SRS self -image and satisfaction scores improved postoperatively. No patients have required extension of fusion into the lumbar spine.

Conclusion
Hybrid fixation with thoracic PSF and lumbar VBT is a viable option for patients with structural thoracic and lumbar curves. Even large lumbar curves (those outside of indications for VBT) demonstrate modulation with high probability of avoiding lumbar fusion.

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Demographic Information				
Total number of VBT	15			
Female	9 (60%)			
AIS	12 (80%)			
Years follow-up	2.6 ± 0.4			
Age at index procedure	13.3 ± 1.6			
Radiographic Information	**PreOp**	**FE**	**Latest**	**p-value**
Proximal thoracic	20.3 ±8.4	7.1 ± 4.5	4.6 ± 4.0	<0.01
Main thoracic	63.9 ±10.3	14.9 ± 5.7	13.8 ± 7.1	<0.01
Lumbar	62.0 ± 10.6	23.9 ± 8.1	13.3 ± 7.8	<0.01
Kyphosis (T5-T12)	24.0 ± 12.2	22.1 ± 8.1	26.5 ± 7.7	0.55
Lordosis (T1-S1)	59.5 ± 9.8	53.8 ± 12.7	61.2 ± 11.4	0.54
Open triradiate cartilage	4 (26.7%)	3 (20.0%)	0 (0%)	0.10
Sanders	3.9 ± 1.7			
Risser	1.5 ± 1.9	1.5 ± 1.9	4.1 ± 1.0	<0.01
Thoracic scoliometer	14.8 ± 4.3		4.3 ± 4.6	<0.01
Lumbar scoliometer	11.2 ± 7.8		3.8 ± 6.3	0.03
Postop correction				
FE % correction thoracic	76.1 ± 8.7%			
FE % correction lumbar	61.6 ± 10.6%			
2Y % correction thoracic	74.1 ± 13.0%			
2Y % correction lumbar	78.2 ± 11.3%			
Reoperation Information				
Number of subjects requiring reoperations		5 (33.3%)		
Months from index		23.6 ± 6.2		
SRS Scores	**PreOp**	**Latest**	**p-value**	
Function	3.9 ±0.9	4.3 ± 0.6	0.24	
Pain	3.7 ±1.4	4.1 ± 0.5	0.44	
Self image	3.4 ± 0.3	4.1 ± 0.6	0.01	
Mental health	3.9 ± 0.4	4.1 ± 0.8	0.55	
Satisfaction	3.4 ± 0.9	4.6 ± 0.5	<0.01	
Total mean	3.7 ± 0.6	4.2 ± 0.5	0.09	

80. First 30 AIS Patients Treated With Posterior Fusion of Structural Disc Levels (SDL) And Fusionless Treatment Of Non-SDL Had Preserved ROM And Less Fusion: A Prospective Study

Saechin Kim, MD, PhD; Nadim J. Kheir, MD; Philip Hanna, ; Hao-Hua Wu, MD

Hypothesis
A posterior angular correction (PAC) surgical method with fusion of structural disc levels (SDL) and with fusionless treatment of non-SDLs (nSDL) that correct fully with bending or are in the compensatory curve can preserve range of motion and decrease fusion levels.

Design
Prospective

Introduction
For PAC, constructs placed transversely into the pedicle screw tulips of the same vertebra have tulips oriented longitudinally. By manipulating the constructs posterolaterally, the disc angle is corrected and maintained with rods inserted into open tulips for fusion and polyethylene terephthalate bands into closed tulips for posterolateral vertebral tethering (PLVT).

Methods
The number of levels fused for each patient is compared to matched historical posterior fusion controls (MHC). Radiographic measurements assess for adding on phenomenon and side bending (SB) ROM. SRS 22r was scored pre-op and at each f/u. T-test statistical analysis (Microsoft Excel) was done with significance set at <.05.

Results
Of the first 30 AIS patients treated with the PAC method (avg 42.3 m, min. 24 m f/u), 4 were lost to f/u, leaving 26 patients. Avg age was 16.1+/-2.3 years, pre-op main curve was 56+/-10, and post-op main curve was 19+/-12 for avg correction of 66% of the main structural curve. The number of levels fused (avg 4.9+/-1.8) was less than in the MHC (avg 11.1+/-1.9) and the difference was statistically significant (p<.0001). SB lumbar ROM was preserved: pre-op (32.1+/-12.9) vs. post-op (36.8+/-13.0) (p=.25). In Fig. 1, for a single curve with central sacral vertical line (CSVL) intersecting the left L4 pedicle, last fused vertebra (LFV) is T12 for T10-T12 fusion as T12L1 was nSDL. PLVT was done between T12 and L4. For double curves, structural disc levels in both structural curves are fused and PLVT done between and below the fusions. There was one complication in which bilateral pedicle screws at the LFV were found to be broken at 1 year f/u but at 5-year f/u, curve correction was maintained and patient declined revision surgery. SRS-22r scores at final f/u was 4.5/5 and pre-op was 4.0/5 (p<.001).

Conclusion
The PAC method appears to be safe and results in significantly fewer levels fused compared to matched historical controls and preserves lumbar SB ROM in AIS with diverse ages and Lenke classifications.

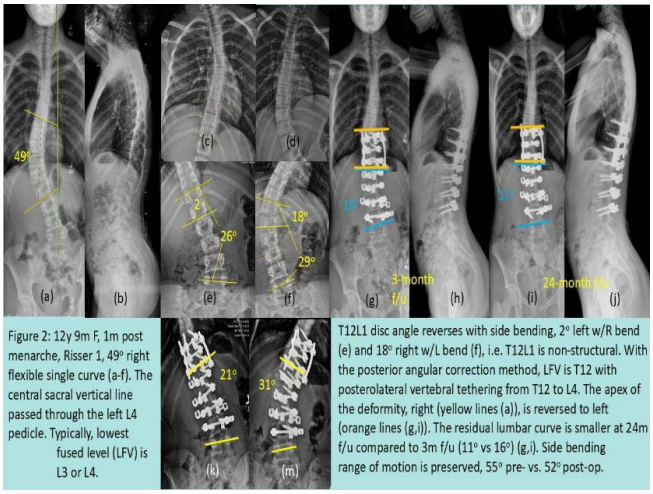

Figure 2: 12y 9m F, 1m post menarche, Risser 1, 49° right flexible single curve (a-f). The central sacral vertical line passed through the left L4 pedicle. Typically, lowest fused level (LFV) is L3 or L4.

T12L1 disc angle reverses with side bending, 2° left w/R bend (e) and 18° right w/L bend (f), i.e. T12L1 is non-structural. With the posterior angular correction method, LFV is T12 with posterolateral vertebral tethering from T12 to L4. The apex of the deformity, right (yellow lines (a)), is reversed to left (orange lines (g,i)). The residual lumbar curve is smaller at 24m f/u compared to 3m f/u (11° vs 16°) (g,i). Side bending range of motion is preserved, 55° pre- vs. 52° post-op.

T10-T12 fusion as T12L1 is non-structural

81. What Could Possibly Go Wrong? A Comprehensive Assessment of Complications Following Vertebral Body Tethering

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† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

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Hypothesis
Less mature patients with greater growth potential will experience a greater frequency of postoperative complications.

Design
Retrospective, multi-center cohort

Introduction
Vertebral body tethering (VBT) is a maturing technology, utilized with increasing frequency to treat scoliosis by growth modulation and without spinal fusion. Several outcome studies on VBT have reported targeted complications, but no study has provided a comprehensive analysis of all complications in a large, multi-center cohort of VBT patients.

Methods
Patients who had minimum 2-year follow up (FU) or who experienced a complication prior to 2-year FU were included. Complications were categorized according to the Clavien Dindo (CD) system. In addition to descriptive statistics, Chi Square and Mann-Whitney U tests were used to analyze differences between groups with and without complications.

Results
323 patients were included with average follow-up 37 months. 97% were treated with off-label use of an adult spinal deformity instrumentation system prior to dedicated VBT systems receiving FDA approval in the United States. 62 patients (19%) experienced 75 CD III complications. (Figure 1) The most common reoperations (CD IIIb) were 38 VBT revisions in 37 patients (11.5%), most commonly for broken tethers or adding on and posterior spinal fusion in 26 (8.0%) patients, most commonly for adding on or broken screws. No patients experienced a CD IV or V complication. In patients with CD III complications, mean age was lower (11.5yrs vs 12.5yrs, P=0.0002), mean Risser score was lower (0 vs 1, P=0.002), mean Sanders core was lower (3 vs 4, P<0.00001), mean weight was lower (42kg vs 48.1kg, P<0.00001), and mean BMI was lower (18.2 vs 19.4, P=0.003) preoperatively. No significant differences in CD III complication rates were found based on curve location, sex, ASA class, preoperative, 1st erect, or final FU curve size, or growth modulation.

Conclusion
Younger, more immature patients had significantly more complications/reoperations following VBT, likely due to the less predictable effects of growth. Older, more mature patients had fewer overall complications. Because the differences were small and the mean follow up still relatively short, these findings should be interpreted with caution until longer term outcome data is available.

Summary of Complications Following Vertebral Body Tethering

	I	II	IIIa	IIIb		I	II	IIIa	IIIb
Curve Progression					**Pulmonary**				
Adding On >10°	14			8	atelectasis	2		1	
LIV migration	1				Chylothorax	1			
Overcorrection >7°	6			10	hypoxia		1		
Instrumentation					low O2 sats	1			
Broken Screw				5	pneumonia		1		
screw pullout	2				Pneumothorax	7	1	2	1
Broken tether	55			10					
Other Reoperations					**Infection**				
PSF (unspecified reason)				11	wound dehiscence				1
removal of screws				1	**GI**				
supplemental fixation				2	constipation	1			
tether other curve				2	nausea and vomiting	1			
tether release				4	**Medical**				
tether removal				5	C diff diarrhea		1		
tether replacement				1	low back pain	1			
tether revision				8	shotness of breath	1			
Dural Tear					superficial wound infection	1			
dural tear				3	tingling thigh	1			
Postop Pain					UE weakness, swelling	1			
back pain	7				**Neurologic**				
chest pain	1				UE tingling	1			
shoulder pain	1								

Unplanned Return to Operating Room (UPROR)	
VBT revision (supplementation, release, replacement, or removal)	38
PSF	26
blood patch	2
tether other curve	2
chest tube	1
I&D	1
lumbar drain	1
reintubated	1
removal of screws	1
thoracic drains	1
thoracoscopy, CT	1

Clavien Dindo Classification of Complications	
Grade I	Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic and radiological interventions
Grade II	Requiring pharmacological treatment with drugs other than such allowed for grade I complications.
Grade III	Requiring surgical, endoscopic or radiological intervention
- IIIa	Intervention not under general anesthesia
- IIIb	Intervention under general anesthesia

Figure 1

82. Tether Breakage Across First-Generation and Second-Generation Vertebral Body Tethering Devices

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Hypothesis
Observable differences in rate of breakage or in breakage patterns will be observed from first generation of VBT devices to second.

Design
Retrospective review of a prospective multi-center study.

Introduction
Tether breakage is a significant complication that can occur when performing vertebral body tethering (VBT) in patients with adolescent idiopathic scoliosis (AIS). This study aims to define the rate of tether breakage in second-generation device systems compared to their

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first-generation counterparts, as the incidence of tether breakage across VBT models remains unknown.

Methods
AIS patients enrolled in prospective and retrospective surgical outcome registries and who underwent thoracic VBT from 2011-2021 with at least two years of follow-up were analyzed. Radiographic tether breakage, as defined by an increase in adjacent screw angle > 5° during the postoperative period, was analyzed across the first-generation and the second-generation VBT devices from within the same product line. Independent-t and Fisher tests were performed to assess differences in pre-surgical clinical factors and tether breakage reported rates and outcomes.

Results
Two hundred thirty-one patients were included in the final analysis. In total, radiographically identified tether breakage occurred in 116 patients (50%). In the first-generation, tether breakage was measured in 93 patients (52%) and was found to occur at a similar rate in the second generation (23 patients; 44%; p =0.46). No differences were observed in the rate of tether revision (6% vs. 4%; p=0.71) or the rate of conversion to posterior spinal fusion (1% vs. 8%; p=0.69) across device generations. Interestingly, the surgeon observed rate of tether breakage significantly decreased from the first generation of VBT devices to the second (21% vs. 2%; p < 0.001).

Conclusion
Tether breakage remains high in cases that utilize the new tether devices and is comparable to rates observed with the older models, despite lower rates of surgeon-reported breakage. This evidence suggests that surgeons should continue to remain hypervigilant during the postoperative period of growth-modulating VBT procedures; however, further investigation is needed to assess the rate of tether rupture in more modern growth-modulating practices such as double-row or hybrid constructs.

	Total (n=231)	First-Generation (n=179)	Second-Generation (n=52)	p-value
Tether Breakage* - *Any location*				
Observed	116 (50%)	93 (52%)	23 (44%)	0.46
Not Observed	115 (50%)	86(48%)	29 (56%)	
Tether Breakage – *Periapical Region***				
Observed	57 (25%)	47 (26%)	10 (19%)	0.36
Not Observed	174(75%)	132(74%)	42(81%)	
Tether Breakage – *End Segments*				
Observed	69 (30)	58 (32%)	11 (21%)	0.12
Not Observed	162 (70%)	121 (68%)	41 (79%)	
Reported Breakage				
Observed	38 (17%)	37 (21%)	1 (2%)	**<0.001**
Not Observed	193 (84%)	142 (79%)	51 (98%)	

Table 1. Observed and Reported Tether Breakage Rates

83. Does Larger-Diameter Tether Improve Outcomes After Vertebral Body Tethering? A 4 mm vs. 5 mm Comparative Study

Alice Baroncini, MD, PhD; Jil Frank; Miguel Pishnamaz, MD; Per D. Trobisch, MD

Hypothesis
A stronger, 5-mm tether provides better correction and less tether breakage than a 4-mm tether after VBT.

Design
Retrospective analysis of prospectively collected data, single-surgeon database.

Introduction
The outcomes of vertebral body tethering (VBT) are improving thanks to a better understanding of surgical technique, timing, and ideal patient characteristics. Still, the influence of implant characteristics on outcomes is largely unknown.

Methods
Consecutive AIS patients treated with VBT were reviewed. Inclusion criteria were Sanders ≤5, preoperative Cobb ≤70°, and ≥2-year follow-up. Cohorts were defined by tether diameter (4 or 5 mm). Analyses were performed by curve (double instrumentations contributed two curves). The primary endpoint was change in Cobb from 6 weeks to 2 years (Δ=2Y−6W; negative values indicate continued correction). The success rate and the rate of tether breakage were calculated for each group (success = curve <35° at the last available follow-up).

Results
Thirty-eight patients were included (4 mm=20; 5 mm=18); with same level of skeletal maturity (Sanders median 3.8±1 vs 3.7±1; p=0.8). Thoracic instrumented curves showed mean Δ of 1.4±8.8° (4 mm) versus −4.8±10.8° (5 mm), mean difference −5.5° (95% CI −13.4 to 1.5), Welch p=0.1; Mann–Whitney p=0.09. Lumbar/thoracolumbar curves showed mean Δ of 8.5±9.2° (4 mm) versus 0.3±12.7° (5 mm), mean difference −8.3° (95% CI −17.7 to 1.2), Welch p=0.08; Mann–Whitney p=0.08. The success rate was 75% in the 4mm group and 83% in the 5mm group (80% for thoracic curves in both groups, 78% and 92% for lumbar curves, respectively). The incidence of tether breakage at 12M was 30% in the 4mm group and 22% in the 5mm group, at 2Y it was 60% in the 4 mm group and 33% in the 5mm group, at 36m it was 25% and 11%, respectively. Tether breakages occurred in 16/20 (80%) patients with 4mm tethers versus 10/18 (55%) with 5mm tethers; thoracic rupture was 11/19 (58%) versus 2/11 (18%) (p=0.057). Overall, 66% of thoracic instrumentations showed a breakage in the 4mm group, vs 20% in the 5mm group. In lumbar curves, a breakage was observed in 78% of the instrumentations with 4mm tether vs. 61% with 5mm.

Conclusion
5mm tethers showed a tendency toward better 6-week to 2-year growth modulation, higher success rate and fewer ruptures, particularly for thoracic curves. Findings are suggestive but not yet conclusive and warrant confirmation in larger cohorts.

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‡ SRS Funded Research Grant

PODIUM ABSTRACTS

84. Who Breaks and Why? A Validated Predictive Model of Tether Failure After Vertebral Body Tethering in Adolescent Idiopathic Scoliosis

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Hypothesis
A multivariable predictive model can accurately identify patient-specific risk of tether failure following vertebral body tethering (VBT).

Design
Single-surgeon retrospective cohort of 117 AIS patients (11-18 years), with primary VBT and minimum 2 year follow up. Retrospective cohort study

Introduction
Vertebral body tethering (VBT) is a motion-preserving alternative to posterior spinal fusion for adolescent idiopathic scoliosis (AIS). Despite increasing utilization, tether breakage remains a common complication and a leading cause of revision. Existing studies describe individual risk factors but do not provide patient-specific risk estimation. A validated predictive model may improve candidate selection, counseling, and surgical strategy.

Methods
A multivariable logistic regression model was developed in 117 AIS patients (ages 11–18) undergoing primary VBT with minimum 2-year follow-up. Demographic, skeletal maturity, curve, and surgical variables were analyzed. Tether breakage timing (<24 months vs ≥24 months), location, and cumulative failures were recorded. Internal validation was performed using a temporal split. Model discrimination was assessed using area under the ROC curve (AUC), determined discrimination with CI=95%.

Results
Overall tether failure occurred in 38.5% of patients, with 15.4% occurring before 2 years and 23.1% after. Patients with failure were younger, less skeletally mature, and had larger preoperative curves. Increasing age, Sanders stage, and Risser grade were independently protective, reducing breakage risk by 28% (OR 0.72, p=0.004), 42% (OR 0.58, p<0.001), and 24% (OR 0.76, p=0.02) per unit increase, respectively. Thoracolumbar/lumbar primary curves increased failure risk by 65% (OR 1.65, p=0.03). Each increase in Lenke classification raised failure risk by 35% (OR 1.35, p=0.02), and each 10° increase in major Cobb angle increased failure risk by 18% (p=0.02). The model demonstrated acceptable discrimination (AUC 0.75, 95% CI 0.67–0.83).

Conclusion
This internally validated multivariable model identifies patients at increased risk for tether failure following VBT and demonstrates clinically meaningful discrimination. Patient-specific risk stratification may improve VBT candidate selection, inform surgical strategy, and enhance preoperative counseling, supporting its role in decision-making for AIS treatment.

85. Is rhBMP-2 Worth the Risk? A Data-Driven Look at Fusion Outcomes and rhBMP-2 Related Complication Burden in High-Risk Adult Spinal Deformity Patients

Duby Okonkwo, BS; Harsh Jain, MBBS; Nick De Oliveira, BA; Sam Kavarana, BS; Advith Sarikonda, BS, BA; Bayard Wilson, MD; Byron F. Stephens, MD; *Scott Zuckerman, MD*

Hypothesis
In adult spinal deformity (ASD) surgery, recombinant human bone morphogenetic protein-2 (rhBMP-2) is associated with reduced pseudarthrosis/rod fractures without increase in BMP-related adverse events, even among biologically high-risk patients.

Design
Retrospective cohort

Introduction
Though rhBMP-2 is widely used to enhance spinal fusion, its use remains controversial due to complication concerns. In patients undergoing ASD surgery, we evaluated the association between rhBMP-2 use and outcomes, with dedicated analyses of high pseudarthrosis risk groups (obesity, diabetes, and osteoporosis/osteopenia).

Methods
A retrospective cohort study was performed of patients undergoing ASD surgery with ≥5-level fusion between 2009-23, and ≥2 year follow-up. Patients were stratified based on rhBMP-2 use. Primary outcome was pseudarthrosis/rod fracture, as this relates directly to the fusion process. Secondary outcomes were mechanical complications and BMP-associated adverse events including new onset radiculitis, wound complications, and seroma. Sub-analyses were performed in high pseudarthrosis risk groups. Multivariable logistic regression was used to adjust for relevant confounders.

Results
Among 288 patients undergoing ASD surgery (mean age: 62.5±17.5 years; 74.0% females), 118 (41.0%) received rhBMP-2. Entire Cohort: rhBMP-2 use was independently associated with reduced risk of pseudarthrosis/rod fracture (16.1% vs. 38.2%, p < 0.001; OR=0.24, 95%CI 0.10–0.58, p=0.002). rhBMP-2 was not significantly associated with increased radiculitis, wound complications, or seroma formation. Obesity: rhBMP-2 use was independently associated with reduced risk of mechanical complications (46.0% vs. 66.1%, p=0.037; OR 0.20, 95%CI 0.05–0.88, p=0.033). Diabetes: Incidence of mechanical complications was similar between BMP-treated and BMP-free groups (p>0.05). Osteoporosis/Osteopenia: rhBMP-2 use was independently associated with reduced risk of reoperation for mechanical complications (16.4% vs. 46.5%, p < 0.001; OR 0.20, 95%CI 0.05–0.83, p=0.026).

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Conclusion
In patients undergoing ASD surgery, rhBMP-2 use was independently associated with fewer mechanical complications without an increase in BMP-related adverse events. rhBMP-2 demonstrated differential efficacy across high-risk populations, benefiting patients with obesity and osteoporosis/osteopenia but not patients with diabetes.

86. Preclinical Targeting of the Osteopontin–α5β1 Integrin Axis Reveals a Disease-Modifying Mechanism in Adolescent Idiopathic Scoliosis †

Alain Moreau, PhD; Mohamed Elbakry, PhD; Anita Franco, MS

Hypothesis
Aberrant activation of the osteopontin (OPN)–α5β1 integrin signaling axis is a causal driver of spinal deformity progression in adolescent idiopathic scoliosis (AIS), and early inhibition of this pathway can modify disease development.

Design
Translational mechanistic study integrating human cellular systems, biological stratification, and interventional scoliosis mouse models.

Introduction
AIS progression varies widely among patients with similar curve magnitudes, indicating that biological mechanisms precede structural failure. Current treatments are mechanical and reactive, targeting deformity rather than its molecular drivers. We investigated whether the OPN–α5β1 integrin signaling axis represents a rate-limiting, druggable mechanism governing scoliosis progression.

Methods
OPN–α5β1 signaling was examined in primary human cells stratified by biological endophenotypes associated with AIS progression. Pathway modulation was tested using pharmacological inhibition of α5β1 integrin engagement or upstream reduction of α5 integrin availability. In vivo efficacy was evaluated in validated scoliosis mouse models with longitudinal radiographic assessment of curve onset and progression.

Results
AIS segregated into reproducible biological states defined by differential sensitivity to OPN, driven by regulation of α5β1 integrin availability rather than ligand abundance alone. Pharmacological modulation of this axis normalized downstream signaling in human osteoblasts derived from AIS patients (surgical cases). Moreover, in scoliosis mouse models, early pathway inhibition prevented completely scoliosis development compared with controls, demonstrating preclinical disease modification.

Conclusion
Our data identify the OPN–α5β1 integrin axis as a causal, disease-modifying mechanism in AIS. Preclinical inhibition of this pathway alters scoliosis development in vivo, supporting a shift toward early, biology-based intervention strategies.

87. A single DNA-based polygenic risk score for adolescent idiopathic scoliosis improved by patient-derived paravertebral muscle gene-activity data. †

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Hypothesis
A single DNA-based polygenic risk score (PRS) can identify children at high risk for future adolescent idiopathic scoliosis (AIS), supporting targeted screening and follow-up.

Design
Predictive modeling study.

Introduction
AIS may progress before detection and severe curves may require spinal fusion, yet intensive surveillance for every child is impractical. We developed a genetics-only PRS, and then tested whether patient-derived paravertebral muscle single-nucleus RNA sequencing (snRNA-seq) gene-activity data prioritize biologically relevant GWAS regions and improve the model.

Methods
We meta-analyzed AIS GWAS (total n > 440,000; AIS cases > 8,000) and built genome-wide and snRNA-seq-informed region-prioritized PRS models. Performance was evaluated in an independent Japanese cohort. Risk stratification was also estimated in a simulated first-degree family-history population.

Results
The genome-wide PRS achieved an AUC of 0.723. The snRNA-seq-informed region-prioritized PRS improved the AUC to 0.761. In the Japanese cohort, individuals in the top 10% of the region-prioritized PRS had higher odds of AIS (OR 7.17; 95% CI, 6.53-7.82) compared with the population average, significantly outperforming a previously reported conventional PRS model (OR 3.36; 95% CI, 2.33-4.88; p = 4.8 x 10^-5). In a simulated population with a family history of AIS, the predicted AIS prevalence was 53.9% in the top 10% and 67% in the top 1% PRS strata.

Conclusion
A genetics-only PRS can meaningfully stratify future AIS onset risk, and prioritizing loci using patient-derived paravertebral muscle gene-activity data (snRNA-seq) improves predictive performance. Clinical take-home: A single genetic test may help identify patients who

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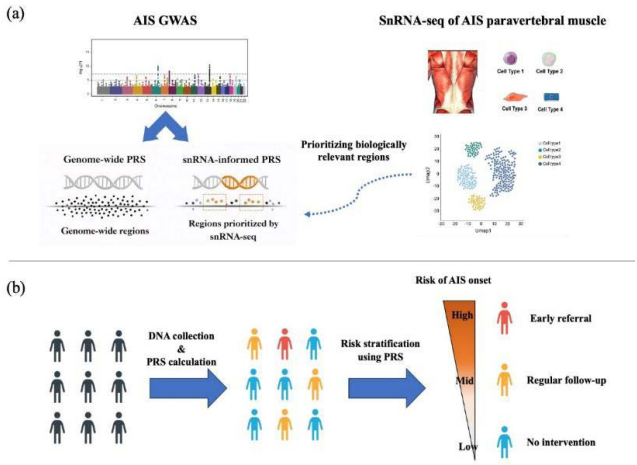
warrants earlier referral and closer, risk-tailored surveillance, especially in families with AIS.



(a): Construction of genome-wide and single-nucleus RNA-seq (snRNA-seq) informed polygenic risk scores (PRSs) for adolescent idiopathic scoliosis (AIS). (b): Schematic illustration of PRS-based risk stratification for AIS onset and clinical decision-making.

88. Gut Microbiome–Derived TMAO Pathway as a Central Metabolic Driver of Biological Aging in Adult Spinal Deformity † ‡

Mitsuru Yagi, MD, PhD; Keitaro Ito, MD, PhD; Ryo Mizukoshi, MD; Norihiro Isogai, MD, PhD; Haruki Funao, MD, PhD; Naobumi Hosogane, MD, PhD; Christopher P. Ames, MD; Retsu Fujita, PhD

Hypothesis
We hypothesized that accelerated biological aging in adult spinal deformity (ASD) is driven by specific metabolic alterations and these metabolites independently contribute to biological aging beyond chronological age.

Design
Prospective multiomics study of consecutive ASD patients.

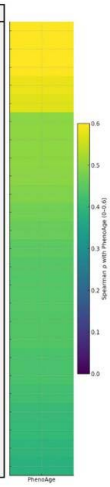
Introduction
Biological aging has emerged as a determinant of vulnerability in ASD than chronological age, yet its metabolic drivers remain unclear. This study aimed to identify metabolomic and proteomic signatures associated with biological aging.

Methods
Fasting plasma samples from 120 ASDs (age ≥40 years) underwent quantitative CE–MS–based metabolomic profiling (1,100 metabolites) and targeted proteomic analysis of inflammatory cytokines and adipokines. Biological age was estimated using PhenoAge. Correlation analyses, ranked metabolite profiling, and pathway enrichment were performed to identify metabolic determinants of biological aging. A composite TMAO Pathway Index was constructed using z-standardized trimethylamine N-oxide (TMAO), trimethyllysine, choline, and dimethylglycine to quantify microbiome-derived metabolic activity.

Results
Among the top metabolites associated with PhenoAge, microbiome-derived metabolites accounted for 28%, including choline (ρ = 0.50), dimethylglycine (ρ = 0.50), phenylacetylglutamine (ρ = 0.49), p-cresol sulfate (ρ = 0.45), 3-indoxylsulfuric acid (ρ = 0.44), trimethyllysine (ρ = 0.43), and TMAO (ρ = 0.35). The TMAO Pathway Index demonstrated a strong association with biological aging (ρ = 0.59, p = 6.5×10^{-7}) and remained an independent predictor after adjustment for chrono age (β = 4.6 years per SD; 95% CI, 0.9–8.3; p = 0.02). IDO activity showed a moderate association with PhenoAge (ρ = 0.25) and correlated with the TMAO Pathway Index (ρ = 0.34, p = 6.5×10^{-4}), whereas conventional systemic inflammatory indices demonstrated minimal associations. Proteomic analyses further revealed selective upregulation of pro-inflammatory cytokines and suppression of adiponectin in association with TMAO Pathway Index.

Conclusion
ASDs demonstrate a distinct metabolic aging phenotype dominated by microbiome-derived metabolites and glycation stress. The TMAO pathway emerged as the strongest metabolic driver of biological aging. These findings identify the microbiome–metabolite axis as a promising biological target to mitigate accelerated aging in ASD.

Metabolite	rho	p value	Pathway
Gluconic acid	0.61	2.73E-07	Glucose oxidation
N-(1-Deoxy-1-fructosyl)leucine	0.57	2.09E-05	Glucose / Glycation
N-Acetylgalactosamine	0.58	3.33E-05	Glucose / Glycation
N-Acetylglucosamine			
N-Acetylmannosamine			
N,N-Dimethylglycine	0.50	5.09E-05	**Microbiome / TMAO axis**
Choline	0.50	5.61E-05	**Microbiome / TMAO axis**
Phe	0.47	1.43E-04	Amino acids (aromatic)
N2-Phenylacetylglutamine	0.49	1.93E-04	**Microbiome / TMAO axis**
Isocitric acid	0.46	1.93E-04	TCA cycle
N-(1-Deoxy-1-fructosyl)valine	0.50	3.67E-04	Glucose / Glycation
p-Cresol sulfate	0.45	3.78E-04	**Microbiome / TMAO axis**
Ile	0.44	4.15E-04	Amino acids (BCAA)
Cystine	0.44	4.57E-04	Redox / antioxidant
3-Indoxylsulfuric acid	0.44	5.12E-04	**Microbiome / TMAO axis**
Val	0.43	6.18E-04	Amino acids (BCAA)
Ornithine	0.40	1.41E-03	Urea cycle
2-Deoxyribonic acid-1	0.50	1.68E-03	Nucleotide / DNA turnover
Alloisoleucine	0.40	1.75E-03	Amino acids (BCAA)
N-Acetylgalactosamine 4-sulfate	0.61	1.84E-03	Glucose / Glycation
N6,N6,N6-Trimethyllysine	0.43	2.90E-03	**Microbiome / TMAO axis**
Gluconolactone	0.41	3.15E-03	Glucose oxidation
SDMA	0.37	3.43E-03	Arginine / NO pathway
Malic acid	0.37	3.63E-03	TCA cycle
Taurine	-0.37	3.71E-03	Redox / antioxidant
Fructosyllysine	0.61	4.50E-03	Glucose / Glycation
Trimethylamine N-oxide	0.35	5.90E-03	**Microbiome / TMAO axis**



Top 25 Metabolites Associated with PhenoAge

89. Genetic Study of 100 Idiopathic Early-Onset Scoliosis Families Provides New Hypotheses to Explain its Pathogenesis †

Nao Otomo, MD, PhD; Yared Kidane, PhD; Behrooz A. Akbarnia, MD; Charles E. Johnston, MD; Amy L. McIntosh, MD; Jonathan J. Rios, PhD; Brandon A. Ramo, MD; Carol A Wise, PhD

Hypothesis
We hypothesized that idiopathic early-onset scoliosis

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(iEOS) has an underlying genetic basis and that systematic genetic analysis can identify candidate genes and pathways contributing to disease risk.

Design
Multi-center cohort study

Introduction
Combining exome sequencing (ES) and inheritance mapping has been effective for discovering the genetic mutations that cause certain forms of early-onset scoliosis. However, the "idiopathic" group has remained enigmatic. The purpose of this study was to define the biologic causes of iEOS by genetic studies in a cohort of 100 well-characterized iEOS patients and their parents.

Methods
Children >3 years, their parents, and other affected relatives were recruited from nine U.S. pediatric orthopaedic centers. Informed consent, blood/saliva, and clinical information documenting their diagnoses was obtained. ES and microarray genotyping were performed, and standard quality controls applied. Single nucleotide variants (SNVs) were identified from the data, annotated by frequency in the general population, and by predicted functional impact. Only variants with frequencies < 0.1% in the population and that fit with the presumed inheritance pattern (autosomal dominant, autosomal recessive, or de-novo) in the family were considered for further analyses.

Results
Of the 100 iEOS families, 90 were ultimately evaluated. A total of 350 genes were identified as candidates by SNV analysis, 14 of which were detected in more than one family. Notably, two of the 14 genes, DNAH6 and DNAH10, encode dynein heavy chains, components of primary cilia that enable cells to sense their environment. Of the remaining 12 genes, 4 (HSPG2, OBSCN, TTN, SYNE1) are muscle related genes. Pathway analysis of the 350 candidate genes showed significant strong association with a muscle structure and motor function-related pathway (p=6.5×10-10).

Conclusion
Initial evaluation of our iEOS cohort suggests that it is genetically heterogeneous. Recurrent variants in DNAH6 and DNAH10 implicate cilia dysfunction in some cases of iEOS, a mechanism we are currently testing in patient cells. Pathway analyses suggest that genetic changes affecting muscle function may contribute to disease susceptibility in many cases of iEOS. Further studies are warranted to understand how disturbances in cilia and muscle function specifically affect the growth and coordinated functioning of the spine in young patients.

90. Surgical vs Nonsurgical Treatment in Patients Living with Adolescent Idiopathic Scoliosis (AIS): A Target Trial Emulation with 30 Years of Follow-up § ‡

Javier Pizones, MD, PhD; Javier Munoz Laguna, MS; Anika Pupak, PhD, BS; Yann Phillippe Charles, MD, PhD; Kenny Y. Kwan, BMBCh(Oxon), FRCSEd; Manuel Rigo, MD; Lucia Moreno-Manzanaro, BS; Antonia Matamalas, MD, PhD; Alejandro Gomez-Rice, MD, PhD; Susana Nunez Pereira, MD, PhD; Sleiman Haddad, MD, PhD, FRCS; Jwalant Mehta, FRCS; Nasir A. Quraishi, PhD, FRCS; Satoshi Suzuki, MD, PhD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Munish C. Gupta, MD, MBA; Miquel SerraBurriel, PhD; Ferran Pellise, MD, PhD; ESSGHistory Study Group

Hypothesis
At the 30-year follow-up (30yFU), adolescents with moderate (40-60º) curves who underwent surgery will have a better quality of life (HRQoL) than those treated nonsurgically

Design
Target Trial Emulation (TTE) (Hernán&Robins, Am J Epidemiol 2016) reproduces the elements of an ideal hypothetical clinical trial protocol using observational real-world data

Introduction
Surgery for AIS improves HRQoL at the 2 and 5-year follow-ups. However, some patients with moderate curves may choose nonsurgical treatment

Methods
Multicenter observational study (13 centers, 9 countries, 3 continents) of AIS patients with baseline Cobb ≥40°, treated during adolescence (ages 10-18), ≥20 years of follow-up, who accepted the invitation to participate. The primary outcome was EQ-5D-5L at the 30yFU. Secondary outcomes included SRS-22, SF-36, ODI, NRS, and Cobb angle. We created comparable surgical (S) vs nonsurgical (NS) groups from the 563 eligible patients by adjusting for baseline confounding factors using inverse probability weighting (IPW). The TTE controlled for confounding and censoring due to loss to follow-up, having a well-defined time zero for eligibility (t0), a 1-year grace period for compliance with treatment assignment, and a follow-up of 30±5 years. Standardized mean difference (SMD) effectiveness estimates were obtained using weighted ordinary least squares regression models

Results
483 patients (S=328, NS=155). After cloning and IPW adjustment, baseline characteristics were: age 14.3±1.9 years; 90% female; Cobb 52.6±11°. At the 30yFU, the SMD for the EQ-5D-5L was small [0.06 (95%CI:-0.12 to 0.24)] in favor of surgery, ruling out minimal clinically important effects (<MCID). SMDs for secondary outcome measures also tended to favor surgery but did not reach clinically important effects. SMDs were greater in mental health dimensions [SRS-22-Satisfaction (0.16); SRS-22-Mental Health (0.12); SRS-22-Self-Image (0.11), and SF-36MCS (0.11)] than in physical dimensions (function, disability, pain). Only the Cobb angle showed a moderate SMD (0.56; 95%CI: 0.39 to 0.74), reaching clinical importance

Conclusion
At the 30yFU, patients with moderate AIS fused during adolescence showed improved Cobb angle compared to those treated conservatively. While fusion does not

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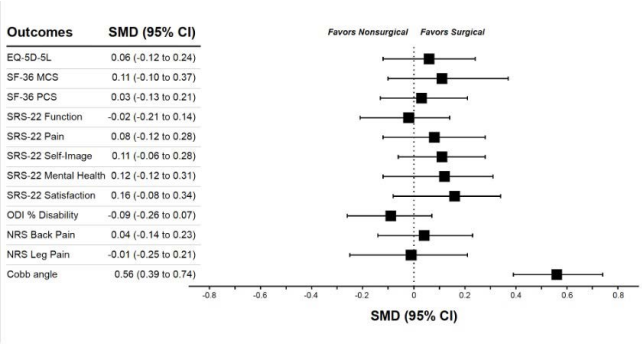
significantly impair pain and function at this timepoint, estimates for HRQoL rule out clinically meaningful effects



91. Does Early Administration of Disease Modifying Therapy (DMT) Prevent Early Onset Scoliosis (EOS) in Spinal Muscular Atrophy (SMA) §

Hiroko Matsumoto, PhD; Yuri Ota, MD, PhD; Thomas A. Coleman, BS; Lennert Plasschaert, MD; Joyce Huang, ; Amy Pasternak, ; Allan Glanzman, PT, DPT, PCS; Jason B. Anari, MD; Elena Losina, PhD; Robert J. Graham, MD; Ron El Hawary, MD, MSc; Patrick J. Cahill, MD; Brian D. Snyder, MD, PhD

Hypothesis
Early DMT initiation reduces the risk of developing EOS compared with late initiation, and the reduction magnitude varies by SMN2 copy number and symptom status at birth.

Design
Multicenter retrospective cohort study of consecutive SMA patients (≤1y/o).

Introduction
Early DMT improves survival and motor function but the impact on mitigating EOS remains unclear. The study aimed to examine the effect of age at DMT initiation on developing EOS and investigate roles of SMN2 gene number and symptom status at birth.

Methods
Patients were categorized into early-DMT (≤6 wk) vs late-DMT (>6 wk). EOS (≥10°) was diagnosed on surveillance spine X-ray. Cox regressions evaluated associations between age of DMT initiation and EOS diagnosis, stratified by SMN2 number (<3 vs. ≥3), and ± symptoms at birth.

Results
Of 128 infants (34% early-DMT; 66% late-DMT), 84 (66%) developed EOS @ 2.2±1.5 yrs. 72% of infants with <3 SMN2 developed EOS vs 36% with ≥3 SMN2 (p<0.001). EOS was observed in 77% of symptomatic and 67% of pre-symptomatic infants (p=0.546). The type of DMT administered appeared to affect EOS (p=0.010), but when adjusted for age of DMT initiation, DMT type was not associated with EOS risk (hazard ratio (HR)=1.15, p=0.500). Age at DMT initiation significantly influenced risk (p<0.001): EOS occurred in 33% of infants treated early vs. 82% treated late (Fig. 1a). DMT initiation >6 wk did not lessen EOS risk regardless of subsequent timing. Stratified analyses demonstrated that the effect of DMT timing on EOS varied by SMN2 number and symptom status: • <3 SMN2 infants with early-DMT = 48% EOS; with late-DMT = 82% EOS (p<0.001); • ≥3 SMN2 infants with early-DMT = 0% EOS; with late-DMT = 82% EOS (p<0.001); • pre-symptomatic infants with <3 SMN2 + early-DMT reduced EOS risk by 54% (HR=0.46, p=0.033, Fig. 1b); • pre-symptomatic infants with ≥3 SMN2 + early-DMT eliminated risk (HR=0, Fig 1c); • No significant associations were observed among symptomatic infants, regardless of SMN2 number (Fig 1d&e).

Conclusion
The effect of DMT to mitigate EOS is influenced by the age of administration, SMN2 number, and symptom status at birth. Among infants with <3 SMN2, most developed EOS by age 4, but risk was partially (~30%) moderated if DMT was initiated before age 6 wk. This study indicates that early, routine spine surveillance should be performed on high-risk children with <3 SMN2 who were treated >6 wk.

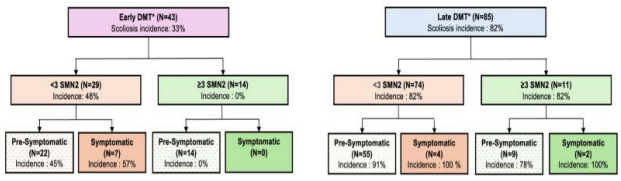


Fig. 1a. Incidence of EOS diagnosis in patients who administered DMT within the first year of their lives

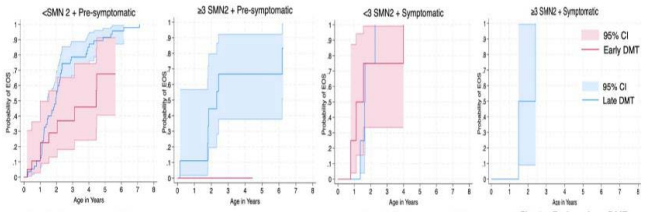


Fig. 1b. Early vs Late DMT (HR=0.46) | Fig. 1c. Early vs Late DMT (HR=0) | Fig. 1d. Early vs Late DMT (HR=1.17) | Fig. 1e. Early vs Late DMT (HR: NA)

92. Tranexamic Acid Dosing in Deformity Spine Surgery: A 3-Year Prospective Randomized Comparison of Low-Dose versus High-Dose Regimens §

Sharif A. Jonayed, MBBS, MS

Hypothesis
A high-dose tranexamic acid (TXA) regimen provides superior reduction in perioperative blood loss and transfusion requirements compared to a low-dose regimen in adult spinal deformity surgery, without increasing the incidence of thromboembolic or neurological complications .

Design
Single-center, prospective, double-blind randomized controlled trial conducted from January 2019 to Decem-

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ber 2023, with a minimum follow-up of 2 years (mean 36 months).

Introduction
While tranexamic acid is a standard antifibrinolytic agent in spinal deformity surgery, the optimal dosing strategy remains undefined. This study compares the safety and efficacy of two distinct TXA dosing protocols—low-dose versus high-dose—in reducing blood loss and improving perioperative outcomes, with longitudinal assessment of complications and functional recovery .

Methods
Ninety-six patients undergoing posterior spinal fusion for adult spinal deformity were randomized into two groups. The low-dose group received a loading dose of 10 mg/kg followed by a maintenance infusion of 1 mg/kg/hr. The high-dose group received a loading dose of 50 mg/kg followed by a maintenance infusion of 5 mg/kg/hr. Primary outcomes were intraoperative and total perioperative blood loss, transfusion volume, and transfusion rate. Secondary outcomes included operative time, postoperative hemoglobin, thromboembolic events, neurological status, and SRS-22r scores. Follow-up was conducted at 6, 12, 24, and 36 months.

Results
The high-dose group had significantly lower intraoperative blood loss (795 ± 138 mL vs. 1185 ± 194 mL; $p < 0.001$) and total blood loss (1195 ± 215 mL vs. 1720 ± 290 mL; $p < 0.001$). Transfusion rates were 22% in the high-dose group versus 48% in the low-dose group ($p = 0.008$). Thromboembolic complications were rare and comparable between groups (1 vs. 2 events; $p = 0.56$). No differences were observed in neurological outcomes or surgical site infection. At final follow-up (minimum 2 years), SRS-22r scores improved equally in both groups, with no late complications attributable to TXA dosing.

Conclusion
In spinal deformity surgery, a high-dose TXA regimen is significantly more effective than a low-dose regimen in reducing blood loss and transfusion needs, without increasing thromboembolic risk . This regimen offers a safe and efficacious strategy for enhancing perioperative management in complex spinal reconstructions.

93. Casting and Bracing as a Bridging Strategy to Delay Surgery in Young Children with Thoracolumbar and Lumbar Formation-Failure Congenital Scoliosis

Kazuki Kawakami, MD; Noriaki Kawakami, MD; Tetsuya Ohara, MD; Hiroaki Nakashima, MD, PhD; Shiro Imagama, MD, PhD; Hiroko Matsumoto, PhD

Hypothesis
In children with thoracolumbar or lumbar formation-failure congenital scoliosis, conservative management with bracing and/or serial casting reduces yearly curve progression compared with observation alone.

Design
Multi-center retrospective cohort study

Introduction
In congenital scoliosis, surgical timing is influenced by vertebral anomaly morphology or level, yet early surgery carries higher complication and reoperation risk. This study aimed to evaluate whether conservative therapy improves curve control in thoracolumbar or lumbar formation-failure congenital scoliosis.

Methods
Patients (≤6 yrs old) with congenital scoliosis, major coronal curve of ≥25°, and ≥1 formation-failure anomalies in the thoracolumbar or lumbar region were included. Conservative treatment consisted of serial casting followed by bracing or bracing alone (Fig. 1a–e). Treatment choice was determined by a combination of patient age, curve magnitude and family preference. Successful curve control was defined as a yearly curve progression of ≤0°. All patients were followed until definitive surgical treatment.

Results
65 consecutive patients (29 males, 36 females) with a mean baseline major coronal curve of 38° and a mean follow-up of 3.6 yrs were included. Patients were categorized into a treatment group (52%) and an observation group (48%). Compared to observation, the treatment cohort was older at baseline (3.3 vs 2.1 y/o, $p=0.001$), had a larger baseline curve (42 ° vs 33°, $p<0.0001$), and had a longer duration of follow-up (4.3 vs 2.9 yrs, $p=0.015$). The treatment cohort had significantly higher success (82% vs 13%, $p<0.0001$) and better curve control (-1.2°/yr vs 3.5°/yr progression, $p<0.0001$) than the observation. These associations did not vary by baseline age or major coronal curve magnitude, indicating no effect modification by these factors. After adjustment for baseline age and major coronal curve, treated patients were 6 times more likely to achieve successful curve control than those under observation (risk ratio = 6.04; $p<0.0001$). Curve-type was not associated with treatment allocation or outcome.

Conclusion
Bracing and/or serial casting effectively controlled curve progression for a mean duration of 4.3 yrs, supporting its role as a bridging strategy to delay surgery and potentially reduce the risk of complications and reoperation in very young children with congenital scoliosis.

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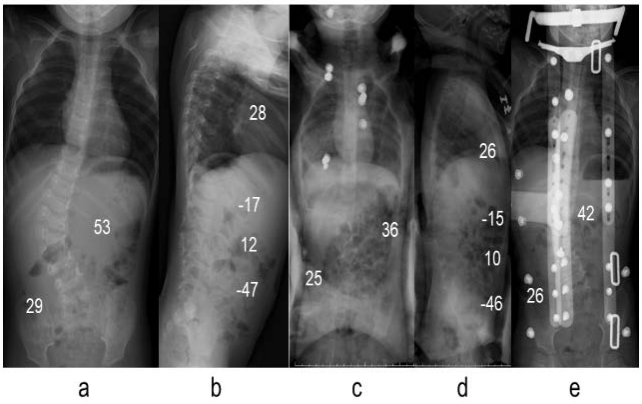

Figure 1. Female (1 year 9 months) with congenital scoliosis due to vertebral formation failure. (a,b) Baseline radiographs. (c,d) Radiographs at initial cast application. (e) Radiograph during Milwaukee brace wear.

94. Non-Operative Treatment for Adult Spinal Deformity: Long Term Results of a Biopsychosocial Intervention – a Prospective Cohort Study With a Mean Follow-Up of 8 Years §

Philip Horsting, MD; Evelien Hoevenaars, ; Michiel Beekhuizen, MD, PhD; John O'Dowd, MD; *Marinus de Kleuver, MD, PhD;* Miranda L. Van Hooff, PhD

Hypothesis
Symptomatic Adult Spinal Deformity (ASD) patients improve after a two week biopsychosocial intervention and these beneficial results are maintained at a minimum of 5-year follow-up.

Design
Prospective cohort study

Introduction
The prevalence and societal burden of disease of adult spinal deformity (ASD) is increasing. Currently, no evidence based non-operative treatment exists for ASD patients with chronic low back pain (CLBP) and reduced quality of life (QoL).

Methods
A prospective cohort study of a biopsychosocial intervention cohort (n=69) with a minimum of 5-year follow-up. Inclusion criteria: age ≥18, no surgical indication, coronal Cobb angle >10, idiopathic (AdIS) or degenerative (de novo) scoliosis (DN), one-year follow-up data. Primary outcome: functional status (ODIv2.1a). Secondary outcomes: pain intensity (NPRS) and QoL (SF36-PCS, SF36-MCS). Clinical relevance: minimal important clinical change (MCIC; improvement in ODI≥10 points), patient acceptable symptom state (PASS; ODI≤22).

Results
Demographics: median age 55 (IQR 15) years, 77% female, median Cobb angle 20° (IQR 13), 29% AdIS – 71% DN, mean follow-up time 8.3 years (100 [SD 22] months). Lost to follow-up 31 patients. There was a significant time effect on functional status ($F(4,272)=13.40$, $p<.001$, $\eta p^2=.17$). Mean baseline ODI improved significantly from 37.4 (SD 11.0) to 30.3 (SD 13.5) post-treatment and this effect was maintained at 8.3-years follow-up with a mean ODI of 28.8 (SD 15.2). Clinical relevance in terms of functional status: 48% of the patients reached an MCIC and 41% reached a PASS (ODI≤22) at 8.3-years follow-up. All secondary outcomes, except SF36-MCS, followed a similar pattern of maintained improvement at 8.3-years follow-up. The proportion of patients using opioids decreased significantly from baseline (32%) to 8.3-years follow-up (16%) (McNemar's exact test, p=.013).

Conclusion
This is the first study to show significant and clinically relevant improvement in symptomatic ASD patients in terms of functional status, pain and quality of life after a biopsychosocial intervention and this improvement is maintained at a minimum of 5-year follow-up. Results on healthcare consumption and work status will be available at the time of the Meeting.

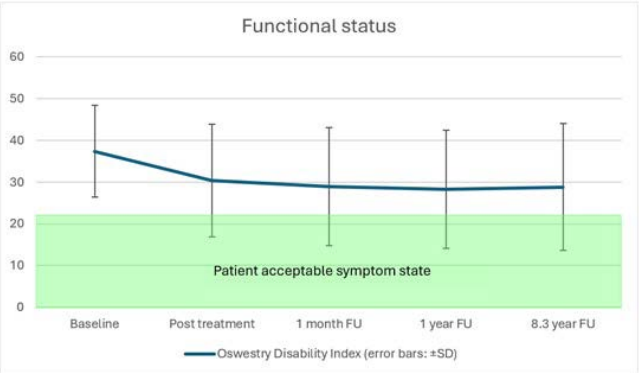

Figure 1. Mean (SD) functional status of 69 ASD patients in a biopsychosocial intervention cohort over time

95. Ten-Year Natural History and Clinical Impact of Distal Adding-on After Posterior Spinal Fusion for Lenke 1A/2A Adolescent Idiopathic Scoliosis §

Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Toru Hirano, MD, PhD; Kazuhiro Hasegawa, MD, PhD; Hideki Tashi, MD; Keitaro Minato, MD, PhD; Yohei Shibuya, MD; Masayuki Sato, MD; Mio Kubota, MD, PhD; Hiroyuki Kawashima, MD, PhD

Hypothesis
Distal adding-on (DA) after posterior spinal fusion (PSF) for Lenke 1A/2A curves progresses over time and negatively impacts clinical outcomes at 10-year follow-up.

Design
A retrospective cohort study

Introduction
Distal adding-on (DA) is a well-recognized radiographic phenomenon following PSF for AIS. However, prior studies with short-term follow-up have failed to demonstrate meaningful effects on HRQOL, raising controversy

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regarding whether DA represents a true postoperative complication or a benign radiographic finding. This study aimed to clarify the long-term postoperative course and clinical significance of DA over a 10-year follow-up in patients with Lenke 1A/2A curves.

Methods

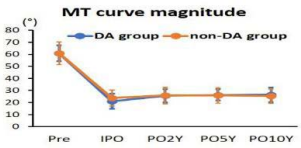
Patients with Lenke 1A or 2A curves who underwent PSF and completed 10-year follow-up were included. DA was defined as either (1) a ≥5° increase in the Cobb angle of the main thoracic (MT) curve with distal curve extension, or (2) a ≥5° increase in disc wedge angle (DWA) below the lowest instrumented vertebra (LIV), compared with immediate postoperative (IPO) erect radiographs.

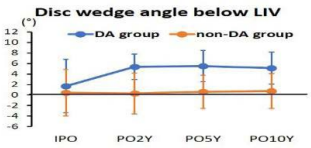
Results

Forty-one patients (34 females; Lenke type 1/2 = 21/20) were included, with a follow-up rate of 74.5%. Mean age was 15.2 years at surgery and 25.2 years at final follow-up. DA occurred in 10 patients (24.4%): 8 at PO2Y, 1 at PO5Y, and 1 at PO10Y. In the DA group, the MT curve magnitude and DWA below LIV significantly increased from IPO (median Cobb 20°, DWA 0.5°) to PO2Y (25° and 5°), and remained stable thereafter through PO10Y (25° and 4.5°) (Figure). Demographic factors, Lenke type, Risser grade at surgery, number of fused segments, and pre- and postoperative curve magnitudes as well as correction rates did not differ between the DA and non-DA groups. DWA was significantly greater in the DA group from PO2Y onward (p<0.01), despite no difference at IPO (p=0.6). SRS-22 scores were comparable between groups up to PO5Y; however, at PO10Y, the DA group demonstrated a significantly lower pain score (4.2 vs 4.6, p=0.02) and a trend toward a lower total score (4.1 vs 4.5, p=0.08) (Table).

Conclusion

Although DA did not consistently progress beyond 2 years postoperatively, it was associated with a significantly worse SRS-22 pain score at 10-year follow-up. These findings indicate that DA should not be considered a benign radiographic finding and could be clinically relevant 10 years after PSF.





SRS-22r	Preop	PO2Y	PO5Y	PO10Y
Pain				
DA group	4.5 (4.2-4.8)	4.4 (4.1-5.0)	4.4 (4.3-4.4)	4.2 (3.9-4.6)
non-DA group	4.8 (4.6-5.0)	5.0 (4.3-5.0)	4.6 (4.4-5.0)	4.6 (4.3-4.9)
p-value	0.1	0.3	**0.07**	**0.02***
Self-image				
DA group	2.8 (2.4-3.1)	3.7 (3.4-4.3)	3.9 (3.7-4)	3.8 (3.4-4.1)
non-DA group	2.8 (2.4-3.2)	4.2 (3.4-4.7)	4.0 (3.4-4.2)	4.0 (3.4-4.9)
p-value	0.8	0.4	0.7	0.2
Function				
DA group	5.0 (4.4-5)	4.6 (4.3-4.8)	4.8 (4.4-4.8)	4.7 (4.6-5.0)
non-DA group	4.8 (4.6-5)	4.8 (4.6-5.0)	4.8 (4.8-5)	4.8 (4.6-5.0)
p-value	0.8	0.2	0.2	0.5
Mental health				
DA group	4.4 (4.0-4.8)	4.5 (4.3-5)	4.6 (4.2-4.9)	4.3 (3.9-4.6)
non-DA group	4.6 (3.8-5)	4.8 (4.1-5)	4.6 (4.2-5)	4.4 (4-4.8)
p-value	0.7	0.9	0.7	0.5
Satisfaction				
DA group	—	4.5 (4.0-4.9)	4.0 (4.0-4.5)	4.0 (3.6-4.9)
non-DA group	—	4.0 (4.0-4.8)	4.5 (3.6-4.9)	4.5 (4.2-4.6)
p-value	—	0.6	0.6	0.4
Total				
DA group	4.0 (3.9-4.1)	4.4 (4.0-4.6)	4.3 (4.1-4.5)	4.1 (4.0-4.3)
non-DA group	4.1 (3.9-4.3)	4.5 (4.3-4.7)	4.5 (4.2-4.7)	4.5 (4.2-4.6)
p-value	0.3	0.4	0.3	**0.08**

96. Multicenter Treatment Patterns and Surgical Outcomes in Marfan Syndrome Associated Scoliosis

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Hypothesis

Surgery for Marfan Syndrome (MFS) achieves radiographic correction but carries substantial complication risk, with differential outcomes between growth-friendly (GF) and posterior spinal fusion (PSF) subgroups.

Design

Retrospective, multicenter cohort.

Introduction

Scoliosis in MFS presents earlier and progresses more rapidly than in AIS. However, surgical outcomes and quality of life (HRQoL) remain incompletely defined. This study evaluates treatment patterns and longitudinal outcomes in a large multicenter MFS cohort.

Methods

159 patients with MFS were identified, of whom 121 underwent surgery and were included. Treatment included GF surgery (N=97, 80%) and PSF (N=24, 20%). Radiographic parameters, major complications (MCDS ≥III), and HRQoL (EOSQ-24) were assessed at pre- and post-index, 2 years, and 5 years after surgery. Surgery type and complication and revision rates were compared temporally in 5-year cohorts using chi-square and Fisher's exact tests. Temporal trends in complications were assessed using logistic regression, stratified by GF and PSF subgroups.

Results

Compared to GF patients, PSF patients were older at index (12.7±3.8 vs 5.7±2.7 years, p<0.001) and had smaller residual coronal deformity at all timepoints, while GF demonstrated greater spine growth (38 vs 18 mm). The proportion of PSF increased from 0% in 2000-09 to 21% in 2010-14, and 30% in 2015-24 (p = 0.030). Major complications occurred in 34%, highest in VEPTR/TGR (51%) versus PSF (12.5%) (p=0.008). Complication and revision rates declined across 5-year index surgery cohorts, driven by improvements in the GF subgroup (p<0.001). Among GF patients, later surgery year was associated with reduced complications (OR 0.92, p=0.008), while no association was observed for PSF patients. Total EOSQ-24 scores did not differ between PSF and GF patients at pre-index (68.7 vs 72.4, p=0.58), post-index (67.5 vs 67.0, p=0.93), or latest follow-up (68.1 vs 71.0, p=0.69).

Conclusion

Surgical management of MFS-associated scoliosis achieves effective deformity correction, with PSF providing more durable alignment and GF surgery preserving spinal growth with higher complication rates, though

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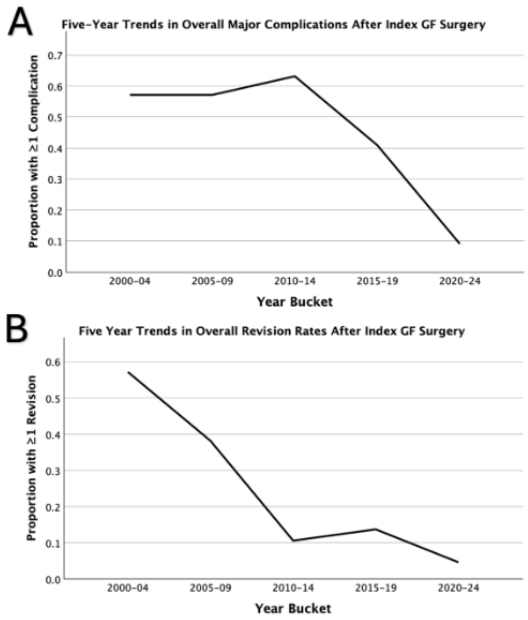
these have improved over time. Surgical strategy shifted toward increased use of PSF over the study period. Despite differing surgical risk profiles, HRQoL outcomes were comparable between GF and PSF patients. Further study to clarify appropriate indications is warranted.

Figure: Trends in major complications (A) and revisions (B) after index GF surgery



97. A Two-Year International Retrospective Cohort Study Comparing the Efficacy and Complication Rates of the OWSER and MCGR Systems in the Treatment of Spinal Muscular Atrophy

Mareille Post, MD; luca F. colombo, MD; Marco Ramella, MD; Lotfi Miladi, MD; Jean-Paul Kaleeta Maalu, MD; Louis Boissiere, MD; Moyo C. Kruyt, MD, PhD; Jeroen Renkens, MD; Esther Janssen, PhD; Barend J. Van Royen, MD, PhD

Hypothesis
We hypothesize that the OWSER and MCGR systems yield comparable radiographic outcomes and complication rates in SMA patients

Design
Retrospective international cohort study

Introduction
Scoliosis is a common and progressive complication in children with spinal muscular atrophy (SMA) and can significantly impair sitting balance, mobility, and respiratory function. Growth-sparing techniques, including magnetically controlled growing rods (MCGRs), have been introduced to mitigate these risks, yet remain associated with substantial complication and revision rates. The One-Way Self-Expanding Rod (OWSER) system is a novel fusionless technique designed to allow passive spinal growth while minimizing the need for repeated surgical interventions. The objective of this retrospective international cohort study was to compare the two-year complication rates and clinical efficacy of the OWSER system and MCGRs in the surgical management of scoliosis in patients with spinal muscular atrophy.

Methods
SMA patients who underwent primary surgical treatment with either the OWSER system or MCGRs between 2016 and 2024 and had a minimum follow-up of two years were included. The primary outcome was the overall two-year complication rate. Secondary outcomes included revision surgery and radiographic correction.

Results
Sixty-five patients (38 female) were included. Baseline characteristics, Cobb angle and T1S1 height were similar in both groups. Figure 1 shows the demographic and radiological data of both groups. In the OWSER group, three complications occurred; 1. revision due to insufficient rod lengthening, 2. prominent cross-link causing delayed scar forming, 3. medical treatment of neurogenic bladder. In the MCGR group, two complications occurred;1. screw pull-out requiring revision, 2. rod breakage resulting in rod revision.

Conclusion
This study represents the first large international comparison of MCGRs and the OWSER system in patients with spinal muscular atrophy. Comparable radiographic and complication-related outcomes were observed between the two treatment modalities. However, patients operated on with the MCGR required an average of 13 lengthening procedures in two years time. To provide more clinically relevant evidence, a large international retrospective cohort study is currently conducted.

	OWSER	MCGR
Number (f)	34 (19)	30 (19)
Age at initial surgery, years, mean (SD)	8.6 (2.3)	7.8 (1.4)
Weight, kg, mean (SD)	19.8 (7)	17.2 (1.6)
Preoperative Cobb angle, degrees, mean (SD)	73 (13)	71 (12)
Postoperative Cobb angle, degrees, mean (SD)	38 (12)	41 (7)
Two-year postoperative Cobb angle, degrees, mean (SD)	37 (12)	40 (10)
Preoperative T1S1 height, mm, mean (SD)	264 (33)	280 (33)
Postoperative T1S1 height, mm, mean (SD)	307 (39)	303 (31)
Two-year postoperative T1S1 height, mm, mean (SD)	318 (43)	320 (33)
Average number of lengthening procedures at two-year follow-up	0	13
Abbreviations: F = female, kg = kilograms, SD = standard Deviation, mm = millimeters		

Figure 1, demographic and radiological data

98. Scoliosis in Pediatric Severe Osteogenesis Imperfecta: A Multicenter Study of Progression and Surgical Outcomes

Cynthia V. Nguyen, MD; Alfonso Ocampo, MD; Bryan Menapace, MD, MBA; Selina C. Poon, MD

Hypothesis
Patients with severe osteogenesis imperfecta (OI)-associated scoliosis are at higher risk for progression of deformity and surgical complications compared to idiopathic scoliosis.

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

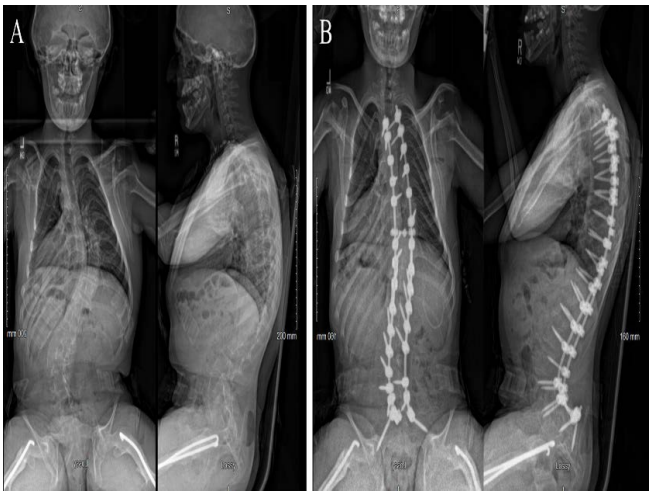
Design
Retrospective multicenter review

Introduction
Treatment of scoliosis in pediatric patients with OI is challenging, particularly in severe forms such as Sillence type III. In this largest-to-date series, we explored the progression of spinal deformity and surgical outcomes.

Methods
Multicenter data search identified pediatric patients with type III OI and scoliosis that had □2 years follow up. Clinical details and radiographic measurements were collected and analyzed.

Results
77 patients from 21 hospitals were included. Mean follow-up was 9.5±3.1 years. Major curves progressed a mean 6.4° per year. At skeletal maturity (defined as 14 for females, 16 for males) 88.9% of the patients had a curve □50°. Larger major Cobb angle at the time of diagnosis correlated with curvatures >50° at skeletal maturity (p=0.01). 44 patients (57%) had spinal fusion. Mean preoperative major Cobb angle was 82.6±18.8° which decreased postoperative to 45.0± 22.7° with a reduction of 47.9± 21.1%. 17 patients had preoperative halo gravity traction (HGT) for average 4.3 weeks. Patients with curves ≥80° and HGT had significantly better postop major Cobb angle reduction (p<0.05); 11.7% had a traction pin complication. Fusion did not change thoracic kyphosis or sagittal vertical axis but significantly decreased lumbar lordosis from 62.3±26.6° to 55.2±16.7° (p<0.05). Intraoperative and total complication rate was 7.1% and 28.6%, respectively. The most common complications were: neuromonitoring events, wound dehiscence and HGT pin issues. All patients recovered neurologically. Patients with Lenke 5 or 6 curves and fused to pelvis had higher postop major curve improvement (p=0.02) but 1/3 lost their ambulatory status postop.

Conclusion
Almost 90% of pediatric patients with severe OI and scoliosis had curvatures □ 50° by skeletal maturity. Spinal fusion had a 29% complication rate and average curve correction was 48%. HGT in curvatures ≥80° resulted in better coronal improvement, but risked traction pin complications. Fusing to pelvis in lumbar major curves led to better correction but risked ambulation. Scoliosis treatment in these patients requires careful individual consideration and counseling.



17-year-old male preop (A) and 1 year postop (B)

99. Intraoperative Neuromonitoring In Neuromuscular Scoliosis: Feasibility, Obstacles, Outcomes, and Resolution

Terrence G. Ishmael, MBBS; Joshua M. Pahys, MD; Steven W. Hwang, MD; Tracey Bryan, MS; Suken A. Shah, MD; Jaysson T. Brooks, MD; Stefan Parent, MD, PhD; Paul D. Sponseller, MD; Peter O. Newton, MD; Harms Study Group; *Amer F. Samdani, MD*

Hypothesis
Patients with CP undergoing PSF with the use of IONM have better outcomes than those without

Design
Retrospective review of multicenter registry

Introduction
Intraoperative neuromonitoring (IONM) is commonly used in spine surgery to protect the spinal cord. Use of IONM in patients with cerebral palsy (CP) undergoing posterior spinal fusion (PSF) is not universal. We sought to evaluate whether the use of IONM provides any added value.

Methods
Our review included CP patients with a GMFCS (Gross Motor Function Classification System) level 4 or 5 who underwent PSF. Baseline demographics, deformity measures, and the use of IONM were gathered. Operative outcomes and perioperative complications were evaluated including neurologic deficits. Student's t-test, chi-square tests, and multivariate logistic regression were performed.

Results
409 patients (23% GMFCS 4 and 77% GMFCS 5) with minimum 2y follow-up were identified. 59% had full (F) baseline IONM, 33% had partial (P) IONM (i.e. SSEPs only), and 8% had no (N) IONM attempted. 13 patients were not able to be monitored and were excluded. The groups were similar with respect to baseline clinical and radiographic characteristics. EBVL, LOS and average transfusion volume were higher in group N (p<0.001), while operative time was lower (p=0.022). There were IONM

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alerts in 13% of patients (groups F and P combined), and patients with larger curves were more likely to have alerts (96° vs. 80°, p<0.001). There were 2 neurological deficits and 7 postoperative bladder dysfunctions in group F, 7 postoperative bladder dysfunctions in group P, and 2 in group N. There were no reported neurologic deficits in group N; however, group N did have significantly more medical complications (p<0.001) and were more likely to have multiple complications (p<0.001). Patients with severe-profound cognitive deficits were more likely to have partial IONM available (p=0.004), and there were no significant differences in outcomes between groups F and P.

Conclusion
Our study found a 13% rate of IONM alerts and 0.5% new neurological deficit in CP patients undergoing PSF. No neurologic deficits were found in patients who were not monitored; however, this complication may be challenging to determine. Patients with partial monitoring available had similar outcomes to those with full IONM. It is likely that IONM alerts led to interventions that potentially avoided permanent neurological deficit.

	Pre - Major Cobb Angle (p=0.444)	FE - Major Cobb Angle (p=0.359)	2y - Major Cobb Angle (p=0.437)	Pre - Pelvic Obliquity (p=0.54)	FE - Pelvic Obliquity (p=0.213)	2yr - Pelvic Obliquity (p=0.027)
None	85°	30°	33°	29°	6°	5°
Partial	81°	27°	29°	27°	7°	9°
Full	84°	29°	30°	28°	8°	10°
Total	83°	28°	30°	28°	8°	9°

100. Perioperative Complication Severity is Associated with GMFCS Sub-Classification in Cerebral Palsy

Jessica Siragusa, MBA; Sydney Thai, BS; Furqan Ahmed, BS; Krystell E Ceballos Alvarez, BS; *Paul D. Sponseller, MD*; Amit Jain, MD, MBA

Hypothesis
GMFCS V patients will experience higher CDS complication severity than GMFCS IV patients after posterior spinal fusion. Within GMFCS IV and within GMFCS V, increasing GMFCS sub-classification will be positively associated with increasing CDS grade.

Design
Retrospective Cohort

Introduction
The Gross Motor Function Classification System (GMFCS) is used to classify functional mobility in patients with cerebral palsy. Although GMFCS IV and V are considered severe, both represent a heterogeneous group of patients with varying degrees of central neurological impairment. Prior work has demonstrated that presence of G-tube, seizure history, non-verbal status, and tracheostomy predict overall rate of complications after scoliosis surgery in this population. However, the correlation of central neurological impairment with complication severity has not been established.

Methods
We retrospectively identified 96 GMFCS V and 25 GMFCS IV patients with cerebral palsy who underwent posterior spinal fusion over a 10 year period. Patients were subclassified based on the number of baseline central neurological impairments (gastrostomy tube, tracheostomy, seizure history, non-verbal status) from x.0 (none) to x.4 (four). Complications within 90 days were graded using the Clavien-Dindo-Sink (CDS) classification system. Associations were assessed using Spearman correlation, Kruskal–Wallis testing with Bonferroni correction, and appropriate parametric or categorical tests.

Results
GMFCS subclass correlated with complication severity ($\rho = 0.491$, $p < 0.001$) after scoliosis surgery. Complication grade differed across GMFCS classes ($p < 0.001$), with higher severity in GMFCS V compared with IV ($p < 0.001$). Subclassification remained associated with complication grade within GMFCS IV and V patients ($\rho = 0.467$, $p < 0.001$, Figure 1). GMFCS V patients had larger preoperative Cobb angles than GMFCS IV patients (85° vs 70°, $p = 0.010$), with no differences in blood loss, operative time, or BMI.

Conclusion
Greater accumulation of central neurological impairments in patients with cerebral palsy, resulting in higher GMFCS subclass, was associated with greater postoperative complication severity following posterior spinal fusion. GMFCS sub-classification may aid not only in the overall complication rate prediction, but also is associated with complication severity.

101. Longer Operative Times are Associated with Increased Morbidity in Pediatric Neuromuscular Scoliosis Surgery

Luke Maclean, MD, PhD; Andrea Simmonds, MD; David L. Parsons, MD, FRCS; David L. Skaggs, MD, MMM; *Vivien Chan, MD, MS*

Hypothesis
We hypothesized that longer operative time is associated with increased morbidity in pediatric neuromuscular scoliosis surgery.

Design
Multicenter retrospective cohort study.

Introduction
Longer operative time has been associated with increased risk of morbidity in various surgical specialities.

Methods
Patients were included in this study if they received a posterior spinal fusion for neuromuscular scoliosis. Operative time was stratified into <4 hours, 4-7 hours, 7-10 hours, and >10 hours and rates of any adverse event, severe adverse event, perioperative allogeneic

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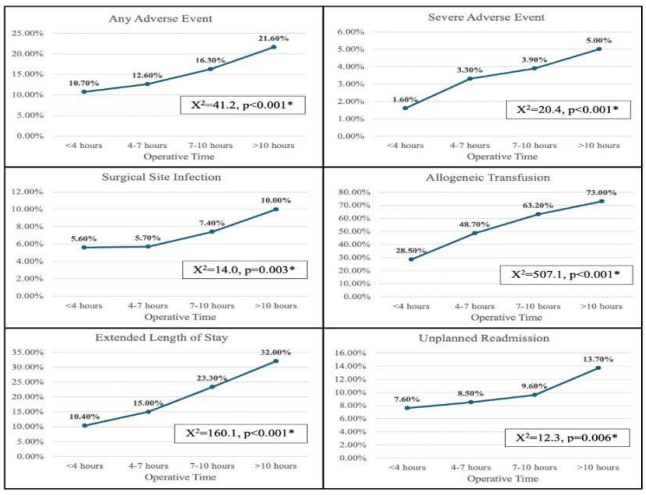
transfusion, surgical site infection, extended length of stay (>10 days), and unplanned readmission for each category were determined and compared. Multivariable logistic regression analysis was performed to determine the relationship between operative time and the outcomes of interest.

Results

There were 8,753 patients. The rates of any adverse event, severe adverse event, perioperative allogeneic transfusion, surgical site infection, extended length of stay, and unplanned readmission were 13.1%, 3.1%, 47.6%, 6.1%, 16.0%, and 8.6%, respectively. The rates significantly increased with increasing operative time, with surgeries greater than 7 hours having rates higher than the rates of the entire cohort. For any adverse event, the rates for surgeries <4 hours and >10 hours were 10.7% and 21.6%, respectively. For allogeneic transfusion, the rates for surgeries <4 hours and >10 hours were 28.5% and 73.0%, respectively. For extended length of stay, the rates for surgeries <4 hours and >10 hours were 10.4% and 32.0%, respectively. In the multivariable logistic regression analysis, compared to surgeries <4 hours, surgeries that were 7-10 hours had higher odds of any adverse event (OR 1.42, p=0.001), severe adverse event (OR 2.02, p=0.002), allogeneic transfusion (OR 3.41, p<0.001), and extended length of stay (OR 2.75, p<0.001). Surgeries >10 hours had higher odds of any adverse event (OR 2.14, p<0.001), severe adverse event (OR 2.81, p=0.004), surgical site infection (OR 1.71, p=0.029), allogeneic transfusion (OR 5.77, p<0.001), extended length of stay (OR 4.56, p<0.001), and unplanned readmission (OR 1.75, p=0.009).

Conclusion

Longer operative times were independently associated with higher odds of perioperative morbidity in pediatric neuromuscular scoliosis surgery.



Rates of events stratified by operative time.

102. Sacro-Alar Angle as a Morphologic Predictor of S2AI Screw Infeasibility in Pediatric Neuromuscular Scoliosis with Pelvic Asymmetry

Juan P. Arispe, MD; Eduardo Galaretto, MD; *Sofia Frank, MD;* Norberto C. Fernandez, MD; Nicolas Bacaloni, MD; Leonel Shteinberg, MD; Cristian Fuster, PhD; Esteban Robledo, PhD; Carlos A. Tello, MD, PhD

Hypothesis

A larger sacro-alar angle (SAA) on the supporting hemipelvis is associated with reduced feasibility of S2-alar-iliac (S2AI) screw placement in pediatric neuromuscular scoliosis.

Design

Retrospective analysis of a prospectively maintained database

Introduction

Pelvic fixation using S2AI screws is widely used in neuromuscular scoliosis (NMS). In severe pelvic asymmetry, safe intraosseous trajectories may be compromised, and objective morphologic predictors of S2AI infeasibility remain poorly defined. This study evaluates the sacro-alar angle as a radiologic predictor of S2AI feasibility and explores whether plain radiographs can raise preoperative suspicion of corridor compromise

Methods

Preoperative pelvic CT scans of 53 non-ambulatory pediatric patients with NMS were retrospectively analyzed. Three-dimensional reconstructions were generated and bilateral virtual S2AI trajectories simulated. Feasibility was defined as a fully intraosseous trajectory ≥50 mm. Sacro-alar angles were measured bilaterally. The supporting hemipelvis was identified based on pelvic asymmetry. Paired analyses compared angles and feasibility between sides. Logistic regression assessed the association between SAA and feasibility on the support side, and discrimination was evaluated using ROC analysis.

Results

Mean SAA was significantly greater on the supporting hemipelvis compared with the non-support side (74.7° ± 11.2 vs. 60.9° ± 8.5). S2AI screw infeasibility occurred more frequently on the support side (p<0.001). Logistic regression demonstrated that increasing SAA on the support side was independently associated with lower screw viability (OR 0.80 per degree increase; p=0.001). The model showed excellent discrimination (AUC 0.91), with sensitivity of 95.2% and specificity of 84.4% at a probability cut-off of 0.5. In contrast, no significant association was observed between sacro-alar angle and screw viability on the non-supporting hemipelvis.

Conclusion

Pelvic asymmetry in neuromuscular scoliosis produces rotational deformity of the sacroiliac complex that narrows the S2AI osseous corridor. The sacro-alar angle is a strong independent morphologic predictor of S2AI infeasibility, with a clinically useful threshold of approximately 70°. Plain radiographs may raise suspicion of

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corridor compromise, but definitive assessment requires 3D CT planning.

103. Long Term Follow-up of Non-ambulatory Children with Cerebral Palsy (CP) Treated for Spine and Hip Pathoanatomy

Rachel L. DiFazio, PhD, RN; Meghana Venkatesh, MS; Patricia E. Miller, PhD, MS; Judith A. Vessey, PhD, RN; Benjamin J. Shore, MD; *Brian D. Snyder, MD, PhD*

Hypothesis
In non-ambulatory children with CP, hip deformities predominate requiring earlier treatment, with subsequent scoliosis development.

Design
10-yr prospective evaluation of health-related quality of life (HRQoL), caregiver burden, radiographic outcomes and risk factors for premature mortality in non-ambulatory CP patients after hip and spine surgery.

Introduction
Hip instability and neuromuscular scoliosis occur in non-ambulatory children with CP, often concomitantly when hip deformities induce pelvic obliquity that provoke thoracolumbar scoliosis. We evaluated the effect of hip and/or spine surgery on HRQoL, caregiver burden, radiographic outcomes, and factors affecting mortality ≥10 yrs post-op.

Methods
IRB-approved prospective study of GMFCS IV/V patients, aged 3-25 yrs, undergoing hip reconstruction and/or spinal fusion 2011-2019. Of 82 patients screened, 72 consented, and 69 participated. At 10-year f/u 44 patients were available (26 hip, 18 spine). Longitudinal changes in HRQoL (CPCHILD), care-giver burden (ACEND), and radiographic outcomes were analyzed before and 6 wks, 3, 6, 12, 24, 60 and 120 months after surgery using linear mixed-effects models. Risk factors for mortality were determined.

Results
Hip instability preceded spine deformity. Spine patients were 6.5 yrs older than hip patients (14y5m vs 9y10m; p<0.001) and were more disabled (GMFCS IV: 8% vs 51%; p=0.004). Of 43 hip surgery patients, 15 required spine surgery 72±39 months later, whereas 3 spine surgery patients required hip reconstruction 45±36 months later. In hip patients, CPCHILD domains improved for positioning, transferring/mobility, comfort/emotions, and health 2-3 years after surgery, remaining stable at 10-yrs. ACEND scores declined over 10-yrs. In spine patients, CPCHILD domains showed smaller (-0.2-+2.8) and less sustained improvements. ACEND scores were unchanged from baseline. Radiographic improvements in hip stability (Migration %) and scoliosis correction (Cobb) remained relatively stable. Twelve (17%) patients (5 hip, 7 spine) died from respiratory issues at a median 4 yrs after surgery. Having >3 comorbidities predicted mortality (HR=3.10; 95% CI: 1.23-7.84; p=0.02).

Conclusion
Hip and spine surgery improve HRQoL long term, especially for painful hips. Caregiver burden did not change as these children remain maximally dependent. Mortality was associated with >3 comorbidities.

104. The Price of Alignment: Cost Drivers in Posterior Fusion for Neuromuscular Scoliosis

Jeremy Siu, ; Vanessa Toomey, MD; Jacquelyn N. Valenzuela-Moss, MPH; Tyler Tetreault, MD; Lindsay M. Andras, MD; *Michael J. Heffernan, MD*

Hypothesis
Increased length of hospital stay, patient complexity, and resource utilization are associated with increased perioperative costs in neuromuscular scoliosis (NMS).

Design
Single center retrospective review

Introduction
NMS imposes a substantial healthcare burden, with surgical costs exceeding those of idiopathic scoliosis. Despite the recognized economic impact of NMS surgery, the specific clinical and surgical factors driving costs remain poorly understood. The purpose of this study was to evaluate patients with NMS undergoing PSF and identify factors associated with increased perioperative surgical costs.

Methods
Patients aged 7-21 years with NMS who underwent PSF to the pelvis were reviewed at a single quaternary pediatric hospital. Clinical data were obtained from the electronic medical record and charge data was queried from the Pediatric Health information System (PHIS) database. Hospital specific costs were calculated from charge data and inflation-adjusted hospital costs were analyzed using a generalized linear model with a gamma distribution and log link. Covariates were selected a priori based on deformity severity, instrumentation strategy, perioperative resource utilization, and patient comorbidities. Adjusted results are presented as percent change in cost.

Results
Ninety-five patients were included. Fusion length ranged from 12-16 levels, median length of stay was 7 days (range: 4-31), and median inflation adjusted PSF cost was $112,689 (IQR $90,763-$146,897). In adjusted analyses, length of stay was a significant contributor to total inpatient cost of following fusion, with a 2.8% increase per additional day (e^β=1.028, p<0.001). Longer fusion constructs increased costs by 10.4% additional fusion level (e^β=1.104, p=0.017). Use of a temporary distraction rod was associated with a 32% increase in cost (e^β=1.321, p=0.005). Flexibility index was shown to decrease cost by 0.5% per degree (e^β= 0.995, p=0.047). Preoperative curve magnitude, number of osteotomies, surgical time and patient comorbidities were not associated with total cost after adjustment.

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Conclusion
Perioperative costs for pediatric NMS were primarily driven by length of hospital stay and fusion construct length rather than preoperative curve magnitude or patient comorbidities.

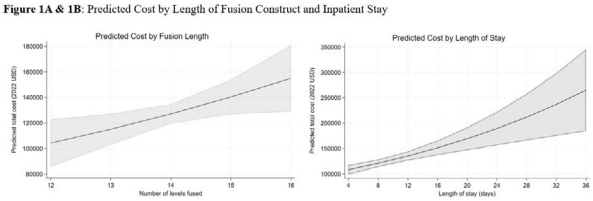


Figure 1A and 1B: Predicted Cost by Length of Fusion Construct and Inpatient Stay

105. Biological Age Predicts Short-Term Outcomes After Adult Spinal Deformity Surgery

Ritvik Jillala, BS; Arjun Menta, BS; Patrick Kramer, MD; Jawad M. Khalifeh, MD; Liam Hughes, MD; Jacob Jo, MD; Daniel Lubelski, MD; Timothy Witham, MD; *Tej Azad, MD*

Hypothesis
Biological age (BA), an objective biomarker-based measure, predicts short-term outcomes after adult spinal deformity (ASD) surgery.

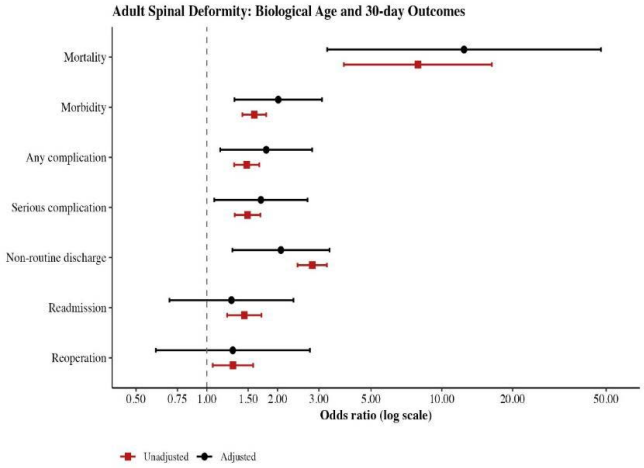
Design
Retrospective cohort study using the American College of Surgeons NSQIP database (2016–2020).

Introduction
ASD surgery carries substantial perioperative risk, yet CA incompletely captures physiologic vulnerability. Frailty and comorbidity drive outcomes, but existing tools require additional data entry or are inconsistently coded. BA, derived from preoperative biomarkers, offers a scalable, complementary indicator of surgical risk.

Methods
Adults undergoing ASD surgery were identified using CPT/ICD codes for spinal fusion and deformity correction. BA was calculated using the Levine outcome-trained framework, derived in the National Health and Nutrition Examination Survey, based on nine biomarkers (albumin, alkaline phosphatase, total bilirubin, AST, BUN, creatinine, WBC, hematocrit, and platelets). Logistic regressions evaluated associations between BA (per 1 SD increase) and 30-day outcomes: mortality, overall morbidity, any complication, serious complication, readmission, reoperation, and non-routine discharge. Adjusted models included CA, demographics, and comorbidities.

Results
Among 2,306 ASD patients (median CA = 62 [49–71]; median BA = 63 [49–73]), mortality was 1.0% and morbidity 20.6%. BA was independently associated with all short-term outcomes (all P < .001). Each SD increase in BA increased odds of mortality (OR = 7.91 [95% CI 3.83–16.34]), morbidity (OR = 1.59 [1.42–1.79]), any complication (OR = 1.48 [1.31–1.67]), serious complication (OR = 1.49 [1.32–1.69]), non-routine discharge (OR = 2.81 [2.43–3.24]), reoperation (OR = 1.29 [1.06–1.58]), and readmission (OR = 1.44 [1.22–1.71]). After adjustment, BA remained a significant predictor of mortality (aOR = 12.43 [3.25–47.50]), morbidity (aOR = 2.01 [1.31–3.09]), any complication (aOR = 1.79 [1.14–2.81]), serious complication (aOR = 1.70 [1.08–2.68]), and non-routine discharge (aOR = 2.07 [1.28–3.33]). The effect of CA was attenuated in all models except non-routine discharge.

Conclusion
In ASD surgery, BA derived from routine labs strongly predicts short-term mortality, morbidity, and discharge outcomes. By quantifying physiologic reserve, BA enhances risk prediction in complex spine surgery.



Unadjusted and adjusted odds ratios of biological age when predicting 30-day postoperative outcomes

106. Surgical Correction of ASD Is Associated with Slower Epigenetic Age Acceleration

Travis Kotzur, MD; Lane H. McCoy, BS; John OMalley, MD; Nicholas A. Pallotta, MD, MS; Munish C. Gupta, MD, MBA; *Brian J. Neuman, MD*

Hypothesis
ASD surgical correction will slow the rate of age acceleration

Design
Prospective longitudinal cohort study

Introduction
Adult spinal deformity (ASD) disproportionately affects older adults and is associated with substantial morbidity. Beyond structural pathology, ASD may function as a chronic physiologic stressor that accelerates biological aging. Epigenetic age (EA), derived from DNA methylation patterns, reflects biological aging and may better capture biological resilience and recovery than chronological age (CA). Whether ASD is associated with accelerated biological aging, and whether this process is modifiable following surgical correction, remains unclear.

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Methods
Patients undergoing ASD surgery were prospectively enrolled. Peripheral blood mononuclear cells were collected preoperatively, at 1 and 2 year follow-up. DNA methylation profiling was performed, and EA was estimated using the Horvath DNAmAge algorithm. Age acceleration was defined as EA minus CA. EA in ASD patients was compared with healthy controls. Longitudinal changes following surgery were assessed using paired testing, with directional trends evaluated using binomial tests.

Results
A total of 114 patients undergoing ASD surgery were compared with 54 healthy controls. Preoperatively, ASD patients demonstrated a greater epigenetic age acceleration (EA–CA), with a mean difference of +9.19 years (95% CI, 7.40–10.98; p<0.001), indicating that ASD patients were epigenetically older than their chronological age relative to controls. A higher proportion of ASD patients exhibited EA exceeding CA compared with healthy controls (88.9%vs29.6%; p<0.001). Among patients with 2-year follow-up (n=19), epigenetic aging rates slowed postoperatively: 79% (n=15) demonstrated a reduction in EA–CA, with a mean decrease of 2.8 years (p=0.002), suggesting partial reversal of preoperative biological aging following surgical correction.

Conclusion
Patients with ASD exhibit greater epigenetic age acceleration compared with healthy individuals, supporting ASD as a contributor to accelerated biological aging. Surgical correction is associated with postoperative deceleration of biological aging, suggesting that ASD-related biological vulnerability may be partially reversible. These findings position ASD as a potentially modifiable driver of biological aging and support DNA methylation–based metrics as dynamic biomarkers of physiologic reserve and recovery following deformity surgery.

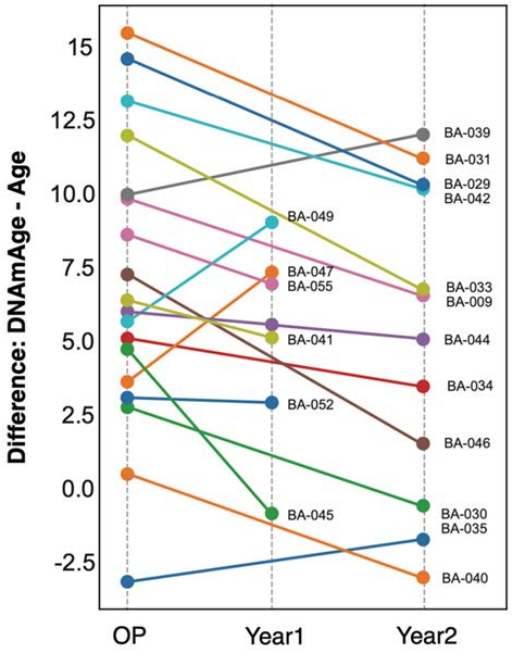

Figure 1. Longitudinal changes in epigenetic age acceleration following ASD surgery. Individual patient trajectories of epigenetic age acceleration (epigenetic age − chronological age) are shown preoperatively (OP), at 1 year, and at 2 years postoperatively. Each line represents a single patient. Most patients demonstrate a reduction in age acceleration over time, indicating postoperative deceleration of biological aging.

107. Insulin-like Growth Factor Outperforms Sarcopenia as a Predictor of Postoperative Recovery

Alexander Upfill-Brown, MD, MS; Han Jo Kim, MD; Anthony Lewis, BS; Annika Bay, MD; Atahan Durbas, MD; Andrea Pezzi, MD; Mihir Dekhne, MD; David Foley, MD; Gregory Kazarian, MD; Christopher Yoo, BS; Chierika O Ukogu, MD; Zora Hahn, BS; Matthew E. Cunningham, MD, PhD; *Francis Lovecchio, MD*

Hypothesis
Insulin-like growth factor–1 (IGF-1) will outperform MRI-based measures of sarcopenia in predicting postoperative recovery following adult spinal deformity surgery

Design
Single-surgeon retrospective cohort study.

Introduction
Recent research has focused on imaging metrics to estimate postoperative risk in ASD patients. Given that postoperative recovery is mediated by changes in the IGF-1/GH hormonal axis, serum biomarkers related to this axis may be more accurate predictors of postoperative recovery reserve.

Methods
Adults undergoing spinal fusion >4 levels for adult spinal deformity were included. Outcomes included discharge destination, length of stay (LOS), distance walked with physical therapy (PT) on postoperative day (POD) 2–3, in-hospital complications, and return to OR within 2 years. Multivariate logistic and linear regression models

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adjusted for confounders, including MRI-based measures of sarcopenia (paralumbar cross-sectional area [pCSA] and Goutallier classification).

Results

32 patients (19 male; mean age 68 years) met inclusion criteria. Mean IGF-1 z-score was 0.66 (Fig 1A). Mean follow-up 321 days (IQR 267-4580). IGF-1 z-score was linearly associated with non-home discharge (OR of 1.5, 95% CI 1.0-2.3, p = 0.031, Fig 1B) for each 0.1 unit increase). An IGF-1 z-score <0 was associated with LOS increase of 9 days (CI 4.4-13.9, p = <0.001). An IGF-1 z-score < 0 was also associated with a reduction of 75 feet walked on POD2–3 (CI 22.2-127, p = 0.010, Fig 1D). Finally, z-score < 0.5 corresponded to a higher likelihood of medical complication (OR 26.3, CI 1.4-506, p = 0.030, Fig 1E). IGF-1 was not associated with reoperation. Measures of sarcopenia were not independently associated with any outcome, and for each model, the addition of pCSA and Goutallier grade did not improve model fit.

Conclusion

IGF-1 outperforms imaging-based metrics of sarcopenia in prediction of early recovery after ASD surgery. Rather than use opportunistic, indirect measures of physiologic reserve, future comprehensive risk prediction models should consider inputs directly related to the hormonal changes that mediate the physiologic response to sterile trauma.

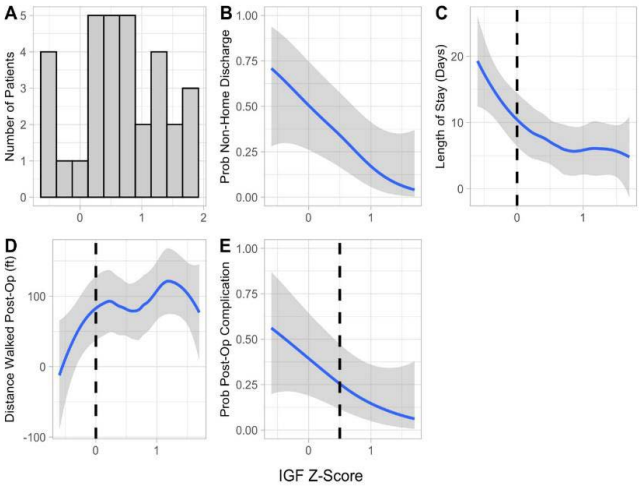


Figure 1: IGF-1 z-score distribution (A) and associations with discharge (B), LOS (C), distance walked (D), and medical complications (E). Dashed line corresponds to thresholds; shaded areas represent 95% CIs.

108. Osteosarcopenia of the Spine Drives Mechanical Complications After Thoracolumbar Adult Spine Deformity Operations

David Chung, MD; Weston Wright, BS; Justin K. Scheer, MD; Alexander Tuchman, MD; *Corey T. Walker, MD*

Hypothesis

We hypothesized that osteoporosis and sarcopenia measures are interrelated and that high-fidelity markers of bone and muscle health predict mechanical complications after adult spinal deformity (ASD) surgery.

Design

Retrospective cohort study of consecutive patients undergoing primary thoracic-to-pelvis ASD correction at a single institution (2018–2023).

Introduction

In ASD surgery, sarcopenia and osteoporosis contribute to surgical frailty and are considered risk factors for complications. However, it remains unclear which measures of muscle quality and bone density best predict poor postoperative outcomes.

Methods

We retrospectively reviewed patients undergoing ASD surgery between 2018 and 2023. Bone density was assessed using femoral neck DXA T-scores, L1 Hounsfield units (HU), and vertebral bone quality (VBQ) scores. Biomechanical CT (BCT) was used to measure volumetric bone mineral density (vBMD) and bone strength (BS) at L1. Sarcopenia was assessed using Goutallier grading and cross-sectional area (CSA) of the psoas, multifidus, and erector spinae (ES). Multivariate logistic regression analyzed predictors of reoperation for mechanical complications.

Results

125 patients were included in the study with mean follow-up of 30 months, of which 107 had BCT analysis. 37(30%) patients had reoperations for mechanical failure. On multivariate regression, the vBMD ($p<0.05$), but not BS, was an independent osteoporosis factor related to re-operation. Regarding sarcopenia, only psoas CSA ($p<0.05$), but not multifidus or ES CSA or Goutallier grade, was an independent risk factor for re-operation. Outside of these bone and muscle quality measures, only the presence of a pure sagittal deformity was an independent predictor ($p<0.05$). There was a significant relationship between ES CSA and vBMD ($r=0.19$, $p<0.05$) and between psoas CSA and BS ($r=0.21$, $p<0.05$), suggesting that there is a deep inter-relationship between bone and muscle quality in this population that may drive results, with overlapping phenotypes of disease states.

Conclusion

Biomechanical CT analysis with vBMD measurements, not HU or DXA, was independently predictive of mechanical complications in our ASD cohort. Psoas CSA was independently predictive. We found relationships between bone density, strength and muscle volume. These findings suggest that both osteoporosis and sarcopenia need to be evaluated pre-operatively separately and together.

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

PODIUM ABSTRACTS

109. Preoperative Musculoskeletal Burden Predicts 1-Year Junctional Complications After Adult Spinal Deformity Surgery

Bassel G. Diebo, MD; *Joseph E. Nassar, BS;* Michael Farias, BS; Micheal Raad, MD; Feyza Achilova; Virginie Lafage, PhD; Renaud Lafage, MS; Richard Hostin, MD; Peter G. Passias, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Themistocles S. Protopsaltis, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Munish C. Gupta, MD, MBA; Brett Rocos, MD, FRCS; Jeffrey Mullin, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Christopher P. Ames, MD; Lawrence G. Lenke, MD; Sang Hun Lee, MD, PhD; Khaled M. Kebaish, MD; Shay Bess, MD; Alan H. Daniels, MD; International Spine Study Group

Hypothesis
Higher preoperative musculoskeletal(MSK) burden is associated with greater distal compensation and independently predicts junctional complications at 1 year following adult spinal deformity(ASD) surgery.

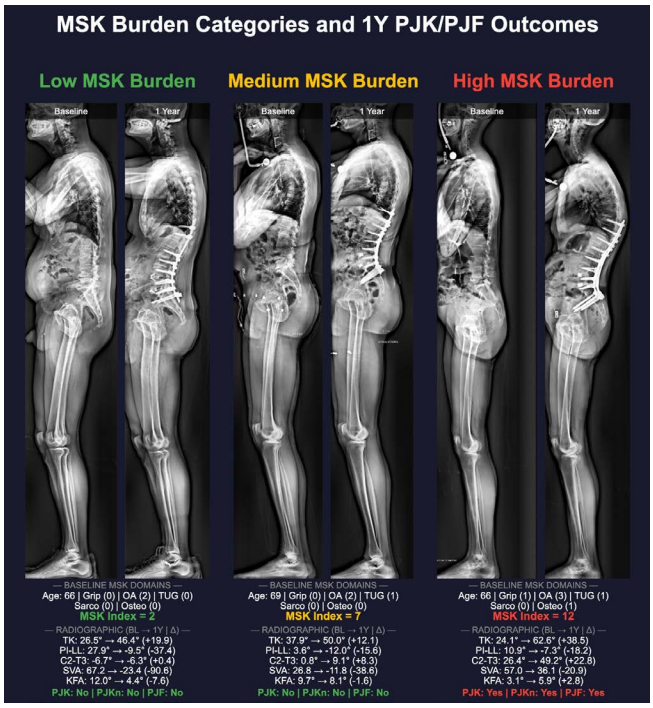
Design
Retrospective analysis of prospectively collected data.

Introduction
Junctional complications remain a major source of morbidity after ASD surgery and may be influenced by patient-level MSK health and compensatory reserve. We applied a novel multidomain MSK Burden Index to quantify cumulative MSK burden(mobility, muscle mass, strength, bone quality, joint health) and predict junctional outcomes.

Methods
Primary ASD patients with full-standing radiographs and 1-year outcomes undergoing long-segment fusion with pelvic fixation and UIV≥T12 were included. Validated cutoffs were used:Timed Up & Go 3m(TUG) 0(<10s), 1(10–20s), 2(≥21s); Grip 0/1 weak(<27kg men,<16kg women); Thigh sarcopenia 0/1 if both AP thigh(<12.47cm men,<10.68cm women) and LAT quadriceps thickness(<3.23cm men,<2.20cm women); Osteoporosis 0/1(T-score≤−2.5); osteoarthritis(OA) burden 0(none), 1(knee only), 2(hip only), 3(both)(KL≥3). MSK burden was quantified using:MSK Index=3×Grip weakness+1×OA burden+5×TUG+4×Thigh sarcopenia+1×Osteoporosis(range 0–21), stratified low(0–5), intermediate(6–10), high(≥11) MSK burden.

Results
214 ASD patients were included: low(51.4), intermediate(35.0), high(13.6%). Increasing MSK burden was associated with older age(60.7 vs 67.2 vs 71.0 years) and higher Edmonton frailty(2.0 vs 3.5 vs 5.0). UT UIV(T1–T6) was more common in low burden(67.3 vs 41.3 vs 41.4%) (all p<0.05). Baseline TK(35.1 vs 34.2 vs 41.2°) was similar(p>0.05) but higher burden had greater SVA(33.7 vs 64.2 vs 74.5mm), CL(8.5 vs 9.7 vs 20.1°), KFA(1.7 vs 5.5 vs 6.2°)(p<0.05). At 1 year, higher burden had greater SVA(12.1 vs 22.2 vs 36.5mm), TK(45.3 vs 49.4 vs 52.5°), KFA(0.1 vs 4.4 vs 6.2°)(p<0.05). Junctional complications increased with burden: PJK(40.2 vs 45.3 vs 64.3%), PJKn(11.8 vs 21.3 vs 37.9%), PJF(7.5 vs 13.3 vs 21.4%) (p<0.05). Adjusted models confirmed increasing MSK burden category predicted PJK(OR 1.65;AUC 0.66), PJKn(OR 2.25;AUC 0.78), PJF(OR 2.66;AUC 0.78)(p<0.05).

Conclusion
Increasing preoperative MSK burden identifies patients with lower extremity compensation and higher risk of 1-year junctional complications, validating its potential role in ASD preoperative risk stratification and surgical counseling.



110. Adult Spinal Deformity Surgery in Patients With Lower Extremity Weakness: Do Preoperative Neurologic Deficits Influence Outcomes?

Scott Zuckerman, MD; Harsh Jain, MBBS; Byron F. Stephens, MD; Thomas Buell, MD; Nima Alan, MD; Sang Hun Lee, MD, PhD; David O. Okonkwo, MD, PhD; Stephen J. Lewis, MD, FRCS(C); Jeffrey Mullin, MD; Peter G. Passias, MD; Darryl Lau, MD; *Anthony L. Mikula, MD;* Jay D. Turner, MD, PhD; Joshua Bunch, MD; Brandon B. Carlson, MD; Michael P. Kelly, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Eric O. Klineberg, MD; Han Jo Kim, MD; Breton Line; Themistocles S. Protopsaltis, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Khaled M. Kebaish, MD; Paul Park, MD; Praveen V. Mummaneni, MD; Munish C. Gupta, MD, MBA; Jeffrey Gum, MD; Alan H. Daniels, MD; Bassel G. Diebo, MD; Richard Hostin, MD; Justin K. Scheer, MD; Lawrence G. Lenke, MD; Frank Schwab, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; International Spine Study Group

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Hypothesis
Preoperative lower extremity motor deficits confer worse outcomes in adult spinal deformity (ASD) surgery compared to no preoperative deficits.

Design
Retrospective analysis of prospective multicenter study

Introduction
We evaluated the impact of preoperative lower extremity motor deficits on: 1) perioperative morbidity, 2) complications, and 3) patient-reported outcome measures (PROMs).

Methods
A retrospective cohort study (2009-18) was performed of patients undergoing ASD surgery. Primary exposure was preoperative lower extremity motor deficits (lower extremity motor score <50). Primary outcomes were: 1) perioperative morbidity: estimated blood loss, operative times, and length of stay, 2) complications/reoperation, and 3) 2-year PROMs: Oswestry Disability Index (ODI) scores, Short-Form 36 physical function (SF36-PF), and Scoliosis Research Society-22r (SRS-22r) satisfaction. Univariate/multivariable regression was performed, controlling for age, sex, body mass index (BMI), and total instrumented levels.

Results
Of 1,290 patients undergoing ASD surgery with baseline neurologic motor exams, mean age was 61.7±13.5 years, 70.3% were female. 323 patients (25.0%) had preoperative lower extremity motor deficits. Perioperative Outcomes: Preoperative lower extremity motor deficits were independently associated with longer operative times (β:17.3, 95%CI:0.4-34.1, p=0.044). Complications: Preoperative motor deficits were independently associated with new postoperative motor deficits (OR:1.9, 95%CI:1.1-3.1, p=0.018) and major complications (OR:1.6, 95%CI:1.2-2.3, p=0.006). PROMs: Preoperative motor deficits were significantly associated with higher/worse 2-year ODI (β:4.5, 95%CI:1.5-7.4, p=0.003) and lower/worse SF36-PF (β:-2.0, 95%CI:-3.7- -0.4, p=0.018). 52.4% of patients with motor deficits achieved full lower extremity recovery (score 50/50) by 6-weeks postoperatively, but motor recovery was not associated with 2-year PROMs (all p>0.05).

Conclusion
Preoperative lower extremity motor deficits before ASD surgery were independently associated with longer operative times, new motor deficits, major complications, and worse long-term disability. These data support potentially intervening before a neurologic deficit ensues, in addition to counseling these patients of the more challenging postoperative course.

111. Impact of Enhanced Recovery After Surgery (ERAS) Protocol on Postoperative Pain and Clinical Recovery in Adult Spinal Deformity Surgery

Yu-Cheng Yao, MD; Jing-Yang Liou, MD, PhD; Hsin-Yi Wang, MD; Po-Hsin Chou, MD, PhD; Shih-Tien Wang, MD

Hypothesis
This study aimed to evaluate the effects of an Enhanced Recovery After Surgery (ERAS) protocol on perioperative outcomes and postoperative analgesic efficacy in patients undergoing Adult Spinal Deformity (ASD) correction.

Design
Prospective cohort study conducted between March 2021 and December 2024.

Introduction
While ERAS protocols have demonstrated benefits in accelerating recovery and ensuring patient safety for ASD correction, their impact on postoperative analgesic efficacy and clinical outcomes remains underexplored.

Methods
Seventy-seven ASD patients who underwent posterior-only correction surgery at a single institution were included. Patients receiving the ERAS protocol were prospectively enrolled in the ERAS group (n=40), while those without ERAS were retrospectively identified from institutional databases as controls (non-ERAS group, n=37). Primary outcomes included surgical time, estimated blood loss (EBL), postoperative nausea and vomiting (PONV) incidence, total morphine sulfate equivalent (MSE) consumption, and visual analog scale (VAS) pain scores. Secondary outcomes encompassed perioperative recovery milestones: time to ambulation, oral intake initiation, Foley catheter removal, drainage tube removal, and length of stay (LOS).

Results
The ERAS group demonstrated significantly shorter operative times (359 ± 80 vs. 433 ± 143 minutes, p=0.008) and reduced MSE consumption (18.8 ± 20.4 vs. 77.7 ± 51.0 mg, p<0.001) compared to controls. Fewer ERAS patients required patient-controlled analgesia (45% vs. 70.3%). The protocol group achieved an average of 1 day earlier functional recovery, with reduced time to ambulation, oral intake initiation, and catheter removal. Mean VAS scores were consistently lower in the ERAS group at postoperative day 1(1.9 ± 1.1 vs. 4 ± 1.2, p<0.001), day 2 (2.0 ± 1.1 vs. 3.4 ± 0.8, p<0.001), and day (2.1 ± 1.2 vs. 3.2 ± 0.8, p<0.001). Hospital stays were also significantly shorter in the ERAS group (9.4 vs. 10.9 days, p=0.005).

Conclusion
Implementation of an ERAS protocol for ASD correction surgery significantly improves perioperative recovery trajectories, enhances postoperative pain control, and optimizes overall recovery quality. These findings support the standardized adoption of ERAS principles in adult spinal deformity surgery.

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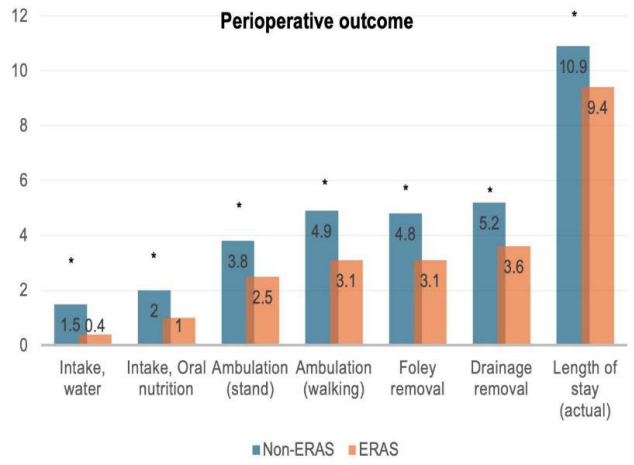

Recovery timelines between groups following ERAS and non-ERAS protocols. * statistically significant

112. Implications of Non-Tobacco Nicotine Use on Adult Spinal Deformity Surgery

Shanthi Deivanayagam, BS; Kendyl Howell, BS; Bradley M. Rao, BS; Madeline Hasson, BS; Omkar Anaspure, BS; Ziad Hassan, BS; Josephine R. Coury, MD; Taylor Jackson, MD; Michael Strong, MD, PhD, MS; David Casper, MD; Amrit Khalsa, MD; Lawrence G. Lenke, MD; Andrew S. Zhang, MD; *Tensae Assefa, MD*

Hypothesis
To evaluate whether non-tobacco nicotine dependence (NTND) is associated with increased risk of pseudarthrosis and postoperative complications following adult spinal deformity (ASD) surgery.

Design
Retrospective cohort study.

Introduction
As non-tobacco nicotine use (vaping, pouches) has increased in popularity, its impact on ASD surgery remains unclear. This study aims to investigate the association between non-tobacco nicotine dependence (NTND) on pseudarthrosis and medical complications after ASD surgery.

Methods
The TriNetX U.S. Collaborative Network was queried for adults (≥18 years) undergoing ASD surgery between 2016 and 2026. Patients with documented NTND were propensity score–matched 1:1 to controls with no tobacco or nicotine use. Postoperative outcomes were assessed at 90 days, 1 year, and 2 years, including pseudarthrosis, hardware failure, proximal junctional kyphosis (PJK), thromboembolic events, and medical complications.

Results
A total of 2,271 patients were included in each matched cohort. At 90 days postoperatively, no significant differences were observed between NTND and control cohorts in hardware failure, thromboembolic events, infectious, neurologic, pulmonary, or other medical complications (all p>0.05). At 1 year, there were no significant differences in rates of pseudarthrosis, hardware failure, pulmonary embolism, or PJK. At 2 years, pseudarthrosis (9.2% vs. 10.2%, p=0.249) and PJK (2.9% vs. 2.9%, p=1.00) remained similar between groups; however, NTND was associated with a significantly higher rate of hardware failure compared with controls (10.5% vs. 8.4%, p=0.017).

Conclusion
Non-tobacco nicotine use was associated with significantly increased risk of hardware failure at two years after major adult deformity surgery. PJK, venous thromboembolic events, neurological or medical complications at any time point up to two years postoperatively. Surgeons should counsel patients of risks with NTND preoperatively.

113. Utility of Chemical Anticoagulation After Adult Spinal Deformity Surgery: A Retrospective Cohort Study

Bradley M. Rao, BS; Ziad Hassan, BS; Amanda M. Moser, MD, BA; Omkar Anaspure, BS; Madeline Hasson, BS; *Tensae Assefa, MD;* Nnaemeka Okorie, MD; Josephine R. Coury, MD; Taylor Jackson, MD; Michael Strong, MD, PhD, MS; David Casper, MD; Amrit Khalsa, MD; Lawrence G. Lenke, MD

Hypothesis
Chemical anticoagulation after adult spinal deformity surgery decreases rates of postoperative venous thromboembolic events

Design
Retrospective cohort study

Introduction
Venous thromboembolism (VTE), including deep vein thrombosis (DVT) and pulmonary embolism (PE), is a clinically significant complication following adult spinal deformity (ASD) surgery. Many risks and benefits exist and remain controversial regarding chemical prophylaxis after such surgeries. Guidance regarding optimal postoperative chemical VTE prophylaxis protocols following surgery remains unclear.

Methods
The TriNetX federated research network was queried to identify adults (≥18 years) undergoing ≥7 level posterior ASD surgery between 2015 and 2025. Patients with prior PE and DVT within 1 year on or before surgery, were excluded. Cohorts were defined by receipt of postoperative chemical anticoagulation therapy within 3 days of surgery versus no anticoagulation. Propensity score matching (1:1) based on demographics, BMI, and major comorbidities was performed, and outcomes were compared in the matched cohorts.

Results
The initial cohorts included 2,294 anticoagulated and 4,694 untreated patients. After propensity matching, 2,270 patients (48.4%/51.6% M/F; mean age 66.6 ± 13.9 years) were retained in the anticoagulated cohort and

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2,270 patients (47.3%/52.7% M/F; mean age 67.4 ± 14.1 years) were retained in the untreated cohort. Thirty-day VTE occurred in 63/2,270 (2.8%) untreated patients compared with 42/2,270 (1.9%) anticoagulated patients (risk ratio 1.500, 95% CI 1.020–2.207; p=0.038). Thirty-day postoperative bleeding occurred in 37/2,270 (1.6%) untreated patients and 33/2,270 (1.5%) anticoagulated patients (risk ratio 1.121, 95% CI 0.704–1.786; p=0.630).

Conclusion

Over the past decade, there were two times as many patients that were not anticoagulated after spinal deformity surgery than received chemical anticoagulation. In this large multicenter cohort, postoperative chemical anticoagulation after adult spinal deformity surgery was associated with a significantly lower 30-day incidence of venous thromboembolism without an increase in postoperative bleeding. These findings suggest a potential protective association of early chemical prophylaxis following ASD surgery, though prospective studies are needed to define optimal patient selection and prophylaxis protocols.

114. Diagnostic and Predictive Value of Upright–Supine Imaging for Treatment Selection in Degenerative Lumbar Spondylolisthesis - A Two-Year PROM Based Comparison with Flexion Extension Radiographs

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Hypothesis

We hypothesized that segmental instability assessed by upright-supine imaging (USI) in patients with degenerative lumbar spondylolisthesis (DLS) would demonstrate stronger associations with postoperative outcomes than flexion-extension radiographs (FER), with greater instability predicting inferior outcomes after decompression-only surgery but superior outcomes after fusion.

Design

Retrospective cohort study.

Introduction

The optimal surgical management of DLS remains controversial. FER are commonly used to assess segmental instability but may underestimate clinically relevant instability due to reliance on active patient motion. USI, comparing upright radiographs with supine MRI, may offer a more sensitive alternative by assessing slip dynamics under physiological loading.

Methods

In 254 patients treated with decompression-only or fusion surgery, slip dynamics were quantified on FER and USI as between-position difference in relative translation (ΔRT; Fig. 1). Multivariable regression and interaction analyses assessed associations with two-year ODI and LBP improvement. ROC analyses identified thresholds for clinically meaningful improvement.

Results

USI identified significantly more unstable segments than FER in both cohorts (p<0.001). ΔRTUSI was independently associated with improvement in ODI and LBP (p<0.001), whereas ΔRTFER showed no association (p=0.434; p=0.358). USI-derived instability demonstrated inverse effects by surgical strategy: greater ΔRT_USI predicted less improvement after decompression-only but greater improvement after fusion (p<0.001). ROC analyses identified thresholds of 7.9% for decompression-only and 5.7% (ODI)/5.3% (LBP) for fusion.

Conclusion

USI detects clinically meaningful occult instability missed by FER and demonstrates significant associations with postoperative outcomes. The impact of instability differs by surgical strategy, highlighting the value of integrating USI-derived slip dynamics into preoperative assessment for individualized surgical decision-making.

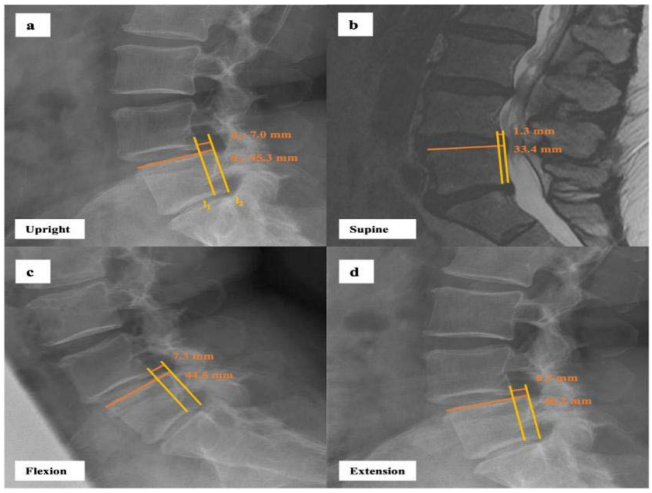

Figure 1. Sagittal slip dynamics in a 60-year-old patient with L4–5 degenerative spondylolisthesis across upright (A), supine (B), flexion (C), and extension (D) positions. Relative translation varied by only 1.9% between flexion-extension but increased to 11.6% between upright-supine imaging.

115. More is better! Multicenter Analysis of Failure Rates and Risk Factors Between Bilateral Single and Multiple Pelvic Fixation in Adult Spinal Deformity Surgery

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Sohaib Hashmi, MD; Scott Zuckerman, MD; Daniel M. Sciubba, MD; Peter G. Passias, MD

Hypothesis
Multiple pelvic fixation (MPF) in adult spinal deformity (ASD) surgery significantly reduces mechanical failure requiring reoperation compared with single pelvic fixation (SPF).

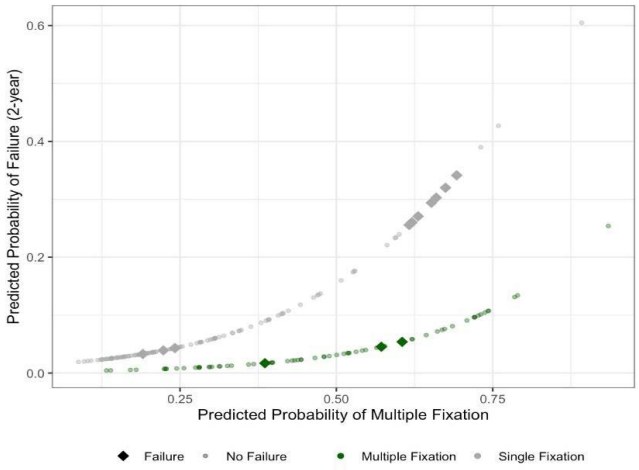
Design
Retrospective analysis of a multicenter prospective ASD database.

Introduction
Despite biomechanical rationale supporting MPF, clinical evidence remains limited. We compared MPF versus SPF outcomes in 196 ASD patients across three centers to evaluate lumbosacral junction stability.

Methods
196 ASD patients from three centers with ≥2-year follow-up underwent fusion to the sacrum meeting SRS-Schwab radiographic criteria. All patients underwent L5–S1 interbody arthrodesis, multilevel fusion (≥5 levels), three-column osteotomy, or multiple two-column osteotomies. MPF (≥3 pelvic fixation points with ≥1 bilateral dual construct) was compared with SPF (bilateral two-screw fixation). Failure was defined as distal implant or construct failure requiring reoperation, excluding proximal failure or adding-on. Propensity scores were adjusted for demographic, operative, and radiographic variables due to preferential fixation use in greater deformity. Propensity-adjusted logistic regression was used to assess failure risk, with sensitivity analyses for low event rates.

Results
Of the 196 patients, 50.0% were female, with a mean age/BMI of 69.9 years/28.7 kg/m². Mean preoperative PT/pelvic incidence was 25.1°/54.8°. Mean fusion length was 8.8 levels, with an average of 2.72 pelvic screws (mean diameter 8.71 mm, mean length 82.04 mm; 49.5% S2AI, 44.9% iliac, 5.6% both). Seventy-two patients (36.7%) received MPF, with 3 failures (4.2%), and 124 (63.3%) received SPF, with 11 failures (8.9%). Compared with SPF, MPF was associated with an 82.4% reduction in failure risk at 2 years (adjusted OR 0.18; 95% CI 0.03–0.67; p=0.019), adjusting for propensity score incorporating age, BMI, and deformity severity. A 0.10 increase in the latent propensity score was associated with a 72% increased failure risk (adjusted OR 1.72; 95% CI 1.29–2.36; p<0.001).

Conclusion
In ASD patients, MPF significantly reduces mechanical failure at 2 years compared with SPF, even after adjustment for baseline severity of deformity. These findings support the use of MPF constructs to improve mechanical and clinical durability in patients undergoing corrective surgery.



Pelvic Fixation and Failure Risk

116. Comparison of Perioperative Outcomes and Frailty in Minimally Invasive and Open Surgery for Adult Spinal Deformity: A Multi-Center Analysis

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Hypothesis
Minimally invasive surgery (MIS) for adult spinal deformity (ASD) may have better perioperative outcomes compared to open surgery in a modern cohort, especially in patients with frailty.

Design
Retrospective analysis of a multicenter prospective database

Introduction
As technology and clinical pathways for MIS have evolved, it is unclear if this has translated into better perioperative outcomes.

Methods
ASD patients who underwent surgery between 2022-2025 (n=1068) were classified as MIS (n=156) or open (n=912). Baseline alignment and demographic characteristics, including Edmonton frailty index, were compared. Perioperative outcomes of interest were length of hospital (LOS) and ICU stay, discharge disposition, operative time, blood loss, and transfusion. Outcomes of interest in the 90d postoperative period were complication (any), reoperation, or readmission. 2:1 propensity

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score matching (open to MIS) was based on baseline alignment abnormalities (PI-LL, PT, GCM, lumbar Cobb, GCM). A doubly robust estimate for LOS was created based on social (opioid MME, work and living status) and surgical factors (number levels fused, osteotomies, and PI-LL and SVA correction).

Results

Before matching, the MIS cohort was older (67.6 yrs ± 9.7 vs 61.8 ± 15.0; p<0.001), had more baseline neurological deficits (49% vs 36.6%; p=0.04), and higher frailty (3.84 ± 2.2 vs 3.38 ± 2.4; p=0.02); the open cohort had more complex baseline deformity (higher SVA & GCM; p<0.01). After 2:1 matching on baseline radiographic alignment with 68 MIS patients vs 136 open patients, the MIS group was still older (67.7 yrs±9.1 vs 58.6±17.5; p<0.001) and more frail (3.66±2.2 vs 3.0±2.2; p=0.05). After prognostic outcome regression, a doubly robust estimate yielded LOS of 4.8 days±2.3 in the MIS group and 7.5 days±3.7 in the open group (ATE=-2.7 days; p<0.001). MIS had similar operative time, but less EBL, fewer transfusions, and fewer ICU admissions (p=0.01 to <0.001). 90-day readmission (p=0.001) and minor complication rates were lower (p=0.002). A similar number of patients went to inpatient rehab or nursing facility after surgery (26.4% MIS vs 35.5% open, p=0.45).

Conclusion

In select patients, MIS may have advantages in perioperative outcomes, including 2.7-day shorter LOS. This may have implications for surgeons who are considering MIS or open surgery for increasingly frail ASD patients in the population.

ISSG MIS vs Open 90d outcomes (2022-2025, Propensity matched on alignment)

Outcome	MIS 2020-2025	Open 2020-2025	p-value
LOS	4.9 days ± 2.2	7.6 days ± 3.4	p <0.001
90d readmission	5.1% (8/156)	14.1% (44/312)	p=0.001
90d reoperation	1.2% (2/156)	4.4% (14/312)	p=0.10
90d minor complication (any)	10.7% (14/156)	21.4% (62/312)	p=0.002
Operative time	414min ± 169	440min ± 146	p=0.09
90d major complication (any)	2.7% (4/156)	4.5% (14/312)	p=0.45
EBL	374mL ± 359	1377mL ± 1053	p<0.001
Transfusion	9.6% (15/156)	57.3% (179/312)	p<0.001
ICU admission	6.4% (10/156)	64.1% (200/312)	p<0.001
ICU LOS	2.3 days ± 2.1	2.5 days ± 3.5	p=0.79
Rehab/SNF	26.4% (18/68)	35.5% (44/135)	p=0.45
Rehab/SNF LOS	13.3 days ± 6.8	12.2 days ± 8.2	p=0.35

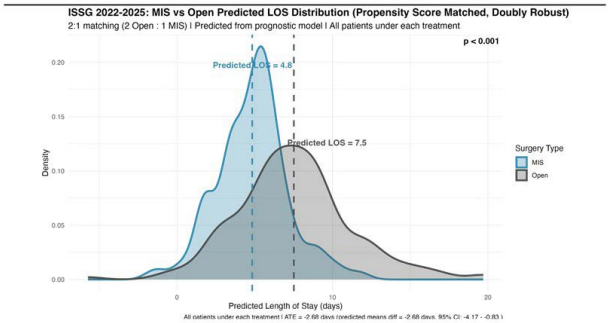

Figure 1. MIS for ASD has better perioperative outcomes in a matched patient sample.

117. Early Postoperative Neurologic Course is the Primary Determinant of Long-Term Lower Extremity Motor Recovery After ASD Surgery

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Hypothesis

Baseline(BL) pt vulnerability & early postoperative neurologic status are associated w/ maintenance/improvement in lower extremity motor scores(LEMS) at 2yrs postop

Design

Prospective, multicenter

Introduction

How baseline characteristics and early postop neurologic events influence long-term LEMS remains unclear

Methods

351 ASD pts undergoing open & MIS surgery w/ ≥2yr fu were dichotomized as maintained/improved(G1) vs deteriorated(G2) at immediate postop(IPO) & 2yrs. Demographics, operative, XR, & neurologic data were compared. Multivariate logistic regression w/ backward elimination retained a priori confounders was built to discern significant factors

Results

At BL, 72% of pts had normal LEMS. At IPO, 10.5%(n=37) experienced LEMS decline (mean −3.6 points), w/ the largest deficits at the R L2(−0.51, p=0.005) and L L5(−0.46, p=0.0076) nerve roots. Despite similar BL LEMS, G2 pts were older, had higher BMI, greater sagittal malalignment, & underwent larger deformity corrections(p<0.05). Operatively, G2 pts had higher ASA scores, more decompressions & PSOs, but fewer PCOs(p<0.05); no differences were observed between open & MIS approaches. Neurologically, G2 pts experienced more IONM changes resulting in new motor deficits(40.5% vs 2.2%, p<0.01), frequently w/in 24hrs & often impairing ambulation (13.5% vs 0%, p<0.01). Multivariable regression adjusting for age, frailty, comorbidity burden, BL LEMS, SVA, & ΔT4PA identified higher ASA score(OR=0.35, p=0.0407), IONM changes(OR=0.02, p=0.0037), acute neurologic deficit onset(OR=0.09, p=0.0228), & motor deficit at discharge(OR=0.03, p<0.0001) as independently associated w/ IPO LEMS decline(AUC=0.88). By 2yrs, 76% (28/37) improved, w/ 89% recovering to normal LEMS. Conversely, 12 pts w/ preserved IPO LEMS developed delayed

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decline(mean −4.1) & were older, frailer, & more comorbid (p<0.05). Adjusted regression identified lower W6 LEMS(OR=1.32, p=0.0096) & ambulation-limiting deficits at discharge(OR=0.04, p=0.0108) as independently associated w/ failure to maintain/improve LEMS at 2yrs(AUC=0.87).

Conclusion

Although frailty & comorbidity burden reflect underlying pt vulnerability, early postop neurologic deficit limiting ambulation emerged as the primary determinant of long-term LEMS recovery after ASD surgery. Pts who experienced motor deficits impacting ambulation were significantly less likely to maintain/improve LEMS at 2yrs F/U.

Multivariable logistic regression analysis to discern significant factors associated with maintaining/improvement in LEMS by 1st postop		
	Adjusted OR [95% CI]	**p-value**
Age	0.96 (0.92 – 1.01)	0.0844
Frailty	0.92 (0.73 – 1.16)	0.4733
Number of Comorbidities	1.15 (0.84 – 1.57)	0.3929
Baseline LEMS	0.86 (0.68 – 1.10)	0.2368
BMI	0.92 (0.83 – 1.01)	**0.0691**
Baseline SVA	1.01 (1.00 – 1.02)	**0.0947**
Δ T4PA	1.05 (0.99 – 1.11)	**0.1252**
ASA Score	0.36 (0.13 – 0.96)	**0.0407**
IONM Deficit Onset		
Intraoperative	0.02 (0.00 – 0.29)	**0.0037**
Acute Postop	0.09 (0.01 – 0.71)	**0.0228**
Delayed Postop	2.43 (0.21 – 28.22)	**0.4789**
Motor Deficit prior to discharge	0.03 (0.01 – 0.18)	**<0.0001**
Model p-value <0.0001, AUC=0.88		
Multivariable logistic regression analysis to discern significant factors associated with maintaining/improvement in LEMS by 2yr postop		
	Adjusted OR [95% CI]	**p-value**
Age	0.95 (0.90 – 1.01)	0.0917
Frailty	0.82 (0.65 – 1.03)	0.0803
Number of Comorbidities	0.82 (0.62 – 1.09)	0.1657
Baseline LEMS	0.91 (0.72 – 1.14)	0.4160
LEMS at 1st Postop Visit	1.33 (1.07 – 1.64)	**0.0096**
IONM alert resulting in a new postop deficit	0.31 (0.07 – 1.29)	**0.1083**
LE deficit involving impact on ambulation prior to discharge	0.04 (0.004 – 0.48)	**0.0108**
Model p-value <0.0001, AUC=0.87		

118. Neurologic Deficit Recovery After Revision Pedicle Subtraction Osteotomy for Fixed Sagittal Imbalance in Previously Fused Adults and its Impact on Patient-Reported Outcomes

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Hypothesis

Motor weakness persisting beyond the immediate postoperative period after revision PSO is associated with worse long-term patient-reported outcomes than early recovery.

Design

Retrospective cohort study of adults in a prospectively maintained database.

Introduction

Revision pedicle subtraction osteotomy (PSO) can restore sagittal alignment in rigid sagittal imbalance. Postoperative motor weakness occurs, but recovery kinetics and prognostic implications remain unclear.

Methods

Adults undergoing revision posterior fusion with a Schwab grade 3-4 lumbar PSO for fixed sagittal imbalance (2015-2022) were reviewed. Motor strength (0-5) across L2-S1 myotomes was recorded preoperatively and at POD5, 6 weeks, 3 months, and latest follow-up. Clinically meaningful weakness was defined as ≤3/5 in any myotome. PROs (SRS-22r, VAS back/leg pain, ODI) were collected preoperatively and at follow-up. Latest follow-up PROs were compared by weakness status at POD5, 6 weeks, and 3 months.

Results

Forty-nine patients (mean age 63 years; mean follow-up 2.0 years (range 1.0-6.9)) were included. Clinically meaningful weakness was present in 4% preoperatively, 27% on POD5, 12% at 6 weeks, and 10% at 3 months. No patient had persistent ≤3/5 weakness at latest follow-up. Weakness at 6 weeks was associated with worse SRS-22r Function (2.5 vs 3.3, p=0.033), Self-Image (2.8 vs 3.7, p=0.012), Mental Health (3.1 vs 4.0, p=0.008), and Satisfaction (2.9 vs 4.5, p<0.001) at latest follow-up. At 3 months, patients with weakness had lower Satisfaction (2.6 vs 4.5, p=0.004) and higher VAS leg pain (6.0 vs 3.9, p=0.009) at latest follow-up. Across the cohort, most PROs and sagittal alignment improved significantly by latest follow-up.

Conclusion

Clinically meaningful motor weakness after revision PSO is common early and typically resolves. However, weakness persisting to 6 weeks or 3 months is associated with worse long-term satisfaction and higher leg pain. These data link early neurologic recovery trajectories with long-term outcomes and support close neurologic surveillance, counseling, and targeted rehabilitation for patients with delayed strength recovery.

Section	Metric	Timepoint / Comparison	Value	p value
Demographics	Population		Adults undergoing revision posterior fusion with Schwab grade 3-4 lumbar PSO for fixed sagittal imbalance (2015-2022).	
	Clinically meaningful weakness definition		Motor strength ≤3/5 in any L2-S1 myotome.	
	N		49	
	Mean age, years		63	
	Mean follow-up, years		2.0	
Weakness incidence	Clinically meaningful weakness (≤3/5), % of patients	Preoperative	4%	
	Clinically meaningful weakness (≤3/5), % of patients	Postoperative day 5	27%	
	Clinically meaningful weakness (≤3/5), % of patients	6 weeks	12%	
	Clinically meaningful weakness (≤3/5), % of patients	3 months	10%	
	Clinically meaningful weakness (≤3/5), % of patients	Latest follow-up	0% (no persistent ≤3/5 weakness)	
Latest follow-up PROs by weakness status at 6 weeks	SRS-22r Function	Weak vs not weak	2.5 vs 3.3	0.033
	SRS-22r Self-Image	Weak vs not weak	2.8 vs 3.7	0.012
	SRS-22r Mental Health	Weak vs not weak	3.1 vs 4.0	0.008
	SRS-22r Satisfaction	Weak vs not weak	2.9 vs 4.5	<0.001
Latest follow-up PROs by weakness status at 3 months	SRS-22r Satisfaction	Weak vs not weak	2.6 vs 4.5	0.004
	VAS leg pain (0-10)	Weak vs not weak	6.0 vs 3.9	0.009

Notes: Values are means unless otherwise stated. PROs are reported at latest follow-up and stratified by presence of ≤3/5 weakness at the indicated earlier timepoint. SRS-22r = Scoliosis Research Society-22r; VAS = Visual Analog Scale.

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119. Understanding Bilateral MEP Changes during Cord Level Spinal Deformity Surgery: Etiology, Significance and Response

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Hypothesis
MEP alert patterns vary based on the preceding event

Design
Prospective multicenter international observational

Introduction
During spine surgery IONM can help reduce the risk of neurologic deterioration.This study aims to enhance our understanding of b/l MEP alerts that occur during cord-level spine deformity surgery.

Methods
20 international centers prospectively documented IONM (EMG, SSEP, MEP), demographics, radiographs and surgical events of patients(10-80 yrs) undergoing correction for a major Cobb>80° or a cord-level osteotomy. Alerts were classified as MEP-only or MEP w/SSEP changes (MEP+SSEP). MEP alerts were defined as loss of ≥50% MEP amplitude from baseline. Surgical(exposure, implant placement, osteotomy, correction/rod placement, traction) and nonsurgical(systemic, anesthesia, technical) events preceding the alert were recorded. Relationships between b/l MEP alerts with mechanical events (osteotomies or implant placement) was assessed.

Results
Out of 349 cord-level surgeries, 25 pts experienced 34 b/l MEP alerts with 19 associated w/surgical events, 9 w/ nonsurgical events, and 6 w/a combination. 85% of the b/l MEP alerts were MEP-only. 76% of the time a surgical event preceded a b/l MEP-only alert. Correction/rod insertion was the most common surgical event preceding the alert(16/22), followed by mechanical event(5/22) and other(3/22). 15% b/l MEP alerts were associated with SSEP changes. A surgical event preceded the MEP+SSEP alert 60% of the time. All MEP+SSEP alerts w/surgical preceding event occurred after a mechanical event. 80% b/l MEP alerts w/surgical preceding event had recovery at closure. Recovery rates varied based on the preceding event with 88% of alerts recovered after a mechanical event and 76% recovered after a nonmechanical event. Pts with a b/l MEP alert, 20% developed a neurological deficit immediately postop with 15% from the b/l MEP-only and 40% from the b/l MEP+SSEP. At discharge, 8% had a neurological deficit in MEP-only and 0 in MEP+SSEP group.

Conclusion
Bilateral MEP changes during cord-level deformity surgery are rare and usually linked to surgical events. Isolated MEP alerts are often related to correction or rod insertion, suggesting ischemia. MEP+SSEP changes after surgery are typically tied to mechanical events, with higher intraoperative recovery rates following corrective maneuvers

120. Development of an Intraoperative Assessment Tool for Predicting Critical Care Transfer Following Major Posterior Spine Surgery

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Hypothesis
An intraoperative risk scoring algorithm, using patient and surgical variables, can accurately predict the likelihood of unplanned critical care transfer within 24 hours following major posterior spine surgery.

Design
This single-institution retrospective study used patient-specific intraoperative measures to develop a clinical risk score for predicting unplanned ICU transfers within 24 hours.

Introduction
Identifying patients at risk of adverse events is a cornerstone of improving outcomes in major surgery, yet allocating care resources remains challenging. This retrospective study aimed to develop a risk score to predict the need for unplanned critical care transfer within 24 hours of major spine surgery.

Methods
This retrospective study (2021–2024) included adults undergoing spine surgery spanning ≥7 levels. The primary outcome was unplanned ICU transfer within 24 hours post-surgery, with a stay exceeding 24 hours. Candidate predictors were selected based on clinical relevance and assessed in a multivariable backward selection logistic regression model. Regression coefficients were used to develop a scoring algorithm using Sullivan's method. The performance of this risk score in predicting unplanned ICU transfer within 24 hours was evaluated using the c-index and Brier score.

Results
Among 688 patients, ICU transfer within 24 hours occurred in 28.9% of patients (n=199). The developed scoring algorithm assigned positive scores for male sex (+1), lowest intraoperative systolic blood pressure <60 mmHg (+2), highest intraoperative diastolic blood pressure ≥90 mmHg (+1), use of a central-line (+3), anterior-posterior surgery (+1), duration of lying prone ≥300 minutes (+3), without use of CT-navigation software (+2), estimated blood loss ≥2000 mL (+2), and intraoperative blood transfusion (+2), with positive scores indicating increased risk of ICU transfer. The resulting risk score ranged from 0 to 17 points. Each 1-point increase in the score was associated with a 56% increase in the odds of

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ICU transfer (OR 1.56, 95% CI 1.46–1.67; p<0.001; c-index 0.83, 95% CI 0.80–0.87; Brier score 0.13).

Conclusion
We developed a spine-specific intraoperative risk assessment algorithm to identify patients at high risk of early postoperative ICU transfer, providing a tool to optimize postoperative surveillance and resource allocation.

121. Efficacy of Oral Silodosin for Preventing Postoperative Urinary Retention (POUR) Following Elective Spine Surgery: A Single-Blind Randomized Controlled Trial

Vidyadhara Srinivasa, MD, MS; Dinesh Iyer, MS; Abhishek Soni, MD, MS; Balamurugan Thirugnanam, MS

Hypothesis
Oral silodosin in post-operative period reduces the incidence of post-operative urinary retention (POUR) after elective spine surgery

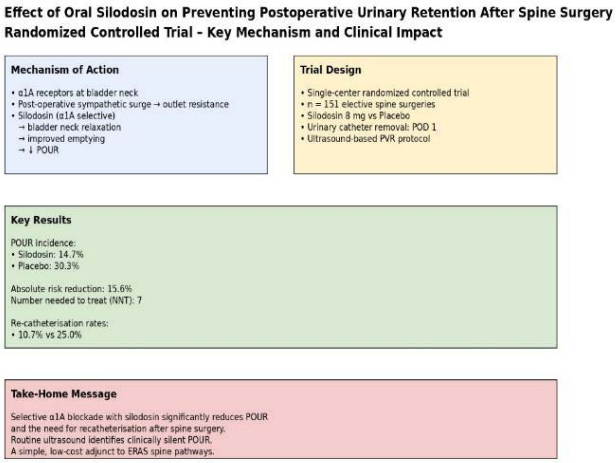
Design
Single-Blind Randomized Controlled Trial

Introduction
Postoperative urinary retention (POUR) is a common complication following elective spine surgery leading to patient discomfort, delayed mobilization, and prolonged hospital stay. Although alpha-1 adrenergic blockers have demonstrated benefit in reducing POUR in other surgical specialties, high-quality randomized evidence in spine surgery remains limited.

Methods
This single-center, single-blind, randomized placebo-controlled trial included adults undergoing elective cervical, thoracic, or lumbar spine surgery. Patients were randomized 1:1 to receive oral silodosin (8 mg administered 8 hours postoperatively and 2 hours before catheter removal) or placebo. Urinary catheters were removed on postoperative day 1. POUR was assessed using a standardized protocol incorporating time to void, voided volume, and ultrasound-measured post-void residual (PVR). POUR was defined as inability to void within 6 hours with bladder volume ≥400 mL or PVR ≥400 mL after voiding with suprapubic discomfort or palpable bladder. The primary outcome was POUR incidence. Secondary outcomes included recatheterisation, urinary parameters, and length of stay. Multivariable logistic regression identified independent predictors of POUR. Trial Registration: Clinical Trials Registry-India (CTRI/2025/10/096166)

Results
Of 210 patients screened, 151 were analyzed (75 silodosin, 76 placebo). Overall POUR incidence was 22.5%. POUR occurred in 14.7% of the silodosin group versus 30.3% of controls (p=0.02), yielding an absolute risk reduction of 15.6% and a number needed to treat of 7. Recatheterisation rates were significantly lower with silodosin (10.7% vs 25.0%, p=0.02). On multivariable analysis, silodosin independently reduced POUR risk (adjusted OR 0.22, 95% CI 0.06–0.80), while higher intraoperative blood loss increased risk.

Conclusion
Postoperative silodosin significantly reduces POUR and recatheterisation after elective spine surgery. Routine ultrasound-based bladder assessment revealed a substantial burden of clinically silent retention. Selective α1A-adrenergic blockade may be a simple and effective adjunct to ERAS-based perioperative spine care.



Key Findings of the RCT

122. Delayed Extubation following Corrective Surgery for Severe Kyphoscoliosis: What are the Roles of Pulmonary Arterial Hypertension and Chronic Respiratory Failure?

Zhen Liu, MD, PhD; Xiaodong Qin, PhD; Saihu Mao, MD; Xiaokang Wang, MD; Yong Qiu, PhD; Zezhang Zhu, MD, PhD

Hypothesis
The coexistence of PAH and T2RF is associated with a significantly increased risk of major postoperative complications following corrective surgery

Design
Patients were divided into four cohorts based on PAH/T2RF status

Introduction
Severe kyphoscoliosis can lead to pulmonary dysfunction, pulmonary arterial hypertension (PAH) and type 2 respiratory failure (T2RF). Untreated patients often progress to fatal cardiorespiratory failure. Although corrective surgery significantly improves outcomes, it carries high perioperative risks.

Methods
This retrospective single-center study analyzed 120 severe kyphoscoliosis patients with pulmonary dysfunction. Patients were divided into four cohorts based on PAH/T2RF status: Group A (PAH−/T2RF−; n=91), B (PAH−/

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T2RF+; n=17), C (PAH+/T2RF−; n=4), and D (PAH+/T2RF+; n=8). Collected data included demographics, preoperative cardiopulmonary function, surgical details, and postoperative outcomes. The impact of PAH and T2RF on outcomes was assessed through intergroup comparisons of delayed extubation rates and postoperative adverse events.

Results

Patients with both PAH and T2RF (Group D) demonstrated the worst outcomes, exhibiting significantly higher rates of delayed extubation (>24 hours: 37.5% vs. others, p = 0.030; >12 hours: 75.0% vs. others, p < 0.001), prolonged ICU stays (median 65.2 vs. others, p = 0.016), and the highest incidence of adverse events (75.0%, p < 0.001). Group D specifically showed elevated risks of respiratory failure (50.0%, p=0.001), severe hypotension (62.5%, p=0.001), heart failure (25.0%, p=0.001), reintubation (25.0%, p=0.033), and mortality (25.0%, p=0.005). Groups B demonstrated moderate risks on the delayed extubation (>24h: 11.8%), while Group C exhibited high adverse event rate (50.0%).

Conclusion

The coexistence of PAH and T2RF is associated with a significantly increased risk of major postoperative complications following corrective surgery, including delayed extubation, prolonged ICU stays, and elevated rates of complications such as cardiorespiratory failure.

123. Transitioning from Preoperative Control to Postoperative Risk: Loss of Postoperative Glycemic Control Increases Pseudoarthrosis After Adult Spinal Deformity Surgery

Travis Kotzur, MD; Lane H. McCoy, BS; *Mark Lambrechts, MD;* Alex Miller, MD; Brian J. Neuman, MD

Hypothesis

Loss of postoperative glycemic control will increase pseudoarthrosis rates in adult spinal deformity patients.

Design

Retrospective cohort study

Introduction

Adult spinal deformity (ASD) surgery is associated with high perioperative risk, and patient-related comorbidities significantly influence outcomes. Diabetes and poor glycemic control have been linked to impaired wound healing, infection, and increased complication rates across surgical specialties. However, the clinical impact of postoperative HbA1c dysregulation in preoperatively well-controlled diabetic patients after ASD surgery remains unclear.

Methods

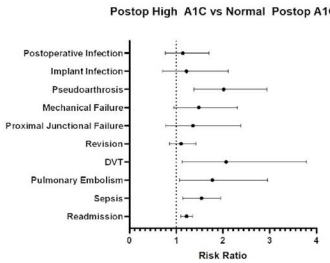
Diabetic patients with preoperative HbA1c ≤ 7.5% undergoing adult spinal deformity surgery were identified using a federated research network. Inclusion required at least two years of follow-up and postoperative HbA1c data. Patients were stratified by postoperative glycemic control, comparing those with any HbA1c > 7.5% during follow-up to those who maintained HbA1c ≤ 7.5%. Propensity score matching was used to balance demographics and Charlson Comorbidity Index between cohorts. Multivariate regression was performed examining postoperative medical and surgical complications within 2 years of surgery.

Results

A total of 9,676 patients met inclusion criteria. Following successful matching 574 patients were included in each cohort. Postoperative uncontrolled HbA1C patients were at increased risk of pseudoarthrosis (RR 2.02; 95% CI 1.38-2.94; p<0.001), deep venous thrombosis (RR 2.07; 95% CI 1.13-3.79; p=0.019), pulmonary embolism (RR 1.77; 95% CI 1.07-2.95; p=0.028), and readmission (RR 1.22; 95% CI 1.10-1.36; p<0.001). No significant increase in risk of postoperative infection, postoperative spinal implant infection, mechanical failure, proximal junctional failure, or all-cause revision was observed in uncontrolled HbA1C patients.

Conclusion

Despite adequate preoperative glycemic control, loss of postoperative glycemic control confers meaningful risk for fusion failure, highlighting postoperative HbA1C as a critical and modifiable determinant of outcome. These findings emphasize that glycemic optimization should extend beyond the preoperative period and remain a central component of postoperative management to reduce pseudoarthrosis in this high-risk population.



	RR	95% Lower CI	95% Upper CI	*P*
Postoperative Infection	1.14	0.77	1.70	0.510
Implant Infection	1.22	0.71	2.11	0.478
Pseudoarthrosis	2.02	1.38	2.94	**<0.001**
Mechanical Failure	1.48	0.95	2.31	0.080
Proximal Junctional Failure	1.36	0.78	2.38	0.282
Revision	1.10	0.86	1.42	0.439
DVT	2.07	1.13	3.79	**0.019**
Pulmonary Embolism	1.77	1.07	2.95	**0.028**
Sepsis	1.54	1.14	1.95	**0.016**
Readmission	1.22	1.10	1.36	**<0.001**

Forest plot of relative risks for those with increased postoperative A1C.

124. Recombinant Human Bone Morphogenetic Protein-2 (BMP) Reduces Long-Term Cost by Decreasing Revision Surgery in Adult Spinal Deformity

David D. Liu, MD; *Shay Bess, MD;* Breton Line; Christopher P. Ames, MD; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Jeffrey Gum, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Eric O. Klineberg, MD; Alan H. Daniels, MD; Munish C. Gupta, MD, MBA; Kojo D. Hamilton, MD, FAANS; Richard Hostin, MD; Praveen V. Mummaneni, MD; Pierce D. Nunley, MD; David O. Okonkwo, MD, PhD; Michael P. Kelly, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Khaled M. Kebaish, MD; Han Jo Kim, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; International Spine Study Group

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Hypothesis
BMP use reduces the aggregate long-term cost of ASD care by decreasing revision surgery.

Design
Retrospective analysis of a multicenter prospective database.

Introduction
BMP reduces pseudarthrosis and revision surgery in ASD, but the long-term cost effectiveness of BMP remains uncertain.

Methods
1355 patients from a multicenter ASD database of 1,355 patients undergoing ≥4-level fusion with ≥2-year follow-up were included. Total cost was defined as index surgery plus all revision costs. Logistic regression on variables such as frailty, number levels fused, and osteotomies created a propensity score reflecting medical and surgical complexity, with 1:1 nearest-neighbor matching to create comparable BMP and noBMP cohorts. Mean total cost, revision rates, and time to mechanical complications were compared. Multivariable regression evaluated cost savings as a function of BMP use and surgical complexity.

Results
Cost data were available for 1029 patients (60.6yo±14.2; 74.8% female), of whom 623 received BMP (mean fu 4.6y±1.3). BMP patients demonstrated greater surgical complexity which increased over time while noBMP patients remained stable (p<0.001). After 1:1 matching (n=288 each), BMP and noBMP had similar surgical complexity. Revision surgery was reduced with BMP (16.4% vs 26.7%; OR 0.55, p=0.002), as was pseudarthrosis (3.4% vs 7.8%; OR 0.41, p=0.03), with similar complication rates. Time to revision was longer in the BMP cohort (HR 0.59, p=0.002). Index surgery cost (2025 USD) was similar between groups ($92,757 BMP vs $100,917 noBMP; p=0.08), while revision costs were lower with BMP ($7,114 vs $12,697; p=0.005), resulting in a mean total cost savings of $13,743 per patient (p=0.015). Cost savings increased with surgical complexity (r=0.38, p=0.004) and scaled with BMP dosage. The break-even threshold for revision cost favored BMP for ≥6 fused levels, pelvic fixation, or any osteotomy, with an optimal dosage of 2.4 mg per level.

Conclusion
BMP is cost-effective over time by preventing revision surgeries in more complex patients. The initial investment in BMP is justified by the financial, clinical, and safety efficiencies of reducing revision ASD surgery. Indications for BMP usage include ≥6 level fusion, pelvic fixation, and/or any osteotomies result in cost-saving with BMP, with an optimal dosage of 2.4mg per level.

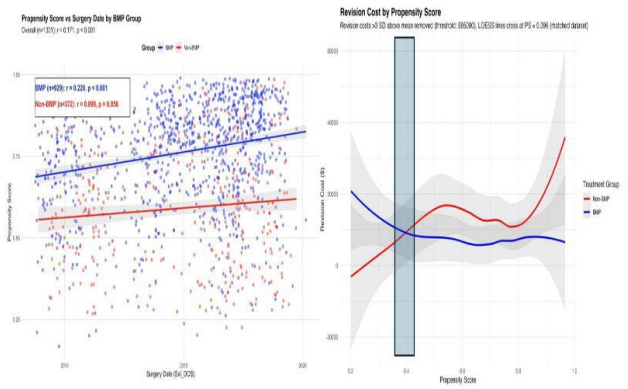

Figure 1. BMP patients are more complex than no BMP patients, and cost savings from reduced revisions scales with patient complexity.

125. Does Osseointegrative Pelvic Fixation Eliminate Traditional Pelvic Fixation Loosening?

Obiajulu Agha, MD; Bahar Shahidi, PhD; Gautham Prabhakar, MD; Timothy Choi, MD; Gregory M. Mundis Jr, MD; Robert K. Eastlack, MD

Hypothesis
Osseointegrative pelvic fixation will experience less loosening than traditional pelvic fixation

Design
Retrospective review of prospectively collected single center data

Introduction
Long fusion constructs to the pelvis are increasingly utilized. These reconstructions carry risks of failure in the lumbopelvic (LP) region as high as 25% with loosening being the most common failure. We aim to investigate the effect of osseointegrative pelvic fixation (OPF) compared to traditional fixation (TF) implant loosening.

Methods
Retrospective review of prospective database of adult deformity patients treated with pelvic fixation in a single institution with 2 year f/u. Patients treated at index operation for infection were excluded. Distal mechanical complications were captured and compared between OPF and TF and defined as: screw loosening (SL), fracture, set screw dislodgement (SD) and rod fracture. Independent student t-tests were used to compare continuous variables and chi-square or fisher exact tests were used to compare categorical variables.

Results
140 patients met the inclusion (54 OPF, 86 TF); mean age 70(+/-11) and 67 (+/-9) in OPF and TF(p=0.15). OPF was 69% female and TPF 76% female(p=0.44). OPF had similar number of levels fused (11.1 vs 11.8; p=0.34). There was a total of 2.2 total bolts in the OPF cohort and 1.9 in TF (p=0.014). Pre-operative alignment between groups was similar for SVA, PT, PI, LL, L1PA, T4PA, C2PA, C2Tilt, and TPA (p>0.15); however, L4-S1 LL was greater in

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the OPF group (36.5 vs 30 deg; p=0.036). Pre-operative max Cobb angle was greater in the TF group (36.9 vs 21.7; p=<0.001) Complication rates were similar between groups(15%, p=0.961). SL was significantly less prevalent in the OPF group (5.6% vs 30.2%; p<0.001). There were similar rates of distal rod fractures in the OPF group (5.6% vs 7.1%; p=1.0). There were more SD in the OPF group (0 vs 3; p= 0.04); Reoperation rates were similar between groups (OPF, 29.5% vs TF, 20.9%; p=0.384).

Conclusion
Osseointegrative fixation experienced significantly less loosening than traditional iliac fixation without differences in distal rod fractures or reoperation rates. There were more set screw dislocations in the OPF group, but this was likely due to open set screw design. The long-term implications of these findings on patient outcomes remains to be studied.

126. Evolution of Minimally Invasive Adult Spinal Deformity Surgery Over Time: A Multi-Center Study

Jay Kumar, MD; David D. Liu, MD; Jang Yoon, MD, MS; Dean Chou, MD; *Robert K. Eastlack, MD*; Gregory M. Mundis Jr, MD; Adam S. Kanter, MD; David O. Okonkwo, MD, PhD; Paul Park, MD; Neel Anand, MD, Mch. Orth; Pierce D. Nunley, MD; Juan S. Uribe, MD; Jay D. Turner, MD, PhD; Michael Y. Wang, MD; Richard G. Fessler, MD, PhD; Ricardo Fontes, MD, PhD; KaiMing G. Fu, MD, PhD; Andrew K. Chan, MD; Nima Alan, MD; Vivian P. Le, MPH; Peter G. Passias, MD; Shay Bess, MD; Praveen V. Mummaneni, MD; International Spine Study Group

Hypothesis
Minimally invasive surgery (MIS) for adult spinal deformity (ASD) has undergone significant technological evolution over the past decade, resulting in improved perioperative outcomes.

Design
Retrospective analysis of two multicenter prospective databases.

Introduction
MIS has become increasingly utilized in ASD. As technology and enhanced perioperative pathways have evolved, it remains unclear whether these advances have translated into improved perioperative outcomes.

Methods
MIS cohorts were categorized as older MIS cohort (2010–2020; n=223) or newer MIS cohort (2021–2025; n=149). Perioperative outcomes were length of hospital stay, length of ICU stay, operative time, blood loss, need for transfusion, 90d complication (any), 90d reoperation, or 90d readmission. A propensity score-derived case-complexity index was created to summarize baseline patient complexity, with logistic regression on baseline clinical (age, gender, ASA, BMI, smoking, osteoporosis, normalized frailty index, abnormal neurological exam) and surgical variables (PI-LL mismatch, SVA, PT, deformity correction, number levels fused).

Results
There was increased baseline patient complexity in the newer MIS cohort (case-complexity index 0.22 vs 0.17; p<0.001), driven by greater frailty burden (age 67.7 years±9.3 vs 61.5±15.2, normalized frailty index +0.19; p=0.02) and abnormal baseline neurological exam (48.2% vs 37.9%; p=0.02). Surgical variables were all stable (all p > 0.1). The newer MIS cohort was associated with fewer ICU admissions (6.6% vs 19.3%; p<0.001), shorter hospital stays (4.7 days±2.4 vs 5.8 days±3.6, p=0.025), lower 90-day reoperation rates (1.2% vs 5.0% older MIS; p=0.048), fewer major (2.4% vs 16.1%; p<0.001) and minor (9.6% vs 17.9%; p=0.002) complications, but similar 90-day readmission rates (4.8% vs 5.5%; p=0.99). Operative time was similar (newer MIS 409 min±164, older MIS 414 min±213; p=0.90) with similar estimated blood loss (380mL±387 vs 447mL±645; p=0.96) but fewer transfusions (9.6% vs 17.5%; p=0.029).

Conclusion
These findings suggest that MIS for ASD has evolved over the past decade to allow decreased ICU and hospital stay, lower reoperations, fewer complications, and decreased need for transfusions in the 90-day perioperative period despite treatment of an increasingly frail patient population. As the population continues to age, MIS surgery may be an option as a treatment avenue to decrease perioperative morbidity.

ISSG MIS 90d outcomes (2010-2020, 2021-2025 periods)

Outcome	MIS 2021-2025	MIS 2010-2020	p-value
LOS	4.7 days ± 2.4	5.8 days ± 3.6	p=0.02
90d readmission	4.8% (8/166)	5.5% (12/217)	p=0.99
90d reoperation	1.2% (2/166)	5.0% (11/217)	p=0.048
90d minor complication (any)	9.6% (16/166)	17.9% (39/217)	p=0.002
90d major complication (any)	2.4% (4/166)	16.1% (35/217)	p<0.001
Operative time	409 min ± 164	416 min ± 212	p=0.90
EBL	380mL ± 387	447mL ± 645	p=0.96
Transfusion	9.6% (16/166)	17.5% (38/217)	p=0.026
ICU admission	6.6% (11/166)	19.3% (42/217)	p<0.001
ICU LOS	2.3 days ± 2.0	2.5 days ± 2.1	p=0.762

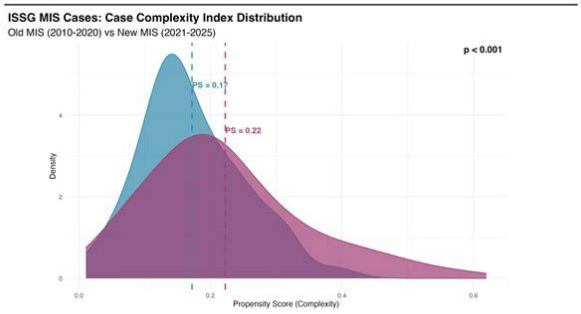

Figure 1. MIS for ASD is becoming more safe and efficient over time, despite increasing patient complexity.

127. Prophylactic Concave-side Decompression and Spinal Cord Medialization Reduces Neurological Complications in Severe Kyphoscoliosis with Type 3 Cord Morphology

Yutong Dai, MD; Ben Long Shi, MD; Zhen Liu, MD, PhD; Saihu Mao, MD; Yong Qiu, PhD; *Zezhang Zhu, MD, PhD*

Hypothesis
Prophylactic TTSC reduces the incidence of intraoperative

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neurological alerts and postoperative deficits in high-risk patients with Type 3 spinal cord morphology undergoing 3CO, thereby providing a neuroprotective effect during deformity correction.

Design
Retrospective comparative cohort study.

Introduction
Severe kyphoscoliosis presents significant risks of cardiopulmonary and neurological compromise. While three-column osteotomies (3CO) provide effective correction, they carry substantial neurological risks. Preoperative Type 3 spinal cord morphology—where the cord is compressed against the concave pedicle—is a critical risk factor. Transvertebral transposition of the spinal cord (TTSC) has been proposed to relieve this tension and restore CSF flow. However, the prophylactic efficacy of TTSC in these high-risk patients has not yet been systematically evaluated.

Methods
This study included 236 patients with severe kyphoscoliosis treated with 3CO, of whom 132 underwent TTSC and 104 did not. Radiographic parameters, neurological status (Frankel grading), patient-reported outcomes (SRS-22), intraoperative neuromonitoring (IONM) alerts, and perioperative complications were analyzed and compared.

Results
The cohort comprised patients of self-reported Asian (Chinese) race and ethnicity. Baseline demographics and preoperative radiographic profiles were comparable between groups. Both cohorts achieved substantial deformity correction. The TTSC group showed significant reductions in coronal Cobb angle (80.8° to 42.2°) and global kyphosis (71.7° to 27.6°), similar to the non-TTSC group (76.7° to 39.6° and 66.3° to 25.2°, respectively). TTSC was associated with lower rates of permanent neurological deficits (1.5% vs. 6.7%, $p = 0.046$) and IONM alerts (8.3% vs. 20.2%, $p = 0.012$). Among patients with preoperative deficits, neurological recovery was more frequent in the TTSC group (86.7% vs. 50.0%, $p = 0.009$). Perioperative complication rates were not significantly different (10.6% vs. 18.3%, $p = 0.130$).

Conclusion
TTSC appears to offer neuroprotective benefits in high-risk 3CO procedures for patients with type 3 spinal cord morphology, with reduced neurological complications and improved functional outcomes. Its use as a preparatory step prior to osteotomy is recommended in selected severe deformity cases.

128. Long-Term Neurological Outcomes Following Significant Intraoperative Neuromonitoring Alarms: A Longitudinal Study of 115 Patients With Severe Spinal Deformities

Tianyuan Zhang, MD, PhD; Junlin Yang, MD, PhD; Yaolong Deng, MD

Hypothesis
Patients with severe spinal deformities who experienced significant IONM alarms could gradually neurologically improve over the 2-year follow-up.

Design
A retrospective cohort study.

Introduction
Intraoperative neurophysiological monitoring (IONM) is crucial for detecting impending iatrogenic neurological injury during high-risk scoliosis surgery. However, the implication of significant IONM alarms on long-term neurological function remains unknown for complex deformity correction. This study aims to report the longitudinal neurological outcomes and identify predictors of long-term neurological survivorship for patients with severe spinal deformities.

Methods
A total of 115 patients who encountered significant intraoperative neuromonitoring alarms (excluding systematic and non-operative confounders) during high-risk surgical maneuvers were analyzed. A longitudinal clinical dataset containing baseline information, surgical details, multimodal IONM data, and follow-up neurological function was collected. Cox regression analysis was performed to identify prognostic factors that could predict long-term neurological survivorship. Kaplan-Meier curves were plotted for these predictors, and a nomogram facilitated the clinical prediction of 2-year neurological function.

Results
Immediately after surgery, 57 patients (49.6%) showed neurological deficits, which decreased to only 5 cases (4.3%) at the 2-year follow-up. Multivariate Cox regression analysis for long-term neurological survivorship identified decreased hazard ratios (HRs) for grade six osteotomy (HR, 0.311; $P = 0.028$), a positive wake-up test (HR, 0.216; $P < 0.001$), and no recovery of descending neurogenic evoked potentials (DNEPs) (HR, 0.162; $P < 0.001$). A nomogram based on osteotomy grade, wake-up test, and DNEP recovery status was established to predict 2-year neurological function.

Conclusion
Overall, patients with severe spinal deformities who experienced significant IONM alarms demonstrated gradual neurological improvement over the 2-year follow-up. Osteotomy grade, wake-up test results, and DNEP recovery status were identified as valuable predictors that could facilitate surgical decision-making, prognostication, and counseling.

129. Current Intra-Operative Neuromonitoring Protocols Fail to Reliably Detect New Neurological Deficits in 3COs Performed Below the Conus

Stephen J. Lewis, MD, FRCS(C); Ran Ankory, MD; So Kato, MD, PhD; Justin S. Smith, MD, PhD; Michael P. Kelly, MD;

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Brian J. Neuman, MD; Munish C. Gupta, MD, MBA; Christopher J. Nielsen, MD; Yukihiro Matsuyama, MD, PhD; Yong Qiu, PhD; Lawrence G. Lenke, MD

Hypothesis
IONM can provide realtime feedback during 3 column osteotomies

Design
Prospective, observational, multicenter study

Introduction
Optimal interpretation of IONM alerts and evidence-based surgical responses remain incompletely defined, particularly during 3COs. Appropriate interventions can reduce the risk of developing new neurological deficits in these complex surgeries.

Methods
Patients undergoing 3CO for spinal deformities were enrolled in a multicenter study and completed detailed forms of events related to IONM alerts in real-time. Alert criteria: ≥50% decrease in MEP or somatosensory evoked potentials (SSEP) from baseline. Cord-level versus non-cord-level (below conus) 3COs were analyzed separately. Alerts were classified as Type I (pre-decompression), Type II (during decompression/bone resection), and Type III (post-osteotomy closure).

Results
IONM alerts occurred in 20 of 146 patients (13.7%): 14 cord-level alerts (70%) and 6 non-cord-level alerts (30%). Cord-level alerts: MEP alerts occurred in 10 VCR (71.4%) and 4 PSO (28.6%) with 2 patients with concomitant SSEP alerts. Alert distribution: Type I (n=2), Type II (n=9), Type III (n=3). Eleven alerts (78.6%) fully resolved intraoperatively. Type I alerts responded to screw repositioning, blood pressure elevation, and transfusion. Type II alerts were managed with steroids, hemodynamic optimization, and expedited osteotomy closure. Type III alerts responded to rod removal, osteotomy opening, and reduced correction. Five patients (35.7%) developed immediate post-op motor deficits; 1 patient (7.1%) had persistent unilateral weakness at discharge. Non-cord-level patients (n=6): Type II (n=3) and type III (n=3) were managed with anesthesia adjustment, steroids, and additional decompression; rods were released in 3 cases. Three patients (50%) developed postoperative deficits, with 2 (33.3%) having unilateral deficits at discharge. Six patients (4.8%) developed new neurological deficits without intra-operative alerts, with 4 (3.2%) having unilateral deficits at discharge.

Conclusion
Appropriate responses reversed the alerts in 11/14 cord-level 3COs. IONM showed limited reliability for predicting nerve root injuries in 3COs below the conus, as evidenced by deficits in 6 patients without alerts. Modifications to our current protocols are needed to minimize the false negative rate in 3COs below the conus.

Variable	No Alert (N=126)	Alert (N=20)	P value
Demographics			
Age (years)	38.6 ± 23.5	38.2 ± 23.8	0.826
Female gender	68 (54.0%)	16 (80.0%)	0.029
BMI (kg/m²)	23.5 ± 5.1	24.2 ± 6.5	0.531
Primary diagnosis			0.202
- Scoliosis	47 (37.3%)	10 (50.0%)	
- Kyphosis	52 (41.3%)	9 (45.0%)	
- Other	27 (21.4%)	1 (5.0%)	
Revision surgery	28 (22.2%)	9 (45.0%)	0.030
Duration of surgery (hours)	6.5 ± 2.3	7.8 ± 2.2	0.031
Outcomes			
De novo neurological deficits (postop)	6 (4.9%)	7 (36.8%)	<0.001
De novo neurological deficits (discharge)	4 (3.2%)	2 (10.5%)	0.181
Decrease in ASIA LEMS (postop)	6 (4.8%)	6 (30.0%)	0.002
Decrease in ASIA LEMS (discharge)	3 (2.4%)	2 (10.0%)	0.139

Data of 3CO Patients

130. Machine Learning (ML) in Intraoperative Neuromonitoring (IONM): Updated Model Integrating Hemodynamic Data Detects Changes 35 Minutes Earlier Than Traditional IONM Surveillance

Varun Arvind, MD, PhD; Anil Mendiratta, MD; Mehdi Elfilali, BA; Madeline C. Monness, BSA; Erik Williams, BS; Miles Bomback, BA, MPH; Michael W. Brown, BS; Alexander Park, BS; Omar Taha, BS; Matthew Weintraub, BS; *Michael G. Vitale, MD, MPH*

Hypothesis
We hypothesized that incorporating hemodynamic variables (mean arterial pressure [MAP] and heart rate [HR]) would improve the performance of our IONM ML model, which previously detected changes 23 minutes earlier than traditional IONM surveillance with motor-evoked potential (MEP) data alone.

Design
IONM and hemodynamic data from pediatric spine surgeries at a single academic center were retrospectively incorporated.

Introduction
IONM improves safety during spinal surgery by providing real-time neurophysiological assessment, enabling the earlier detection and prevention of permanent neural injury. However, current IONM interpretation is subject to variability, relies on human expertise, and does not account for related hemodynamic factors. We introduce an updated ML model for pediatric spinal deformity surgery that integrates MAP and HR with MEP data.

Methods
An ML model was trained using time-series trans-cranial evoked MEPs, MAP, and HR data from each patient to identify changes during surgery. The model continuously analyzed real-time data, creating risk scores. A "red-flag" alert was triggered if the risk score exceeded a set threshold. Model performance was assessed using sensitivity, specificity, predictive values, and accuracy, and compared against standard clinical alerts.

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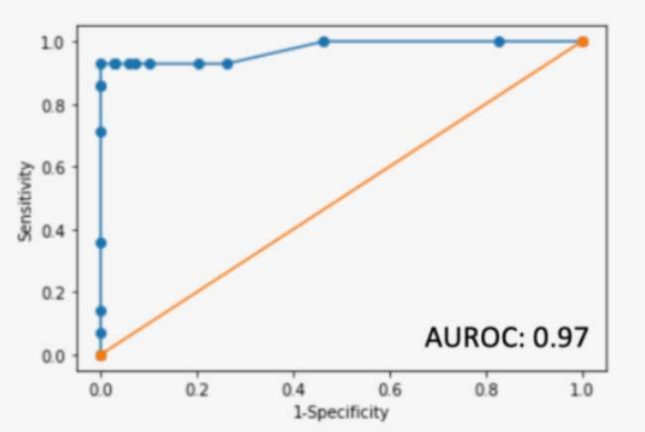
Results
Data from 84 patients (51 female, 33 male; mean age at surgery 14.2 years) were included. Fourteen patients experienced intraoperative MEP signal loss, with six developing postoperative deficits. The model achieved 92.8% sensitivity, 79.7% specificity, 98.2% negative predictive value, and 81.9% overall accuracy (AUC = 0.97). ML-generated alerts preceded clinical IONM alerts by an average of 35.4 minutes. Among patients with postoperative deficits, 6 of 6 were correctly flagged. Among patients with IONM loss, 13 of 14 were correctly flagged.

Conclusion
This ML-based tool demonstrated standardized, near perfect performance with substantially earlier detection of IONM changes compared with clinical alerts. By unifying neurologic and hemodynamic data within a single analytic framework, the model reflects a novel, physiologically informed approach to real-time spinal cord monitoring. While prospective validation is needed, these findings highlight the model's potential to support intraoperative decision-making and safer surgical care.



ROC (AUC - 0.97).

131. Influence of Baseline IONM Data Quality on Neuromonitoring Performance and Surgical Actions in Pediatric Spinal Deformity Surgery

Christopher K. Bozorgmehr, BS; Leah Rakers, MBS, CNIM; *Scott J. Luhmann, MD*

Hypothesis
This study examined how baseline intraoperative neuromonitoring (IONM) quality influences intraoperative alerts, responses, and outcomes in pediatric spinal deformity surgery.

Design
Retrospective Cohort

Introduction
IONM detects potential neurologic injury and guides corrective action. Incomplete, inconsistent IONM occurs in a minority of cases and its impact is poorly defined.

Methods
An institutional IONM database (11/1992–4/2024) identified 5317 consecutive patients (0–18 yrs) undergoing pediatric spine deformity surgery at three tertiary hospitals. Pre-incision IONM data were classified as normal or abnormal using established criteria.

Results
Abnormal baseline data was documented in 292 (5.5%) cases. There were 223 cases with IONM alerts and 43 had abnormal baseline data (19.2%). Abnormal baseline data quality was associated with a higher incidence of IONM alerts compared with normal baselines (14.7% vs 3.6%, p < 0.001). Abnormal signals were motor only in 44% (n=19/43), SSEP only in 44% (n=19/43), and both in 12% (n=5/43). The alert modality and modality with poor baselines matched in 74% of cases. Diagnoses included idiopathic (n=8), kyphosis (n=11), neuromuscular (n=12), congenital (n=5), syndromic (n=2), spondylolisthesis (n=2), hemivertebrae (n=1), and unknown (n=2). Abnormal preoperative neurologic status, failure of data return, initial actions taken, and earlier stage of surgery of IONM alerts were all significantly associated with abnormal baseline data and are detailed in Table 1. Immediate (14% vs 14%) and final (5% vs 9%) neurologic deficits were similar between patients with normal and abnormal baselines, respectively.

Conclusion
Cases with poor baseline IONM quality had a 3x increase in alerts which occurred at an earlier stage of surgery, and a 18% decrease in data return, but no difference in postoperative or final neurologic outcomes. Recognition of poor baseline quality at case initiation is essential to guide interpretation and tailor responses (e.g. wake-up tests). Despite intraoperative differences, outcomes were similar, underscoring that proactive strategies can mitigate the risks associated with abnormal baseline data. Future work should focus on optimizing baseline data acquisition, particularly in high-risk patients.

	Normal Baseline Data (n = 180)	Abnormal Baseline Data (n = 43)	
Preoperative Status		(n = 41; 2 unknown)	P = 0.018
Normal	145 (80.6)	26 (63.4)	
Abnormal	35 (19.4)	15 (36.6)	
Alert			P = 0.024
Return	132 (73.3)	24 (55.8)	
Did Not Return	48 (26.7)	19 (44.2)	
Initial Action Taken			P = 0.003
No intervention	10 (5.5)	6 (14.0)	
Abort	1 (0.6)	0 (0)	
Decompression/Further Decompression	8 (4.4)	4 (9.3)	
Correction adjustment	44 (24.4)	4 (9.3)	
Raise blood pressure	47 (26.1)	6 (14.0)	
Other/technical adjustment	4 (2.2)	0 (0)	
Instrumentation adjustment	19 (10.6)	3 (7.0)	
Reduce traction weight	12 (6.7)	0 (0)	
Reposition retractors	6 (3.3)	6 (14.0)	
Reposition patient	20 (11.1)	8 (18.6)	
Non–MAP anesthetic/systemic adjustment	9 (5.0)	6 (14.0)	
Stage of Surgery			P < 0.001
Exposure/Baseline	10 (5.5)	12 (27.9)	
Decompression	40 (22.2)	15 (34.9)	
Placing Instrumentation	46 (25.5)	7 (16.3)	
Correction, Following Correction	81 (45.0)	9 (20.9)	
Wound Closure	1 (0.6)	0 (0)	
Other/unknown	2 (1.1)	0 (0)	

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Table 1: Characteristics of IONM Alerts in Cases with Abnormal Baselines

132. Free hand vs navigation guided pedicle screw insertion in scoliosis - an analysis of 5000 screws using intra operative low dose CT scan

Ahmad Hussien, MD; Sai Balasubramanian, MBBS, MS; Paul Cool, FRCS; Jayesh Trivedi, FRCS; Neil T. Davidson, MBBS, FRCS; *Sudarshan Munigangaiah, FRCS*

Hypothesis
To evaluate whether there is a significant difference in revision rates between pedicle screws inserted using the freehand technique versus navigation-guided placement, assessed using intra operative low-dose CT for assessment.

Design
A retrospective analysis of all consecutive operative cases of scoliosis between 2018 to 2022 at Alder Hey children's hospital, Liverpool , UK.

Introduction
Pedicle screw placement accuracy is critical in scoliosis correction surgery. Previous studies have shown up to 3.6 % rate of malposition despite using navigation. Malposition can lead to a return to theatre up to 2 % in free hand technique.

Methods
All consecutive operative cases of scoliosis between 2018 to 2022 at Alder Hey Children's hospital , Liverpool, UK, was undertaken. patients and a total of 5,006 implanted pedicle screws were included. Of these, 4,449 were inserted freehand and 557 using navigation. Screw positioning was assessed intraoperatively with low-dose CT, and intra operative revisions were recorded. Statistical analyses included the Wilcoxon test, Kruskal–Wallis test, and chi-square test as appropriate.

Results
A total of 5,006 screws were inserted, of which 4,803 (95.9%) were deemed to have been in acceptable position, while 203 (4.1%) were unsatisfactory and required intra operative revision. Counter intuitively the revision rates were similar between the freehand and navigation groups, with no statistically significant difference. No association was found between revision rates and gender, vertebral level, instrumentation length, Cobb angle, or operation time. The median Cobb angle was 75° (IQR: 63–90), median operation time was 300 minutes (IQR: 240–360), and median instrumentation length was 12 levels (IQR: 10–13). Two patients returned to theatre, one for PJK and the second for rod breakage. No patient returned to theatre for screw malposition.

Conclusion
The revision rates for pedicle screws inserted freehand and navigation guided in scoliosis surgery in a high-volume specialist unit are comparable. Intrao perative low-dose CT is an effective tool for real-time assessment after screw placement. It allows for intra-operative revision and eliminated the risk of return to theatre

134. 10-Year Review of 24,140 Freehand Pedicle Screws Placed in the Thoracic, Lumbar and Sacral Spine for Pediatric and Adult Spinal Deformity: Is This Still a Relevant Technique?

Meredith Luhmann, BS; Amrit Singh, MPH; Erik Lewerenz, BS; *Lawrence G. Lenke, MD*

Hypothesis
The freehand technique of pedicle screw placement in pediatric and adult spinal deformity is safe and accurate.

Design
Single surgeon independent retrospective study.

Introduction
Recent studies on freehand pedicle screw placement are limited due to the increased use of Navigation and Robotic screw placement which espouse safer and more accurate placement. Previous studies investigating the freehand technique for thoracolumbar (TL) screws note a screw-related return to OR (RTOR) rate of 0.4% and a screw revision rate of 8.97%.

Methods
A single-surgeon consecutive patient (pt) independent review was performed on adult and pediatric spine deformity pts who underwent true de novo freehand pedicle screw placement (using anatomic landmarks, a blunt gearshift and without any image guidance) in levels from T1-S1 from 2015 to 2025. Screws were assessed for any placement-related intraoperative (intraop) neuromonitoring (IONM) data changes, low triggered screw electromyography (t-EMG) thresholds (<10mA), or altered positioning on intraop imaging. Screw redirect and RTOR rates for malpositioned screws were determined by the percentage of total revised screws and RTORs out of all the included cases.

Results
A total of 24,140 pedicle screws were placed in 1,148 consecutive cases. 908 (3.76%) screws were removed and the track checked after intraop imaging or low t-EMG thresholds. 686 (75.55%) of these screws were redirected, resulting in a screw revision rate of 2.80%. Of the 625 screws redirected based on imaging, 22 (3.52%) were from x-ray and 603 (96.48%) were from intraop CT. 71 of the 179 (40%) screws checked for low t-EMG thresholds were redirected (39.66%). There were 4 (0.35%) cases where a screw impacted IONM data, and in all 4 cases, the affected screw was removed with recovery of IONM data and no postop neurologic sequalae. 3 (0.26%) pts. had RTOR due to lumbar screw malposition causing radiculopathy with resolution following screw removal.

Conclusion
In this largest single surgeon study of 24,140 pedicle screws placed from T1-S1 for pediatric and adult deformity, the true freehand technique was found to be extreme-

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ly safe and accurate. There was a low (0.26%) RTOR rate for screw malposition and no screw-related neurologic sequelae, thus confirming the technique as still relevant in this evolving era of Navigation and Robotics.

135. How Low Can We Go? Can We Further Reduce Radiation Exposure During Scoliosis Radiographic Examination?

Rachelle Imbeault; Marjolaine Roy-Beaudry, ; Justin Dufresne; Sylvain Deschenes, PhD; *Stefan Parent, MD, PhD*

Hypothesis
We hypothesized that a new biplanar imaging system with dose modulation emits lower radiation than a standard stable dose biplanar imaging system, while maintaining image quality.

Design
Prospective clinical trial.

Introduction
From diagnosis, pediatric patients with idiopathic scoliosis need to undergo frequent radiological evaluations. Due to their longer life expectancy and higher sensibility to ionizing radiation, using technologies that optimize image quality according to the dose received is advisable in the pediatric population. This study intends to compare two biplane radiography systems, one using dose modulation and one using fixed dose throughout the entire acquisition.

Methods
Fifty patients were recruited between February 2024 and July 2024. All patients had a diagnosis of idiopathic scoliosis with an average Cobb angle of 29.7±15.0° and with a mean age of 13.7 years (8-18). Each patient underwent two successive biplanar examinations (PA and lateral views), one using the dose modulating device and the second one using a fixed dose device. Entrance skin dose was measured for 30 patients using optically stimulated luminescence dosimeters located near seven radiosensitive anatomic areas. The minimum detection value of the dosimeters is 50µSv, with an accuracy of ±10% (Landauer). Acquired X-rays were randomized and evaluated by one pediatric orthopedic surgeon and one pediatric radiologist. Statistical analysis was performed using Wilcoxon signed-rank tests.

Results
Dose analysis on 30 patients allowed to observe an average dose reduction of 48% (range: -26% to 71%) when dose modulation was used. Dose distribution shows a 63% reduction in the cervicothoracic region, while the reduction was 29% in the lumbosacral region. X-ray analysis revealed that while decreasing the dose, dose modulation also improves global image quality (p-value = <0.001). Furthermore, analysis of specific anatomical structures showed that visibility is improved for more than 84% of the anatomical landmarks being scored (p-value = <0.05).

Conclusion
Results indicate that dose modulation can reduce patient exposure to radiation by 48%, while improving global image quality. The greater reduction in the cervicothoracic region suggests better protection of the radiosensitive organs located in this area.

Dose Modulated Standard Dose

136. Implant Density and Deformity Angular Ratio Predict Risk of Complications in Three-Column Osteotomies

Travis S. CreveCoeur, MD; Alexander J. Schupper, MD; Amer F. Samdani, MD; Joshua M. Pahys, MD; Terrence G. Ishmael, MBBS; Benjamin A. Schmidt, BA; Joshua McCalister-Afflick, BS; Emily Nice, BS; *Steven W. Hwang, MD*

Hypothesis
Within three-column osteotomies (3CO), greater deformity angular ratio (DAR) is associated with a greater number of complications.

Design
Retrospective single-center cohort

Introduction
We sought to describe outcomes and identify risk factors for complications after 3CO.

Methods
Patients ≤21 years of age who underwent single-level 3CO were identified. Demographics, operative details, radiographic parameters, and complications were recorded.

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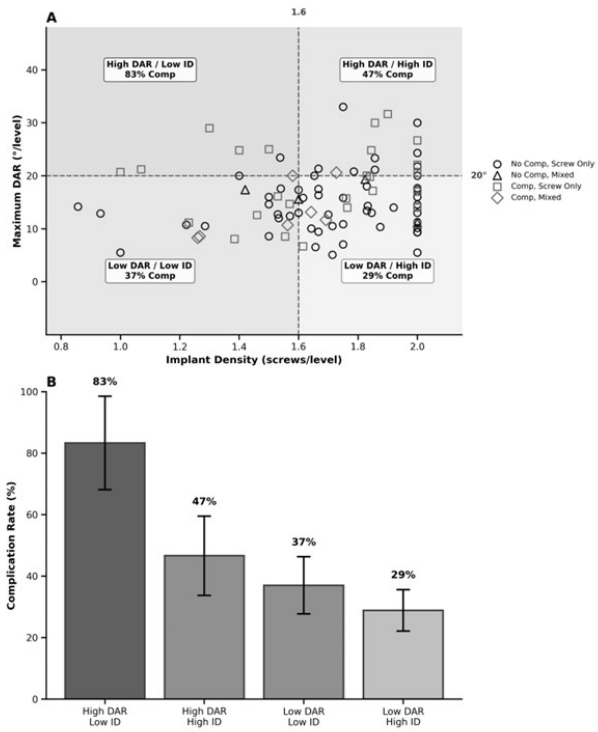
Univariate analyses identified risk factors for complications.

Results
97 patients (51% female, mean age 13.1±4.4 years, mean follow-up 51.9 months) were included. Etiologies included: congenital (59%), idiopathic (19%), neuromuscular (12%), syndromic (4%). The most common location was thoracolumbar (57%) with a mean curve angle of 87±31° and a coronal/sagittal DAR of 17±6°/level. 22% had prior spine surgery and 27% underwent pre-op halo gravity traction. OR time was 481±254 minutes with EBL of 1365±1653mL. Mean implant density was 1.7±0.3; 88% had screw-only constructs and 12% had hybrid (hooks/screws). At last follow-up, coronal correction was 66% and sagittal correction was 48%. The overall complication rate was 37% (intra-op 20%, post-op 22%). New neurologic deficits occurred in 5%; with 1 permanent deficit. Revision rate was 6 % mostly for instrumentation failure. Lower implant density was the only factor associated with complications (1.6±0.3 vs. 1.7±0.3, p=0.03). Hybrid constructs had more complications, but this was not statistically significant (64% vs. 33%, p=0.10). When including only index surgery patients (no revisions), DAR (19±7°/level vs. 16±5°/level; p=0.012) was predictive of complications. Patients with complications had higher residual sagittal DAR (9±6°/level vs. 6±4°/level; p=0.01). There were no significant factors associated with the overall need for revision surgery; however, higher pre-op DAR (20±6°/level vs. 16±7°/level; p=0.045) was associated with instrumentation complications. Decision tree analysis revealed that pre-op DAR >20°/level combined with implant density ≤1.6 identified a high-risk cohort with an 83% complication rate, while patients with DAR ≤20°/level and implant density >1.6 screws/level had the lowest risk at 29%.

Conclusion
Single-level 3CO carries a 36% complication rate, but this may be partially mitigated with higher implant density and, if possible, intervention when DAR <20.



137. Rod Diameter, Material, and Texture Influence Screw-Rod Fixation Strength in Spinopelvic Construct

Cale J. Hendricks, BS; Samuel Hendricks, BS; *David W. Polly Jr, MD;* Arin M. Ellingson, PhD

Hypothesis
Rod diameter, material, and surface finish influence gripping capacity.

Design
This study aimed to evaluate the influence of rod diameter, material, and surface texture on axial gripping capacity (AGC) of the screw–rod interface.

Introduction
Spinopelvic fixation is critical in adult spinal deformity surgery, yet mechanical failure rates range from 4.5–38%. Failure often involves the screw–tulip–rod interface, where rod diameter, composition, and surface texture may affect fixation strength. However, the combined biomechanical effects of these variables remain understudied.

Methods
Axial gripping capacity tests were performed in accordance with ASTM F1798-21 using porous fusion/fixation screws (iFuse Granite, SI-Bone). Rods of 5.5 mm and 6.0 mm diameter were tested in cobalt-chrome (CoCr) and titanium (Ti) with three finishes: grit blast, bead blast, and anodized bead blast. Maximum AGC was defined as the peak load within 1.5 mm of displacement; ultimate AGC (UAGC) within 5 mm. Ten trials per condition were

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performed. A two-way ANOVA with Bonferroni correction evaluated effects of diameter and material/surface combinations (α=0.05).

Results
Each tested variable significantly affected AGC (p<0.001). Independent of material or finish, 6.0 mm rods had significantly higher AGC than 5.5 mm (2518.0 ± 30.9 N vs. 2091.1 ± 30.9 N; p<0.001). Among material/finish groups, bead-blasted Ti rods produced the highest AGC (2776.0 ± 61.9 N for 5.5mm; 2910.3 ± 61.9 N for 6.0 mm), while anodized bead-blast Ti rods yielded the lowest (1656.6 ± 61.9 N and 2076.8 ± 61.9 N, respectively). CoCr grit-blast rods outperformed bead-blast CoCr. UAGC trends mirrored AGC, with minor differences in select comparisons. Pairwise comparisons are in Figures.

Conclusion
Rod diameter, material, and surface finish each significantly influenced gripping capacity. Larger diameters consistently improved fixation, but surface finish strongly modulated outcomes within each material. Bead-blasted Ti rods provided the highest fixation strength, while anodized bead-blast Ti rods performed worst. Among CoCr rods, grit-blast outperformed bead-blast, reinforcing that surface texture can alter performance even within a single material class. These findings emphasize that rod selection should consider both size and finish, as optimization at the screw–rod interface may reduce mechanical failure in spinopelvic constructs.

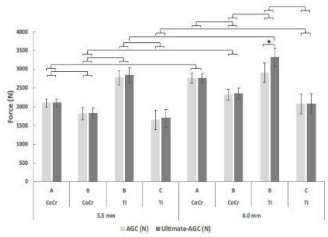

Figure 1: Axial and Ultimate Gripping Capacity (AGC, UAGC). *Eight conditions were tested with variation in rod diameter (5.5 mm, 6.0 mm), material (CoCr, Ti), and surface texture (A: grit-blast; B: bead-blast; C: bead-blast + type 2 anodized). Vertical error bars represent ± standard deviation, and horizontal bars mark statistically significant differences (α < 0.05). Comparisons testing for significant difference was performed only between conditions differing by a single parameter.*

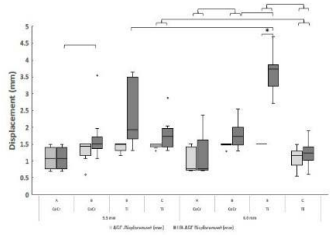

Figure 2. Displacement of Axial and Ultimate Gripping Capacity (AGC, UAG). *Eight conditions that were tested with variation in diameter (5.5 mm and 6.0 mm), material (CoCr and Ti), and surface coating (A: grit-blast, B: bead-blast, C: bead-blast + type 2 anodized). The vertical error bars represent the minimum and maximum values (excluding outliers) and horizontal bars mark statistically significant differences (α < 0.05). Comparisons testing for significant difference was performed only between conditions differing by a single parameter.*

Captions are embedded in the figure

138. Time-to-Failure Analysis of Implant Constructs in Severe Spinal Deformity Surgery: Seven-Year Outcomes From a West African Cohort

Kwadwo Poku Yankey, MD; Derrick Nyantakyi Owusu, MS; Arthur Sackeyfio, MD; Sarah K. Obiri, BS; Liudmila Gross, MD; Irene A. Wulff, MD; Francis Addai, MD; Benjamin H. Blackson, MD; Oheneba BoachieAdjei, MD

Hypothesis
Clinical and surgical factors are not significantly associated with time to implant construct failure in severe spinal deformity surgery.

Design
Retrospective cohort review

Introduction
Implant construct failure remains a significant complication following surgical instrumentation for severe spinal deformity, with profound implications for patient outcomes and health system burden. This challenge is particularly profound in low-resource settings. Identifying the factors associated with long term implants failure may be beneficial in the development of more effective surgical strategies

Methods
We conducted a longitudinal cohort study of 402 pts undergoing surgical correction of severe spinal deformity. Implant failure was defined as clinically significant construct-related complications requiring revision. Kaplan–Meier (KM) methods estimated implant survival, and Cox proportional hazards models identified independent predictors. Model discrimination was assessed using Harrell's concordance index (C-index).

Results
The cohort had a mean age of 14.7 years and was 57% female, with a mean follow-up of 865.1 days. Implant failure occurred in 38 pts (9.5%). KM survival estimates were 97.4% at 1 year, 88.8% at 2 years, 82.9% at 3 years, 72.8% at 5 years, and 60.7% at 7 years. In adjusted analyses, age 10–15 years was associated with increased hazard of failure compared with <10 years (AHR 2.5, p = 0.017). Post TB kyphosis had higher failure risk compared idiopathic etiology (AHR 1.4, p < 0.001). Sagittal correction above 40% was a strong independent predictor of failure (AHR 4.5, p < 0.001. Longer fusion constructs showed lower adjusted hazards compared with short fusions (7–11 levels: AHR 0.07, p = 0.010; 12–15 levels: AHR 0.06, p < 0.001; ≥16 levels: AHR 0.19, p < 0.001). The C-index was 82% p=0.03

Conclusion
In this West African cohort, implant survival declined to approximately 61% at seven years. Younger patients (10–15), Post TB Kyphosis, and aggressive sagittal correction were major predictors of construct failure. These findings highlight the need for context-specific construct planning, cautious sagittal correction strategies, and enhanced long-term surveillance to improve implant durability in low-resource settings.

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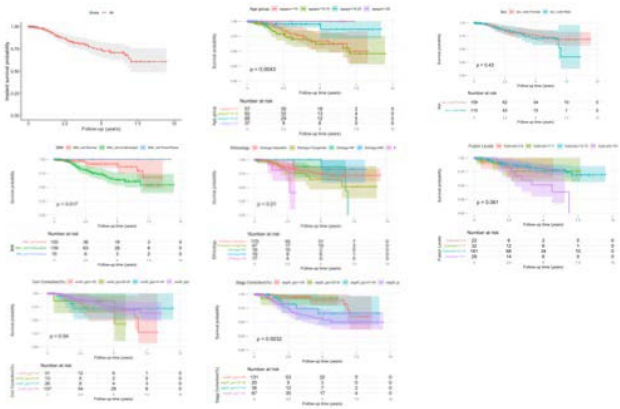

KM survival estimates of implant survival.

139. Do Patient-Specific Precontoured Rods Justify a Ten-Fold Increase in Cost Compared With Manual Contouring in Adolescent Spinal Deformity Surgery?

Matthew Miyasaka, AB; *Alexander Fleisher, BS;* Kingsley Ogelle, BS; Alexander Kucherina, BS; Mina Eskandar, MS, BS; Garima Paul, MD; Constance Maglaras, PhD; Themistocles S. Protopsaltis, MD; Juan Carlos Rodriguez-Olaverri, MD

Hypothesis
Patient-specific precontoured rods offer limited clinical benefit over manually contoured rods.

Design
Single-center retrospective cohort study

Introduction
Patient-specific precontoured rods derived from three-dimensional planning have been introduced to improve precision and reproducibility in adolescent spinal deformity correction. However, these constructs are associated with substantially higher implant cost (approximately $2,000 per construct) compared with standard manually contoured rods (approximately $200). Whether this cost differential translates into clinically meaningful alignment benefits remains uncertain.

Methods
Adolescents ≤25 years undergoing posterior spinal fusion above L4 with an apex osteotomy and complete preoperative and 24-month postoperative standing radiographs were included. Patients were stratified into patient-specific precontoured (PC) and manually contoured (MC) rod cohorts. PC constructs used a 6.0-mm cobalt-chrome rod on the concave side and a 6.0-mm titanium rod on the convex side; MC constructs reflected standard surgeon-directed contouring. Coronal and sagittal alignment parameters and shoulder balance metrics were analyzed. Achievement of normative thoracic kyphosis (20–40°) and PI–LL mismatch within ±10° was compared. Independent t-tests and χ^2 analyses were performed.

Results
A total of 129 patients were included (PC = 79, MC = 50), with no preoperative demographic or radiographic differences. At two-year follow-up, PC patients demonstrated greater pelvic tilt (15.1 ± 9.7° vs 10.8 ± 11.2°, p = 0.029), thoracic kyphosis (33.4 ± 11.6° vs 28.9 ± 9.9°, p = 0.020), and T1 tilt (7.1 ± 4.9° vs 5.4 ± 4.4°, p = 0.049). However, the proportion of patients achieving normative thoracic kyphosis and optimal PI–LL alignment did not differ between cohorts (p > 0.05). Coronal correction and postoperative shoulder balance were equivalent.

Conclusion
Despite statistically greater pelvic tilt and thoracic kyphosis, patient-specific precontoured rods did not improve the likelihood of achieving normative global alignment or shoulder balance compared with manual contouring. Given the ten-fold increase in implant cost, these modest radiographic differences may not justify routine use in adolescent spinal deformity surgery. Selective application may be appropriate for specific sagittal alignment phenotypes.

COST COMPARISON (VISUAL ANCHOR)		ALIGNMENT YIELD (CLINICAL REALITY)	
Patient-Specific Precontoured	Manually Contoured	Normative Thoracic Kyphosis (20-40°)	PC: 58% MC: 66% *No significant difference*
$2,000	$200	PI-LL within ±10°	PC: 61% MC: 46% *Trend but not significant*
10x cost increase		Shoulder Balance (T1 Tilt, Clavicle Angle)	PC ≈ MC *Equivalent outcomes*

Cost vs Clinical Comparison between Rods

140. Intraoperative Neuromonitoring Alerts During Surgery for Congenital Spinal Deformity: Prevalence, Risk Factors, and Outcomes in a Prospective Study of 100 Patients

Anuj Gupta, MD; Brett Shannon, MD; Petya Yorgova, MS; Paul D. Sponseller, MD; Oheneba BoachieAdjei, MD; Jennifer M. Bauer, MD, MS; Burt Yaszay, MD; Purnendu Gupta, MD; Kwadwo Poku Yankey, MD; Munish C. Gupta, MD, MBA; Lawrence G. Lenke, MD; Peter O. Newton, MD; Michael P. Kelly, MD; Amer F. Samdani, MD; Joshua M. Pahys, MD; Daniel J. Sucato, MD, MS; David B. Bumpass, MD; *Suken A. Shah, MD*

Hypothesis
There are multiple preoperative curve characteristics and intraoperative variables responsible for high incidence of IONM alerts in congenital scoliosis

Design
Retrospective

Introduction
Surgical goals for congenital spinal deformity (CSD) include correction of deformity and prevention of progression without affecting neurological function. CSD has a higher incidence of IONM alerts than other scoliosis types and a potential for risk of postoperative neurological deficit. This study investigates incidence, risk factors, and outcomes associated with IONM alerts in surgically-treated CSD.

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Methods
A prospectively-collected pediatric database was queried for surgically-managed patients with CSD. Demographic, surgical, and IONM details were analyzed and neurological outcomes were tracked.

Results
100 patients included. Diagnoses: scoliosis, kyphosis, and kyphoscoliosis. Mean dominant-plane curvature was 64°. Hemivertebrae were in 51 patients. IONM alerts occurred in 19%: 11 transcranial motor-evoked potential (TcMEP) alone and 8 both TcMEP and somatosensory-evoked potential (SSEP). 15 alerts occurred in patients undergoing 3-column osteotomy & 4 posterior spinal fusion (PSF) alone. Significant risk factors for alerts: curve magnitude, sagittal-DAR, total-DAR, % blood loss (%BL), & number of levels fused. The 40% alert likelihood values were 98° (Cobb), 17 (S-DAR), 27.1 (T-DAR), and 52% (%BL). Three-column osteotomy was not statistically correlated with a higher IONM alert rate (p=0.145); however, higher alerts were seen in patients with osteotomy (23% vs 11%). Twenty-six alerts occurred in 19 patients; 5 had >1 alert. Most occurred during hemivertebrae excision/VCR & rod/correction maneuvers. Intraoperative mitigation measures included increasing MAP and reducing correction. Signals returned to baseline in 58% alerts. Four of 19 cases had a postoperative neurological deficit–all with combined TcMEP and SSEP loss–but all recovered by 4-6 weeks.

Conclusion
This is the first, large, contemporary multicenter prospective study to highlight a 19% incidence of IONM alerts & favorable outcomes of neurologic deficit in CSD. Curve magnitude, sagittal-DAR, total-DAR, more levels fused, & %BL have significant risk associations. Measures adopted by spine surgeons intraoperatively are described. Combined loss of TcMEP and SSEP should be considered threatening.

Variable	IONM alert		Total	Categorical analysis	Binary logistic regression analysis			40% likelihood value
	Yes	No		p value	OR	95% CI	p value	
Gender (F:M)	16:3	47:34	100	**0.034**	0.242	0.64-0.916	**0.037**	
Curve magnitude	77°	61°	64°	**0.006**	1.030	1.007-1.054	**0.010**	**98°**
C-DAR	11.1	8.6	9.1	0.048	1.019	0.996-1.234	0.058	
S-DAR	10.3	5.9	6.8	**0.005**	1.101	1.023-1.184	**0.010**	**17**
T-DAR	21.4	14.5	15.8	**0.001**	1.094	1.031-1.162	**0.003**	**27.1**
Osteotomy (VCR/PSO)	15	50	65	0.160	2.447	0.735-8.144	0.145	
PSF	4	31	35					
% blood loss	30	17.4	19.82	**0.004**	1.036	1.009-1.063	**0.008**	**52**
% correction	41	42	42	0.931	1.002	0.978-1.027	0.863	

141. Impact of Age at Growing Rod Insertion on Final T1-T12 Spinal Height

Blake K. Montgomery, MD; Patrick J. Cahill, MD; Scott J. Luhmann, MD; Jason B. Anari, MD; Simon Y. Tang, PhD; Pediatric Spine Study Group; Michael J. Heffernan, MD; Brett Lullo, MD

Hypothesis
Children with idiopathic early-onset scoliosis who receive growing rods at a younger age will have a shorter final T1-T12 spinal height compared to children who receive growing rods at an older age.

Design
Retrospective

Introduction
Growing rod (GR) surgery for early-onset scoliosis (EOS) does not reliably achieve a T1-T12 spinal length comparable to children without scoliosis. Autofusion is a potential contributing factor. A recent study found that autofusion is 10 times more likely when GR are inserted in children aged ≤7. This study aimed to determine whether the age of GR insertion is associated with the final T1-T12 height.

Methods
We reviewed a multicenter database. Inclusion criteria were patients with idiopathic EOS who had growing rod surgery from ages 2-9, completed GR treatment, and had pre-insertion and post-definitive X-rays. T1-T12 height was measured at various time points: before and after GR surgery, and before and after definitive fusion. The growing phase was defined as T1-T12 length after GR surgery to immediately prior to definitive fusion. ANOVA, multiple linear regression, and t-tests were performed with significance set at <0.05.

Results
A total of 149 patients met the inclusion criteria. Final T1-T12 height was shortest when the index procedure was performed at age 3 (18.6 cm [SD: 3.4]) and steadily increased as the age at index surgery increased up to age 9 (23.7 cm [SD: 2.8]). Final T1-T12 height was most influenced by the T1-T12 height prior to the index procedure (13.0-18.7 cm). For every 1-year delay, the final T1-T12 height increased by 6 mm (95% CI 3-9 mm, p<0.001). All ages gained less than 3 cm average T1-12 height during the growth period. Increases in T1-T12 height occurred during GR insertion (1.6-4.3 cm), GR lengthening (-0.3-2.7 cm), and graduation (0.4-1.4 cm).

Conclusion
Final T1-T12 height steadily increases as the age at GR insertion increases and is most influenced by the T1-T12 height prior to the index procedure. There may be a "starting of the clock" when growing rods are inserted, which allows for a finite amount of growth before the spine will no longer meaningfully lengthen.

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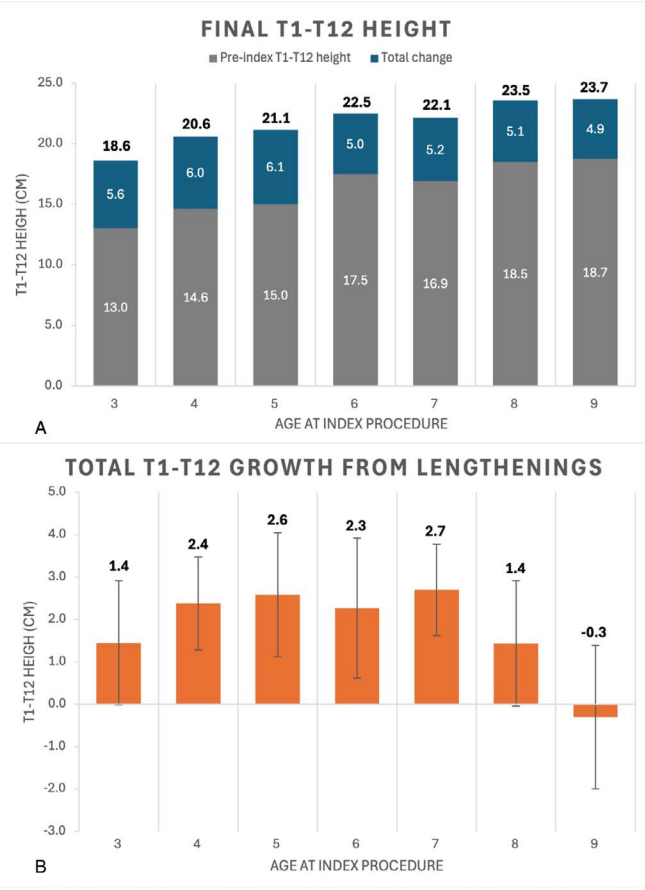

A) Final T1-T12 height was lowest when index procedure was performed at age 3 and steadily increased as age at index surgery increased. B) Contrary to expectations, younger age at growing rod insertion does not lead to clinically significantly increased T1-T12 growth during lengthening.

142. Physical Function of Early-Onset Scoliosis: An International Multisite Prospective Study

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Hypothesis
The six-minute walk test (6MWT) will correlate with the 1-min and 2-min walk tests (1MWT/2MWT), EOSQ24 physical function domain, pulmonary function test (PFT), and curve magnitude.

Design
Multisite prospective study

Introduction
Early-onset scoliosis (EOS) outcomes are typically limited to radiographs, which do not illustrate physical function. We evaluated correlations between the 6MWT and the 1MWT, 2MWT, EOSQ24, PFTs, and curve magnitude, and compared 6MWT results by EOS etiology.

Methods
4 institutions (3 US; 1 Ghana) prospectively enrolled children with EOS from 2023-25 who could perform a 6MWT and/or 6-min push test (6MPT), PFT, and EOSQ24/self. Children walked (6MWT) or propelled their wheelchair (6MPT) for 6 min. A pulse oximeter monitored heart rate and oxygen saturation. Concomitant 1MWT/1MPT and 2MWT/2MPT were recorded during the 6MWT/6MPT.

Results
142 children (74 Idiopathic [I], 33 Congenital [C], 22 Syndromic [S], 13 Neuromuscular [N]) completed a 6MWT, and 11 a 6MPT. The 6MWT strongly correlated with the 1MWT ($r=0.81$, $p<0.001$) and 2MWT ($r=0.80$, $p<0.001$). The 6MWT moderately correlated with EOSQ24 physical function ($r=0.41$, $p<0.001$) and weakly correlated with EOSQ24 transfer, parental impact, satisfaction, and daily living ($r=0.35$-30, $p<0.001$). The 6MWT weakly correlated with FVC% predicted ($r=0.23$, $p=0.018$), and did not correlate with curve magnitude ($r=-0.15$, $p=0.07$). Of the 142 6MWTs, I vs C vs N/S did not differ by age (10.5 yrs vs 10.4 vs 11.0, $p=0.67$), sex (70% vs 61% vs 63%, $p=0.55$), and distance walked (406 m vs. 416 vs 386, $p=0.45$). I had smaller curves than C and N/S (40° vs 59° vs 55°, $p<0.01$), better FVC% predicted (75% vs 62% vs 63%, $p<0.05$), and better EOSQ24 physical function scores (91 vs 83 vs 86, $p<0.05$). The only other EOSQ24 domain difference by etiology was worse financial impact scores for N vs. C (64 vs. 82, $p=0.020$). The distance walked did not differ by geographic location ($p=0.50$).

Conclusion
International multi-site collaboration in reporting physical function in EOS is valid and feasible. Unlike radiographs which quantify structure, the 6MWT provides a clinically meaningful measure of physical function regarding how EOS impacts daily life. Multiple EOSQ24 domains (physical function, transfer, parental impact, satisfaction, and daily living) correlated with the 6MWT. The 1MWT and 2MWT may serve as practical surrogates to the 6MWT.

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6MWT correlations with the 1MWT, 2MWT, EOSQ24, PFT, and curve magnitude

	6MWT	
	Correlation (r)	p-value
1MWT	0.81	**<0.001**
2MWT	0.80	**<0.001**
EOSQ24 domain		
General health	0.13	0.133
Pain/discomfort	0.07	0.432
Pulmonary function	0.17	0.052
Transfer	0.35	**<0.001**
Physical function	0.41	**<0.001**
Daily living	0.30	**<0.001**
Fatigue/energy level	0.25	**0.003**
Emotion	0.22	**0.010**
Parental impact	0.32	**<0.001**
Financial impact	0.21	**0.016**
Satisfaction	0.31	**<0.001**
PFT		
FVC absolute (L)	0.16	0.106
FVC% predicted	0.23	**0.018**
FEV1 absolute (L)	0.15	0.129
FEV1% predicted	0.17	0.072
Curve magnitude	-0.15	0.068

143. Proximal Junctional Kyphosis in Distraction-Based Growth-Friendly Treatment:Definition, Risk Factors, and Timeline

Ataberk Beydemir, MD; Rafik Ramazanov, MD; Mehmet Berktas, MD; Mehmet Ayvaz, MD; Gokhan H. Demirkiran, MD; *Muharrem Yazici, MD*

Hypothesis
In early-onset scoliosis(EOS) treated with dual growing rod(GR) systems, proximal junctional kyphosis(PJK) occurs in distinct temporal patterns and is associated with specific radiographic and construct-related factors.

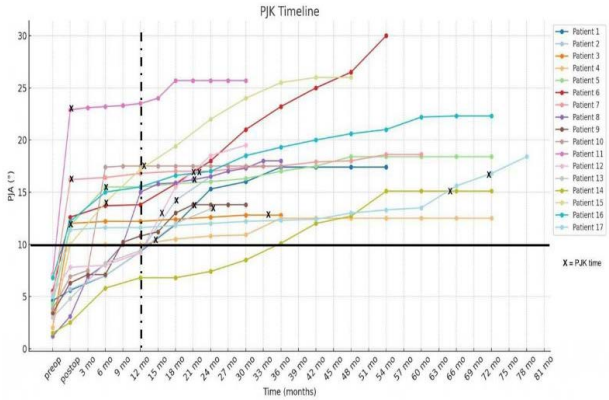
Design
Single-center retrospective cohort study of EOS patients treated with dual GRs, using serial radiographs to determine the timing and risk factors of PJK.

Introduction
PJK may complicate distraction-based growth-friendly treatment(DB-GFT) and negatively affect overall treatment success. This study aimed to re-evaluate the definition, timing, and risk factors of PJK.

Methods
95 EOS patients treated with GR systems between 2004 and 2023 and with ≥ 2 years of follow-up were retrospectively reviewed.Radiographic parameters were assessed at preoperative,postoperative, and final follow-up.PJK was defined as a roximal junctional angle (PJA) ≥10° at the latest follow-up with an increase of ≥10° compared with preoperative PJA values.Serial lateral radiographs were examined at 3 or 6 month intervals to assess both the occurrence and timing of PJK.Univariate and multivariate logistic regression analyses were performed to identify risk factors.

Results
The age of the 95 patients at the time of index surgery was 6.84, the mean follow-up was 5.83 years, and the age at the last follow-up was 12.7 years.PJK developed in 17 patients(17.8%).It developed immediate postoperatively in 3 patients(mechanical) and gradually in 14 others(biological), of whom 12 were diagnosed after the first year. The univariate logistic regression identified the following significant risk factors: upper instrumented vertebra(UIV) at T3 and distal, T5–T12 thorasic kyphosis(TK) correction ≥30°.There was a 3% increase in PJK risk for every 1° increment in preoperative T5–T12 TK and a 3% increase in PJK risk for every 1° increment in the postoperative lumbar lordosis difference.The multivariate logistic regression revealed that UIV at T3 or below was an independent risk factor.

Conclusion
Patients with preoperative T2-T12 TK ≥ 45°, those undergoing extensive kyphosis correction, or with a UIV located below T3 appear to have a higher risk of developing PJK. Normative segment-adjusted PJA values may serve as a more useful metric for identifying clinically meaningful PJK cases that have the potential to progress to proximal junctional failure(PJF).Since most PJK manifests after 1 year, long-term follow-up is essential.



144. Crankshaft Phenomenon and Its Related Factors Following Traditional Growing Rod Surgery in Early-Onset Scoliosis: A Computed Tomography-based Analysis

Hong Jin Kim, MD, PhD; Hyung Rae Lee, MD; Subin Lim, MD; *Jae Hyuk Yang, MD, PhD;* Seung Woo Suh, MD, PhD

Hypothesis
Considering the law of diminishing returns in traditional dual growing rod (TDGR) technique, the crankshaft phenomenon characterized by auto-fusion and progressive vertebra rotation may be inevitable complication in early-onset scoliosis (EOS).

Design
A retrospective cohort study

Introduction
TDGRs are widely used in the treatment of EOS because of their effectiveness in controlling coronal and sagittal alignment while permitting spinal growth. However,

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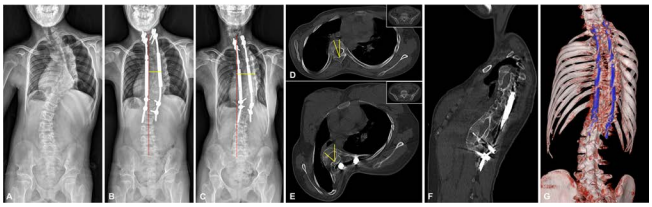
auto-fusion and progressive vertebral rotation at the time of final fusion surgery are frequently observed.

Methods
A total of 39 EOS patients who underwent growth-friendly surgery using TDGRs were categorized into two groups according to the development of the crankshaft phenomenon, defined as the presence of autofusion and increased vertebral rotation >5°: the crankshaft group (C group) and the non-crankshaft group (non-C group). Computed tomography (CT) scans were obtained at baseline and at the last follow-up before final fusion. Multivariate logistic regression analysis was performed to identify factors associated with the crankshaft phenomenon.

Results
The incidence of the crankshaft phenomenon was 64.1% (25 of 39) over a mean follow-up of 42.7 months. The mean main Cobb angle was significantly higher in the C group (46.2°) than in the non-C group (35.6°) (P = 0.038). The mean apical translation (AT) at the final follow-up was greater in the C group (46.2 mm) than in the non-C group (35.6 mm) (P = 0.014). The change in apical vertebral (AV) rotation was 13.5° in the C group compared with 0.2° in the non-C group. The rate of autofusion was 100% in the C group and 57.1% in the non-C group (P < 0.001), primarily observed on the convex side, involving a mean of 4.9 segments around the AV. Multivariate logistic regression analysis identified AT at final follow-up and the number of autofused segments as significant factors associated with the crankshaft phenomenon.

Conclusion
The crankshaft phenomenon was relatively common following growth-friendly surgery using TDGRs in EOS. AT at final follow-up and the presence of multiple autofused segments were significantly associated with its development. These findings suggest that improved apical control in growing rod techniques may help reduce the risk of the crankshaft phenomenon.



Crankshaft phenomenon in the traditional growing rod surgery

145. Implant Survival after Graduation by "Observation" in Patients Treated with Growing Rods: a 10-year Follow-up Study

Ana Hurtado, MD; Gloria Talavera, MD; Lucia Moreno-Manzanaro, BS; Irene Zarcos, MD; Jose Miguel Sanchez-Marquez, MD, PhD; Nicomedes FernandezBaillo, MD; *Javier Pizones, MD, PhD*

Hypothesis
Graduation by observation (with implant retention) at skeletal maturity after growing rod (GR) treatment can provide long-term curve stability and durable implant survival without requiring definitive fusion

Design
Retrospective single-center observational study.

Introduction
The optimal management strategy at skeletal maturity in patients with EOS treated with GR remains controversial. While definitive spinal fusion is traditionally recommended, graduation by observation may avoid final surgery in selected, low risk, well-aligned patients. The aim was to evaluate long-term implant survival, curve stability, and the rate of treatment failure when implants are retained.

Methods
Patients treated with GR who reached skeletal maturity and were graduated by observation with a minimum follow-up of 5 years were retrospectively reviewed. Radiographic evolution was analyzed assessing Cobb angle variation. Implant survival free from mechanical failure: rod breakage, pull-out, proximal junctional kyphosis (PJK), and distal junctional kyphosis (DJK), was assessed using Kaplan–Meier survival analysis. Strategy failure was strictly defined as conversion to definitive fusion, while mechanical failures not leading to fusion were recorded separately.

Results
Fifty-three patients were included, with a mean age at graduation of 14.4 ± 1.8 years, mean follow-up of 10.4 ± 4.2 years. The mean preoperative Cobb angle (88.1° ± 21.1) significantly decreased to 40.8° ± 11.3 postoperatively (p < 0.001). At graduation, the mean Cobb angle was 48.2° ± 14.3 and remained stable at 48.6° ± 14.1 at final follow-up (p > 0.05). Kaplan–Meier analysis showed a mechanical failure-free implant survival of 75% at both 5 and 10 years, with risk stabilization beyond the fifth year. Only 5 patients (9.4%) required conversion to definitive fusion. Two additional patients showed severe progression (110° and 80°) but remained under observation by clinical/family decision. The overall complication rate was 32% (mechanical failure 24.5%, infection 7.5%).

Conclusion
Graduation by observation at skeletal maturity in selected cases represents a viable alternative to definitive fusion, providing long-term radiographic stability in most patients. Although conversion to fusion is uncommon, isolated mechanical complications and cases of significant curve progression underscore the need for rigorous follow-up.

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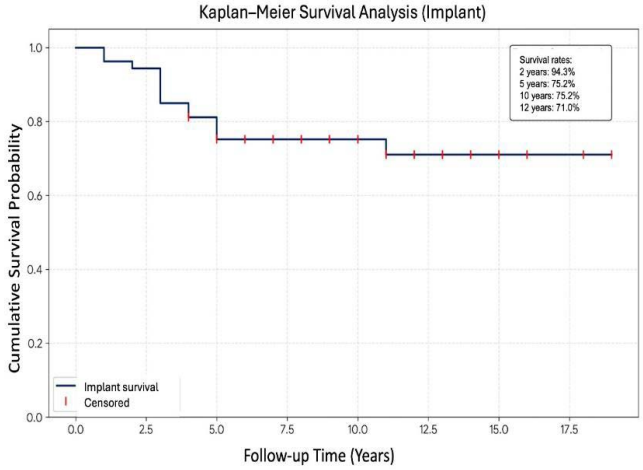

complications occurred in 5/6 (83.3%) vs 2/12 (16.7%) (P=0.013; RR=0.20, 95%CI 0.05–0.74). Non-reoperation complications occurred in 5/6 (83.3%) vs 4/12 (33.3%) (P=0.131). Final max Cobb (44.4±25.1° vs 39.7±18.4°, P=0.85), pre-to-final Cobb correction (54.4±21.8% vs 50.5±27.4%, P=0.82), and final TK (50.7±27.2° vs 48.2±16.7°, P=0.71) were similar. In the sensitivity cohort (N=26; 13 each), reoperation-requiring complications occurred in 7/13 (53.8%) vs 2/13 (15.4%) (P=0.097; RR=0.29, 95%CI 0.07–1.13).

Conclusion
Staged GR implantation was associated with markedly fewer reoperation-requiring complications in extremely severe EOS while maintaining comparable radiographic correction; the benefit was most evident using Cobb >100° or TK ≥60°.

146. Staged Growing-Rod Implantation Is Associated With Lower Rates of Reoperation-Requiring Complications in Extremely Severe Early-Onset Scoliosis

Kota Watanabe, MD, PhD; Satoshi Suzuki, MD, PhD; Kazuki Takeda, MD, PhD; Takahito Iga, MD, PhD; Toshiki Okubo, MD, PhD; Masahiro Ozaki, MD, PhD; Narihito Nagoshi, MD, PhD; Morio Matsumoto, MD, PhD; Masaya Nakamura, MD, PhD

Hypothesis
Staged growing-rod (GR) implantation reduces complications requiring reoperation in extremely severe early-onset scoliosis (EOS) without compromising radiographic correction.

Design
Retrospective cohort study.

Introduction
Complication-related reoperations remain common after growing-rod surgery for EOS, particularly in extreme deformity. Staged implantation (anchor placement followed by delayed rod insertion) was adopted to mitigate implant-related failure in the most severe cases.

Methods
EOS patients treated with dual-rod GR and ≥2-year follow-up were reviewed (N=54). Same-day implantation (anchors+rods) was compared with staged implantation (median 4.6 months [IQR 3.5–5.1] from anchor placement to rod insertion). Complications were categorized as requiring reoperation or not (patient-level incidence, ≥1 event). Primary analysis included severe-eligible cases defined a priori as preop max Cobb >100° or thoracic kyphosis (TK, T2–T12) ≥60°. Sensitivity analysis used Cobb ≥90° or TK ≥60°. Max Cobb and TK were measured preop, 1 month post-op, and at final follow-up.

Results
Overall, 39 patients underwent same-day and 15 staged implantation (age at index surgery 7.8±3.1 years; follow-up 9.0±4.2 years). In the severe-eligible cohort (same-day N=6; staged N=12), reoperation-requiring

147. Growth guidance or posterior based distraction in EOS: Can the modified Clavien-Dindo-Sink Classification System Tell Them Apart?

Rayyan Abid, ; Jason B. Anari, MD; *Christina K. Hardesty, MD;* Katerina M. Kourpas, AB; Stone R. Streeter, BS; Pediatric Spine Study Group

Hypothesis
TGR and MCGR will demonstrate more severe complications than Shilla growth guidance as designated by the mCDS classification system.

Design
Retrospective analysis of a multicenter database.

Introduction
The Shilla growth guidance (SGG) system was developed to treat spinal deformity without repeated lengthenings associated with posterior based distraction (PBD) techniques, including traditional growing rods (TGR) and magnetically controlled growing rods (MCGR). The modified Clavien-Dindo-Sink (mCDS) classification system is a validated method of evaluating complications in pediatric spine surgery. Previous studies have compared SGG and PBD in early onset scoliosis (EOS), but none have compared rates of severe complications using a standardized classification system like the mCDS.

Methods
We identified 2021 EOS patients who were treated with index SGG, TGR, or MCGR procedures, were less than 10 years-old when receiving their index procedure, had minimum 2-year follow-up from their index procedure, had no prior spine surgery, and had mCDS grading for associated complications. After dividing patients by etiology, a negative binomial regression model was used to compare rates of severe complications (mCDS ≥ IIIa) between patients receiving SGG and MCGR. Descriptions for mCDS ratings can be found in Table 1. This analysis was repeated comparing SGG and TGR patients.

Results
Among all etiologies, patients treated with SGG experi-

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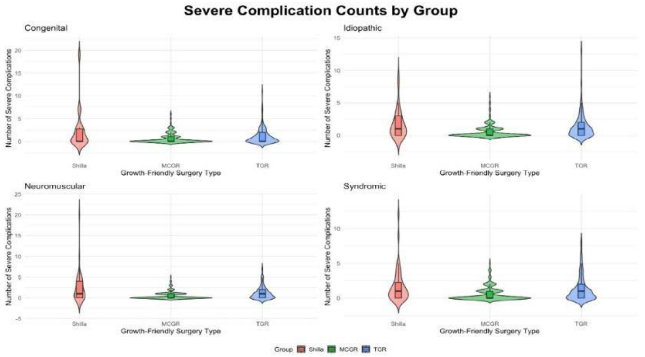
enced more severe complications than those receiving MCGR and TGR despite undergoing fewer surgeries than patients with TGR. MCGR patients generally underwent fewer surgeries than both groups but also had shorter follow-up from index procedure. Mean complications for SGG were greatest among syndromic patients at 2.6. Incidence rate ratio (IRR) comparing MCGR and SGG was lowest among neuromuscular patients at 0.21 (95% CI:0.15-0.30), indicating greater rates of severe complications among SGG patients. The IRR comparing TGR and SGG was lowest among congenital patients at 0.49 (95% CI:0.24-0.92) and neuromuscular patients 0.49 (95% CI:0.34-0.70). Shilla GG also had greater rates of severe complications than MCGR and TGR for all etiologies (Table 2).

Conclusion

Patients receiving SGG demonstrated greater rates of severe complications than TGR and MCGR patients despite undergoing fewer surgeries than patients with TGR. This relationship holds true for all etiologies.



mCDS Complication Grade*	Definition
0	No change in protocol, no change in routine follow-up, does not result in a return to the operating room.
I	Does not result in deviation from routine follow-up in the postoperative period and requires minimal or no treatment.
II	Unplanned clinic visits that require close monitoring/outpatient treatment or results in prolonged initial inpatient hospital stay.
IIIa	Treatable but requires an unplanned hospital readmission.
IIIb	Unplanned surgical or interventional procedure(s).
IVa	Life threatening, and/or requires ICU admission. Potential for permanent disability but treatable. No long-term disability.
IVb	Life threatening, and/or requires ICU admission. Not treatable, a complication that requires salvage surgery. With long-term disability.
V	Death

Table 1. Description of mCDS Complication Grades
*Bolded grades are considered "severe"

	N	Mean Severe Complications	Incidence Rate Ratio*	IRR 95% Confidence Interval	Mean Number of Surgeries	Mean Follow-up (years)
Congenital						
Shilla GG	22	2.3 ± 4.2	-	-	8.3 ± 9.5	5.1 ± 3.3
MCGR	146	0.6 ± 1.1	0.27	0.13, 0.61	6.1 ± 2.0	3.3 ± 1.0
TGR	140	1.1 ± 1.7	0.49	0.24, 0.92	8.1 ± 4.5	4.4 ± 1.1
Idiopathic						
Shilla GG	32	1.8 ± 3.3	-	-	8.0 ± 7.4	6.3 ± 3.0
MCGR	312	0.6 ± 1.0	0.33	0.18, 0.47	7.0 ± 6.7	3.8 ± 1.6
TGR	140	1.0 ± 1.7	0.72	0.46, 1.15	10.8 ± 4.4	4.3 ± 3.0
Neuromuscular						
Shilla GG	18	2.4 ± 3.4	-	-	6.3 ± 9.5	5.1 ± 2.0
MCGR	292	0.3 ± 0.8	0.21	0.15, 0.30	5.0 ± 5.4	3.3 ± 1.0
TGR	289	0.4 ± 1.0	0.49	0.34, 0.70	7.0 ± 4.2	4.1 ± 2.1
Syndromic						
Shilla GG	28	2.6 ± 2.4	-	-	8.9 ± 9.5	2.9 ± 3.0
MCGR	152	0.6 ± 0.9	0.23	0.20, 0.40	5.1 ± 6.2	2.7 ± 1.0
TGR	154	1.0 ± 1.1	0.40	0.34, 1.01	9.1 ± 10.7	3.3 ± 1.0

Table 2. Relative Rates of Severe Complications, Surgeries, and Follow-up by Etiology
*Shilla GG to GG

148. Revision Surgery for Deep Surgical Site Infection Differs by Instrumentation Type but Is Not Associated With Inferior Patient-Reported Outcomes in Early-Onset Scoliosis

Antti J. Saarinen, MD, PhD; John T. Smith, MD; Paul D. Sponseller, MD; Amer F. Samdani, MD; John (Jack) M. Flynn, MD; Michael G. Vitale, MD, MPH; Pediatric Spine Study Group; *Ilkka J. Helenius, MD, PhD*

Hypothesis

We hypothesized that infection-related revision would worsen patient-reported outcomes and differ by instrumentation type.

Design

A multicenter registry cohort of surgically treated EOS patients younger than 10 years at index surgery was analyzed.

Introduction

Deep surgical site infection is a common complication in the surgical treatment of early-onset scoliosis (EOS) and often necessitates reoperation. The impact of revision surgery for infection on patient-reported outcome measures remains unclear.

Methods

Unplanned revision surgeries performed to treat a deep surgical site infection were identified: 78 children underwent surgery with traditional growing rods (TGR), 46 with magnetically controlled growing rods (MCGR), 143 with VEPTR, and 20 with Shilla. All patients had a minimum 2-year follow-up. Only the first infection-related postoperative revision per patient was considered for analysis. Revisions were classified as early (<90 days) or late (≥90 days) following index surgery. EOSQ-24 domain scores were compared within patients before and after the first infection-related revision. Logistic regression was used to compare revision risk between instrumentation types.

Results

Within-patient PROM changes were not statistically significant following infection-related revision surgery, with Wilcoxon signed-rank p-values ranging from 0.052 to 1.00 for early revisions (minimum p adjusted for etiology = 0.54) and from 0.086 to 0.97 for late revisions (minimum adjusted p = 0.37). Revision rates due to infection differed significantly by instrumentation type. Compared with TGR, MCGR was associated with a lower risk of late revision (OR 0.35, 95% CI 0.22–0.54, p<0.001) and VEPTR was associated with higher risk (OR 2.19, 95% CI 1.60–3.04, p<0.001). There were no statistically significant differences between Shilla and TGR. No significant differences were observed for early revisions. Compared with idiopathic EOS, syndromic patients demonstrated a lower risk of early revision (OR 0.25, 95% CI 0.08–0.74, p=0.013) but a higher risk of late revision (OR 4.00, 95% CI 1.36–12.42, p=0.013).

Conclusion

EOSQ-24 scores did not change following early or late infection-related revision surgery. There were significant differences in infection-related revision risk by instrumentation type.

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	Early infection	OR (95%CI)	Late infection	OR (95%CI)	
MCGR	18 (28.6%)	0.87 (0.43–1.74)	28 (12.4%)	0.35 (0.22–0.54)	
Shilla	5 (7.9%)	1.88 (0.61–4.89)	15 (6.6%)	1.46 (0.78–2.57)	
TGR	16 (25.4%)	Reference	62 (27.4%)	Reference	
VEPTR	23 (36.5%)	1.54 (0.81–2.99)	120 (53.1%)	2.19 (1.60–3.04)	
Female	29 (46.0%)		117 (51.8%)		
Congenital	17 (27.0%)	0.57 (0.23–1.45)	67 (29.6%)	1.76 (0.69–4.36)	
Idiopathic	9 (14.3%)	Reference	20 (8.8%)	Reference	
Neuromuscular	31 (49.2%)	0.77 (0.33–1.87)	84 (37.2%)	1.30 (0.54–3.03)	
Syndromic	6 (9.5%)	0.25 (0.08–0.74)	55 (24.3%)	4.00 (1.36–12.42)	

	Early infection	Median [IQR]	Late infection	Median [IQR]	Significance Early vs. Late
Age at Surgery		6.35 [3.80, 7.99]		5.19 [3.19, 7.52]	0.141
Age at Infection		6.39 [3.93, 8.03]		9.03 [6.73, 11.27]	<0.05
Preoperative weight	51	17.10 [12.40, 21.66]	189	15.47 [12.20, 20.00]	0.182

Risk of Early and Late Infection-Related Revision

149. Radiographic and Functional Outcomes for Sagittal Alignment in Growth Rod Graduates: Are We Able to Rebuild it?

Anuj Gupta, MD; Brett Shannon, MD; Benjamin Crain, MD; Petya Yorgova, MS; Paul D. Sponseller, MD; Lindsay M. Andras, MD; Pediatric Spine Study Group; *Suken A. Shah, MD*

Hypothesis
Final fusion does not change sagittal alignment significantly

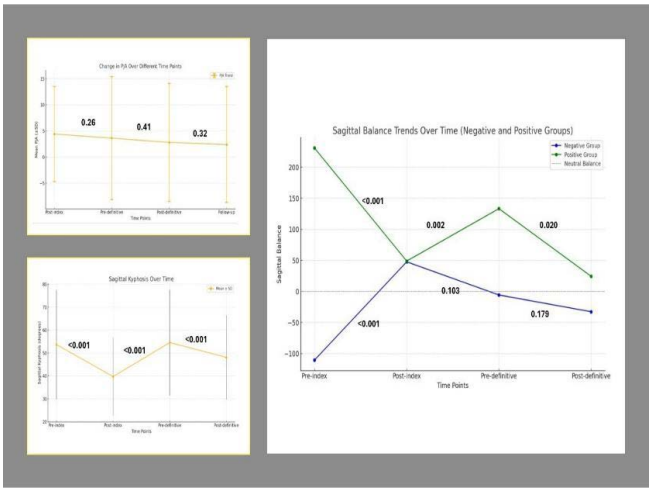
Design
Retrospective

Introduction
Role of sagittal alignment is extensively studied in adults and has been extended to pediatric. The inability to restore the sagittal parameters has direct impact on functional outcomes. Sagittal alignment in EOS managed with growth-friendly implants is modifiable, but what about after definitive fusion?

Methods
A prospective database was queried, patients managed with dual TGR or MCGR & anchors at spine were included. Anchors to the ribs, and follow-up of less than 2 years were excluded. The variables were collected at pre-index (before growth rod implantation), post-index, pre-definitive, post-definitive (final fusion), & at latest follow-up.

Results
420 patients (257 females), mean age 8.1 years at index implantation & 13.2 years at final follow up were included. Most common etiologies were neuromuscular (135), idiopathic (127), & syndromic (119). 234 patients were managed with TGR & 186 with MCGR. There was significant change in curvature & T1-S1 length at all time points (p<0.0001). TGR had better maintenance of curvature (loss of 8° vs 12°, p=0.016) & increase in length (36.8 mm vs 11.7 mm, p=0.001) during lengthening. There was a significant change (p<0.001) in sagittal kyphosis & LL overall, & MCGR patients ended with lower kyphosis & LL at post-definitive (p=0.02). Sagittal balance move towards neutral after index & definitive. Patients with +ve balance shifted to more +ve (+84.4mm, p=0.002), & those with -ve balance, to more -ve (-53.3mm, p=0.10) during lengthening. No significant change in these variables from post-definitive to mean follow-up of 2.9 years. PJA decreased from post-index to follow-up (p=0.003). The EOSQ-24 was not in normative range at pre-definitive & follow-up. It showed no significant change from pre-definitive to follow-up in all 3 domains except transfer (77% vs 72%, p=0.013) & fatigue/energy level (75% vs 70%, 0.0008), where deterioration observed. 28% (119/420) needed UPROR, most common reason rod fracture (53), & anchor pull-out (43).

Conclusion
Sagittal balance & PJA are not changed after definitive surgery. Kyphosis & LL are reduced & MCGR patients have lower values. The EOSQ-24 are not in normative range & not impacted by definitive surgery. Restoration of "normal" sagittal alignment remains difficult with current techniques and may affect long term HRQoL.



150. Effect of Distraction-based Growth Friendly Implants on Spinopelvic Parameters and Health-Related Quality of Life after Growth-Friendly Spine Surgery in EOS Patients at a Minimum of 5 Years Follow-up

Todd F. Ritzman, MD; Dominick A. Tuason, MD; Jaime A. Gomez, MD; Patrick J. Cahill, MD; Mark A. Erickson, MD; Sumeet Garg, MD; Scott J. Luhmann, MD; Paul D. Sponseller, MD; Michael G. Vitale, MD, MPH; Pediatric Spine Study Group

Hypothesis
The kyphogenic effect of posterior distraction-based

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‡ SRS Funded Research Grant

growth friendly instrumentation contributes to deteriorating sagittal imbalance over time.

Design
Retrospective, longitudinal observational cohort study using PSSG registry

Introduction
The kyphogenic effect of posterior distraction via either traditional growing rods (TGR) or magnetically controlled growing rods (MCGR) may contribute to deteriorating sagittal imbalance requiring correction at definitive fusion.

Methods
The PSSG database was queried for all ambulatory patients with growth friendly procedures with 5 year or pre-definitive fusion follow up radiographs. In the sagittal plane, the straight proportion of growth friendly instrumentation over the total length of instrumentation (Instrumentation Ratio, IR) was measured over serial radiographs as a surrogate for implant lengthening. Statistical analysis was performed via mixed model two-way ANOVA with instrumentation type as a grouping factor and time as a repeated factor.

Results
68 patients met inclusion criteria with either 5-year or pre-definitive fusion follow up radiographs. Despite interval posterior distraction (IR p=0.004), no significant change occurred in Pelvic Incidence (PI), Sacral Slope (SS), Pelvic Tilt (PT), Lumbar Lordosis (LL), or Thoracic Kyphosis (TK). Radiographic markers of global sagittal balance remained normalized when comparing pre-operative and 5-year or pre-definitive fusion for this cohort and did not demonstrate significant change throughout lengthening: Sagittal Vertical Axis (SVA) normalized while T4-L1 Pelvic Angle mismatch and PI:LL mismatch were unchanged. 44 of 68 had EOSQ results within 6 months of both their pre-operative and 5-year follow-up visits. Pain Discomfort decreased (76 to 65, p=0.019) and Parental Impact increased (70 to 77, p=0.006). No other statistically significant differences in domains exist over this time interval.

Conclusion
This longitudinal cohort of ambulatory patients treated with TGR or MCGR demonstrate maintenance of balanced global sagittal alignment and stable sagittal parameters. Sample size is too small to make significant conclusions regarding HRQOL in this cohort, however, evidence of deterioration of EOSQ is lacking.

	Pre-operative	5-yr / pre-definitive	p value
IR	0.39	0.43	p=0.004
PI	48.1°	50.9°	p=0.144
SS	42.1°	41.8°	p=0.866
PT	6.3°	9.3°	p=0.132
LL	53.6°	54.6°	p=0.771
TK	35.6°	31.6°	p=0.233
SVA	24.4 mm	9.6 mm	p=0.016
T4L1PA	3.8°	4.3°	p=0.407
PI:LL	11.1°	14.3°	p =0.136

Comparison of pre-operative and 5-year/pre-definitive fusion sagittal parameters

151. Long-term Outcomes in Adulthood Following Traditional Growing Rods for Early-Onset Scoliosis

Masaaki Ito, MD, PhD; Teppei Suzuki, MD, PhD; Koki Uno, MD, PhD

Hypothesis
TGR patients have poorer long-term QOL and social outcomes than AIS patients.

Design
Retrospective case series study

Introduction
Traditional growing rods (TGR) for early-onset scoliosis (EOS) impose significant burdens due to repeated surgeries. We investigated the long-term clinical and social outcomes of patients who reached adulthood following TGR.

Methods
Forty patients (20 female) who underwent TGR at our hospital between 1999 and 2012 were studied. Radiographic findings, survival, and employment status were assessed. Patient-reported outcomes (SRS-22, ODI) were compared with those of AIS patients (>10 years post-operative).

Results
The patients were categorized by etiology: congenital/structural (n=17), neuromuscular (n=6), syndromic (n=10), and idiopathic (n=7). The mean age was 7.9 years [2.7–13.4] at initial TGR surgery and 26.0 years [19.7–33.3] at final follow-up, with a mean follow-up duration of 17.9 years. During the postoperative period, four patients (10%) died (cardiovascular disease: 2, sepsis: 1, unknown: 1) at a mean age of 17.4 years [11–20.2]. Definitive fusion was performed in 36 patients. Chronological changes in mean scoliosis and thoracic kyphosis were: 85°/53° (pre-TGR), 51°/41° (post-TGR), 53°/51° (pre-definitive fusion), 40°/49° (post-definitive fusion), and 46°/53° (final follow-up). Corresponding T1-S1 lengths were 259, 298, 341, 361, and 361 mm. The mean number of lengthening procedures was 9.1, resulting in a total of 11.9 surgical interventions per patient. Complications included surgical site infections in 17 patients (43%) and unplanned surgeries in 20 patients (50%). Regarding social outcomes for survivors without intellectual disability (n=27), work status included: sedentary (n=9), light (n=8), medium (n=2), student (n=2), and unemployed (n=6). Compared to the AIS control group, the TGR group demonstrated significantly lower scores in SRS-22 domains: Function (3.88 vs. 4.30), Self-image (3.53 vs. 4.02), and Satisfaction (3.62 vs. 4.20) (all P<0.01).

Conclusion
TGR treatment entails a high surgical burden and complication rate. Adult TGR patients report significantly lower function, self-image, and satisfaction than AIS patients.

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Their limited employment highlights the critical need for long-term multidisciplinary support in adulthood.

Table. Comparison of SRS-22 and ODI scores between TGR and AIS groups

		TGR	AIS	P value
SRS-22	Function	3.88±0.59	4.30±0.45	<0.01
	Pain	4.62±0.45	4.68±0.39	0.59
	Self-image	3.53±0.52	4.02±0.54	<0.01
	Mental health	4.14±0.58	4.37±0.56	0.18
	Satisfaction	3.62±0.63	4.20±0.75	<0.01
ODI (%)		10.2±11.8	7.0±6.7	0.24

Compared to AIS, the TGR group had significantly lower SRS-22 Function, Self-image, and Satisfaction scores, with no differences in ODI or Pain.

152. Congenital Scoliosis: An Update to Its Natural History and Clinical Approach

Mihir Sharma, BS; Alexander Bhatt, MS; Jason Brenner, BS; Ashlyn Callan, MS; Priya Singh, MD; Edina Gjonbalaj, BS; Pediatric Spine Study Group; Jacob F. Schulz, MD; Leila Mehraban Alvandi, PhD; *Jaime A. Gomez, MD*

Hypothesis
The natural history of congenital scoliosis follows the discoveries of McMaster and Ohtsuka.

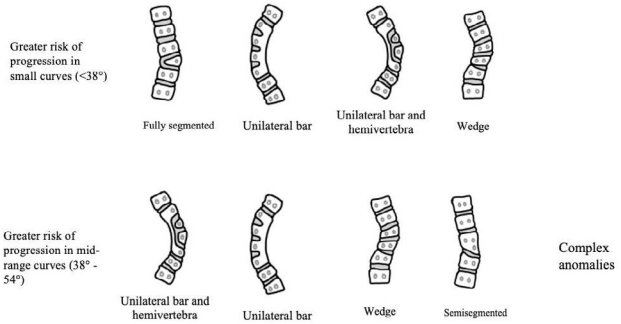
Design
Retrospective cohort analysis.

Introduction
Congenital scoliosis exhibits a variable natural history. Predictive modeling could improve care.

Methods
This multicenter study included 464 patients with congenital scoliosis with baseline and follow-up X-rays. Patients with neurological conditions were excluded. Deformities were classified using McMaster's system. The primary outcome was a Cobb angle ≥50° assessed at final follow-up or at last follow-up before surgical or casting/bracing treatment. A Kaplan-Meier survival analysis was used to analyze curve progression by deformity type, deformity location, and gender. A Chi-squared Automatic Interaction Detection (CHAID) decision tree was used to find predictors of progression. A Cox regression model was used to assess independent associations between progression and baseline age, deformity type, and gender.

Results
The mean baseline and follow-up ages were 3.5 ± 3.5 years and 8.8 ± 4.7 years, respectively. Most patients underwent surgical correction (55.3%), followed by observation (40.1%) or casting/bracing (4.5%). Baseline and follow-up Cobb angles averaged 46.5° ± 18.9° and 51.3° ± 22.9°, respectively. Kaplan–Meier analysis demonstrated that patients with unilateral unsegmented bars, with or without hemivertebra (HV), were at the highest risk of progression. Thoracic and thoracolumbar curves also showed higher progression risk, and female patients were more likely to progress. Cox regression identified higher baseline Cobb angle (OR 1.05 per degree increase, $p < 0.001$), older age at baseline (OR 1.12 per year increase, $p < 0.001$), and female sex (OR 1.38, $p = 0.024$) as independent predictors of progression. CHAID analysis through recursion identified baseline Cobb angle as the strongest predictor. Cobb ≤38°: Low progression risk (20.8%), especially in block vertebra, incarcerated HV, and complex anomalies (6.9%). Cobb 38–54°: Moderate progression risk (53.2%), with higher risk in patients with semisegmented HV, wedge, and unilateral unsegmented bar deformities (70.6%). Cobb >54°: High risk of maintenance at >50° (92.2%) regardless of deformity type.

Conclusion
Baseline Cobb angles with deformity classifications are a predictors of curve progression in congenital scoliosis.



Results from the CHAID Analysis.

153. The interesting morphological changes of adjacent vertebra after posterior hemivertebrectomy with unilateral short segment fusion for long-term follow-up in children

Xuhong Xue, MD, PhD; Kai Li, MD; Sheng Zhao, MD

Hypothesis
Morphological changes of adjacent vertebra after hemivertebrectomy is beneficial for scoliosis corrction in pediatric congenital hemivertebra

Design
A retrospective study

Introduction
This study aimed to investigate morphological changes of adjacent vertebra and long-term efficacy of posterior hemivertebrectomy with unilateral short-segment fusion in pediatric congenital hemivertebra.

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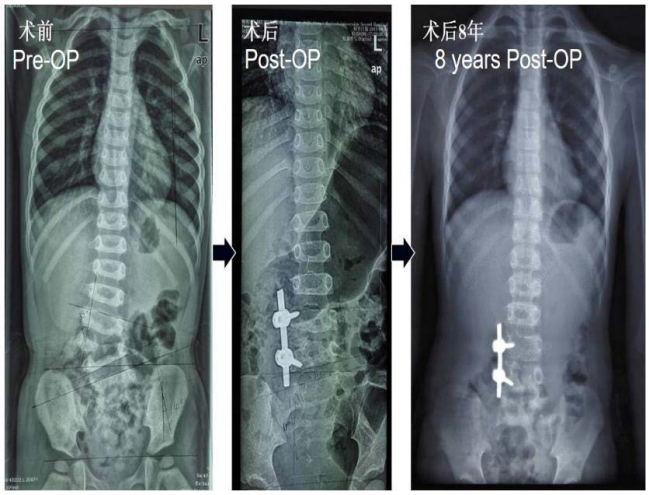
Methods
The patients with hemivertebra were included in a single spine center from Jan 2000 to Jan 2018, which were treated with posterior hemivertebrectomy with unilateral short segment fusion. The Cobb angle of main curve, TK, and SVA before surgery; immediately, 6 months, and 5 years after surgery were compared. The correction rates of the immediate postoperative and final follow-up were compared. The convex and concave heights of proximal vertebral bodies (PVB)and distal vertebral bodies (DVB) were compared before and 5 years after surgery.

Results
In total, 26 patients were included undergoing posterior hemivertebrectomy, consisted of 12 males and 14 females, average aged 2-10(5.4±2.9) years. All patients were followed up for 60-82 (68.8±8.1) months. The operation time ranged from 84 min to 174 (120.0±24.0) min. The bleeding loss was 75-130 (100.0±16.1) ml. The correction rate was 66.3%±18.4%. The preoperative, immediate postoperative and 5-year postoperative Cobb angles of main curve were 36.3° ±11.4° , 12.3° ±7.4° and 12.6° ±7.4° , respectively. The differences were statistically significant (P<0.05). The convex height, concave height of the PVB and DVB showed an increasing trend from 1 year to 5 years after surgery compared with the preoperative. The differences were statistically significant(P<0.001). The total growth rates of the PVB and DVB in concave side at 5 years after surgery were 106.4%±89.3% and 96.9%±74.1%, respectively; the total growth rates of convex side were 91.0%±93.5% and 96.2%±101.3%, respectively; the BLPD total growth rates were 37.0%±47.7% and 40.4%±70.3%, respectively.

Conclusion
The posterior hemivertebra resection with unilateral short segment fusion for the treatment of congenital hemivertebra in pediatric patients can achieve satisfactory results at long-term follow-up. The morphological changes of adjacent vertebra is interesting: from cuneiform or irregularly shaped into a square.



Demo case

154. Three Year Results of a Randomized Controlled Trial Comparing Two Novel Distraction-Based Devices for Neuromuscular Early Onset Scoliosis

Justin V. Lemans, MD, PhD; Casper S. Tabeling, MD; Hilde W. Stempels; Agnita Stadhouder, MD; Jeroen Renkens, MD; Lotfi Miladi, MD; Tom P. Schlosser, MD, PhD; René M. Castelein, MD, PhD; Moyo C. Kruyt, MD, PhD

Hypothesis
The One-Way Self-Expanding Rod (OWSER) and the Spring Distraction System (SDS) have similar outcomes at 3 year follow-up when treating Neuromuscular Early Onset Scoliosis (NM EOS) patients.

Design
Randomized controlled trial

Introduction
Current surgical management of NM EOS in skeletally immature patients often relies on serial distractions, imposing substantial burdens on patients and healthcare systems. To address this limitation, two novel growth-friendly implants that do not require in-hospital lengthenings were introduced: the One-Way Self-Expanding Rod (OWSER) and the Spring Distraction System (SDS) (Figure 1). This multicenter, RCT investigates and compares the efficacy and safety of these two "growth-friendly" systems.

Methods
Non-ambulatory, NM EOS patients indicated for surgical treatment were enrolled at three Dutch academic spine centers. Based on a power analysis to detect a 5° difference in loss of correction, 30 patients were randomized, blinded and treated with either the OWSER or SDS. Both groups were compared with respect to the radiographic and clinical outcomes at three years of follow-up, including curve correction, spinal growth, complications and UPRORs.

Results
Thirty patients (mean age 9.0 years; 20 boys) with a variety of NM disorders were included. One OWSER patient died after two years of follow-up. Two SDS patients died within the first postoperative year and were replaced. All deaths were caused due to underlying disease and unrelated to the treatment. Main coronal curve correction was -34° (-47%) in OWSER and -40° (-52%) in SDS and was maintained similarly. Pelvic obliquity improved after surgery (OWSER -60%; SDS -70%) and was maintained in both groups. T1-S1 growth during follow-up was physiological for both devices, but slightly higher for OWSER (+13%) as compared to SDS (+12%). The OWSER group had 6 implant-related complications and 6 UPRORs (0.14/patient/year). In the SDS group, there were 3 implant-related complications and 3 UPRORs (0.07/patient/year).

Conclusion
Both the OWSER and SDS achieved approximately 50% main curve correction which was maintained during three years of follow-up. Spinal growth was physiological, with

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greater T1-S1 growth for OWSER. Complication- and UPROR rate was favourable for both systems.

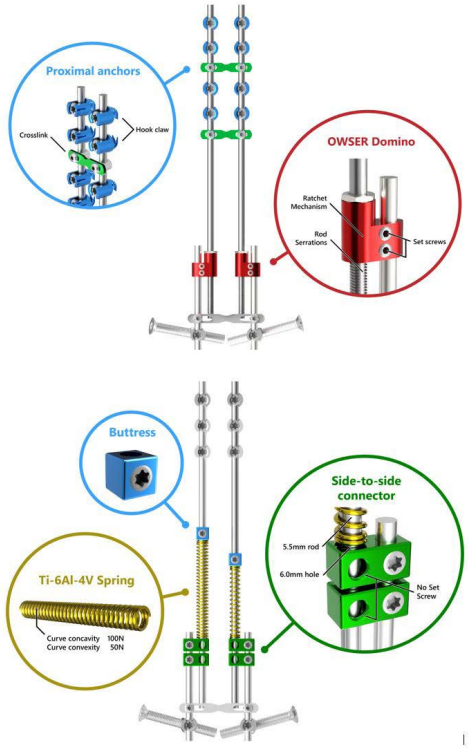


Figure 1: Schematic overview of the OWSER (top) and SDS (bottom) implant

155. Spinopelvic Alignment Parameters using the T4L1PA Hip Axis Predicts PJK and Reoperation in Scheuermann's Kyphosis Correction

Brandon A. Ramo, MD; Jesse P. Robinette, MD; Anna McClung-Booth, BSN; Matthew Siebert, MD; Megan Johnson, MD

Hypothesis
Surgical intervention for Scheuermann's Kyphosis (SK) achieves radiographic correction but carries substantial complication risk, which can be minimized by achieving normal spinopelvic parameters

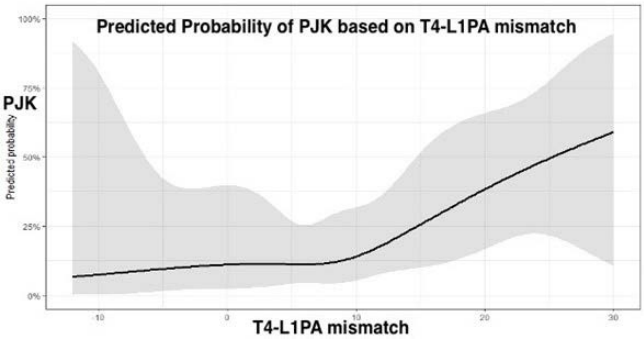
Design
Retrospective, single center cohort

Introduction
Scheuermann's kyphosis presents a unique surgical challenge in pediatric spinal deformity because restoration of normal sagittal parameters within the region of kyphosis alone or over-correction of kyphosis has been associated with risk of junctional failures. In adults, sagittal plane imbalance based on patient-specific T4L1PA hip axis predicts junctional/mechanical failures. We sought to apply these concepts to predict failure in pediatric patients with SK undergoing deformity correction.

Methods
Radiographic spinopelvic parameters (pelvic incidence, L1PA, T4PA, C2PA) were measured preoperatively, immediately postop and at final follow-up. Outcomes were PJK, defined as proximal junctional angle >15°, DJK, and revision surgery for PJK or DJK. Spinopelvic parameters of T4-L1PA mismatch and L1PA mismatch from ideal state (L1PA=0.5PI -19±2) were correlated to outcomes using multivariable non-linear (cubic spine) logistical regression. Fishers exact test was also used to compare between groups.

Results
77 SK patients (55M, 22F), mean 16.4±2.1years, mean kyphosis 87.3±9°, min 2y follow-up, underwent deformity correction. 18 patients (23%) experienced radiographic PJK (n=15) or DJK (n=3). All-cause reoperation was 7/77 (9.1%). 2 PJK and 2 DJK patients had reoperations for sagittal problems (5.2% of total cohort). Having PJK or DJK led to increased risk of reoperation vs. not: 4/18 (22.2%) vs 3/59 (5.1%), p =0.048. The 15 patients with PJK had similar L1PA postop but significantly different T4PA (5.35 vs. 0.06°, p=0.023) than those 62 without PJK, leading to higher rates of T4-L1PA mismatch. Logistic regression identified that T4-L1PA mismatch was the single significant predictor of PJK as an outcome (estimate = -2.449 Std Error 0.555, p<0.0001).

Conclusion
Spinopelvic alignment parameters using the T4L1PA hip axis seem to predict poor outcomes related to PJK and mechanical failure in the Scheuermann's Kyphosis population. Pediatric deformity surgeons should consider spinopelvic alignment goals pre- and intraoperatively to avoid junctional problems and mechanical failure.



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156. Aiming to Stop More Proximally When Determining Distal Fusion Level According to Stable Sagittal Vertebra in Scheuermann's Kyphosis. Comparison of Two X-ray Methods Lateral Traction Under General Anesthesia vs Standing Full-spine Lateral X-ray

Hamisi M. Mraja, MD; Ibrahim Dag, MD; Sepehr Asadollahmonfared, MD; Mustafa Buğra Ayaz, MD; Ahmet Hamdi Olcar, MD; Burak Abay, MD; Mehmet Zamanoglu, MD; Ilyas Dolas, MD; Sinan Kahraman, MD; *Meric Enercan, MD;* Selhan Karadereler, MD; Azmi Hamzaoglu, MD

Hypothesis
Lateral Traction X-ray Under General Anestesia (L-TrUGA) helps to stop proximally in selection of distal fusion level and save more distal mobile segments in Scheuermann's kyphosis

Design
Retrospective

Introduction
Over the past 15-20 years, selection of the distal fusion level in SK has been based on the stable sagittal vertebra (SSV) identified on standing lateral x-ray (S-LX) described by Lenke. The aim of study is to evaluate whether distal fusion level selection based on SSV on the lateral-TrUGA allows a more proximal stopping level with preservation of additional distal mobile segments and to assess the incidence of distal junctional kyphosis.

Methods
50 pts (34M,16F) underwent posterior spinal fusion for SK. Curves were classified as thoracic (T-SK; apex above T10) in 38 pts and thoracolumbar (TL-SK; apex at T10 or below) in 12 pts. Fusion was stopped at SSV identified on L-TrUGA in all pts. Sagittal parameters and DJK were evaluated on preop, postop and final f/up EOS lateral images.Clinical outcomes were assessed using SRS-22r.

Results
Mean age was 18 yrs (15–32), mean f/up was 8,65 yrs (2-18). In T-SK group, TK improved from 76.8° to 49.9°, LL improved from 67.2° to 47.7°, resulting in PI–LL mismatch of 8°. In TL- SK group, TK improved from 76.0° to 46.0°, LL from 63.0° to 32.0°, with a PI–LL mismatch of 11°. Corrections were maintained at final f/up in all pts. In 28 of 50 pts (56%), L-TrUGA identified more proximal SSV than S-LX, preserving one or more additional mobile segments. The greatest segment preservation was observed in T-SK, with 40% of pts gaining at least one level, followed by TL-SK in 33%. L-TrUGA saved 2 distal mobile segments in 8% of pts. None of pts developed DJK during f/up. Only 1 patient (2%) in T-SK group required revision for pseudarthrosis.SRS-22r scores improved significantly from 3.62 to 4.52.

Conclusion
In this 50 pts cohort, distal fusion level selection based on stable sagittal vertebra on lateral-TrUGA preserved one or more additional distal mobile segments in 56% of pts when compared with standing full-spine x-rays. The absence of distal junctional kyphosis indicates that distal fusion can be safely stopped more proximally when lateral-TrUGA is used for desicion making compared with standing x-ray in Scheuermann's Kyphosis

157. Operative Treatment for Scheuermann Kyphosis: A Comparison of Outcomes Between Adult and Adolescent Patients

Alan H. Daniels, MD; Amer F. Samdani, MD; Michael Farias, BS; Joseph E. Nassar, BS; David D. Liu, MD; Bassel G. Diebo, MD; Peter O. Newton, MD; Feyza Achilova; Lawrence G. Lenke, MD; Jeffrey Gum, MD; Kojo D. Hamilton, MD, FAANS; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Shay Bess, MD; *Baron S. Lonner, MD;* Harms Study Group; International Spine Study Group

Hypothesis
Adults with Scheuermann kyphosis present with more severe baseline deformity, achieve lower rates of thoracic kyphosis normalization, and experience higher pathologic junctional failure than adolescents despite similar fusion lengths.

Design
Multicenter, Multi-study group retrospective comparative cohort study

Introduction
No large-scale studies have directly compared Scheuermann kyphosis (SK) pathology and surgical outcomes by age. Age-dependent differences may guide optimal treatment.

Methods
Adolescent and adult SK patients undergoing posterior spinal fusion were identified from two prospective multicenter spinal-deformity registries. Demographics, perioperative outcomes, complications, radiographic alignment, reciprocal sagittal changes, occurrence of proximal junctional kyphosis and failure (PJK, PJF), and Scoliosis Research Society-22 (SRS-22) scores were compared. Continuous variables were compared with t-tests and Hedges' g; categorical variables with Fisher's exact tests.

Results
A total of 158 patients were included (97 adolescents, 61 adults). Adolescent patients had less severe preoperative thoracic kyphosis (TK; 74.7° vs 87.4°, p<0.001) and higher baseline SRS-22 total scores (3.60 vs 2.90, p<0.001). Levels fused were similar (12.8 vs 13.3, p=0.187), with less pelvic fixation (0% vs 8.2%, p=0.008), shorter operative time (337 vs 402 min, p=0.005), and lower ICU admission (36.9% vs 59.3%, p=0.011) in adolescent patients. Adolescent patients achieved greater TK correction (28.6° vs 18.4°; Hedges' g=0.71; p<0.001), more frequent TK normalization (20-50°) (64.9% vs 7.8%, p<0.001), and lower residual TK >70° (1.0% vs 45.1%, p<0.001); with less change in PI-LL (+8.9° vs +15.1°, p=0.001). Normative PJK (3.1% vs 17.5%, p=0.005) and PJF (2.1% vs 21.1%, p<0.001)

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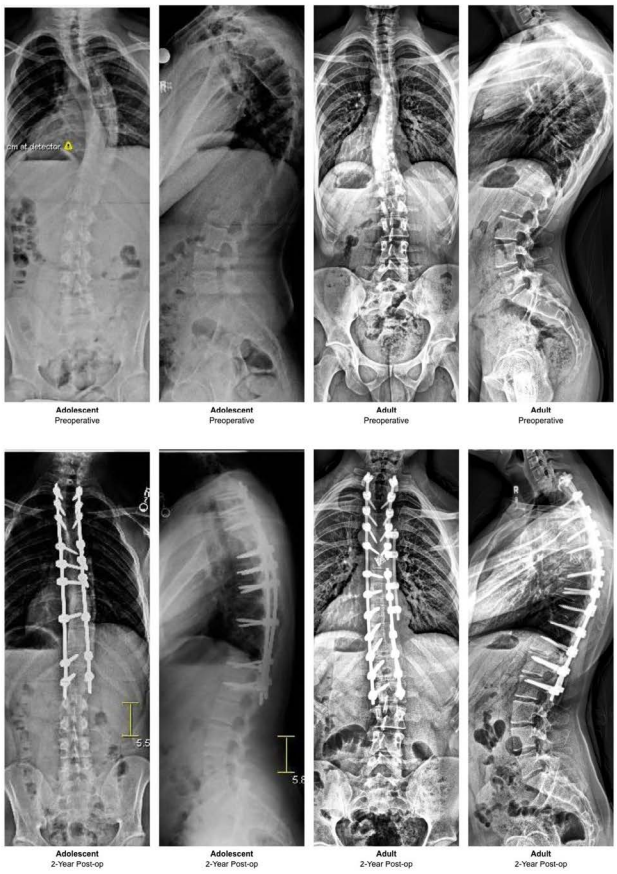
were markedly lower in adolescent patients. Both groups improved on SRS-22; adolescents had higher follow-up total (4.29 vs 3.92, p=0.005) and pain (4.21 vs 3.70, p=0.003) scores.

Conclusion
Adolescent and adult SK represent distinct surgical phenotypes. Adolescent patients achieve greater correction and substantially lower pathologic junctional failure than adults despite similar fusion lengths, supporting age-specific surgical planning, junctional protection in adults, and consideration of earlier intervention when clinically indicated.

Figure 1. Representative adolescent and adult Scheuermann kyphosis cases



158. Surgical Treatment of Post-tuberculosis Kyphosis with Ossification of Ligamentum Flavum: Identification of the Primary Causes of Neurological Deficits.

Jiahao Zhang, MD; Jiale Zhu, MS; Yan Zeng, MD

Hypothesis
In patients with post-tuberculosis kyphosis (PTK), ossification of the ligamentum flavum (OLF) at adjacent segments is not an incidental finding. Its occurrence is likely associated with biomechanical alterations in the ligament induced by the local kyphotic deformity. Accurate preoperative identification of the neural compression is essential for PTK patients complicated with OLF.

Design
A retrospective comparative study.

Introduction
PTK is a severe sequela of spinal tuberculosis, often leads to progressive angular deformity and neurological deficits, primarily attributed to direct spinal cord compression at the kyphotic apex. However, emerging evidence indicates that in some patients, neurological impairment is mainly caused by secondary OLF and spinal stenosis at segments adjacent to the primary deformity. The presence of OLF complicates surgical planning, as the primary cause of neural compression must be accurately identified to choose between extensive corrective osteotomy or more localized decompression.

Methods
We retrospectively collected 100 PTK patients underwent surgeries from two centers between 2015 and 2025, including 17 PTK patients complicated by OLF. The 17 Patients were divided into three groups based on preoperative imaging: Group A1 (n=8) underwent posterior vertebral column resection (PVCR) with simultaneous OLF resection; Group A2 (n=6) underwent PVCR alone; Group B (n=3) underwent simple posterior decompression and OLF resection. Neurological function was assessed using ASIA impairment scale and modified JOA scores.

Results
All groups showed neurological improvement at the final follow-up. Group B showed a distinct advantage in reduced surgical trauma, with significantly shorter operative time (138.0±35.6 min) and less estimated blood loss (286.7±201.33 ml) compared to Groups A1 and A2 ($p<0.05$).

Conclusion
The incidence of OLF in PTK patients is 17%, and OLF is a significant independent cause of neurological deficits in PTK patients. Precise preoperative identification of the primary compressive causes is essential for surgical planning. For patients with OLF as the dominant cause of compression, simple posterior decompression and OLF resection is a safe and effective, less invasive alternative to complex PVCR, resulting in excellent neurological recovery with significantly reduced surgical trauma.

159. Predicting the Benefit of Bracing for Adolescent Idiopathic Scoliosis Using Sanders Maturity Stages

Lori A. Dolan, PhD; Stuart L. Weinstein, MD; *Donna J. Oeffinger, PhD;* Richard M. Schwend, MD; BrAIST Study Group

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

Hypothesis
Treatment outcome is a function of SMS, Cobb angle and hours of brace wear

Design
Prognostic model derivation and validation

Introduction
Research suggests the Sanders' maturity stages (SMS) precisely reflect the current and future growth of patients with adolescent idiopathic scoliosis (AIS), hence a prognostic model including SMS would be clinically relevant and potentially useful. We sought the first model using the SMS to reliably and accurately estimate the benefit of bracing relative to patient, curve and wear time characteristics.

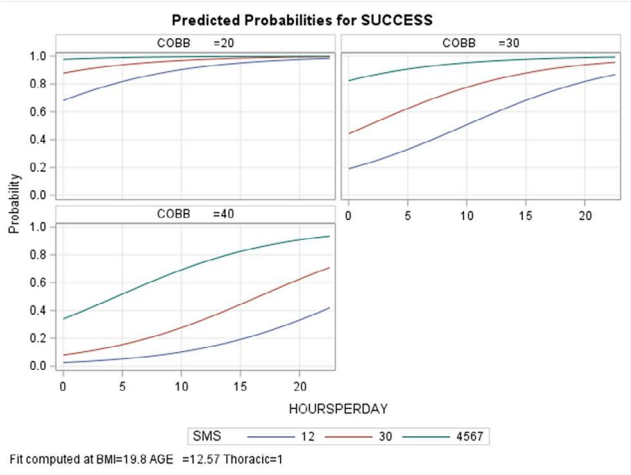
Methods
The model was derived and internally validated using patients treated within a multicenter trial and in routine clinical practice at four different locations. 585 subjects (Trial n=262; Clinical n=323) were included; 337 (58%) were braced. All were followed to either skeletal maturity (Risser 4), or Cobb angle ≥45° or surgery. Candidate variables included the SMS, sex, age, BMI, Cobb, presence of a thoracic curve, in-brace correction and estimated average hours of wear (per temperature monitoring). Multivariate logistic regression estimated the probability of success (maturity with a Cobb angle <45°). Calibration (prediction accuracy) and discrimination (reliability) were estimated in the derivation sample, and then in the Trial, Clinical, Braced and Untreated patient subsets.

Results
53% were at SMS <4, average Cobb angle was 29°, and brace wear averaged 10 hrs/day (range 0-23). 72% had a successful outcome. The final model included the baseline age, SMS (1-2, 3, 4-7), Cobb angle, presence of a thoracic curve, BMI, and average hours of brace wear (model c-statistic = 0.885, Brier score = 0.135). The model showed minimal loss of discrimination or calibration in the subsets (see table). The figure summarizes the relationship between the baseline Cobb angle, SMS and hours of brace wear with success: increasing hours of brace wear had the largest effect for patients at SMS <4 and those with larger curves.

Conclusion
This model produced accurate and reliable predictions of the benefits of bracing in routine clinical practice. This work adds to the available models providing prognostic evidence families and providers can use to jointly weigh individualized, risk-based treatment options. We welcome additional testing of this model and its potential impact on patient outcomes.

Summary of SMS Model Performance

Performance Statistics by Subset	c-statistic	Brier score	Calibration in the Large (Difference in Success: %Observed vs %Predicted)	Calibration Intercept	Calibration Slope
Entire Sample	**0.876**	**0.135**	**0%**	**-0.0002**	**1.02**
Trial	0.884	0.134	-3%	-0.25	0.97
Clinical	0.857	0.112	3%	0.25	1.03
Braced	0.831	0.119	1%	0.17	0.87
Untreated	0.891	0.124	0%	-0.05	1.11



Model Performance and Influence of Cobb Angle, Hours of Brace Wear and SMS on Probability of Success

160. In-brace Correction May Gate the Effect of Wear Time on Curve Regression in AIS Bracing

Tomoyuki Asada, MD, PhD; Toshiaki Kotani, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Yasushi Iijima, MD, PhD; Yusuke Setojima, MD; Kotaro Sakashita, MD; Yosuke Ogata, MD; Shohei Minami, MD, PhD; Seiji Ohtori, MD; Yasuhiro Homma, MD, PhD

Hypothesis
Curve regression in AIS bracing is associated with early IBCR, daily wear time, wear regularity, and night-time wear proportion.

Design
Retrospective cohort study of a prospectively maintained bracing registry

Introduction
Brace treatment in AIS aims to prevent progression, and curve regression has been observed in patients with high adherence. However, how brace wear time, IBCR, and wear patterns (regularity and night-time wear) are associated with curve regression remains unclear.

Methods
We included AIS patients with major Cobb angle (25–40°) treated with Boston brace. IBCR was defined as the

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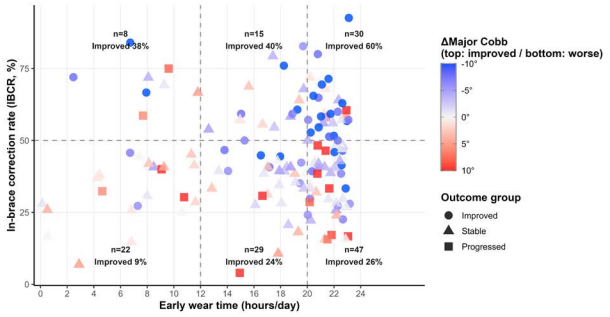
correction rate on the first in-brace radiograph. The primary outcome was curve regression, defined as Improved (<−5°), Stable (±5°), or Progressed (>+5°). Wear time was categorized as <12, 12–<18, 18–<20, and ≥20 h/day. Wear consistency was the interquartile range of daily wear hours (higher IQR indicates greater day-to-day variability). Night-time wear proportion was the proportion of total wear occurring during 10 PM–6 AM. Multivariable logistic regression modeled improvement (Improved vs Stable/Progressed) with wear-time category and IBCR (per 10% increase), adjusting for age, sex, Sanders stage, and baseline major Cobb angle.

Results
Of 154 patients, 48 (31%) experienced curve regression. Improvement increased with higher wear time (16% for <12 h/day; 26% for 12 to <18; 32% for 18 to <20; 39% for ≥20). Improved patients had higher IBCR (52.3% vs 39.9%, p<0.001) and higher early wear time (18.9 vs 16.7 h/day, p=0.033). In adjusted analysis, IBCR remained strongly associated with improvement (OR 1.83, p<0.001) and ≥20 h/day wear independently increased odds of improvement versus <12 h/day (OR 3.43, p=0.044). Wear consistency and night-time wear proportion were not independently associated with regression. In a spline model, the predicted probability of improvement crossed 50% at IBCR ≈52%. When stratified by both early wear time and IBCR, improvement was the most frequent with IBCR ≥50% and ≥20 h/day wear (60%) versus IBCR <50% (9–26%).

Conclusion
IBCR near 50% may gate the benefit of high wear time. Optimizing brace fit and correction quality at initiation, with adherence support to achieve ≥20 h/day, may maximize probability of curve regression, while wear regularity and night-time proportion were not independently associated with improvement.



Scatterplot of brace wear time (hours/day) vs in-brace correction rate (IBCR, %).

161. In-Brace Correction, Wear-time Compliance, and Outcomes in TLSO Bracing for Adolescent Idiopathic Scoliosis

Donna J. Oeffinger, PhD; Shelby White, PhD; Vincent Prusick, MD; Vishwas R. Talwalkar, MD

Hypothesis
In patients with AIS treated with TLSO braces, initial in-brace correction depends on patient and curve factors, but brace wear-time drives treatment success.

Design
Retrospective observational case review

Introduction
TLSO bracing in AIS aims to prevent curve progression and surgery. Treatment failure has been associated with inadequate IBC and poor wear compliance, yet factors influencing %IBC and its relationship to objectively measured wear-time compliance remain unclear. This study evaluated predictors of %IBC, its association with brace wear-time, and their impact on treatment outcomes.

Methods
Patients ≥10 years with AIS initiating TLSO bracing between January 2015 and April 2024 were included. Objective brace-wear compliance (iButtons), radiographic measures (curve magnitude, IBC, skeletal maturity), BMI%, and brace data were collected. Percentage curve correction at brace discontinuation was calculated. Analyses: descriptive statistics, ANOVAs, and linear regression (significance p<0.01).

Results
334 patients (77% Female; age 12.7±1.4;BMI% 60.2±31.3 @BracePrescribed) Mean IBC=55.1%±27.3 (≥50% correction achieved in 57.5%).Higher %IBC was associated with lower BMI percentile and curve type, with lumbar curves resulting in greater correction than thoracic curves (67.8% vs 47.7%). Normal-weight patients achieved higher %IBC than overweight/obese patients (67.7% vs 31.7%). Curve magnitude weakly correlated with %IBC (r=-.319). Among patients who discontinued bracing (N=110), mean %IBC was 53.2±29.0 and mean wear-time was 8.5±5.8 hours/day. Mean curve change at discontinuation was 1.9° (range: 84% correction to 118% progression). %IBC was not associated with wear-time compliance. Brace wear-time was the strongest predictor of curve progression, while %IBC showed only weak correlation (r=−0.276). Patients with curve improvement averaged 10.7±5.5 hours/day of brace wear compared to 6.6±5.1 hours/day among those without improvement.

Conclusion
Achieving ≥50% initial in-brace correction was most strongly associated with BMI percentile and curve type and was not related to brace wear-time compliance. Brace-wear compliance emerged as the strongest predictor of successful TLSO treatment, underscoring adherence as the key determinant of curve outcomes. Ongoing analyses are evaluating psychosocial factors and their association with compliance.

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162. Radiographic and Pulmonary Function Outcomes in Lenke 4-6 (TL/L-Dominant) Adolescent Idiopathic Scoliosis: Relationship to Diaphragm Intrusion

Zaid Elsabbagh, BS; William ElNemer, BS; Eric Mao, BA; Peter G. Gabos, MD; Gregory Redding, MD; Baron S. Lonner, MD; Firoz Miyanji, MD, FRCS(C); Peter O. Newton, MD; Paul D. Sponseller, MD

Hypothesis
TL/L-dominant AIS is associated with diaphragmatic intrusion and impaired pulmonary function, and posterior spinal fusion (PSF) improves diaphragm positioning and pulmonary outcomes.

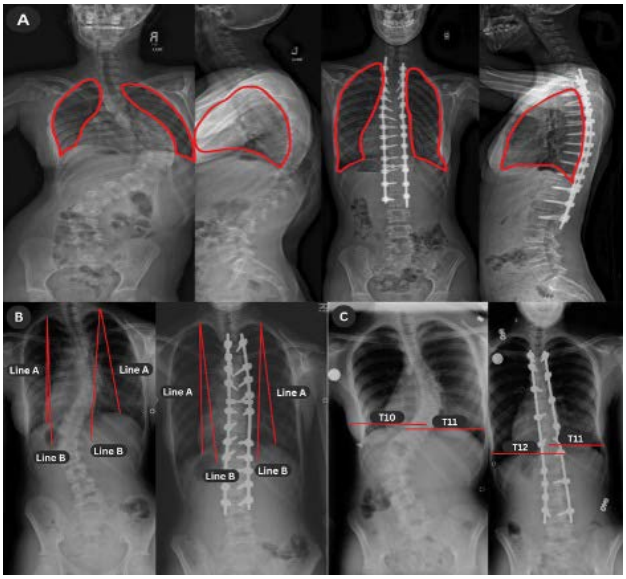
Design
Retrospective cohort study.

Introduction
Pulmonary dysfunction in adolescent idiopathic scoliosis (AIS) is typically attributed to thoracic deformity. However, thoracolumbar and lumbar-dominant (TL/L; Lenke 4–6) curves may impair respiration through diaphragmatic and abdominal displacement. The impact of this mechanism and its response to surgical correction remain incompletely defined.

Methods
We retrospectively reviewed 540 AIS patients with Lenke 4 (n=130), 5 (n=209), or 6 (n=201) curves who underwent PSF with ≥2-year follow-up and available pulmonary function testing (PFT). Radiographic measures included Diaphragm Intrusion Index (DII), Diaphragm Vertebral Level (DVL), calculated lung volume (CLV), and T1–S1 height. PFT outcomes included forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and total lung capacity (TLC). Multivariable regression assessed associations between diaphragm metrics and pulmonary function.

Results
The cohort was 83% female with mean 5-year follow-up. Across curve types, PSF significantly improved diaphragmatic positioning, lung volume, and spinal height (all $p<0.001$). DII and DVL increased significantly, CLV increased by ~12%, and T1–S1 height increased by ~3 cm. Pulmonary function improved primarily through increased lung volumes, including FVC and TLC. Among patients with severe baseline impairment (FVC <60% predicted), mean FVC improved by ~15–19 percentage points at mid-/long-term follow-up, with 67–86% improving to ≥60% predicted. Diaphragm dome height decreased by ~0.6 cm following surgery. Both DII and DVL were independently associated with FVC and FEV1 (all $p<0.02$). Despite improvement, Lenke 4 patients retained lower pulmonary function than Lenke 5 and 6 patients.

Conclusion
PSF improves diaphragmatic positioning and volume-based pulmonary function in TL/L-dominant AIS. Radiographic diaphragm metrics correlate with pulmonary function and may serve as useful adjunctive markers of respiratory impairment in this population.



Radiographic assessment of diaphragmatic positioning in AIS demonstrating measurement of Calculated Lung Volume, Diaphragm Intrusion Index (DII), and Diaphragm Vertebral Level (DVL).

163. Contextualizing Chest Radiograph–Based Pulmonary Function Estimation in Scoliosis Using Multimodal Deep Learning

Beomsu Kim, MD; Wounsuk Rhee, MD; Ihnseok Chae, MD; *Jeuk Lee, MD;* Sung Taeck Kim, MD; Bong-Soon Chang, MD, PhD; Sam Yeol Chang, MD; Hyoungmin Kim, MD

Hypothesis
Thoracic deformity associated with scoliosis can lead to impaired pulmonary function; however, the availability of pulmonary function testing (PFT) is often limited. We hypothesize that pulmonary function in scoliosis patients can be estimated using a multimodal deep learning framework incorporating chest radiographs and clinical information.

Design
Retrospective single-center study with multimodal deep learning model development.

Introduction
Scoliosis is a three-dimensional spinal deformity that can impair pulmonary function through thoracic cage deformation, while pulmonary function testing remains limited in clinical practice. This study proposes a multimodal deep learning framework to estimate pulmonary function in patients with scoliosis using routinely acquired chest radiographs and basic clinical data.

Methods
We retrospectively analyzed patients with scoliosis who underwent PFT and chest radiographs at a single institution between December 2013 and June 2025. After

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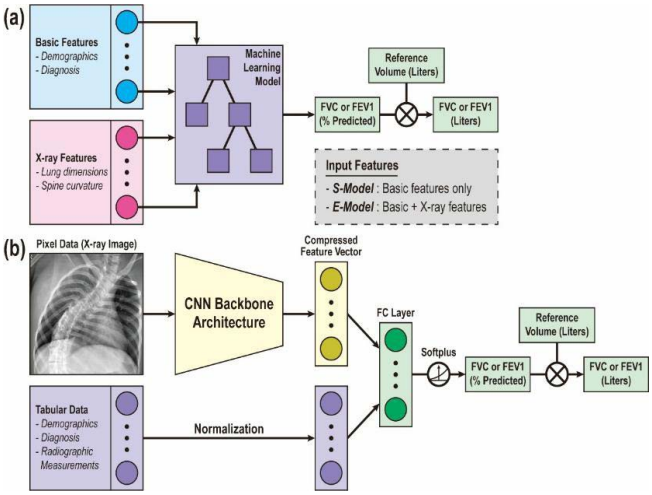
exclusions, 336 patients were included and divided into train-validation (80%) and independent test (20%) sets. Three model families were developed: S-Model using clinical data only; E-Model incorporating clinical and manual radiographic measurements; and M-Model integrating clinical data with raw chest radiograph images. Models predicted forced vital capacity (FVC) and forced expiratory volume in one second (FEV1). Restrictive ventilatory pattern was defined as FVC < 80% predicted.

Results
The cohort included 336 patients (mean age 31.0 ± 24.1 years; 125 male). The EfficientNetV2-B3–based M-Model achieved the best performance for FVC prediction, with a test MAE of 0.31 L. For FEV1 estimation, the EfficientNetV2-B0–based M-Model achieved a test MAE of 0.37 L. Significant improvement in FVC prediction was observed with increasing model complexity (S-Model vs. E-Model, p=0.04; E-Model vs. M-Model, p=0.002). For restrictive ventilatory pattern classification, the ResNet-34–based M-Model achieved test accuracy, sensitivity, and specificity of 0.90, 0.85, and 0.93, respectively.

Conclusion
Pulmonary function in patients with scoliosis can be estimated using routinely acquired chest radiographs and clinical data. This multimodal deep learning framework provides noninvasive, opportunistic FVC estimation and may serve as a complementary screening tool to prioritize confirmatory PFT when formal spirometry is unavailable.



Model designs.

164. Postoperative Anemia Predisposes to Serious Complications Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

Josephine R. Coury, MD; Fthimnir Hassan, MPH; Mehdi Elfilali, BA; Alexander Park, BS; Mia OConnell, BS; Michael W. Brown, BS; Justin L. Reyes, MS; Nicholas Laskay, MD; Evan Joiner, MD; Lawal A. Labaran, MD; Matthew E. Simhon, MD; Zeeshan M. Sardar, MD; Benjamin D. Roye, MD; Michael G. Vitale, MD, MPH; Lawrence G. Lenke, MD

Hypothesis
In contemporary AIS surgery with low transfusion rates, postop anemia, rather than transfusion exposure, may be associated with increased postop complications and impaired early recovery.

Design
Retrospective cohort

Introduction
Contemporary blood conservation strategies have reduced blood transfusions (BT) in AIS surgery, but leave patients variably anemic postop. While BT has been previously seen as a risk factor, the impact of postop anemia on complications and recovery remains unclear. We evaluated the relationships between BT, hematocrit (HCT), complications, and early functional recovery after AIS surgery.

Methods
AIS pts undergoing primary PSIF from 2020–2023 with max Cobb <75° were included. Early functional recovery was measured by PT-documented ambulation documentation. Associations between ambulation and HCT, BT, and covariates were analyzed using mixed-effects models with piecewise modeling to assess HCT thresholds. Secondary analyses evaluated postop complications among pts with ≥2-year follow-up.

Results
Among 225 AIS pts with ≥2-year f/u 27 received BT, with rates declining from 13% (2020) to 5% (2023). Mean HCT decreased from 36.5±5 preop to 31.1±4 postop. 6 pts had postop wound complications, with 4 infections requiring I&D, postop HCT was lower (25.9 vs 31.2,p=0.03), while BT rates were similar (1/6 vs 26/218,p=0.83). 2 pts developed postop neurologic deficits despite normal intraop monitoring (1 sensory, 1 motor deficit requiring urgent revision) and had lower postop HCT comparatively (24.8 vs 31,p=0.01). LOS did not differ in BT vs non-BT pts (3.7 vs 3.2days,p=0.06). For early functional recovery, postop day was the strongest predictor of ambulation(β=105.5 ft/day,p<0.0001). Higher postop HCT independently predicted greater ambulation (β=2.33 ft per unit,p=0.003), while BT, demographics, and surgery magnitude did not. A threshold was seen at HCT 28, below which HCT was significantly associated with ambulation (p=0.038), with attenuation above this level.

Conclusion
In AIS surgery, BT rates are low and not independently linked with postop complications or delayed recovery. In contrast, postop anemia was related to increased wound complications, delayed neurologic deficits, and reduced early ambulation, with a threshold at HCT 28. These findings suggest anemia, rather than transfusion exposure, may be a modifiable risk factor for postop safety and recovery.

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Table 1. Linear Mixed-Effects Model of Factors Associated with Postoperative Ambulation Distance

Variable/Effect	Estimate (β)	Standard Error	p-value
Intercept	-89.67	43.04	0.0380
Hematocrit (HCT)	**2.33**	**0.78**	**0.0030**
Postoperative Day (POD)	**105.51**	**4.53**	**<0.0001**
Age	-0.40	1.54	0.7946
BMI	-0.13	0.77	0.8647
Female gender	8.53	8.84	0.3348
Total Instrumented Levels	-0.77	2.03	0.7050
Number of PCOs (Levels)	1.99	2.06	0.3343
Estimated Blood Loss (cc)	0.005	0.02	0.8345
Cell Saver Transfused (cc)	-0.04	0.05	0.4423
Intraoperative pRRBC transfused	10.07	17.03	0.5544
Perioperative pRBC Transfused	6.24	13.87	0.6531

Table 1

165. Biomechanical analysis of Ponte-osteotomies vs No Osteotomies in Adolescent Idiopathic Scoliosis (AIS) – Radiographic Analysis from Randomized Clinical Trial

Matti Ahonen, MD, PhD; Johanna Syvänen, MD, PhD; Linda Helenius, MD, PhD; Jenni Jalkanen, MD, PhD; Aarno Nietosvaara, MD, PhD; Antti J. Saarinen, MD, PhD; Ilkka J. Helenius, MD, PhD

Hypothesis
Use of Ponte-osteotomies results in superior sagittal and coronal correction in AIS.

Design
Randomized clinical trial.

Introduction
Ponte osteotomies (PO) are routinely used to facilitate curve correction in surgical treatment of adolescent idiopathic scoliosis (AIS). To date, the role of PO in AIS surgery has not been evaluated in a randomized clinical trial.

Methods
A randomized, multicenter clinical trial on 107 consecutive AIS patients scheduled for segmental pedicle screw instrumentation were prospectively randomized to PO (n=53) and non-PO (n=54) groups. PO group received minimum two and maximum four Ponte-osteotomies in the apical area of deformity. Radiographs were analyzed after the surgery

Results
Mean (SD) preoperative major curve was 50° (9.5°) in the non-PO and 50° (12°) in the PO group and preoperative thoracic kyphosis (T5-T12) was 19° (11°) in non-PO group and 15° (18°) in PO group. Postoperative major curve was in non-PO group 19° (8.4°) and PO group 18° (5.5°) mean difference (MD) -0.86 (95%CI -3.00 to 1.29). Postoperative kyphosis was 20° (7.5°) in non-PO group and 22° (7.8°) in PO group, MD 1.62 (95% CI -0.59 to 3.83). Thoracic kyphosis increased by 1.3° in non-PO group and by 4.0° in PO group MD -2.64 (95% CI -6.1 to 0.8). In subgroup analysis of AIS patients with preoperative kyphosis of less than 20°, postoperative kyphosis was 16° (4.3°) in non-PO group and 17° (5.1°) in PO group MD -1.44 (95% CI -4.22 to 1.33).

Conclusion
Ponte osteotomies do not provide superior sagittal or coronal radiographic correction in AIS.

	Non-Ponte osteotomy (n=54)	Ponte osteotomy (n=53)	Mean difference (95%CI)
Postoperative Major Curve	18.7° (8.4°)	18.3° (5.5°)	- 0.86 (95%CI -3.00 to 1.29)
Postoperative Main Thoracic Curve	17.7 (8.6)	17.2 (5.4)	- 0.7 (95% CI -2.71 to 1.30)
Postoperative Proximal Thoracic Curve	13.2° (9.6°)	14.9° (8.3°)	0.20 (95% CI -2.86 to 3.26)
Postoperative Lumbar Curve	13.4° (6.3°)	13.6° (7.0°)	-0.26 (95% CI -2.65 to 2.14)
Postoperative Thoracic Kyphosis	20.0° (7.47°)	21.9° (7.8°)	1.62 (95% CI -0.59 to 3.83)
Postoperative Lumbar Lordosis	49.0° (12.4°)	47.0° (12.4°)	0.34 (95% CI -3.66 to 4.33)
Fused vertebrae	11.3 (1.7)	11.2 (1.7)	0.09 (95% CI -0.55 to 0.73)
Screw density	1.96 (0.03)	1.92 (0.14)	-0.038 (95% CI -0.076 to -0.000)
Number of Ponte osteotomies	N/A	2.4 (0.6)	N/A

Table 1. Comparison of Non-Ponte osteotomy and Ponte osteotomys groups.

166. Determining the Optimal Extent of Rib Resection during Thoracoplasty With Respect To Pulmonary Function in Adolescent Idiopathic Scoliosis

Hong Jin Kim, MD, PhD; Hyung Rae Lee, MD; Jae Hyuk Yang, MD, PhD; Subin Lim, MD; Seung Woo Suh, MD, PhD

Hypothesis
A dose-response relationship exists between the number of resected ribs and pulmonary function changes in adolescent idiopathic scoliosis (AIS), and that a specific threshold for rib resection can be identified to optimize the balance between airflow improvement and lung volume preservation.

Design
Retrospective cohort study

Introduction
Thoracoplasty is often performed concomitantly with spinal fusion in AIS to correct rib hump deformity. However, concerns persist regarding its potential negative impact on pulmonary function. While extensive resection may maximize cosmetic outcomes, the optimal extent of resection to preserve pulmonary function remains unclear.

Methods
A total of 178 patients with AIS who underwent deformity correction with concomitant thoracoplasty were retrospectively reviewed. Patients were grouped according to the number of ribs resected. Pulmonary function test parameters, including forced vital capacity (FVC), forced expiratory volume in one second (FEV□), and peak expiratory flow (PEF), were analyzed preoperatively and at final follow-up. Clinically relevant outcomes were defined as FVC loss >10% and PEF gain >12%. Nonparametric smoothing splines were used to model continuous dose–response relationships, and multivariate logistic regression was performed to identify factors associated with significant FVC loss.

Results
At final follow-up (mean, 42.3 months), predicted FEV□ and PEF increased, whereas predicted FVC showed no

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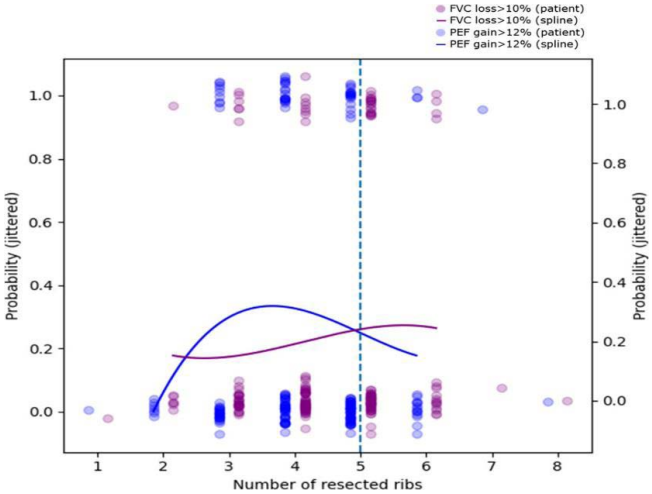
significant overall change. Among patients with normal-to-mild preoperative FVC, 84.3% maintained their functional grade, while 40.4% of those with moderate-to-severe restriction improved. Dose–response modeling demonstrated increasing PEF gains up to 4–5 rib resections and an increased probability of FVC loss >10% beyond 5 ribs. In multivariate logistic regression analysis, age and preoperative predicted FVC were independently associated with FVC loss > 10%.

Conclusion
Pulmonary function after thoracoplasty reached optimized balance point between airflow and lung volume capacity. Resection of up to four ribs was associated with preservation of FVC while providing meaningful airflow improvement. However, the extent of rib resection should be individualized, taking into account, preoperative pulmonary function, age, and rib hump severity.



A dose dependent model between pulmonary function and rib resection

167. Effectiveness of Dual Rod Translation in Thoracic Kyphosis Restoration for AIS: A Comparison with the Conventional Technique

Yusuke Hori, MD, PhD; Takashi Namikawa, MD, PhD; Masaki Kawamura, MD; Brando Guarrera, MD; Akira Matsumura, MD, PhD

Hypothesis
Dual rod translation (DRT) provides superior restoration of thoracic kyphosis compared with traditional rod rotation (RR) while achieving equivalent coronal curve correction in thoracic adolescent idiopathic scoliosis (AIS).

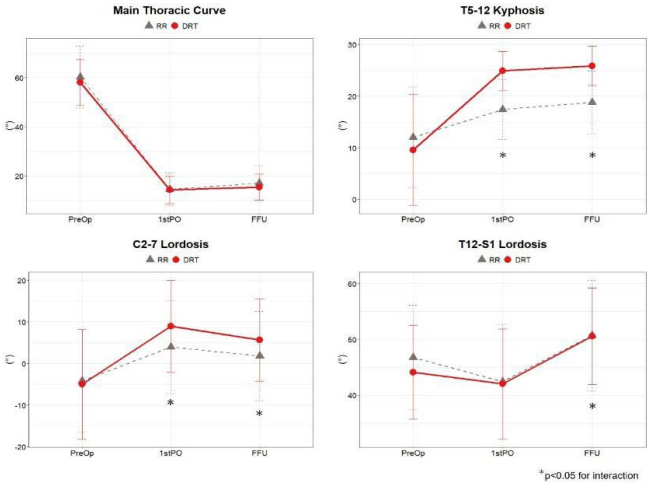
Design
Retrospective cohort study.

Introduction
Thoracic hypokyphosis is common in thoracic AIS and has been associated with adverse reciprocal changes in cervical and lumbar alignment as well as compromised thoracic morphology and pulmonary function. Although RR remains widely used, translation-based correction strategies have been developed to improve sagittal plane control. This study compared radiographic and clinical outcomes between DRT and RR techniques.

Methods
Patients with thoracic AIS (Lenke type 1 or 2) who underwent posterior spinal fusion between 2010 and 2023 were reviewed. RR was used in earlier cases, whereas DRT was adopted in later cases. Standing whole-spine radiographs were obtained preoperatively, at 1 week postoperatively, and at final follow-up. Changes in coronal and sagittal parameters were analyzed using mixed-effects models with group-by-time interaction terms. Patient-reported outcomes were assessed using the SRS-22 questionnaire.

Results
A total of 239 patients were included (DRT, n = 90; RR, n = 149). Preoperative characteristics and coronal curve magnitudes were comparable. Both techniques achieved equivalent correction of the main thoracic curve, improving from approximately 60° preoperatively to 16–17° at final follow-up. Thoracic kyphosis increased from 10° to 26° in the DRT group and from 12° to 19° in the RR group, resulting in a significantly greater kyphosis gain with DRT (+16° vs. +6°, $p < 0.001$). More favorable reciprocal changes in cervical and lumbar lordosis were observed with DRT, whereas global sagittal balance was similar between groups. Improvements in SRS-22 scores at 2 years were comparable.

Conclusion
DRT achieved coronal correction equivalent to RR while providing significantly greater restoration of thoracic kyphosis and more favorable reciprocal sagittal alignment changes. Although short-term patient-reported outcomes were similar, improved sagittal restoration with DRT may be important for long-term spinal and thoracic health in thoracic AIS.



Changes in main thoracic curve, TK, CL, and LL are shown. *$p < 0.05$ for group-by-time interaction.

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‡ SRS Funded Research Grant

168. Manual Rod Contouring is Non-Inferior to Patient-Specific Rods for Achieving Goal Alignment in Adolescent Idiopathic Scoliosis

Conner Paez, MD; Julienne Ryland, DO; Alexandria Rundell, BS; Richard P. Steiner, PhD; *Todd F. Ritzman, MD;* Lorena Floccari, MD

Hypothesis
Pre-fabricated patient-specific rod (PSR) technology will outperform manual rod (MR) contouring in adolescent idiopathic scoliosis (AIS)

Design
Retrospective cohort

Introduction
Patient-specific rod (PSR) technology uses preoperative planning and AI-aided design to pre-shape rods to individual anatomy. Prior literature suggests potential for improved restoration of sagittal alignment parameters, but evidence remains mixed and limited by a focus on adult deformity and lack of direct MR comparison. This study evaluates PSR performance compared to MR using comprehensive coronal and sagittal parameters.

Methods
We retrospectively reviewed AIS patients ≤21 years who underwent spinal fusion with either MR (10/2020-1/2023) or PSR (1/2023-2/2025) instrumentation. Preoperative and early postoperative upright radiographs were analyzed for coronal and sagittal parameters, including Cobb angle, 2D T5-T12 thoracic kyphosis (TK), 3D TK conversion, sagittal vertical axis (SVA), T4 pelvic angle (T4PA), L1 pelvic angle (L1PA), and sagittal balance, defined as |T4PA–L1PA| ≤4°. MR was compared to PR across the entire cohort, with subanalysis for selective thoracic fusions (STF) (Lenke 1, 2) and lumbar/thoracolumbar (TL) fusions (Lenke 3-6).

Results
A total of 129 patients were included (53 PSR, 76 MR). Groups were similar in age, sex, preop Cobb, 2D-TK, 3D-TK, and sagittal alignment (all p>0.2). The MR group trended towards slightly better coronal correction index for STF (71% vs 66%, p=0.061) and for TL fusions than PSR (63% vs 57%, p=0.026). Sagittal correction measured by delta 2D and 3D-TK (p=0.770, p=0.413 respectively) did not differ between groups. Mean |T4PA–L1PA| was similar for MR vs PR across the entire cohort (0.1 vs 0.3, p=0.643), and after both STF (0.6 vs 0.4, p=0.512) and TL fusions (0.2 vs 1.1, p=0.459), but a higher percentage of MR patients achieved postop sagittal balance with |T4PA–L1PA| ≤4° than PSR (71.6% vs 54.7%, p=0.05).

Conclusion
While both techniques produce acceptable deformity correction, manual rod contouring achieved slightly better coronal correction, similar TK, similar mean |T4PA–L1PA|, and a higher rate of postoperative sagittal balance, thereby demonstrating noninferiority to PSR. These findings challenge the proposed advantage of PSR technology; further refinement of PSR design and performance is needed to reliably achieve ideal sagittal profiles.

169. Patient-specific Rod Planning is Often Too Optimistic in Hypokyphotic Adolescent Idiopathic Scoliosis Patients

Aren Joe Bizdikian, MD, MS; Jean-Charles Serero, MD; *Emmanuelle Ferrero, MD, PhD;* Anne Laure Simon, MD, PhD; Brice Ilharreborde, MD, PhD

Hypothesis
The planned value for thoracic kyphosis is often not reached in hypokyphotic AIS patients treated with PSR, mainly due to intraoperative rod flattening

Design
Retrospective analysis of prospectively collected data

Introduction
Thoracic kyphosis (TK) restoration remains challenging in adolescent idiopathic scoliosis (AIS), especially in flattened or lordotic spines. Patient-specific rods (PSR) aim to enhance surgical execution, and the plan tries to restore a physiological sagittal alignment. However, there is still little knowledge regarding the sagittal flexibility of the scoliotic thoracic spine, and the intraoperative rod bending is difficult to anticipate. The purpose of this study was therefore to evaluate the difference between the planned and the postoperative TK in hypokyphotic AIS.

Methods
All consecutive patients operated with PSR were included, with a minimum 2-year follow-up. Planned and postoperative TK were compared, and the execution was considered excellent if the difference was <5°, acceptable between 5 and 15°, and insufficient if >15°. The reliability of the predictions was compared between hypokyphotic (<20°) and normokyphotic (20-40°) patients.

Results
Among the 217 patients analyzed, 92 were hypokyphotic (mean preoperative TK 11±7°) and 125 were normokyphotic (mean TK 29±6°). Age and sex ratio were comparable between groups. The planned TK was significantly lower in the hypokyphotic group (30±4° vs 35±4°, p<0.001), but the target was an average gain of 19° (vs 6° in the normokyphotic group). Despite a significant postoperative increase (+10°, p<0.001), TK remained significantly lower at follow-up in hypokyphotic patients (21±7° vs 28±7°, p<0.001). TK correction remained significantly lower than expected in both groups (-9±6° and -6±5°, p=0.001), and the plan execution was considered insufficient in 20% of the hypokyphotic group (vs 12% in normokyphotic, p=0.004). However, only 3% of the cohort remained hypokyphotic according to Lenke's criteria (<10°).

Conclusion
PSR TK predictions are often too optimistic in hypokyphotic AIS patients. The plan should therefore be adapted to the surgeon's specific outcomes in order to optimize the execution accuracy.

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PODIUM ABSTRACTS

170. Does Preoperative Pelvic Incidence Influence Postoperative Sagittal Balance? Evaluation of Standardized Rod Curvature in AIS Surgery.

Katsuhisa Yamada, MD, PhD; Akira Fukushima, MD; Soya Miura, MD; Terufumi Kokabu, MD; Takashi Ohnishi, MD, PhD; Hiroyuki Tachi, MD; Hideki Sudo, MD, PhD

Hypothesis
In Lenke 1 adolescent idiopathic scoliosis (AIS) surgery using standardized anatomically bent rods, physiological thoracic kyphosis (TK) is consistently restored regardless of the preoperative pelvic incidence (PI). Furthermore, the postoperative lumbar and global sagittal balance naturally adapt to the individual's pelvic morphology, thereby maintaining spinopelvic harmony.

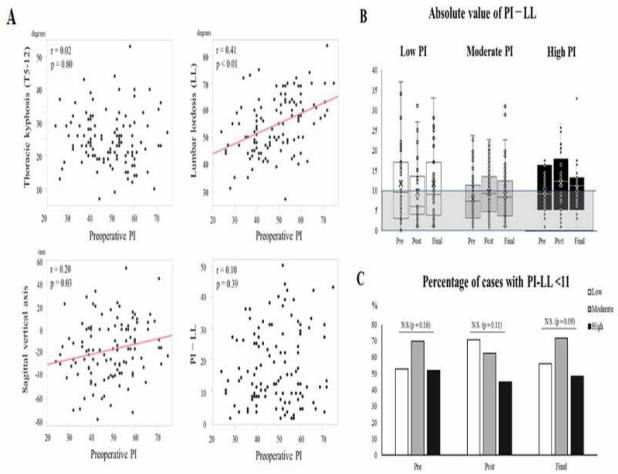
Design
Retrospective comparative study

Introduction
The goal of surgery for AIS is 3D correction including TK restoration. While contouring rods to a standardized anatomical shape provides a robust template for TK formation, it remains unclear how such a uniform rod shape interacts with the patient's unique pelvic morphology to achieve global sagittal balance.

Methods
116 patients with Lenke1 AIS (mean: 14.4years) who underwent posterior corrective fusion (follow-up≥ 2 years) were categorized into three groups based on preoperative PI: low (□40), moderate (41-57), and high (□58). Standardized anatomically bent rods (mean maximum angle: 43.2°) were utilized to restore physiological TK. Radiographic parameters were analyzed preoperatively, postoperatively, and at the final follow-up.

Results
Final TK was restored to physiological levels in all groups (mean: 24.7°), showing no correlation with preoperative PI (r = 0.02, p = 0.80)(Fig.A). In contrast, preoperative PI was significantly correlated with final lumbar lordosis (LL) (r = 0.41, p < 0.01) and final sagittal vertical axis (r = 0.20, p = 0.03). Although the low PI group exhibited a wider variability in outcomes, the mean absolute PI-LL mismatch remained comparable among the three groups through the final follow-up (Fig.B, C).

Conclusion
Standardized anatomically contoured rods provide consistent restoration of TK regardless of PI. Postoperative lumbar and global sagittal balance naturally adapt to the patient's pelvic morphology, maintaining spinopelvic harmony. These results validate the efficacy of standardized anatomical rod geometry in achieving individualized physiological alignment.



A. Correlation analysis between preoperative PI and final TK(T5-12), LL, absolute PI-LL mismatch, and SVA. B. Box-and-whisker plots showing absolute PI-LL mismatch for low, moderate, and high PI groups. C. Bar charts showing the percentage of cases achieving PI-LL<11°

171. Utilizing Intrathecal Morphine in Rapid Recovery Pathway Protocol For Economic Benefit

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Hypothesis
The Rapid Recovery Pathway (RRP) protocol utilizing intrathecal morphine (ITM) contributes to economic benefits and simultaneously improves pain and minimizes opioid consumption.

Design
Retrospective Study

Introduction
The RRP protocol was introduced at our institution in 2018, utilizing ITM (ITM-RRP), and eliminated the standard Patient Controlled Analgesia (PCA) protocol. ITM-RRP decreases opioid consumption, LOS, narcotic refills, & provides adequate pain control. This study aims to examine cost outcomes of ITM-RRP in this large population.

Methods
Pts with AIS undergoing primary instrumentation and fusion between 2014-2023 were included. Pts operated on prior to 2014-2017 were in the PCA group (n=250). Pts operated on after 2018 were in the ITM-RRP group (n=400). Pt outcomes measured include op & anesthesia time, EBL, max VAS pain score (POD0–2), OOB, LOS, 90-day complications, narcotic refills, & morphine consumption at various timepoints. Cost outcomes measured included intraoperative anesthesia, postoperative morphine, ICU stay, non-ICU hospital room, operating

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room, implantation, & total cost. A contemporaneous cost analysis between 2017 PCA and 2018 RRP, & a matched analysis, controlling levels fused and fixation points were conducted. Wilcoxon rank-sum, Kruskal-Wallis, and Chi-Squared tests were used.

Results
Operative time (p<0.001), anesthesia time (p=0.03), EBL (p<0.001), LOS (p<0.001), time to OOB (p<0.001), and morphine consumption (p<0.001) were significantly lower in the ITM-RRP group. Max VAS scores were lower for the ITM-RRP group. Intraoperative (p<0.001) and postoperative morphine (p<0.001), operating room (p<0.001), and non-ICU hospital room costs (p<0.001) were significantly lower for ITM-RRP. Implantation costs were significantly higher in ITM-RRP (p<0.001). No difference in ICU stay cost (p=0.36). Total cost was lower in ITM-RRP by a median $7,283 due to shorter hospital stay, lower anesthesia, & operating room costs.

Conclusion
TM-RRP decreases total cost with savings of over $7000 USD per case, despite implantation costs being $8400 more in the ITM-RRP group. As an institution performing 100+ cases a year, this results in significant cost savings. This protocol decreases both opioids prescribed and consumed while improving pain scores, earlier ambulation, & earlier discharge. Better cost benefits due to shorter length of stay and reduction in anesthesia medications.

172. Radiographic-Cosmetic Discrepancy in Adolescent Idiopathic Scoliosis: Impact of Extremely Low BMI

Zhen Liu, MD, PhD

Hypothesis
We hypothesized that AIS patients with extremely low BMI would demonstrate poorer postoperative cosmetic improvement and weaker correlations between radiographic and cosmetic parameters compared to those with higher BMI, due to insufficient soft tissue coverage and altered body composition.

Design
Retrospective matched cohort study.

Introduction
Postoperative cosmetic improvement is a primary concern in AIS surgery. Patients with AIS often exhibit lower BMI, which may influence soft tissue volume and cosmetic outcomes. However, the impact of BMI on cosmetic improvement remains underexplored. This study aimed to establish an AIS-specific BMI classification system and compare cosmetic outcomes between extremely low and non extremely low BMI groups.

Methods
We included 737 female AIS patients and established an AIS-specific BMI threshold (10th percentile: 15.57 kg/m²). Thirty-five matched pairs (extremely low vs. non extremely low BMI) of Lenke type 1 cases were analyzed. Radiographic parameters (Cobb, SHD, T1 tilt, FRA, CA, CRCI, CB) and cosmetic parameters (SAI1, SAI2, SA, AA, TLAI, RLWAD, PSIS angle) were measured pre- and postoperatively. SRS-22 scores were collected. Statistical analysis included paired t-tests and Pearson correlation.

Results
Radiographic correction was comparable between groups. However, the extremely low BMI group showed significantly less improvement in shoulder-related (ΔSAI1, ΔSAI2, ΔSA, ΔAA) and lumbar-related (ΔRLWAD, ΔPSIS) cosmetic parameters (all P < 0.05). SRS-22 self-image and mental health scores were lower in the extremely low BMI group (P = 0.005 and 0.010). Correlation between radiographic and cosmetic improvements was weaker in the extremely low BMI group.

Conclusion
AIS patients with extremely low BMI exhibit poorer cosmetic improvement and lower self-image despite comparable radiographic correction. Extremely low BMI weakens the correlation between radiographic and cosmetic outcomes, highlighting the need for BMI-specific cosmetic assessment and integrated nutritional and psychological support in surgical planning.

173. Revisions for Pseudoarthrosis in Adolescent Idiopathic Scoliosis: Strategies and Outcomes from a Multicenter Registry

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Hypothesis
Advanced techniques such as anterior interbody support, additional rods, and enhanced grafting strategies will be utilized frequently in pseudoarthrosis repair procedures for AIS.

Design
Multicenter retrospective cohort study using a prospectively collected registry

Introduction
Pseudoarthrosis is an uncommon but clinically relevant complication after PSF for AIS, often presenting with pain or implant failure. Due to its low incidence, evidence guiding revision strategy and graft selection is limited.

Methods
AIS patients undergoing PSF with more than two years of follow-up were screened for pseudoarthrosis using complication codes for "pseudoarthrosis" or "instrumentation failure." Diagnosis was confirmed through review of radiographs, operative reports, and clinical records, defined as failed arthrodesis more than six months after index surgery. Presentation details, revision approach, implant strategy, graft utilization, and post-revision outcomes were summarized descriptively.

Results
Of 3,532 AIS patients, 22 had pseudoarthrosis treated

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with revision (prevalence 0.8%). Mean age at index surgery was 14.8 ± 1.9 years, and at revision was 17.9 ± 2.3 years. Median time from index to revision was 2.5 years [IQR 2.0], with post-revision follow-up of 1.2 years [IQR 2.6]. All revisions were posterior only. Most (77.3%) had revision at the same levels; 5 (22.7%) had extension due to junctional deformity. Only one patient underwent lumbar interbody fusion, and one patient had a three-rod construct. Allograft (68.2%) and local autograft (45.5%) were most commonly used grafts, while BMP-2 (22.7%) and distant autograft (4.5%) were used infrequently. Two patients (8.7%) experienced postoperative surgical site infections, one of which underwent re-operation. No recurrent pseudoarthrosis or implant failure was observed.

Conclusion

This study represents the largest multicenter analysis of revision surgery for pseudoarthrosis in AIS. Posterior-only, level-preserving strategies predominated, with targeted implant revision. Construct extension was performed only in the presence of associated junctional deformity. Outcomes were favorable, supporting posterior-only revision as a safe and effective approach that may inform future management guidelines.

Presentation Details			
Pain, n (%)	12 (54.5%)		
Implant failure at presentation, n (%) *(patients may present with >1 mode of failure)*			
Broken Rods	7 (31.8%)		
Broken Screws	6 (27.3%)		
Loose Screws	9 (40.9 %)		
Screw Rod Dissociation	6 (27.3%)		
No Obvious Implant Failure (i.e. Subtle screw loosening confirmed with Computed Tomography)	1 (4.5%)		
Associated junctional deformity, n (%)			
Proximal Junctional Kyphosis	1 (4.5%)		
Distal Junctional Kyphosis	3 (13.6%)		
Coronal plane "Adding on"	1 (4.5%)		
Revision Surgery Details			
Operative Metrics	**Mean ± SD**	**Min**	**Max**
Surgical Time (minutes) *n=18; missing=4*	187.4 ± 109.3	77	480
Estimated Blood Loss (mL)	260.9 ± 212.3	10	800
Length of Hospital Stay (days)	3.2 ± 1.9	1	10
Revision Approach	**N**	**%**	
Posterior-only Approach	22	100%	
Anterior or Combined Approach	0	0%	
Thoracoplasty Performed	2	9.1%	
Interbody Fusion	1 (TLIF)	4.5%	
Revision Type	**N**	**%**	
Revised full rod	10	45.5%	
Revised partial rod (connector)	8	36.4%	
Supplemental rods (≥2 rods)	1	4.5%	
Revised screws	18	81.8%	
Added instrumented levels	5	22.7%	
Removed instrumented levels	1	4.5%	
Graft only	0	0%	
Bone Graft Use in Revision Surgery *(patients may have >1 graft type used)*			
Graft Type	**# of patients**	**% of patients**	
Allograft	15	68.2%	
Local Autograft	10	45.5%	
Cellular Allograft	5	22.7%	
BMP-2	5	22.7%	
No Graft	1	4.5%	
Distant Autograft	1 (Iliac crest)	4.5%	
BMA	0	0.0%	
Synthetics	0	0.0%	
TLIF = transforaminal lumbar interbody fusion; BMP-2 = bone morphogenetic protein-2; BMA = Bone Marrow Aspirate; Patients may have received more than one graft type. Missing data noted when unavailable; n=22 if not otherwise mentioned.			

Table 1: Presentation and Revision Surgery Details (N = 22)

174. Influence of Cervical Range of Motion and Dynamic Cervical Sagittal Vertical Axis on Distal Junctional Kyphosis Following Adult Cervical Deformity Surgery

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Hypothesis

Dynamic cervical sagittal vertical axis (cSVA) is associated with distal junctional kyphosis (DJK) following cervical deformity (CD) surgery.

Design

Retrospective analysis of prospective, multi-center study

Introduction

Adult CD surgery aims to restore sagittal alignment and biomechanical stability across the cervicothoracic junction. Prior work has demonstrated that upper cervical extension reserve is associated with postoperative functional outcomes; however, the contribution of dynamic cervical alignment to DJK remains incompletely understood.

Methods

A total of 360 patients undergoing CD surgery were included (mean age 61.3±10.8 years; 64% female). DJK at one year was defined as a distal junctional angle ≥10° with a change of ≥10° from baseline. Dynamic cervical parameters included C0-2, C2-7, and T1 slope range of motion (ROM) on flexion/extension radiographs as well as dynamic cSVA range, defined as the difference between flexion and extension cSVA (C2-7). Multivariable logistic regression models adjusted for age and baseline alignment were constructed, with missing data addressed using multiple imputation.

Results

Dynamic imaging was available in 82% of patients, with DJK occurring in 39 patients (10.8%). On univariable analysis, greater C0-2 ROM was associated with lower odds of DJK (OR 0.96, P=0.02), whereas increased dynamic cSVA range was associated with higher DJK risk (OR 1.2 per 10mm, P=0.01). In multivariable analysis, dynamic cSVA range remained the strongest independent predictor of DJK (OR 1.6 per 10 mm, 95% CI 1.2–2.3), while C0-2 ROM demonstrated a protective trend. In a parsimonious model, both dynamic cSVA range and C0-2 motion were independently significant. Sensitivity analysis using complete cases confirmed the robustness of these findings. Quartile analysis suggested a dose-response relationship, with DJK rates increasing from 8.3% in the

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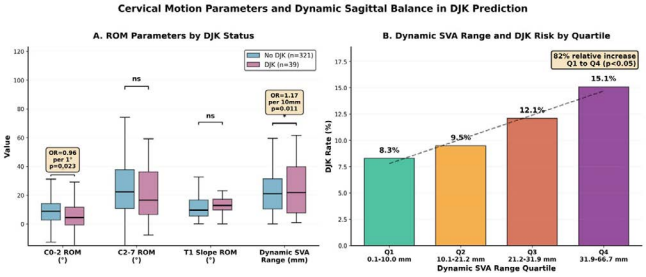
lowest quartile to 15.1% in the highest quartile of dynamic cSVA range.

Conclusion
Greater dynamic cervical sagittal vertical axis range is independently associated with distal junctional kyphosis following adult cervical deformity surgery. Incorporating dynamic cervical alignment and upper cervical mobility into preoperative assessment may improve risk stratification and inform surgical planning aimed at reducing distal junctional complications.



175. How Reliable is Intraoperative Neurophysiological Monitoring for Detecting Postoperative Deficits During Cervical Spine Surgery?

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Hypothesis
Intraoperative neurophysiological monitoring (IONM) provides high sensitivity and specificity for detecting postoperative neurological deficits in cervical spine surgery.

Design
Retrospective Review

Introduction
IONM is commonly used during thoracolumbar deformity and multi-level degenerative spine surgery to detect and mitigate neurological deficits. Understanding when IONM provides reliable reassurance and which patients are at higher risk for signal loss/alerts may improve operative planning and counseling. The purpose of this study was to quantify the diagnostic performance of IONM for postoperative neurologic deficits in cervical spine surgery and to identify factors associated with intraoperative IONM signal alert.

Methods
Patients who underwent cervical spine surgery with IONM at a single center consecutively between September 2015 and December 2021 were retrospectively reviewed. IONM alerts and postoperative neurologic deficits were extracted from the medical record. A positive IONM alert was defined as either a 50% or greater decrease in waveform amplitude or a 10% or greater increase in waveform latency. A postoperative deficit was defined as a new deficit present by postoperative day 1 that persisted until the first follow-up appointment. Firth's analyses were performed to model relationships between predictors and IONM positive readings.

Results
Among 1,020 operations, there were 54 IONM positives including 4 true positives and 50 false positives (PPV 0.07). There were 966 IONM negatives including 956 true negatives and 10 false negatives (NPV 0.99). Specificity was 0.95 (95% CI 0.94-0.96) and sensitivity was 0.29 (4/14). Prior fusion (OR 2.23, p=0.01), combined anterior-or-posterior approach (OR 3.98, p=0.004), and myelopathy (OR 4.70, p=0.006) were associated with higher odds of IONM signal alert.

Conclusion
In cervical spine surgery, intraoperative neurophysiological monitoring (IONM) provides strong reassurance when signals remain stable (NPV 0.99) that there will not be any postoperative deficits. However, IONM demonstrates low PPV and limited sensitivity for postoperative deficits. Prior fusion, combined approach, and myelopathy increase risk for IONM alerts.

	Postop Deficit	No Postop Deficit	Total
IONM Alert	4	50	54
No IONM Alert	10	956	966
Total	14	1006	1020

Variable	OR	95% CI	p-value
Base model (demographics only, n = 919, p = 0.040)			
Age (per year)	0.99	0.97-1.01	0.32
Sex (female vs male)	0.56	0.28-1.08	0.08
BMI (per kg/m^2)	1.01	0.95-1.06	0.83
Prior fusion	2.23	1.20-4.05	**0.01**
Surgical factors (n = 909, p < 0.001)			
Anterior levels (per level)	1.02	0.86-1.21	0.81
Posterior levels (per level)	1.15	0.96-1.37	0.12
Anterior approach (vs posterior approach)	1.52	0.54-4.69	0.44
Combined approach (vs posterior approach)	3.98	1.56-10.56	**0.004**
Neurologic presentation (n = 919, p < 0.001)			
Radiculopathy	1.82	0.58-5.07	0.30
Myelopathy	4.70	1.58-13.13	**0.006**
Radiographic characteristics (n = 599, p = 0.235)			
Kyphosis	1.66	0.52-5.27	0.38
Lordosis	1.78	0.66-5.21	0.26
cSVA (per mm)	1.02	0.99-1.04	0.23
Comorbidities (n = 919, p = 0.052)			
Comorbidities (per comorbidity)	1.24	0.79-1.69	0.30

176. Does Preoperative Myelopathy Portend Worse Outcomes After Cervical Deformity Surgery?

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PODIUM ABSTRACTS

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Hypothesis
Myelopaths experience worse outcomes after cervical deformity surgery than non-myelopaths.

Design
Retrospective analysis of prospective multicenter study

Introduction
We evaluated the impact of preoperative myelopathy on: 1) perioperative morbidity, 2) complications, and 3) patient-reported outcome metrics (PROMs).

Methods
A retrospective cohort study (2009-18) was performed of patients undergoing cervical deformity surgery. Primary exposure was preoperative myelopathy, measured by the modified Japanese Orthopedic Association (mJOA) score and analyzed as both continuous and binary variables (severe ≤11; moderate/mild >12). Primary outcomes were: 1) perioperative morbidity: estimated blood loss, operative time, and length of stay, 2) complications/reoperations, and 3) PROMs at 2-years, including Neck Disability Index (NDI) and EQ-5D Scores. Univariate/multivariable linear/logistic regression was performed, controlling for age, sex, and total instrumented levels.

Results
Of 153 patients (mean age 61.5±10.4 years; 61.2% female), the mean mJOA score was 13.5±2.8 and 37(24%) had severe myelopathy. Perioperative Outcomes: Higher/better mJOA scores were independently associated with shorter length of stay (β:-0.6, 95%CI:-1.1- -0.05, p=0.033), but no other perioperative metric. Severe myelopathy trended toward longer length of stay on bivariate (10.1±15.0 vs. 6.8±7.2 days, p=0.205) and multivariable analysis (β:3.3, 95%CI:-0.2-6.8, p=0.063). Complications: Higher/better mJOA scores or severe myelopathy were not significantly associated with complications or reoperations (all p>0.05). PROMS: At 2-years, higher/better baseline mJOA scores were independently associated with lower/better 2-year NDI scores (β:-3.8, 95%CI:-5.2--2.3, p<0.001) and higher/better 2-year EQ-5D scores (β:0.02, 95%CI:0.01-0.03, p<0.001). Severe myelopathy predicted significantly higher/worse 2-year NDI score (OR:20.4, 95%CI:10.5-30.4, p<0.001) and significantly lower/worse 2-year EQ-5D (OR:-0.1, 95%CI:-0.1- -0.04, p=0.002).

Conclusion
In patients undergoing adult cervical deformity surgery, more severe myelopathy was independently associated with longer length of stay and worse 2-year PROMs without an increase in complications/reoperations. These data support intervening before myelopathy ensues.

177. Pelvic Tilt Modifies the Effect of Cervicothoracic Kyphosis Correction on T1 Slope After Cervical Deformity Surgery

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Hypothesis
The effect of cervicothoracic correction on T1S is modified by preop pelvic tilt (PT).

Design
Retrospective analysis of prospective, multicenter study.

Introduction
T1 slope (T1S) is a key determinant in cervical deformity (CD). Despite cervical lordosis (CL) and thoracic kyphosis (TK) correction, unchanged or increased T1S may occur.

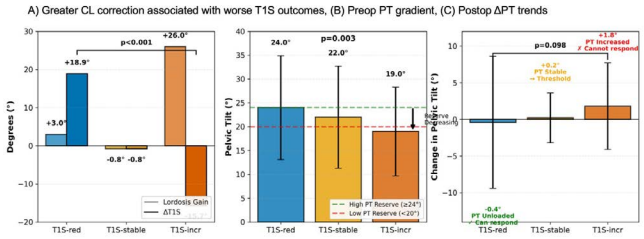
Methods
We analyzed 272 adult CD patients with pre- and postop 3 months imaging. T1S outcomes were categorized as T1S reduced (T1S-R, >5° decrease), T1S stable (T1S-S, ±5°), or T1S increased (T1S-I, >5° increase) groups. We evaluated CL restoration, TK correction, preop PT, C2 tilt (C2T), global alignment parameters, surgical factors. Hierarchical regression assessed main effects for both CL and TK correction. Postop PT change (ΔPT) was measured to explore predicted compensation behavior.

Results
Mean ΔT1S was -0.3° ± 16.9°, with 32% achieving T1S-R (>5°). A 3-tier T1S gradient emerged: T1S-R (n=87, ΔT1S -19±12°), T1S-S (n=79, −1°±3°), and T1S-I (n=106, +16°±9°; p<0.001). The T1S-I group received greater CL correction than the T1S-R group (+26° vs +3°, p<0.001) yet achieved similar postop CL (+8° vs +6°, p>0.1). TK correction also differed (T1S-R +6°±15°, T1S-S −2°±6°, T1S-I −6°±11°; p<0.001), with both CL and TK demonstrating similar correlations with ΔT1S (r=0.5-0.6). T1S-I predominantly upper thoracic LIV (74%) vs T1S-R lower thoracic LIV (47%). Upper thoracic 3 column osteotomy (UT3CO) was more frequent in T1S-R (21 vs 3%), (all p<0.001). Preop pelvic compensation demonstrated a clear gradient: PT was highest in T1S-R (24.0°±10.9°) and lowest in the T1S-I group (19.0°±9.3°; p=0.003), with parallel differences in C2T (p<0.001). Postop ΔPT was −0.4°±9.0° in the T1S-R group, +0.2°±3.4° in the T1S-S group and +1.8°±5.9° in the T1S-I group (p=0.098). Baseline PT and C2T were associated with ΔT1S, even accounting for CL and TK restoration. Including surgical factors, the model explained 62% of variance (p<0.001).

Conclusion
T1S can be reduced by more TK correction with UT3CO,

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

caudal LIV after CD surgery but may also be modified by preop pelvic compensation reserve. High preop PT enables T1S reduction, whereas exhausted reserve predisposes to paradoxical T1S increase despite greater cervicothoracic correction. This suggests preop pelvic compensation as a predictor for risk stratification.



178. Is the Addition of Anterior Cervical Corpectomy Superior to Anterior Cervical Discectomy and Fusion Only for the Correction of Cervical Focal Kyphosis?

Thomas Hunt, BA; Justin L. Reyes, MS; James Y. Chen, BA; Jacob Okulewicz, BS; Demetrius Bryson, BS; Shonik Ganjoo, BS; Hamzah Abbas, BS; Kenji Kaproth, BS; Joseph M. Lombardi, MD; Ronald Lehman Jr, MD; Daniel Riew, MD; Zeeshan M. Sardar, MD

Hypothesis
Patients undergoing anterior cervical discectomy and fusion with corpectomy (ACDF + Corp) will demonstrate significantly greater cervical focal kyphosis (CFK) correction than those undergoing anterior discectomy and fusion (ACDF) alone.

Design
Retrospective Comparative Cohort Study

Introduction
Preoperative focal kyphosis is associated with greater preoperative symptom burden and postoperative symptom recurrence, while surgical CFK correction correlates with improved clinical outcomes. Despite this, few studies compare the efficacy of various surgical approaches in correcting CFK. This study aims to compare CFK correction and surgical complication rates between ACDF alone and ACDF + Corpectomy.

Methods
We retrospectively reviewed patients with cervical spondylotic myelopathy who underwent ACDF or ACDF + Corpectomy. Inclusion criteria were preoperative CFK > 0° spanning 1-3 vertebral levels. Patients were stratified into ACDF and ACDF + Corp cohorts. Demographics, operative characteristics, radiographic parameters, and complications were collected. Wilcoxon rank-sum test and Fisher's exact tests were used with significance set to P < 0.05.

Results
68 pts were included, (mean age 59.8 ± 12.4 years) with 29 in the ACDF cohort and 39 in the ACDF + Corp cohort. Baseline demographics were similar, including comorbidities and prior cervical fusions. Both the ACDF + Corp and ACDF groups had similar preoperative radiographic alignment, including comparable CFK (6.7° vs 8.3°, P = .741). Immediate postoperative CFK correction was greater (-12.0° vs -8.4°, P = .036), and CFK was significantly less (-5.3° vs -0.15°, P = .026), in ACDF + Corp compared to ACDF alone. Immediate post-operative and final follow-up complications were comparable between the two groups.

Conclusion
In patients with preoperative cervical focal kyphosis (CFK), ACDF + Corpectomy creates greater immediate CFK correction and focal lordosis than ACDF alone with no increase in surgical complications. While ACDF also corrects CFK, these findings support consideration of ACDF + Corpectomy when greater immediate CFK correction is desired.

Demographics and Operative Characteristics

Variable	ACDF (n=29)	ACDF + Corp (n=39)	*P*-value
Age (years, mean ± SD)	58.4 ± 13.8	60.9 ± 11.3	.478
Female (N, %)	14 (48.3%)	16 (41.0%)	.625
BMI (kg/m², mean ± SD)	26.5 ± 5.1	28.6 ± 5.1	.337
Smoking History (N, %)	9 (31.0%)	15 (38.5%)	.612
Prior Cervical Fusion (N, %)	0 (0%)	2 (5.1%)	.504
Surgical Time (min, mean ± SD)	210.1 ± 86.7	225.3 ± 92.4	.603
Estimated Blood Loss (mL, mean ± SD)	73.7 ± 43.2	85.0 ± 34.5	.099
Neck Disability Index: Baseline (mean ± SD)	37.1 ± 19.2	28.0 ± 17.9	.180
Follow-Up Period (months, mean ± SD)	16.7 ± 20.4	18.7 ± 21.7	.689

Number of Instrumented Levels

Levels	ACDF	ACDF + Corp	*P*-value
2 levels	8	5	
3 levels	11	20	
4 levels	10	12	
5 levels	0	2	
Overall Analysis			.26

Baseline Pre-Operative Radiographic Parameters (mean ± SD)

Parameter	ACDF	ACDF + Corp	*P*-value
C2–C7 Cervical Sagittal Angle (°)	-0.21 ± 12.2	-0.98 ± 11.7	.780
C2 Slope (°)	24.9 ± 12.6	23.6 ± 9.1	.968
T1 Slope (°)	28.3 ± 12.1	26.5 ± 10.5	.637
C2–C7 SVA (mm)	31.3 ± 18.5	29.8 ± 13.8	.920
Cervical Focal Kyphosis (°)	8.3 ± 8.3	6.7 ± 5.3	.741

Immediate Post-Operative Radiographic Parameters (mean ± SD)

Parameter	ACDF	ACDF + Corp	*P*-value
CSA (°)	-12.0 ± 14.0	-17.2 ± 9.6	.313
Δ CSA (°)	-11.4 ± 13.6	-16.0 ± 11.9	.242
C2 Slope (°)	21.0 ± 11.9	18.0 ± 8.6	.363
Δ C2 Slope (°)	-3.8 ± 8.2	-5.6 ± 10.5	.162
T1 Slope (°)	37.3 ± 7.1	35.4 ± 11.7	.373
Δ T1 Slope (°)	12.1 ± 7.2	7.4 ± 10.4	.052
cSVA (mm)	33.9 ± 18.2	28.2 ± 10.3	.447
Δ cSVA (mm)	2.4 ± 10.7	-1.2 ± 12.8	.358
CFK (°)	-0.15 ± 11.3	-5.3 ± 5.5	**.026**
Δ CFK (°)	-8.4 ± 11.1	-12.0 ± 7.2	**.036**

Complications (N, %)

Complication (Timepoint)	ACDF	ACDF + Corp	*P*-value
Wound Complication (90 Day)	0	1 (2.6%)	1
Wound Complication (2 Year)	0	1 (2.6%)	1
Mechanical Complication (90 Day)	0	1 (2.6%)	1
Mechanical Complication (2 Year)	0	0	1
Pseudoarthrosis (2 Year)	1 (3.4%)	1 (2.6%)	1
Revision (90 Day)	0	1 (2.6%)	1
Revision (1 Year)	1 (3.4%)	0	1
Revision (2 Year)	0	1 (2.6%)	1
Dysphagia (90 Day)	7 (24.1%)	15 (38.5%)	.296
New Sensory Deficit (90 Day)	1 (2.9%)	0	1
New Sensory Deficit (2 Year)	1 (3.4%)	1 (2.6%)	1
New Motor Deficit (90 Day)	1 (3.4%)	1 (2.6%)	1
New Motor Deficit (2 Year)	0	0	1

Patient Reported Outcomes (mean ± SD)

Patient Reported Outcome (Timepoint)	ACDF	ACDF + Corp	*P*-value
NDI (6 Months)	9.7 ± 15.3	10.1 ± 10.6	.234

Table 1: Patient Characteristics, Radiographic Outcomes, and Complications Stratified by Procedure

179. Cervical Pedicle Screws are not the Safest Lateral Mass Screws are not the Best Fixation. What about Cervical Pedicle Inlet?

Mahmoud AbuAlkebash, MD; *Jeffrey Gum, MD;* Steven D. Glassman, MD; Haseeb Tariq, BS

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

PODIUM ABSTRACTS

Hypothesis
Hounsfield units (HU) will be greater in the pedicle inlet compared to lateral mass

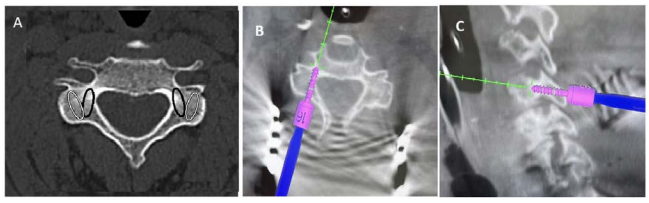
Design
Retrospective observational cross- sectional study

Introduction
Cervical deformity correction or fusions into the cervical spine are rising, increasing the need for optimal cervical fixation. Lateral mass screw fixation is widely used in the posterior cervical spine as it is safe relative to vital structures. A recent technique alters the traditional lateral mass screw trajectory through the pedicle inlet. Improved mechanical stability with this trajectory may be due to superior bone quality around the pedicle inlet compared to the lateral mass, particularly in elderly and osteoporotic patients.

Methods
Patients aged 40-80, with no prior cervical surgeries, a DXA scan within 14 months of a cervical CT were identified. HU were obtained from axial CT scans from C3 to C6 bilaterally for both trajectories. Elliptical regions of interest (Figure 1), 10mm x 3.5mm to simulate screws sizes and trajectories, were created in the lateral mass (white ellipse) and pedicle inlet (black ellipse). DXA T-scores, BMD, BMI, smoking history, chronic medications, and comorbidities were collected.

Results
45 patients met inclusion criteria, mean age of 61.5 years; 9 were osteoporotic, 16 were osteopenic and 14 were normal based on DXA T-scores. There was a statistically significant difference in HUs between the lateral mass (498.38±175.89) and pedicle inlet (765.09±213.36, p<0.001). There was a statistically significant decrease in lateral mass HUs between normal (521.03±178.12), osteopenic (496.95±183.36) and osteoporotic (445.58±146.06, p=0.010) cases. This decrease was not seen in the pedicle inlet HUs (793.86±175.70, 738.84±253.92, 739.11±209.16, p=0.053). There were no statistically significant associations between age and lateral mass HUs or pedicle inlet HUs.

Conclusion
BMD in the pedicle inlet is 65% higher than that in the lateral mass, partially explaining the improved mechanical stability and pull-out strength. A decrease in lateral mass BMD is seen in osteopenic/osteporotic patients is not seen in the pedicle inlet BMD. This may confer an advantage to pedicle inlet screws over the lateral mass. The pedicle inlet trajectory may satisfy the increasing need for optimal cervical fixation.



180. The Influence of Halo-Gravity and Halo-Pelvic Traction on Osteotomy Grades in Severe Spinal Deformities: A Retrospective Study Based on Predictive Modeling

Zifang Huang, MD, PhD; Junlin Yang, MD, PhD; Lei He, MD, PhD; Pan Zhou, PhD

Hypothesis
Preoperative traction is effective for reducing the severity of spinal deformity and osteotomy grade

Design
Retrospective

Introduction
The traction technique is beneficial for treating severe spinal deformities, but the impact of preoperative traction on reducing osteotomy grade remains unclear.

Methods
Sixty patients with severe spinal deformity underwent preoperative Halo-pelvic traction (HPT) or Halo-Gravity traction (HGT) were included. Radiographic assessments were conducted at the beginning and end of traction, as well as during postoperative follow-up. Changes in osteotomy grade were evaluated using the osteotomy grade classification predictive model. Differences in the orthopedic effects and contribution to reducing osteotomy grade between the two traction methods were compared using inverse probability of treatment weighting (IPTW).

Results
This model can effectively anticipate the osteotomy grade. Before traction, the sagittal kyphosis was 131.82 ± 30.29°, and the scoliosis was 132.70 ± 28.77°, with a predicted average osteotomy grade of 5.1 ± 0.9242. After traction, there was an average decrease of 34.3 ± 29.5° in the sagittal kyphosis and 31.8 ± 20.8° in the scoliosis angle. A significant reduction of 0.958 ± 1.01 in osteotomy grade post-traction compared to pre-traction was observed ($p < 0.001$). Moreover, the actual osteotomy grade decreased by 0.758 ± 1.022 compared to the predicted osteotomy grade before traction ($p < 0.001$). After IPTW adjustment, the efficacy of the two traction methods in reducing osteotomy grade was comparable; however, HPT demonstrated a significantly greater reduction in sagittal deformity angular ratio (SDAR) compared to HGT ($p = 0.014$), with notable advantages in kyphosis correction rate ($p < 0.001$).

Conclusion
This is the first study to utilize a precise osteotomy prediction model to quantify the effects of traction in patients with severe spinal deformity. The results illustrate that preoperative traction can effectively decrease the osteotomy grade in patients with severe spinal deformity. Importantly, for cases of severe spinal deformity, the preoperative HPT regimen outperforms the HGT in our study. These findings are crucial for clinical decision-making regarding severe spinal deformities.

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

181. Safety and Efficacy of One-Staged Spine-Shortening by Using Posterior Vertebral Column Resection for Severe Spinal Deformity Associated with Multiple Spinal Cord Malformation

Junlin Yang, MD, PhD; Zifang Huang, MD, PhD; Pan Zhou, PhD; Lei He, MD, PhD

Hypothesis
To elevate the safety and efficacy of spine-shortening by using posterior vertebral column resection (PVCR) for severe rigid spinal deformity with cord malformations.

Design
Retrospective case series.

Introduction
One-stage spinal-shortening osteotomy are suggested in previous articles for cord tethered treatment. However, the safety and efficacy of one-stage spinal-shortening osteotomy in the treatment of severe spinal deformity with variety cord malformations is still limit.

Methods
The records of 32 severe spinal deformity patients with variety cord malformations treated with spine-shortening by using vertebral column resection were retrospectively analyzed. Intraoperative combined monitoring of SEPs, MEPs and DNEPs was used in all cases. Radiographic parameters and neurological complications were analyzed to evaluate the clinical safety and efficacy.

Results
Spine-shortening by using PVCR were successfully conducted in all 32 patients. The mean main curve and kyphosis were corrected from 119.8° and 119.1°to 58.6° and 53.9°, with 51.4% and 54.3% corrective rates, respectively. The average correction loss of major curve and kyphosis were 2.3°and 2.6°respectively at mean 37.6 months follow-up. Intra-operative monitoring events occurred in 9 patients, of these patients, three were transient spinal cord injury who all recovered within one year (without complete paralysis).

Conclusion
Spine-shortening by using PVCR were successfully conducted in all 32 patients. The mean main curve and kyphosis were corrected from 119.8° and 119.1°to 58.6° and 53.9°, with 51.4% and 54.3% corrective rates, respectively. The average correction loss of major curve and kyphosis were 2.3°and 2.6°respectively at mean 37.6 months follow-up. Intra-operative monitoring events occurred in 9 patients, of these patients, three were transient spinal cord injury who all recovered within one year (without complete paralysis).

182. Beyond Cord Compression: Instability is a major driver for neurological deficit in Active Thoracic Spinal Tuberculosis

Ajoy Prasad Shetty Tonse, MS; Shanmuganathan Rajasekaran, MD, PhD, FRCSA, MCh; Harikrishna R. Raghuraj, MS

Hypothesis
Mechanical instability, as assessed by the Spinal Tuberculosis Instability Scoring System (STISS), is an independent and dominant driver of neurological deficit in thoracic spinal TB.

Design
Retrospective observational study

Introduction
Neurological deficit remains the most serious complication of spinal TB, often leading to irreversible disability. While canal compromise, kyphotic deformity, and cord signal changes have been extensively studied as predictors, the role of mechanical instability has not been systematically assessed. This study aimed to evaluate the association between mechanical instability and neurological deficit in thoracic spinal TB and to compare its predictive strength against established radiological parameters.

Methods
Clinical and radiological data of 122 patients with active thoracic spinal TB were analysed. Instability was assessed using the STISS and categorised as stable, potentially unstable, or definitely unstable. Neurological status was documented at presentation. Radiological parameters, including canal encroachment area (CEA), kyphotic deformity, vertebral body loss, spine-at-risk signs, cord signal changes, and epidural compression, were evaluated.

Results
The mean age of the cohort was 51 ± 18 years, with 54.9% of participants male. Neurological deficit was present in 40 patients (32.8%). Based on STISS, 71 (58%) were stable, 10 (8.2%) were potentially unstable, and 41 (34%) were definitely unstable. MRI revealed cord signal changes in 18% and epidural compression in 64%. Definite instability emerged as the strongest independent predictor of neurological deficit (OR 9.77, 95% CI 2.85–38.9, $p<0.001$), followed by greater canal encroachment area (OR 1.08, 95% CI 1.03–1.13, $p=0.002$). In stable spines with epidural compression, the predicted probability of neurological deficit was 27%. In unstable spines, the likelihood was 50% even without epidural compression, and it was highest (63%) when instability coexisted with epidural compression.

Conclusion
Mechanical instability in thoracic spinal TB is an independent and dominant predictor of neurological deficit, even in the absence of epidural compression. Incorporating the STISS into routine clinical evaluation enhances risk stratification, facilitates timely surgical decision-making, and may prevent irreversible neurological deterioration.

§ Hibbs Award Nominee – Best Clinical Paper
† Hibbs Award Nominee – Best Basic Science/Translational Paper
‡ SRS Funded Research Grant

PODIUM ABSTRACTS

183. Does Surgical Approach Affect Reoperation Rate in Surgical Treatment of L4-5 Degenerative Spondylolisthesis?

Pooria Salari, MD; Richard N. Chang, PhD; Jessica E. Harris, MS; Kathryn E. Royse, PhD; Harsimran S. Brara, MD; Elizabeth P. Norheim, MD; Akasha I. Barreto Vega, MS; Jacob H. Fennessy, MD

Hypothesis
There is no difference between reoperation rate for surgical treatment of L4-5 spondylolisthesis using different surgical approaches.

Design
Retrospective Cohort Study

Introduction
Degenerative L4-5 spondylolisthesis is a common pathology and often treated with spinal fusion. However, few studies have compared the outcomes of different surgical approaches. The purpose of this study was to investigate reoperation rate for treatment of L4-5 spondylolisthesis using different surgical approaches.

Methods
We used data from a US-based integrated healthcare system. Adult patients with L4-5 spondylolisthesis who underwent lumbar fusion (2009-2024) were included. Patients were divided into four groups, 1) posterolateral fusion and instrumentation (PSF), reference group, 2) anterior interbody fusion and posterior instrumentation (ALIF+PS), 3) transforaminal interbody fusion and posterior instrumentation (TLIF+PS), 4) lateral interbody fusion and posterior instrumentation (LLIF+PS). Cox proportional hazards regression was used to evaluate reoperation risk for acute reasons (infection, hematoma/seroma, and wound dehiscence) and delayed reasons (adjacent segment disease (ASD) and nonunion)

Results
4,454 cases met the inclusion criteria: 2,019 with PSF, 363 with ALIF+PS, 1,789 with TLIF+PS, and 183 with LLIF+PS. Median follow-up was 4.5 years (interquartile range 2.1-6.7). Acute reoperation rate was 3.1%, 0.2%, 1.9%, and 0.6% respectively. Acute reoperation was rare in ALIF +PS and LLIF+PS groups and no difference was observed for TLIF+PS vs PSF. ASD had a 5-year incidence of 10.1%, 9.1%, 10.4%, and 9.6% for the respective groups, no differences were observed in ASD risk for ALIF+PS, TLIF+PS, and LLIF+PS compared to PSF. Nonunion incidence was 3.8%, 3.9%, 1.5% and 1.5% respectively at 5-years. No difference was observed for nonunion risk for ALIF+PS, however, a lower risk was observed for TLIF+PS compared with PSF. (Table 1).

Conclusion
In this large cohort, we found a lower risk of reoperation for nonunion in patients who underwent TLIF+PS compared to PSF, and a rare incidence of nonunion in LLIF+PS group. There was no difference between PSF and other groups for ASD. Additionally, acute reoperation was rare in ALIF +PS and LLIF+PS groups, however due to the low number of events this could not be analyzed with this statistical regression model.

Non-union	67 (3.8)	19 (3.9)	1.33 (0.65-2.74), P=0.44	21 (1.5)
Mean follow up years (standard deviation)	4.7 (2.6)	5.5 (2.8)		4.3 (2.7)

CIF= cumulative incidence function, HR= hazard ratio, CI= confidence interval, PSF = Posterior spinal fusion, ALIF+PS = anterior interbody fi
LLIF+PS= Lateral interbody fusion + pedicle screw
Models adjusted for age, BMI, gender, race/ethnicity, ASA category, BMP use, rod material, peripheral vascular disease
Acute reoperations include infection, hematoma/seroma, and wound dehiscence
-- could not assess due to a low number of events

Figure 1. Cumulative Incidence of ASD reoperations.

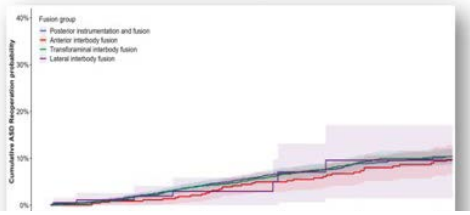


Figure 2. Cumula

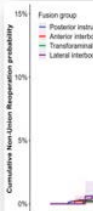


Table 1. Figure 1. Figure 2.

184. Sagittal Spinal Shape Remodeling and Inflection Point Migration After Anterior Versus Posterior Short-Segment Lumbar Fusion

Erh Ti E. Lin, MD; Yi Hsun Huang, MD; Jyun Hong Kuan, MD; Ben Long Shi, MD; Yi Chin Fong, MD, PhD; Yong Qiu, PhD; Yuan Shun Lo, MD, PhD

Hypothesis
Anterior short-segment lumbar fusion better preserves sagittal spinal shape (SSS) geometry and inflection point (IP) location, resulting in superior clinical outcomes and lower reoperation rates compared with posterior fusion.

Design
Retrospective cohort study.

Introduction
Sagittal alignment is a key determinant of outcomes after lumbar fusion. Beyond traditional spinopelvic parameters, sagittal spinal shape (SSS) geometry, particularly the locations of curve apexes and the inflection point (IP), may better reflect age-related and surgery-induced remodeling. However, how different surgical approaches influence SSS and its clinical relevance remains unclear.

Methods
We retrospectively analyzed 215 patients undergoing short-segment (≤5 levels) lumbar fusion for degenerative disease. Patients were divided into an anterior group (OLIF with percutaneous posterior instrumentation, n=103) and a posterior group (TLIF, n=112). Whole-spine standing radiographs were obtained preoperatively, postoperatively, and at 1-year follow-up. Spinopelvic parameters and SSS geometric features, including thoracic apex (TA), lumbar apex (LA), inflection point (IP), and SVAratio, were measured. Clinical outcomes were assessed using VAS, ODI, and SRS-22. Associations between SSS relocation and adverse outcomes or reoperation were analyzed.

Results
The posterior group showed greater early correction of C7 SVA and PI–LL mismatch, but these differences were

§ Hibbs Award Nominee – Best Clinical Paper
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not maintained at final follow-up. The anterior group demonstrated significantly greater cranial preservation of LA, TA, and IP, whereas the posterior group exhibited significant caudal migration of the IP over time. A postoperative downward shift of the IP was a strong predictor in univariate analysis of poor clinical outcome and reoperation. The anterior group achieved higher MCID rates for leg pain and had lower adverse event and reoperation rates (2.9% vs. 20.5%, $p < 0.001$). Preservation of youthful SSS geometry and stable IP location was associated with superior patient-reported outcomes.

Conclusion
Anterior and posterior approaches yield different SSS remodeling patterns. Anterior fusion better preserves SSS geometry, stabilizes alignment, and improves outcomes, supporting its consideration in lumbar short-segment fusion surgery.

185. Prevalence of Severe Sagittal Malalignment in Patients Undergoing Short-Segment Lumbar Fusion

Michael Farias, BS; Joseph E. Nassar, BS; Manjot Singh, BS; Alex Hernandez, BS; Zvipo Chisango, BS; Gabriel Gonzalez, BS; Catherine B. Hurley, MS; John Czerwein, MD; Bassel G. Diebo, MD; *Eren Kuris, MD;* Alan H. Daniels, MD

Hypothesis
Patients undergoing short-segment lumbar fusion have high prevalence of baseline sagittal alignment.

Design
Retrospective Cohort Study

Introduction
Short-segment 1-2 level lumbar fusion is frequently performed to address localized degenerative spine conditions. However, the prevalence and impact of baseline sagittal malalignment in these patients are not well understood. This study aimed to determine the prevalence and severity of baseline sagittal malalignment using Schwab modifiers and segmental L4-S1 lordosis in patients undergoing short-segment lumbar fusion.

Methods
Adult patients (≥18 years) who underwent 1-2 level lumbar interbody fusion were included. Sagittal alignment was classified using SRS-Schwab modifiers: pelvic incidence-lumbar lordosis (PI-LL; 0: <10°, +: 10-20°, ++: >20°), pelvic tilt (PT; 0: <20°, +: 20- 30°, ++: >30°), and sagittal vertical axis (SVA; 0: < 40mm, +: 40-95mm, ++: >95mm). SVA was assessed in a sub-group with full-body radiographs. Schwab modifier distribution was described overall and compared across age groups (<40, 40–60, >60 years), and surgical history (primary or revision) using chi-square analyses. Regional L4-S1 alignment was also compared across Schwab modifiers.

Results
Among 1,023 patients (mean age = 59.0 years, 54.5% female), 21.0% met severe SRS-Schwab criteria overall. Individually, 12.1% had PT++, 15.0% PI-LL++, and 14.6% SVA++. Severe malalignment rose with age (PT++: 5.1% <40 yrs, 8.9% 40–60 yrs, 15.8% >60 yrs; PI-LL++: 3.8%, 10.0%, 20.5%; SVA++: 0.0%, 4.7%, 21.1%; all $p < 0.01$). Revision fusions showed greater deformity (PT++: 21.7% vs 10.4%; PI-LL++: 24.3% vs 13.3%; $p < 0.01$ for both). Decreased regional L4-S1 lordosis was significantly associated with increasing PT (0: 33.5°, +: 30.9°, ++: 24.2°), PI-LL (0: 33.5°, +: 31.7°, ++: 23.7°), and SVA (0: 33.0°, +: 28.2°, ++: 21.3°).

Conclusion
In this study of over 1,000 patients undergoing 1-2 level lumbar fusion, over 20% had baseline severe SRS-Schwab ++ sagittal malalignment. Rates of severe sagittal malalignment were higher in patients with increasing age and those undergoing revision fusion. These findings underscore the importance of standard preoperative assessment of segmental, regional, and global sagittal alignment to guide surgical planning and potentially prevent iatrogenic deformities.

186. Surgeon Achievement of Computer-Assisted Planning Targets in Lumbar Fusion Surgery: A Learning Curve Analysis

Catherine B. Hurley, MS; Michael Farias, BS; Feyza Achilova; Gabriel Gonzalez, BS; Nicolas Carayannopoulos, BS; John Czerwein, MD; Dina Kaplan, BS; Joseph E. Nassar, BS; Bassel G. Diebo, MD; Eren Kuris, MD; Alan H. Daniels, MD

Hypothesis
Surgeon achievement of computer-assisted patient-specific pre-contoured rod alignment targets in short-segment lumbar fusion improves over time.

Design
Retrospective cohort

Introduction
Computer-assisted surgical planning systems guide spinal fusion surgery through quantitative targets, yet success in achieving these targets remains poorly characterized. This study characterizes surgeon success in achieving patient-specific pre-contoured rod (PSPR) planned targets in lumbar fusion.

Methods
Patients undergoing degenerative spinal fusion procedures (≤3-level constructs) who underwent PSRS planning between 2019 and 2025 were retrospectively reviewed. Target achievement was defined as postoperative measurement within 4° or 4 mm of the PSPR-planned values. Achievement rates were assessed overall and for SRS-Schwab modifiers. Learning curves were evaluated using: (1) chronological quartiles based on surgery date, and (2) sequential case number quartiles, with 60 patients per period.

Results
The overall achievement rate was 59.0% across 242 patients. Achievement rate varied significantly by parameter: L1 pelvic angle (L1PA) demonstrated the highest success (74.7%), followed by PI-LL (51.9%), L4-S1 (46.7%), and lumbar lordosis (47.5%) in patients with available

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L1PA measurements (n=158; p < 0.001). PT demonstrated higher achievement than PI-LL (63.6% vs 50.8%, p = 0.010), L4-S1 (p < 0.001), and lumbar lordosis (p < 0.001). SVA had the lowest achievement rate (7.1%). Achievement rates increased by 14.9% from 47.9% between October 2019 and April 2022 (first quartile) to 62.8% between June 2023 and May 2024 (third quartile). Between May 2024 and June 2025 (i.e., the most recent quartile), the achievement rate was 60.2%, demonstrating an overall improvement of 12.3% from first to last quartile.

Conclusion
Surgeons achieve approximately 60% of computer-assisted planning targets in lumbar fusion surgery, with substantial variability across radiographic parameters. Improvement over time demonstrates a clear learning curve, suggesting increased aptitude with PSPR adoption. Pelvic parameters show consistently high achievement, whereas SVA remains difficult to achieve, likely reflecting dependence on global spinal alignment beyond the surgical construct. The recent plateau in achievement may reflect need for further refinement of planning algorithms and intraoperative execution.

187. Patient-Reported Outcomes in Pediatric Spondylolysis

Samantha Snyder, BS; Vivien Chan, MD, MS; Sonja Kleven; James Caruso, MD; *Kenneth D. Illingworth, MD;* David L. Skaggs, MD, MMM

Hypothesis
Baseline functional impairment in pediatric spondylolysis is due to increased pain and a decrease in physical activity.

Design
Cross-sectional study.

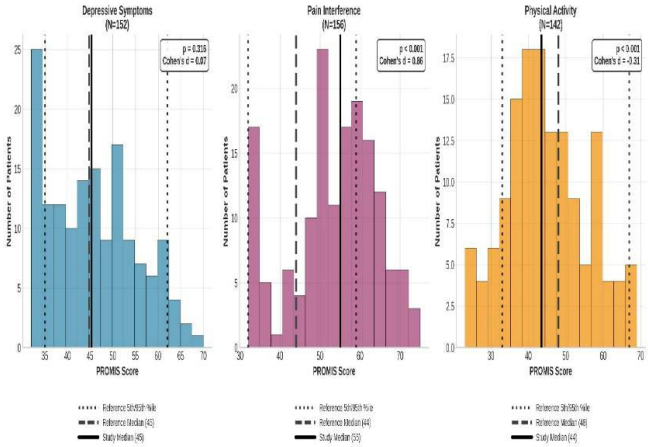
Introduction
Lumbar spondylolysis is a common cause of back pain in children and the leading identifiable cause in young athletes. Patient-Reported Outcomes Measurement Information System [PROMIS] scores for newly diagnosed spondylolysis have not been previously reported.

Methods
We analyzed PROMIS scores in new patients with symptomatic spondylolysis who were newly diagnosed (mean age 15.6 years, range 7-23) from a single institution. Three domains were assessed: pain interference (N=156), depressive symptoms (N=152), and physical activity (N=142). Scores were compared to published pediatric reference norms which included severity score cut off points. Cohen's d was calculated for effect size.

Results
Patients with spondylolysis reported significantly elevated pain interference (mean 53.5 vs. 44, Cohen's d=0.86, p<0.001). Thirty-three percent of patients reported severe pain interference, and 40% had moderate-severe pain interference. Physical activity was significantly lower in spondylolysis patients (mean 44.7 vs. 48, Cohen's d=-0.31, p<0.001). Spondylolysis was not associated with elevated depressive symptoms (mean 45.7 vs. 45, Cohen's d=0.07, p=0.316). Within the cohort, patients 16 and older reported more pain (58 vs. 51, p<0.001) and depressive symptoms (mean 49 vs. 44, p=0.014) than patients less than 16 years old with spondylolysis.

Conclusion
This is the first study to use PROMIS scores to demonstrate patient-reported outcomes in young people with newly diagnosed spondylolysis. Pain interference is the dominant patient-reported feature in this pediatric spondylolysis group, affecting one-third at severe levels. Depressive symptoms do not differ from norms.

Figure 1. Spondylolysis Patients' PROMIS Score Distribution vs. Reference Population



Distribution of PROMIS T-scores for depressive symptoms, pain interference, and physical activity in spondylolysis patients compared to reference population. Solid black lines indicate study medians; dashed black lines indicate reference medians. Dotted black lines represent reference 5th and 95th percentiles. For depressive symptoms, the study median was not statistically different from the reference median (45).

188. Back in the Game: High Return-to-Sport Following Direct Pars Repair in Young Patients

Sydney Thai, BS; Krystell E Ceballos Alvarez, BS; Emmanuel N. Menga, MD; Paul D. Sponseller, MD; Amit Jain, MD, MBA

Hypothesis
We hypothesize that Buck's direct repair will allow patients to return to pre-injury activity levels and result in good clinical outcomes.

Design
Retrospective cohort

Introduction
Direct repair and intralaminar screw fixation are among the most popular surgical treatments for spondylolysis. The aim of this study is to analyze the radiographic and clinical outcomes of patients undergoing direct pars repair at a single institution.

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Methods
A single-center retrospective review was conducted of patients currently aged <25 years who underwent direct grafting and fixation with an intralaminar screw (Buck's technique) for spondylolysis repair over a 25-year period. Predisposing factors (mechanism, duration and methods of conservative treatment, level, and laterality); radiographic parameters (lysis distance and disc health), computed tomography (CT), and magnetic resonance imaging (MRI); and operative data (procedure, operative time, implants used, blood loss, and length of stay) were abstracted. Revision operations, complications, time to return to activity, and patient-reported outcomes were analyzed. Modified Odom criteria were used with the following definitions: "Excellent" outcome was defined as >90% pain relief and return to preinjury sport, while "good" was defined as >80% pain relief without requiring return to sport.

Results
87 patients were included in the study; average age at procedure was 16 years; 95% were competitive athletes. Preoperatively, 71 of 87 patients (82%) discontinued sports entirely. Sixty-one (70%) tried bracing for an average of 4 months, and 59 (68%) patients tried physical therapy (PT); mean duration of symptoms was 20 months. The mean preoperative VAS score was 6.0 and improved to 1.3 postoperatively ($p<0.001$). Average time to return to activity was 3.3 months after surgery. Twelve patients (14%) experienced complications, including 6 revision surgeries. Lysis distance on X-ray, CT, and MRI were not significantly associated with pain improvement. The caudal disc height, cephalad and caudal disc Pfirmann grade were significantly associated with postoperative VAS scores ($p<0.05$). The mean duration of follow-up after surgery was 15.7+/-18.5 months (range, 1 month – 92 months). 97% of patients returned to sports or baseline activity postoperatively.

Conclusion
The direct pars repair to treat spondylolysis-related low back pain results in clinical success in majority of young patients.

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200. Scoliosis After Repair of Congenital Diaphragmatic Hernia: A Study of Incidence and Associated Risk Factors

San Kim, MD; Chang Ju Hwang, MD, PhD; Suhyeon Ha, MD; Dong Ki Ahn, MD, PhD; *ByungSuk Kim, MD*, Jiseon Ahn, MD

Hypothesis:
The study hypothesized that scoliosis in congenital diaphragmatic hernia (CDH) survivors is driven more by disease severity and pulmonary compromise than by surgical tension from defect repair.

Design:
Single-Center Retrospective Cohort Study

Introduction:
Scoliosis is prevalent in CDH survivors, yet its etiology remains unclear. Conflicting theories attribute it to surgical mechanics (e.g., defect size, patch repair) or intrinsic disease severity (e.g., lung hypoplasia). This study aimed to determine the prevalence of scoliosis in long-term CDH survivors and identify independent risk factors by analyzing both surgical and patient-related variables.

Methods:
A retrospective review was performed on 376 patients who underwent CDH repair (1995–2021). Patients who died within 6 months were excluded. Survivors were screened for scoliosis (Cobb angle ≥10° with rotation). Variables included demographics, defect size (length, area, Relative Defect Index), and treatment factors (patch use, ECMO, oxygen at discharge). Univariate and multivariate logistic regression analyses were conducted to identify predictors.

Results:
Of 335 survivors, 12 (3.6%) developed scoliosis. Defect size and area showed no significant difference between groups. Although patch repair (p=0.036) and revision for eventration (p=0.048) were more frequent in the scoliosis group in univariate analysis, they lost significance after adjustment. Multivariate analysis identified oxygen demand at discharge as the sole independent predictor (OR 8.036, p=0.017), while ECMO and patch repair were not significant.

Conclusion:
Scoliosis occurred in 3.6% of survivors. Surgical factors, such as defect size or patch repair, were not independent predictors of deformity. Instead, the requirement for supplemental oxygen at discharge—a surrogate for chronic respiratory insufficiency and lung hypoplasia—was the strongest risk factor. This suggests spinal deformity in CDH is linked to underlying disease severity rather than surgical mechanics. Long-term monitoring is warranted for these high-risk patients.

201. The Treatment of Severe Congenital Scoliosis Associated with Type I Split Cord Malformation: Is a Preliminary Bony Septum Resection Always Necessary? ±

Junlin Yang, MD, PhD; Zifang Huang, MD, PhD; Pan Zhou, PhD; Lei He, MD, PhD

Hypothesis:
To evaluate the safety and efficacy of a single-stage spine-shortening osteotomy in the treatment of severe congenital scoliosis associated with type I SSCM.

Design:
A retrospective study

Introduction:
Single-stage spine-shortening osteotomy without treating spinal cord malformations may have potential advantages for the treatment of severe congenital scoliosis (CS) with type I split spinal cord malformation (SSCM); however, the study of this technique was limited.

Methods:
A retrospective study was designed to compare two case series including 12 severe CS patients with type I SSCM and 26 patients with type A cord function (without spinal cord malformations, evoked potential abnormalities and neurological dysfunctions preoperatively) treated with a single-stage spine-shortening PVCR. Patients' demographic, clinical, operative and radiographic data were obtained and compared between groups.

Results:
The surgical procedure was successfully performed in both groups, and the patients were observed for an average of 44.9 months (range 25-78 months) after the initial surgery. The radiographic parameters, intraoperative data and new neurological deficits showed no difference, while deformity angular ratio (SSCM group : control group = 16.6±3.6 : 20.1±3.9, P=0.01) and corrective rate (SSCM group : control group = 50% : 58% , P=0.046) of the main curve were statistically different between groups. All of the new neurological deficits recovered within one year.

Conclusion:
The single-stage spine-shortening PVCR with moderate correction could be applied to the treatment of CS associated with type I SSCM. This strategy can achieve safe spinal deformity correction while obviate the neurological complications brought by the detethering procedures, which merits further clinical investigation.

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202. 10-Year CT Follow-up of Hemivertebra Resection: Block Vertebra-Like Morphology in Younger Children with Longer Constructs Despite Preserved Canal Dimensions

Junduo Zhao, MD; Jianxiong Shen, MD; Haoyu Cai, MD; Heng Sun, MD; Xuan Huang, MD; Yizhen Huang, MD; Jiafeng Dai, MD

Hypothesis:
10-year CT follow-up would provide detailed assessment of vertebral body morphology and spinal canal dimensions not readily evaluated by conventional radiographs in long-term follow-up.

Design:
Retrospective study

Introduction:
Early spinal fusion after hemivertebra resection may affect long-term growth. Prior studies rely primarily on AP radiographic parameters or have limited follow-up duration. Long-term CT morphometric data over 10 years quantifying vertebral body and canal changes have not been reported.

Methods:
Fifteen patients who underwent posterior hemivertebra resection with short-segment fusion (2-4 vertebrae) underwent CT at mean 12.4-year follow-up (range: 10.1-15.8 years). Mean age at surgery was 7.9 years (range: 2.4-15.1 years). Anterior concavity depth (ACD) was measured as maximum perpendicular distance from idealized anterior column to actual contour. Vertebral body parameters and spinal canal dimensions (AP diameter, lateral diameter, area) were measured at fused and adjacent levels. Patients were stratified by ACD severity and analyzed for age and fusion length correlations.

Results:
All patients demonstrated anterior concavity (mean ACD: 3.8±2.1mm, range: 1.2-8.9mm). Five patients (33%) showed severe concavity (ACD >6mm), all aged <4 years at surgery with 4-vertebra fusions. The most severe case was a 3-year-old with 4-level fusion showing ACD of 10.2mm by CT, creating block vertebra-like morphology (Figure). Other vertebral parameters including pedicle dimensions and disc heights remained within normal ranges. Despite morphological changes, spinal canal dimensions remained within age-matched normal ranges at all levels in all patients (AP diameter: 14-22mm, lateral diameter: 16-31mm). Curve progression occurred in 2 patients (13.3%) with no other complications reported.

Conclusion:
This first 10-year CT morphometric study reveals a anterior growth restriction change forming block vertebra-like morphology, predominantly in patients fused before age 4 with 4-level constructs. While, other vertebral parameters and canal dimensions remain preserved, supporting safety of early fusion when indicated.

203. When Can a Pediatric Scoliosis MRI Be Performed Without Sedation? A Multicenter Study

Meghanna Bomma, BS; Andrea Palmer, BS; Ryan Parrish, MD; Catalina Baez, MD; Jennifer Shumway, BS; Pediatric Spine Study Group; G Ying Li, MD; Sumeet Garg, MD; Lorena Floccari, MD; Scott Yang, MD; Susan Nelson, MD; John S. Vorhies, MD; *Jessica McQuerry, MD*

Hypothesis:
Contemporary MRI practices in pediatric scoliosis are associated with decreasing sedation rates over time

Design:
Retrospective review of prospectively collected multicenter data

Introduction:
MRI is frequently used in the evaluation of pediatric scoliosis but often requires sedation, particularly in younger patients. Despite advances in MRI techniques, there is no consensus regarding sedation practices or age thresholds for completing MRI without sedation. This study evaluates current MRI utilization, sedation trends, scan duration, and age-based thresholds for non-sedated MRI in a large multicenter pediatric scoliosis cohort.

Methods:
An international multicenter database was queried for pediatric scoliosis patients undergoing MRI between 01/01/2019 and 10/01/2024. Demographics, scoliosis etiology, MRI duration, sedation status, year of imaging, and availability of rapid-sequence MRI (RS-MRI) protocols were collected. Sedation rates were compared over time and by etiology using Chi2 and ANOVA. ROC curves were used to determine age cut-offs for MRI sedation using the Youden Index.

Results:
A total of 895 MRIs from 789 patients were analyzed (mean age 7.9±4.6y; 61.8% female). Idiopathic scoliosis was most common (45.2%). The overall MRI sedation rate was 50.6% and decreased significantly over time ($p<0.001$), from 50.3% in 2019 to 39.3% in 2024. Idiopathic scoliosis patients had lower sedation rates (38.2%) than neuromuscular (61.8%), congenital (55.9%), and syndromic (69.2%) ($p<0.001$). Sedated patients were younger than non-sedated patients (5.0±3.4 vs 10.9±3.7y, $p<0.001$) and had longer scan times (66.1±30.6 vs 54.8±27.2min, $p<0.001$). Mean MRI duration was 60.3±29.5min and did not vary by year ($p=0.364$) or etiology ($p=0.075$). RS-MRI duration was shorter than standard-sequence MRI (61.5±29.0 vs 70.0±29.0min, $p=0.018$). The age cut-off for sedation was 7.8 years, regardless of MRI sequence or diagnosis (AUC 0.87, $p<0.001$).

Conclusion:
MRI sedation rates in pediatric scoliosis have decreased

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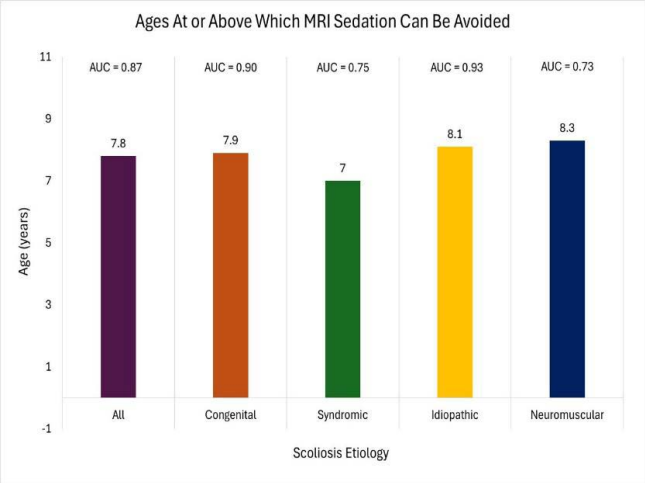
over time despite stable scan durations. RS-MRI protocols were associated with only modest reductions in scan time. Younger age and longer imaging time remain strongly associated with MRI sedation, with an 87% probability that patients aged 7.8 years and older can complete an MRI without sedation. These findings support age-based expectations for MRI tolerance and underscore the need for a standardized definition of rapid-sequence scoliosis MRI.



204. Do Magnetically Controlled Growing Rods Reach Their Intended Length? Construct-Level Outcomes in Early-Onset Scoliosis

Jeffrey T. Galla, BS; Kirsten Brouillet; Brian A. Kelly, MD; *Scott J. Luhmann, MD*

Hypothesis:
A majority of magnetically controlled growing rods (MCGR) will reach maximal length, while heavier, older patients are less likely to reach maximal actuator expansion prior to stall or failure.

Design:
Retrospective chart review

Introduction:
MCGRs are used to manage early-onset scoliosis (EOS) by correcting deformity while allowing for spinal growth with noninvasive lengthening. MCGRs reduce the need for repeated surgeries, but there is a higher up-front cost and they may not reach maximal expansion. This study evaluates MCGR construct outcomes, including rates of maximal expansion, stall, and failure, and identifies predictors of successful performance.

Methods:
EOS patients treated with MCGRs as their first intervention were reviewed at a single institution. Patients with care at outside centers were excluded. Stall was defined as failure to reach 95% maximal actuator capacity due to inability to lengthen, and failure was defined as complications requiring rod replacement. Radiographs were reviewed preoperatively, postoperatively, and at final follow-up. All subjects were followed for greater than 2 years and univariate analysis compared constructs reaching maximal expansion with those that did not.

Results:
43 patients (25 female) were analyzed. 24 constructs (55.8%) reached maximal expansion, 13 (30.2%) stalled, and 6 (14.0%) failed. Mean follow-up was 3.4 years, with time to reach maximal expansion 3.8 years and stall or failure 2.6 years. Stalled rods extended a mean of 61% of actuator capacity. Constructs not reaching maximal expansion were implanted in older patients (8.5 vs 7.4 years, p=0.039) with greater weight (26.6 vs 20.5 kg, p=0.012) and BMI (18.8 vs 15.4, p=0.002). Coronal deformity correction improved from preoperative to postoperative (33%, p<0.001) and final follow-up (38%, p<0.001). 10 patients (23%) received a 2nd MCGR, and 8 went on to fail (p=0.0764).

Conclusion:
Over half of MCGR constructs achieved maximal expansion, exceeding previously reported rates. Older age, greater weight, and increased BMI were associated with reduced likelihood of mechanical completion, and 2nd sets of MCGRs trended toward reduced likelihood. MCGRs provided durable coronal correction. These findings highlight the importance of patient selection and shared decision making when considering MCGRs for EOS management.

Variable	Overall	Maximally Expanded	Stalled or Failed	P value
Demographics				
No. Patients	43	24 (56%)	19 (44%)	-
No. Female	25 (58%)	15 (63%)	10 (53%)	-
Follow-up, yrs	3.41 ± 1.35	3.83 ± 1.37	2.61 ± 1.03	-
Age, yrs	7.9 ± 2.1	7.4 ± 2.2	8.5 ± 2.0	**0.039**
Height, cm	116 ± 14	114 ± 14	118 ± 13	NS
Weight, kg	23.2 ± 8.9	20.5 ± 7.2	26.6 ± 9.9	**0.012**
BMI, kg/m²	16.9 ± 4.0	15.4 ± 2.3	18.8 ± 4.8	**0.002**
Radiographic Measurements				
Coronal Preop	66° ± 20°	68° ± 20°	64° ± 21°	NS
Sagittal Preop	49° ± 23°	49° ± 25°	50° ± 21°	NS
Coronal Preop to Postop Correction	33% ± 22% (**p<0.001**)	36% ± 18%	30% ± 26%	NS
Coronal Preop to Final Correction	38% ± 36% (**p<0.001**)	47% ± 31%	27% ± 41%	NS
Sagittal Preop to Postop Correction	4% ± 31% NS	-3% ± 37%	10% ± 21%	NS
Sagittal Preop to Final Correction	-6% ± 42% (NS)	-4% ± 47%	-7% ± 36%	NS

Table 1. Demographics and MCGR Construct Outcomes

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205. Growing Rods Lead to Increased Collagen Accumulation and Enrichment of TGF-β Pathways in The Murine Intervertebral Disc

Lucas Budd, BS; Olanrewaju Akande, BS; Rachana S. Vaidya, PhD; Christian E. Gonzalez, BS; Simon Y. Tang, PhD; *Blake K. Montgomery, MD*

Hypothesis:
Mechanical loading mimicking growth rod treatment induces fibrotic matrix remodeling and transcriptomic changes in the murine juvenile intervertebral disc (IVD), contributing to spinal stiffening.

Design:
Experimental design murine study.

Introduction:
Early-onset scoliosis adversely affects quality of life and may shorten life expectancy. Distraction-based growing rods are used to increase thoracic height and correct deformity in skeletally immature patients but frequently lead to autofusion, occurring in up to 90% of patients. Autofusion limits thoracic growth which impairs pulmonary function and reduces quality of life. The biological response of the IVD to growing rods remains poorly understood.

Methods:
Six-week-old female C57BL/6 mice underwent growth rod instrumentation (n=8). Metal pins anchored 3D-printed washers connected by screws and springs to distract caudal spinal segments (Co7/8–Co12/13); adjacent segments served as non-distracted controls. Distraction force equaled twice body weight and was maintained for 20 weeks. Disc Height Ratio (DHR) was measured longitudinally. After sacrifice, contrast-enhanced microCT, dynamic compression testing, biochemical assays for sulfated glycosaminoglycans (sGAGs) and collagen (n=4), and bulk RNA sequencing (n=3) were performed. One-way ANOVA and paired t-tests were used.

Results:
The disc height was initially increased in distracted segments (DHR distracted = 0.525 vs non-distracted = 0.268, p <0.0001) but subsequently declined. After 14 weeks the discs that were spanned by the growing rod were shorter than discs outside of the growing rod (DHR distracted = 0.226 vs non-distracted = 0.295, p =0.0124). Discs that were spanned by the growing rod exhibited reduced volume and sGAG content, while collagen content trended higher, resulting in a reduced sGAG-to-collagen ratio. RNA sequencing demonstrated upregulation of genes associated with TGF-β signaling, inflammation, and collagen formation.

Conclusion:
Growth rod surgery induces structural, compositional, and transcriptional changes consistent with fibrotic remodeling of the juvenile IVD. Activation of TGF-β and inflammatory pathways provides a potential mechanistic link to spinal stiffening which may contribute to autofusion after growing rods are inserted in patients.

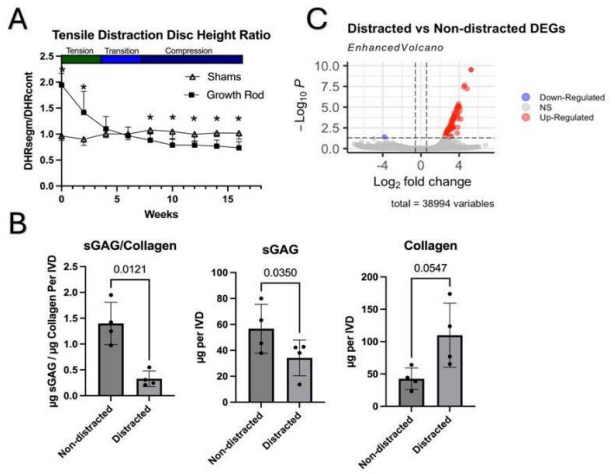

Figure 1: (A) Longitudinal DHR, (B) sGAG and collagen quantification, and (C) volcano plot of distracted vs non-distracted IVDs.

206. Radiographic Progression of Scoliosis After Triradiate Cartilage Closure in Non-Ambulatory Cerebral Palsy ±

Satoshi Takada, MD; Jason J. Howard, MD; Hiroshi Taneichi, MD, PhD; Alice Taylor, BS; Anuj Gupta, MD; M. Wade Shrader, MD

Hypothesis:
Non-ambulatory cerebral palsy (CP) patients with larger spinal curvature and pelvic obliquity at triradiate cartilage (TRC) closure are at increased risk for scoliosis progression after skeletal maturity.

Design:
Retrospective cohort study.

Introduction:
The natural history of scoliosis after skeletal maturity in non-ambulatory CP patients remains poorly understood, and evidence-based guidelines for radiographic surveillance are lacking. This study aimed to determine the prevalence and rate of scoliosis progression after TRC closure and identify risk factors for curve progression.

Methods:
Consecutive patients with spastic non-ambulatory CP (GMFCS IV-V) and minimum 2-year follow-up after TRC closure were included. Patients with prior spinal surgery before TRC closure were excluded. Radiographic parameters including major curvature, pelvic obliquity (PO), apical vertebral translation, and central sacral vertical line deviation were measured. Primary outcome was progression to major curvature ≥50° or surgical intervention. Risk

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factors were analyzed using multivariate logistic regression and ROC curve analysis.

Results:
Eighty-one patients (47 males; mean age 14.6 years at TRC closure) were analyzed. Mean follow-up was 4.3 years. At TRC closure, mean major curvature was 31.5° and mean PO was 9.5°. Forty-eight patients (59.3%) experienced significant progression; 42 underwent surgery. Mean time to progression was 34 months. Multivariate analysis identified three independent risk factors: major curvature at TRC (OR 1.16, p<0.001), PO (OR 1.12, p=0.02), and epilepsy (OR 2.17, p=0.02). ROC analysis identified major curvature ≥34° as optimal threshold (sensitivity 72%, specificity 82%, AUC 0.76). PO ≥8° showed moderate predictive value (AUC 0.69). Patients with prior hip surgery had significantly shorter progression-free survival (p=0.004).

Conclusion:
Scoliosis progresses after TRC closure in nearly 60% of non-ambulatory CP patients. Major curvature ≥34° at TRC closure, PO ≥8°, epilepsy, and prior hip surgery are significant risk factors. These thresholds support continued surveillance in high-risk patients after skeletal maturity.

207. Paediatric Patients with Complex Neuromuscular Scoliosis Do Not Require Routine Admission to ICU Following Scoliosis Surgery.

Hannah Phillips; Giuliana Antolovich, PhD, MBBS; Mia Percival; Moya Vandeleur, PhD; Katherine Frayman, PhD, MBBS; Donna Peachey, RN; Ingrid Sutherland, RN; Michael B. Johnson, MD, PhD; Tali Gadish, MD; *Kristopher M. Lundine, MD*

Hypothesis:
Not all patients with complex neuromuscular scoliosis require admission to PICU following their scoliosis surgery.

Design:
Retrospective Cohort Study

Introduction:
Paediatric patients with neuromuscular scoliosis represent a challenging population due to the severity of their spinal deformities and their medical comorbidities. Following scoliosis corrective surgery in this population, typical post-operative care across most paediatric institutions in Australia includes routine admission to the Paediatric Intensive Care Unit (PICU). PICU is an expensive and limited resource. Current practice at most paediatric centres across Australia is for routine admission to PICU following surgery for this population which can lead to prolonged surgical wait-times and day-of-surgery cancellations if a PICU bed is unavailable. At our institution, these patients are reviewed pre-operatively by a Multidisciplinary Team (MDT) and the Pre-Anaesthetic Resource Centre (PARC) to determine whether a post-operative PICU admission will be required. The purpose of this study was to assess the frequency of planned ICU admission, unplanned ICU admission and the main reasons for unplanned ICU admission to help optimize post-operative clinical care.

Methods:
Retrospective chart of review of all patients at a single paediatric institution with neuromuscular spinal deformity undergoing a pre-operative MDT review between January, 2019 and December, 2024 and subsequent spinal corrective surgery.

Results:
115 patients underwent scoliosis corrective surgery for their neuromuscular spinal deformity. Mean age was 14 years and most common primary diagnosis was Cerebral Palsy. 45 patients had a planned post-operative admission to PICU based on pre-op MDT and/or PARC review. Of the 70 patients that did not have a planned post-op PICU admission, 10 (14%) had an unplanned PICU admission. The most common reason for unplanned ICU admission was the need for post-operative respiratory support.

Conclusion:
Over half of patients (60/115) undergoing surgical correction for their neuromuscular scoliosis were safely managed post-operatively without the need for any PICU admission. Rate of unplanned PICU admission was 14% in patients deemed not to need PICU based on pre-operative assessment. Further research is needed to optimize pre-operative decision making to help guide clinical utilization of this limited resource.

208. Functional Response to Halo Gravity Traction (HGT) in Ambulatory Children with Severe Spine Deformity

Amareesa Robinson, BS; *Amy L. McIntosh, MD;* Charles E. Johnston, MD; Tiffany Thompson, BS; Karina A. Zapata, PhD, DPT

Hypothesis:
Ambulatory children undergoing HGT will demonstrate improved physical and respiratory function.

Design:
Retrospective

Introduction:
HGT improves radiographic alignment in severe pediatric spine deformity, yet its impact on functional capacity remains uncertain. We evaluated changes in physical and pulmonary function during HGT in ambulatory children with spine deformity, with a subgroup analysis post-halo.

Methods:
Children who underwent HGT completed six-minute walk tests (6MWT) and pulmonary function tests (PFT) pre- and during-halo. A subgroup completed 6MWT/PFT post-halo following definitive fusion. Clinically important 6MWT

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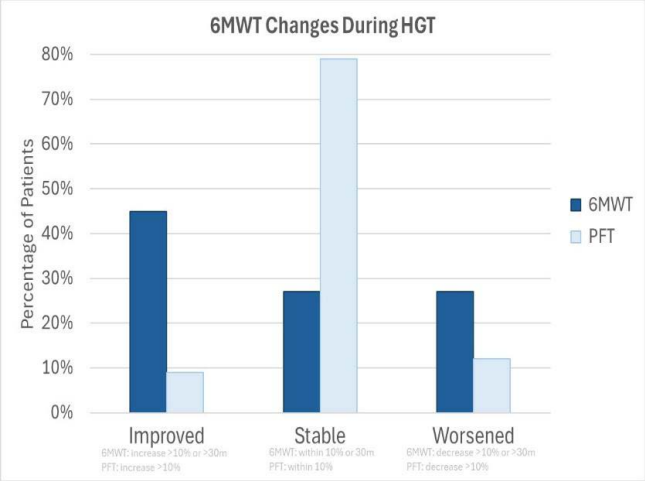
outcomes were defined as improved (increase >10% or >30 meters), stable (within 10% or 30 m), or worsened (decrease >10% or >30 m). PFT outcomes were defined as improved (FVC% >10%), stable (within 10%), or worsened (decrease >10%).

Results:
66 children (16 Congenital, 16 Idiopathic, 17 Neuromuscular, 17 Syndromic) averaging 11.2±3.6 years completed pre- and during-halo 6MWT. In HGT, the coronal curves improved from 98±27° to 76±27°, and thoracic kyphosis from 67±27° to 51±25°. Median traction duration was 51 days, achieving 49±10% body weight. Mean 6MWT distance remained stable (405□408 m), though 45% of children demonstrated clinically important improvement; 27% worsened and 27% remained stable. The 30 pts with 6MWT improvement did not differ by etiology, age, curve magnitude, traction duration, traction body weight %, or pulmonary metrics (p>.17). Among 33 patients with spirometry, absolute FVC (1.2 L) and FEV1 (1.0 L) remained unchanged, with predicted values stable at FVC% 43□42% and 38%. Only 9% showed clinically important improvement in FVC%; 79% remained stable and 12% worsened. For the post-traction fusion group (n=13), 6MWT improved (322□404 m, p=.013) after 3.5±1.8 yr. However, this was unchanged compared to age- and sex-matched controls (-4.1□-4.0 SD, p=.86). Pulmonary function remained stable (FVC% 42%□45%, p=.33).

Conclusion:
Nearly half of the ambulatory older children (mean age 11) undergoing HGT experienced clinically important improvements in physical function, independent of etiology, deformity magnitude, traction parameters, or spirometry. In fact, pulmonary spirometry revealed little or no change while in traction. In the post-fusion cohort, intermediate-term follow-up suggests gains in physical capacity, although unchanged from controls.



6MWT Changes in HGT

209. Deep Dive in DiGeorge: Spinal Deformities and Outcomes in Scoliosis Patients

Zachary Trotzky, BS; Alexa J. Karkenny, MD; Jacob F. Schulz, MD; Edina Gjonbalaj, BS; Leila Mehraban Alvandi, PhD; John (Jack) M. Flynn, MD; Pediatric Spine Study Group; *Jaime A. Gomez, MD*

Hypothesis:
The aim of this study was to provide preliminary radiographic, patient-reported, and clinical outcomes of operative and non-operative scoliosis treatment in children with DiGeorge syndrome.

Design:
Retrospective review of a multicenter database of patients with early-onset-scoliosis (EOS)

Introduction:
DiGeorge syndrome is the most common microdeletion syndrome, characterized by broad phenotypic variability. Patients frequently have cardiac anomalies, immunodeficiency, and musculoskeletal defects, with 50% of affected children developing scoliosis. Given its multisystem involvement, this disorder presents a unique challenge in scoliosis management and surgical decision-making. Current evidence on treatment of pediatric spinal deformity in this population is limited to case-level data.

Methods:
Children diagnosed with DiGeorge syndrome were identified. Patients were grouped based on treatment method: non-operative (brace), growth-friendly (GF) devices, or spinal fusion. Quality of life was measured using the 24-item Early Onset Scoliosis Questionnaire (EOSQ-24). Complications and unplanned returns to the operating room (UPRORs) were recorded.

Results:
This cohort included 75 patients (30 non-operative, 33 GF, and 12 fusion; mean 5 ± 3-year follow-up). Among non-operative patients, major scoliosis curves progressed from 42 to 48° (Table 1). Surgical treatment decreased the major Cobb angle in the GF (69 to 48°) and fusion groups (66 to 44°). In the GF group, there were 47 complications (13 implant-related, 10 pulmonary) among 19 patients (58%), resulting in 16 UPRORs in 12 patients (36%). In the fusion group, there were 3 complications among 2 patients (17%), resulting in 0 UPRORs. Compared to baseline, mean EOSQ-24 scores improved in 8 of 12 domains in the non-operative group and in all domains in the GF and fusion groups.

Conclusion:
Non-operative treatment effectively maintained major Cobb angle while surgical intervention achieved curve correction. Improvements in quality of life were observed across all groups. Complication rates were higher in the GF group than the fusion group, particularly implant- and pulmonary-related events. Due to systemic comorbidities, children with DiGeorge syndrome may be at higher risk

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for complications, emphasizing the need for tailored treatment strategies.

Table 1. Characteristics and EOSQ-24 Scores of Non-Operative, Growth-Friendly, and Fusion Patients

Characteristic	Non-Operative (n=30)		Growth-Friendly (n=33)		Fusion (n=12)	
Demographic						
Age at baseline (years)*	5.9 ± 3.1		8.6 ± 2.9		12.1 ± 3.8	
Sex (female)	19 (63%)		20 (61%)		8 (67%)	
Baseline BMI (kg/m^2)*	16.6 ± 2.8		16.6 ± 3.0		19.6 ± 4.5	
Radiographic						
Major curve magnitude						
Baseline major Cobb (degrees)*	42.4 ± 17.7		68.5 ± 21.9		65.8 ± 20.5	
Most recent major Cobb (degrees)	47.9 ± 14.6		47.5 ± 18.0		44.3 ± 11.2	
Kyphosis magnitude						
Baseline kyphosis (degrees)	43.8 ± 10.6		49.9 ± 29.5		54.2 ± 10.5	
Most recent kyphosis (degrees)*	44.0 ± 23.7		57.9 ± 20.2		41.2 ± 10.0	
EOSQ-24 scores	**Non-Operative**		**Growth-Friendly**		**Fusion**	
	Baseline	Most Recent	Baseline	Most Recent	Baseline	Most Recent
General Health	55.6 ± 18.9	70.4 ± 20.9	68.3 ± 20.0	74.0 ± 16.9	64.3 ± 8.6	70.8 ± 15.1
Pain & Discomfort	83.3 ± 16.5	73.7 ± 19.0	68.3 ± 24.5	73.4 ± 20.0	55.4 ± 17.5	66.7 ± 31.3
Pulmonary Function	84.7 ± 21.4	86.2 ± 18.1	84.2 ± 14.5	85.4 ± 20.1	60.7 ± 34.1	95.8 ± 6.5*
Transfer	66.7 ± 39.5	75.0 ± 36.3	78.3 ± 24.8	86.5 ± 16.5	71.4 ± 22.5	83.3 ± 30.2
Physical Function	79.6 ± 33.9	76.9 ± 33.3	75.0 ± 26.0	77.1 ± 23.1	61.9 ± 29.2	79.2 ± 20.2
Daily Living	52.8 ± 38.9	61.1 ± 34.0	51.7 ± 30.2	64.6 ± 27.3	35.7 ± 29.3	64.6 ± 34.8
Fatigue & Energy Level	66.7 ± 32.5	81.9 ± 22.8	65.8 ± 29.3	67.2 ± 23.8	55.4 ± 34.5	75.0 ± 26.2
Emotion	86.1 ± 22.0	80.6 ± 22.4	69.2 ± 22.6	74.5 ± 23.5	64.3 ± 19.7	68.8 ± 22.0
Parental Impact	65.0 ± 19.5	73.5 ± 21.1	63.8 ± 25.1	77.1 ± 16.3	62.1 ± 25.3	88.3 ± 11.2*
Financial Impact	86.1 ± 22.0	86.8 ± 21.9	75.0 ± 31.0	78.1 ± 24.8	87.5 ± 30.6	91.7 ± 20.4
Child Satisfaction	80.6 ± 32.5	73.6 ± 18.1	62.5 ± 25.5	69.8 ± 22.1	53.6 ± 30.4	79.2 ± 24.6
Parent Satisfaction	63.9 ± 33.3	70.8 ± 23.1	61.7 ± 24.8	66.7 ± 22.9	53.6 ± 26.7	87.5 ± 13.7*

Data presented as Mean ± SD or n (%); *p < .05

210. Comparison of Traditional Bipolar Constructs and Bipolar Growing Rods (NEMOST) in Paediatric Non-Ambulatory Neuromuscular Scoliosis

Liam Rose, FRCS; Benjamin Prentice, MBBS; Kristopher M. Lundine, MD

Hypothesis:
NEMOST provides superior correction compared to standard bipolar with no further risk.

Design:
Retrospective comparative study

Introduction:
Bipolar constructs are a less invasive option for neuromuscular scoliosis, reducing operative time, blood loss, complications, and improving scoliosis and pelvic obliquity correction. NEMOST, a one-way self-expanding growing rod addition to the bipolar construct, is suitable for younger children requiring continued spinal growth. We compared outcomes of NEMOST versus traditional bipolar constructs.

Methods:
We retrospectively reviewed all children in the seven years since the technique's adoption in our unit, comparing preoperative parameters, blood loss, complications, and radiographic correction. Most had ≥2 years follow-up. An age-adjusted bipolar subgroup (<13 years old) was also analysed to account for a trend towards NEMOST in younger patients. Unpaired t-tests, Mann-Whitney-U and Fisher's exact tests assessed significance.

Results:
115 Bipolar patients were compared against 30 NEMOST patients, and an age-adjusted subgroup group of Bipolar (n=35). Preoperative Cobb angle and pelvic obliquity were similar (90.3 vs 96.5, p>0.2; 25.2 vs 25.9,p>0.8). Hb drop and transfusion rates were comparable, (34.8 vs 45.0, p= 0.07, and 17% vs 18.3%), especially when age- adjusted (17%). Surgical time, length of stay, ICU stay, and immediate postoperative Cobb and pelvic obliquity were similar across groups (p > 0.05 for all) in age-adjusted groups. At both one-year and two-years post-op, NEMOST achieved lower Cobb angles than the age-adjusted Bipolar group (42.5° vs 56.1°, p = 0.007 and 45.3 v 58.3, p = 0.009). In the age-adjusted Bipolar group, the Cobb angle increased at one (5.2°) and two years (7.3°) post op, whereas in NEMOST it was stable for one year (-0.4°) and increased slightly at two years (2.5°). There was no significant difference in pelvic obliquity. Hardware failure and return-to-theatre rates were similar in all groups (p > 0.5). 90-day mortality was low, with one death in the bipolar group.

Conclusion:
NEMOST showed superior Cobb angle correction up to two-years follow-and a lower risk of cranksgafting, showing that there is value in a growing rod construct for younger patients. This did not come at the cost of increased complication rates, length of stay or return to theatre.

211. Index Complications and 30-Day Readmission Vary by Etiology After Posterior Spinal Fusion for Pediatric Neuromuscular Scoliosis

Charlene W. Cai, BS; Suhas Parise, MBA; Victoria Izsa, MS; Ahmad Hudaihed, BA; Amog Mysore, BS; Alice Chu, MD; *Neil Kaushal, MD*

Hypothesis:
Patients with different neuromuscular scoliosis etiologies experience distinct index complication patterns and 30-day readmission risk following posterior spinal fusion.

Design:
Retrospective cohort study

Introduction:
Neuromuscular scoliosis (NMS) comprises heterogeneous etiologies with differing perioperative risk after posterior spinal fusion (PSF).

Methods:
The 2016–2021 Nationwide Readmissions Database was queried using ICD-10 codes for patients <18 years undergoing posterior spinal fusion for scoliosis, stratified by neuromuscular etiology: cerebral palsy (CP), muscular dystrophy/myopathy, paralysis (paraplegia/quadriplegia, excluding CP), spinal muscular atrophy (SMA), and spina bifida/myelomeningocele (SB/MMC). Primary outcomes included index hospitalization complications, length of stay, and 30-day all-cause readmission. Survey weights generated national estimates. Groups were compared using design-adjusted tests (Rao–Scott χ^2 for categorical and design-based tests for continuous outcomes).

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Results:
There were 2,511 admissions (weighted N=7,003). Age and sex differed by etiology (both p<0.001): Patients with SMA were youngest (9.99±0.34 years) and myopathy oldest (13.28±0.18), with female proportion lowest in myopathy (26.3%) and highest in SMA (62.2%). Length of stay did not differ (p=0.112). Any index complication differed across etiologies (CP 87.5%, paralysis 82.4%, SMA 75.6%, myopathy 66.9%, SB/MMC 65.8%; p<0.001). Neurologic complications were highest in CP and paralysis (66.2% and 50.7%) versus SMA and myopathy (6.2% and 9.5%; p<0.001). GI complications also varied (CP 43.2%, SMA 42.8% vs SB/MMC 20.1%; p<0.001), as did renal/metabolic complications (SMA 25.9% vs paralysis 13.7%; p=0.038). Pulmonary, hematologic/thrombotic, and infectious complications were similar across etiologies (p>0.05). Thirty-day readmission differed by etiology (p=0.013), highest in SB/MMC (18.1%) and paralysis (15.9%) and lowest in SMA (7.0%) and myopathy (7.5%).

Conclusion:
After PSF for scoliosis, different NMS etiologies are associated with distinct complication patterns and 30-day readmission risk. Complications are not uniform across NMS subtypes for neurologic, GI, and renal/metabolic domains, supporting etiology-specific perioperative optimization pathways.

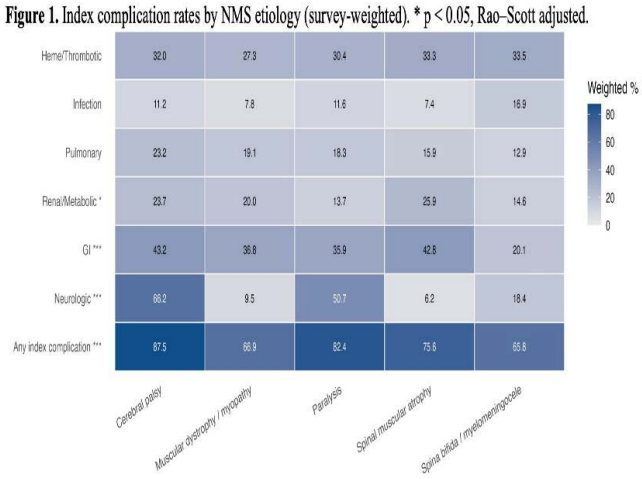

Figure 1. Index complication rates by NMS etiology (survey-weighted %). * p < 0.05, Rao–Scott adjusted.

212. Efficacy of Halo-Gravity Traction in the Perioperative Treatment of Severe Scoliosis and Kyphosis: A Comparison of Adolescent and Adult Patients. ±

Zifang Huang, MD, PhD; Junlin Yang, MD, PhD; Pan Zhou, PhD; Lei He, MD, PhD

Hypothesis:
To evaluate and compare the efficacy of halo-gravity traction (HGT) as a perioperative management strategy for severe scoliosis and kyphosis in adolescent versus adult patients, specifically focusing on radiographic correction, pulmonary function improvement, and clinical complication rates.

Design:
A retrospective comparative study

Introduction:
evere spinal deformities exceeding 100° present extreme surgical risks and compromised pulmonary function. Halo-gravity traction (HGT) serves as a vital perioperative adjunct by providing gradual correction and improving respiratory capacity. However, comparative evidence regarding HGT's efficacy across different age-related skeletal maturities remains limited.

Methods:
51 patients with severe scoliosis/kyphosis who underwent HGT followed by posterior spinal instrumented fusion were enrolled. Patients were divided into two groups: Adolescents (10–18 years, n=22) and Adults (>18 years, n=29). Standardized assessments included full-length spine radiographs (pre-traction, post-traction, and post-operation), pulmonary function testing (FVC% and FEV1%), and monitoring for neurological or traction-related complications over a minimum 2-year follow-up period.

Results:
We identified 29 adults (8 males and 21 females, mean age = 23.7 ± 8.7 years) and 22 adolescents (10 males and 12 females, mean age = 13.0 ± 4.5 years). In the adult group, the mean Cobb angle of the main curve before HGT was 141.7 ± 18.2°, which improved to 126.4 ± 8.6° and 67.5 ± 10.2° after traction and operation, respectively. The kyphotic angle was corrected from 137.1 ± 15.6° before traction to 122.5 ± 11.3° after traction to 67.6 ± 13.8° after operation. The mean functional vital capacity% and forced expiratory volume in one second% were 43.1% and 37.5%, which improved to 46.7% and 41.7% after traction, respectively. In the adolescent group, the mean correction of the main curve improved from 139.3 ± 12.6° before traction to 112.1 ± 8.3° after traction to 59 ± 13.1° after surgical intervention. The kyphotic angle was corrected from 130.7 ± 9.4° before traction to 101.5 ± 12.2° after traction and then to 48.2 ± 10.1° after surgical intervention. Overall, patients in both groups showed significant improvement in their main scoliosis and kyphosis (P < 0.05), while the correction rate of the main curve and kyphosis was significantly higher in the adolescent group than that in the adult group (P < 0.05). The functional vital capacity% increased from 44.8% to 55.0% and the forced expiratory volume in one second% increased from 44.0% to 51.0% after using HGT. In terms of surgical outcomes, the incidence of postoperative neurological complications was 27.6% and 18.2% in the 2 groups, respectively.

Conclusion:
HGT is an effective and safe method to correct spinal deformities and improve lung function, especially in

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adolescent patients with severe scoliosis. In addition, it can potentially reduce the risk of neurological complications and the level of osteotomy in posterior spinal instrumented fusion surgery.

213. Sagittal Alignment in Scheuermann's Kyphosis Is Poorly Predicted by Pelvic Incidence Using Vertebral Pelvic Angles

Fthimnir Hassan, MPH; Joshua M. Pahys, MD; Justin L. Reyes, MS; Travis S. CreveCoeur, MD; Zeeshan M. Sardar, MD; Michael G. Vitale, MD, MPH; Benjamin D. Roye, MD; Suken A. Shah, MD; Peter O. Newton, MD; Patrick J. Cahill, MD; Lawrence G. Lenke, MD; Michael P. Kelly, MD; Harms Study Group

Hypothesis:
Sagittal alignment in Scheuermann's kyphosis (SK) follows a distinct vertebral pelvic angle (VPA) pattern that is not well predicted by pelvic incidence (PI) alone

Design:
Multicenter, retrospective study

Introduction:
In asymptomatic adults and AIS, VPA demonstrate strong, predictable relationships with PI. However, sagittal plane organization in Scheuermann's kyphosis (SK) has not been characterized using VPA.

Methods:
A multicenter and single-center registry was queried for adult and pediatric SK patients with min 2yr follow-up. Preop VPAs, including C2PA, L1PA, T4PA, and T4-L1PA mismatch, and PI were measured for all patients. Linear regression analyzed relationships between PI and VPAs. R2 measured strength of model fit.

Results:
44 SK pts w/ ≥2yr follow-up were included. Mean age was 20.3±8.4yrs, 22.7% (n=10) were female. Mean TK and LL were 78.9±13.5 and 68.0±16.5 degrees, respectively. Mean C2 Tilt, C2PA, L1PA, T4PA, T4-L1PA mismatch, and PI were -5.2±7.65, 6.3±9.7, 4.4±13.4, 3.0±9.8, -1.4±9.7, and 38.9±12.9 degrees, respectively. When examining the relationship between VPAs and PI, L1PA demonstrated a weak but statistically significant relationship with PI (R^2=0.15, p=0.0107), described by the equation: L1PA = 0.40·PI − 11.1 ±16.7° (80% prediction interval). Similarly, T4PA showed a weak yet significant association with PI (R^2=0.16, p=0.0065): T4PA = 0.31·PI − 9 ±12°. In contrast, neither C2 Tilt (R^2=0.01, p=0.6091), C2PA (R^2=0.04, p=0.1706), nor T4–L1PA mismatch (R^2=0.01, p=0.4335) demonstrated significant relationships with PI. Corresponding equations were C2 Tilt = 0.05PI – 7.01 ± 10.2°, C2PA = 0.16·PI + 0.18 ±12.7°, T4–L1PA = −0.10·PI + 2.1 ±12.9°.

Conclusion:
Vertebral pelvic angles in Scheuermann's kyphosis show weak coupling to pelvic incidence and wide variability, reflecting disruption of normal sagittal alignment rather than an alternative physiologic pattern. Unlike adolescent idiopathic scoliosis and asymptomatic adults, patients with Scheuermann's kyphosis exhibit malalignment in sagittal shape despite maintaining global balance. These findings support the use of vertebral pelvic angles to characterize sagittal deformity and reinforce restoration toward normal alignment targets as a biomechanical goal of correction.

214. Long-Term Assessment of Complications and Reoperations Following Posterior Spinal Fusion for Scheuermann's Kyphosis

Prudhvi Kodali, BA; James Caruso, MD; Christian Calderon, MD; Maveric Abella, MD; *David L. Skaggs, MD, MMM*

Hypothesis:
Patients undergoing spinal fusion for Scheuermann's kyphosis experience higher complication and reoperation rates in the early postoperative period, with lower incremental risk at longer-term follow-up.

Design:
Retrospective Database Study

Introduction:
Surgical treatment of Scheuermann's kyphosis has evolved with the development of pedicle screw-based segmental instrumentation, and deformity correction can provide reliable alignment correction and pain relief. However, the frequency and timing of complications and reoperations are incompletely defined. Therefore, this analysis leverages a large patient dataset to evaluate complication and reoperation rates after posterior fusion for Scheuermann's kyphosis.

Methods:
A national insurance claims database identified patients with Scheuermann's kyphosis who underwent index posterior spinal fusion spanning ≥7 levels with a minimum 2-year follow-up. Demographic and postoperative outcome data were collected and analyzed, including the following variables: Reoperations for revision or exploration of fusion, hardware removal, interbody fusion, and irrigation and debridement, and incidence of deep vein thrombosis, pneumonia or respiratory failure, urinary tract infection, sepsis, acute kidney injury, myocardial infarction, or stroke.

Results:
Two hundred fourteen patients were identified (59.3% male, mean follow-up ≥2 years). Pseudarthrosis occurred in 12 patients (5.6%) within 1 year. Reoperation rates were 7.0% at 1 year, 7.9% at 2 years, and 9.3% at 5 years, indicating that most reoperations occurred within the first postoperative year. Medical complications occurred in 7.5% of patients within 30 days and 7.9% within 90 days of surgery.

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Conclusion:
Spinal fusion for Scheuermann's kyphosis is associated with moderate early reoperation rates, a slower increase in revision surgery risk beyond the first postoperative year, and low early medical complication rates. This suggests that posterior spinal fusion is a well-tolerated treatment for Scheuermann's kyphosis, but close surveillance is especially necessary during the first postoperative year.

215. Scheuermann's Kyphosis: Are Ponte Osteotomies Necessary?

Jesse P. Robinette, MD; Matthew Siebert, MD; Anna McClung-Booth, BSN; Megan Johnson, MD

Hypothesis:
Ponte osteotomies are not necessary for adequate deformity correction in Scheuermann's kyphosis.

Design:
Retrospective cohort study

Introduction:
Scheuermann's kyphosis (SK) is characterized by hyperkyphosis that often results in cosmetic dissatisfaction, and, rarely, neurologic compromise. While conservative measures are effective for many patients, surgical correction is indicated when symptoms persist. Posterior spinal fusion (PSF) with Ponte osteotomies is considered the gold-standard treatment; however, Ponte osteotomies increase operative time, blood loss, and neurologic risk. This study evaluates whether Ponte osteotomies are necessary to achieve adequate correction of SK.

Methods:
Single-institution retrospective chart review of patients with SK who had a PSF between 2006 and 2024. Patients with other forms of kyphosis and >2 hooks in their PSF construct were excluded. Demographic, radiographic and operative data were included.

Results:
77 patients (55 males, 22 females) were included. Age at surgery was 16.4±2.1yrs with max thoracic kyphosis of 87±9°, and average flexibility of 34±12% on lateral bolster x-ray. 60 patients had Ponte osteotomies (P+) and 17 (P-) did not. There was no significant difference in age, BMI, pre-operative kyphosis, flexibility, and implant density between groups (Table 1). There was no significant difference in post-operative correction (P+ 27.8°±11.2° vs. P+ 27.0°±8.7°, p=0.814). The Ponte group had significantly greater EBL (P+ 877±446mL vs. P- 617±363mL, p=0.003) and operative time (P+ 339±132min vs. P- 292±158min, p=0.018). Four (7.3%) patients had IONM alerts in the P+ group vs. 0 in the P- group (p=0.57). The P+ group had significantly lower rates of radiographic proximal junctional kyphosis (defined as PJK > 15˚ at 2 year follow-up) than the P- group (13.3% vs. 41.2%, OR 0.18, 95% CI 0.04-0.74).

Conclusion:
In patients with SK undergoing PSF, Ponte osteotomies are not necessary to achieve adequate deformity correction. The use of Ponte osteotomies is associated with higher EBL and longer operative times. Patients who had Ponte osteotomies did, however, have lower rates of radiographic PJK at 2 years, suggesting that shortening the posterior column may have a protective effect against this complication.

	Ponte (n=60)	No Ponte (n=17)	p
Age (years)	16.5±2.0	15.9±2.4	0.407
BMI	28.5±7.2	28.1±7.1	0.771
Maximum Pre-operative Kyphosis(˚)	85.9°±8.9°	93.1±7.2	0.0046
Pre-operative Flexibility Over Bolster (%)	35.8±11.8%	31.1±9.9%	0.206
Implant Density(n)	1.5±0.2	1.5±0.3	0.588
EBL (ml)	877±446	617±363mL	0.003
Operative Time (min)	339±132	292±158	0.018
IONM Alert	4	0	0.569
Immediate Post-op Kyphosis Correction (°)	27.8°±11.2°	27.0°±8.7°	0.814
Immediate Post-op Kyphosis Correction (%)	32±12 (3-65%)	29±9 (7-41%)	0.353
Maximum Immediate Post-Operative Kyphosis (°)	58.1°±9.88° (35-82°)	66.1°±9.3° (50-83°)	0.0057
Rate of Radiographic PJK (%)	13.3	41.2	0.008

Table 1

216. Instrumentation to the Sacrum/ Pelvis Achieves Greater Sagittal Correction Compared to Shorter Instrumentation in Adult Spinal Deformity Patients with Thoracic Hyperkyphosis

James Y. Chen, BA; Alex Hernandez, BS; Justin L. Reyes, MS; Miranda McDonaldStahl, BS; Matthew Rendon, BA; Amrit Singh, MPH; Joseph M. Lombardi, MD; Ronald Lehman Jr, MD; Lawrence G. Lenke, MD; Zeeshan M. Sardar, MD

Hypothesis:
In pts with thoracic hyperkyphosis, fixation to the pelvis achieves greater correction of sagittal alignment compared to shorter instrumentation.

Design:
Retrospective cohort

Introduction:
Selection of the lowest instrumented vertebra (LIV) in adult spinal deformity (ASD) pts with thoracic hyperkyphosis is not completely understood. This study aims to characterize parameters influencing LIV selection and the respective post-operative outcomes.

Methods:
We reviewed all ASD pts with primary thoracic hyperkyphosis, defined as max kyphosis ≥60° with major Coronal

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Cobb angle <30°, who underwent fusion extending from T4 or higher to a LIV in the lower thoracolumbar spine (T10 or lower) and had 2+ year follow-up. Proximal/Distal junctional kyphosis (PJK/DJK) were defined as post-operative proximal/distal junctional angle (PJA/DJA) >10° that increased by 10°+ from baseline. Wilcoxon rank-sum test and Fisher's exact tests were used with significance set to P<0.05.

Results:
20 pts were included (age 50.9±18.0 years; 50% female). 11 pts were fused to the pelvis while 9 were fused shorter (range L1-L3). Pelvic fixation pts were older (P=0.019), had higher BMIs (P=0.006), and had lower L1 Hounsfield Units on computed tomography (CT, P=0.049). At baseline, the pelvic fixation group had lower lumbar lordosis (LL, P=0.005), greater pelvic tilt (PT, P=0.015), greater T4 pelvic angle (T4PA, P=0.001), greater T4-L1PA mismatch (P=0.004), and greater sagittal vertical axis (SVA, P=0.002). Post-operatively, thoracic kyphosis improved significantly in both groups (P<0.005 at all timepoints). Post-operative alignment was comparable, but L1PA (P=0.03) and SVA (P=0.02) were greater in the pelvic fixation group at final follow-up. 4 (36%) pts in the pelvis group and 1 (11%) in the non-pelvis group had complications. Baseline Oswestry Disability Index (ODI) and Scoliosis Research Society (SRS) Function scores were worse in the pelvic fixation group, but all scores were comparable at 2-year follow-up.

Conclusion:
Compared to those fused short of the pelvis, adults with hyperkyphosis treated with pelvic instrumentation had greater baseline sagittal malignment yet achieved statistically similar post-operative alignments, complication rates, and functional outcome improvements.

	LIV		
	Non-Pelvis N = 9	Pelvis N = 11	*P*-value
Age (years, mean, SD)	38.8 ± 19.0	60.8 ± 9.6	**0.019**
Female (N, %)	3 (33%)	7 (64%)	0.37
BMI (kg/m^2, mean, SD)	21.5 ± 3.0	29.0 ± 7.0	**0.006**
Comorbidities (N, %)			
Osteoporosis	2 (22%)	8 (73%)	0.07
Smoking History	0	1 (9%)	1.00
Prior Lumbar Decompression (N, %)	0	3 (27%)	0.22
Pre-Op L1 CT Hounsfield Units (mean, SD)	201 ± 51	150 ± 113	**0.049**
Fixation Including Stable Sagittal Vertebra (SSV) (N, %)	3 (33%)	-	
Fixation Including First Lordotic Vertebra (FLV) (N, %)	7 (77%)	-	
Radiographic Parameters (mean ± SD)			
Baseline Pre-Operative			
T2-T12 Thoracic Kyphosis (TK, °)	79.3 ± 15.3	74.2 ± 21.9	0.70
Maximum Kyphosis (°)	87.3 ± 11.6	89.9 ± 18.0	0.94
L1-S1 Lumbar Lordosis (LL, °)	67.1 ± 11.9	46.3 ± 17.1	**0.005**
Pelvic Incidence (PI, °)	47.3 ± 13.3	48.3 ± 15.6	0.88
Pelvic Tilt (PT, °)	12.5 ± 7.7	25.9 ± 12.5	**0.015**
T4 Pelvic Angle (T4PA, °)	0.2 ± 6.7	16.0 ± 12.8	**0.001**
L1 Pelvic Angle (L1PA, °)	0.8 ± 9.9	1.4 ± 13.6	0.82
T4-L1PA (°)	-0.5 ± 5.7	14.5 ± 10.4	**0.004**
C7 Sagittal Vertical Axis (SVA, mm)	-14.8 ± 18.0	41.9 ± 42.9	**0.002**
Proximal Junctional Angle (PJA, °)	0.2 ± 7.6	1.7 ± 14.1	0.73
Coronal Major Cobb Angle (°)	11.3 ± 7.7	14.0 ± 8.6	0.45
Immediate Post-Operative			
TK (°)	49.0 ± 7.0	48.6 ± 13.9	0.65
Max kyphosis (°)	49.9 ± 7.2	53.5 ± 12.6	0.29
LL (°)	40.1 ± 11.4	45.9 ± 9.6	0.40
PI (°)	47.7 ± 13.0	47.8 ± 14.0	0.94
PT (°)	21.1 ± 8.4	16.6 ± 10.0	0.36
T4PA (°)	13.3 ± 8.9	9.4 ± 9.6	0.45
L1PA (°)	10.3 ± 9.0	7.4 ± 9.0	0.60
T4-L1PA	3.0 ± 4.6	2.0 ± 3.8	0.65
SVA (mm)	25.7 ± 31.8	32.1 ± 48.5	0.70
PJA (°)	-4.2 ± 8.2	-1.8 ± 13.4	0.56
Coronal Major Cobb Angle (°)	6.0 ± 3.5	6.9 ± 3.9	0.60
Final Follow-up			
TK (°)	48.5 ± 5.6	46.7 ± 12.6	0.71
Max kyphosis (°)	52.5 ± 6.3	56.4 ± 11.9	0.49
LL (°)	50.8 ± 13.4	42.2 ± 12.4	0.22
PI (°)	49.2 ± 12.6	48.7 ± 11.6	1.00
PT (°)	16.1 ± 8.0	20.5 ± 9.5	0.22
T4PA (°)	4.9 ± 7.8	12.9 ± 9.5	0.10
L1PA (°)	3.4 ± 7.9	10.4 ± 7.6	**0.03**
T4-L1PA	1.5 ± 3.8	2.5 ± 4.3	0.49
SVA (mm)	-20.6 ± 20.2	26.2 ± 47.3	**0.02**
PJA (°)	0.2 ± 7.6	1.7 ± 14.1	0.73
Coronal Major Cobb Angle (°)	5.2 ± 3.5	6.2 ± 4.9	0.88
Complications (N, %)			
Proximal Junctional Kyphosis (PJK)	1 (11%)	1 (9%)	1.00
Distal Junctional Kyphosis (DJK)	0	0	1.00
Pseudoarthrosis	0	4 (36%)	0.09
Rod Fracture	0	3 (27%)	0.22
Vertebral Fracture	1 (11%)	0	0.45
Revision	1 (11%)	4 (36%)	0.32
Patient-Reported Outcomes (mean ± SD)			
Baseline Pre-Operative			
Oswestry Disability Index (ODI)	23.4 ± 10.6	38.5 ± 15.8	**0.014**
Scoliosis Research Society (SRS)	71.5 ± 15.6	60.4 ± 11.4	0.15
Function	3.7 ± 0.8	2.8 ± 0.6	**0.01**
Pain	3.0 ± 1.1	2.9 ± 0.9	0.80
Self-Image	2.8 ± 0.7	2.2 ± 0.7	0.11
Mental Health	3.6 ± 1.1	3.2 ± 0.8	0.48
2-Year Post-Operative			
ODI	7.2 ± 6.7	13.2 ± 10.4	0.27
SRS	99.2 ± 8.2	92.0 ± 7.0	0.22
Function	4.6 ± 0.4	4.2 ± 0.5	0.32
Pain	4.5 ± 0.5	4.1 ± 0.5	0.15
Self-Image	4.6 ± 0.4	4.1 ± 0.5	0.05
Mental Health	4.2 ± 0.6	4.2 ± 0.5	0.32

Table 1: Patient Characteristics and Outcomes Stratified by Lowest Instrumented Vertebra (LIV).

217. The Influence of Patient–Physician Concordance on Bracing Adherence in Adolescent Idiopathic Scoliosis: A Multicenter Prospective Cohort Study ‡

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Hypothesis:
Patients with similar demographic characteristics as their physicians will demonstrate greater adherence to treatment recommendations.

Design:
Retrospective review of a multicenter prospective study.

± Louis A. Goldstein Best Clinical Research E-Point Presentation
*John H. Moe Best Basic Research E-Point Presentation
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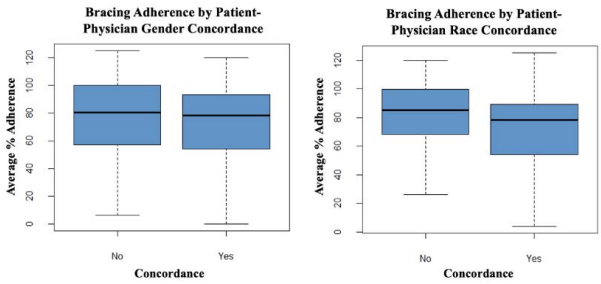
Introduction:
Patient-provider concordance (PPC) is associated with increased patient satisfaction in orthopaedic care. However, its impact on patient adherence to treatment recommendations remains unclear. Given the potential behavioral malleability of adolescent patients with idiopathic scoliosis (AIS), this study aimed to determine if PPC in age, gender, or race influences bracing adherence in this population.

Methods:
This study included patients >10 years old who initiated bracing for AIS between 2021-2025. Patient demographics and clinical information were obtained from the EHR. Physician demographics were collected via survey. Patients without brace sensor data within one year of brace initiation were excluded. Adherence, calculated as average brace wear divided by prescribed wear time, was treated as both a continuous and binary variable using 80% as a threshold. Mann-Whitney tests and univariate regressions were used for statistical analysis.

Results:
This study included 122 patients (mean age 13.0±1.5 years, 76% female, 68% white) and 16 physicians (mean age 51.6±11.0 years, 19% female, 81% white). Patients initially presented with an average major Cobb angle of 29.8°±7.0°. Six months after bracing initiation, the median adherence rate for all patients was 80% (range: 0-125%). When controlling for curve severity, Sanders score, and brace type, adherence was not related to PPC in age, gender, or race. Furthermore, there was no statistically significant relationship between PPC and patient progression to either successful nonoperative treatment or surgical intervention.

Conclusion:
In this study, PPC did not influence bracing adherence or outcomes in patients with AIS. These results suggest that alternative factors such as brace discomfort, parental involvement, or social pressures may be more influential. Furthermore, concordance may have a more substantial impact on subjective outcomes – including trust and perception of care – than objective behaviors. Further investigation into the role of the patient-physician relationship in shaping treatment adherence is warranted.



Comparison of bracing adherence between groups stratified by patient-physician concordance

Comparison of bracing adherence between groups stratified by patient-physician concordance.

218. Brace Adherence Is Not the Whole Story: High Rate of Curve Progression Despite Hyper-adherence in Idiopathic Scoliosis

Annie Lu, BS; Kristen Peterson, CPO; Kara Davis, MS, CPO; David C. Thornberg, BS; Jaysson T. Brooks, MD; Brandon A. Ramo, MD; Amy L. McIntosh, MD; Daniel J. Sucato, MD, MS; *Megan Johnson, MD*

Hypothesis:
Curve progression in patients who are hyper-adherent with bracing will be influenced by curve magnitude and in-brace correction.

Design:
Single institution retrospective review

Introduction:
Some patients with idiopathic scoliosis experience curve progression despite being hyper-adherent with brace wear, suggesting that brace adherence is just one of many factors influencing brace success. This study aims to assess the rate of curve progression in a cohort of idiopathic scoliosis (IS) patients who were hyper-adherent with brace wear and to evaluate additional factors associated with curve progression in this population.

Methods:
IRB approved review was conducted of IS patients who were braced between 2015-2024. Patients were included if ≥80% of their treatment was monitored by a temp. sensor and their brace adherence averaged ≥100% (Providence: ~8hrs/day; TLSO: ~18hrs/day) for the entire duration of bracing. Progression was defined as major curve Cobb progression ≥6°, major curve Cobb ≥45° at discontinuation, or progression to surgery. Patients who progressed and those who did not were compared using $\chi 2$ tests and Mann–Whitney/t tests, as appropriate, with significance set at $p < 0.05$

Results:
112 patients were included (86% Female). Average age for

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the cohort was 12.0 ± 1.6 yrs. Overall wear time for patients treated with a TLSO and Providence was 20.4 ± 1.3 and 9.3 ± 0.9 hrs/day, respectively. 22 patients (19.6%) progressed during treatment. There was no difference in age, sex, menarche, or skeletal maturity between patients who progressed vs. those who did not. Patients who progressed had significantly larger pre brace major curve Cobbs (33° vs 27°, p=0.01) and demonstrated less in brace correction (52% vs 84%, p<0.01). Patients treated with a TLSO were more likely to progress than those prescribed a Providence (p<0.01). 10 patients in the TLSO group had curves ≥45° at brace discontinuation and 8 patients progressed to surgery vs. no patients in the Providence group for either outcome (p<0.01).

Conclusion:
Curve progression for patients with idiopathic scoliosis remains problematic even in patients who are hyper-adherent with brace wear. In this population, larger baseline curves, worse in brace correction and use of a TLSO vs. Providence were associated with curve progression. These findings may help guide patient discussions at the time of brace initiation and throughout brace treatment.

Table 1. Comparison of Curve Progression vs. Non-Progression in Patients Who Are Hyper-adherent with Bracing

Variable		Overall			TSLO			Providence		
		No Progression N=90	Progression N=22	P	No Progression N=33	Progression N=17	P	No Progression N=57	Progression N=5	P
Sex	Female	79 (88%)	17 (77%)	0.2	30 (91%)	13 (77%)	0.2	49 (86%)	4 (80%)	0.6
	Male	11 (12%)	5 (33%)		2 (9%)	4 (23%)		8 (14%)	1 (20%)	
Brace Type	Anterior TLSO	6 (7%)	3 (14%)	<0.01	6 (18%)	3 (18%)	0.6			
	Posterior TLSO	27 (30%)	14 (64%)		27 (82%)	14 (82%)				
	Providence	57 (63%)	5 (22%)							
Pre-Brace Menarche Status	Pre	52 (66%)	11 (65%)	0.9	20 (67%)	9 (69%)	0.6	32 (65%)	2 (50%)	0.5
	Post	27 (34%)	6 (35%)		10 (33%)	4 (31%)		17 (35%)	2 (50%)	
Pre-Brace Risser	Risser 0-2	78 (87%)	21 (95%)	0.2	31 (94%)	16 (94%)	0.7	47 (83%)	4 (80%)	0.6
	Risser 3-5	12 (13%)	1 (5%)		2 (6%)	1 (6%)		10 (17%)	1 (20%)	
Progression ≥ 6°	No	90 (100%)	2 (5%)	<0.01	33 (100%)	2 (12%)	<0.01	57 (100%)	-	<0.01
	Yes	-	20 (91%)		-	15 (88%)		-	5 (100%)	
≥45° at Discontinuation	No	90 (100%)	12 (55%)	<0.01	33 (100%)	7 (41%)	<0.01	57 (100%)	5 (100%)	-
	Yes	-	10 (45%)		-	10 (59%)		-	-	
Surgery	No	90 (100%)	14 (63%)	<0.01	33 (100%)	9 (53%)	<0.01	57 (100%)	5 (100%)	-
	Yes	-	8 (36%)		-	8 (47%)		-	-	
Age		12.01 ± 1.6 (7.7 - 16.17)	12.0 ± 1.41 (8.95 - 14.19)	1.0	11.63 ± 1.6 (7.7 - 15.18)	11.88 ± 1.5 (8.95 - 14.19)	0.6	12.23 +/- 1.56 (8.57 - 16.17)	12.38 +/- 1.05 (11.1 - 13.74)	0.8
Pre-Brace Major Curve Cobb (°)		29.64 ± 6.57 (17 - 46)	32.64 ± 9.45 (19 - 47)	0.01	31.85 ± 7.1 (20 - 46)	34.94 ± 9.16 (20 - 47)	0.2	23.63 +/- 4.09 (17 - 34)	24.8 +/- 5.85 (19 - 31)	0.8
In-Brace Correction (%)		83.6 ± 43.06 (-195 - 0)	51.95 ± 38.87 (-195 - 3)	<0.01	47.52 ± 18.75 (-65 - 0)	39.65 ± 18.37 (-70 - 3)	0.2	104.49 +/- 39.17 (-195 - -30)	93.8 +/- 61.21 (-195 - -30)	0.6
Discontinuation Major Curve Cobb (°)		22.23 ± 8.75 (3 - 44)	43.0 ± 10.54 (27 - 61)	<0.01	26.67 ± 9.77 (5 - 44)	45.0 ± 10.88 (28 - 61)	<0.01	19.67 +/- 7.0 (3 - 36)	36.2 +/- 5.89 (27 - 41)	<0.01
Brace Duration (months)		22.26 ± 9.43 (7 - 49)	25.91 ± 8.83 (11 - 50)	0.036	23.64 ± 8.77 (12 - 40)	25.12 ± 9.4 (11 - 50)	0.6	21.46 +/- 9.77 (7 - 49)	28.6 +/- 6.56 (21 - 37)	0.04
Percent of Treatment Covered by Sensor (%)		97.64 ± 5.25 (80.67 - 100.0)	97.58 ± 4.76 (84.43 - 99.9)	0.4	96.77 ± 6.18 (91.01 - 99.92)	97.1 ± 5.31 (84.43 - 99.9)	0.7	98.15 +/- 4.61 (80.67 - 100.0)	99.24 +/- 1.42 (96.7 - 99.9)	0.2
Average Compliance (hours)		13.26 +/- 5.42 (7.98 - 22.48)	18.1 +/- 4.97 (8.57 - 22.9)	<0.01	20.21 +/- 1.29 (17.39 - 22.46)	20.65 +/- 1.33 (18.48 - 22.9)	0.3	9.24 +/- 0.89 (7.98 - 11.67)	9.41 +/- 0.61 (8.57 - 9.88)	0.5

219. 30% of Brace-Compliant Patients with Idiopathic Scoliosis End Treatment with Smaller Curves when Treated with a Modern 3D Brace

Katerina M. Kourpas, AB; *Simon Blanchard, BS;* Lucas Hauth, BS; Sulagna Sarkar, MS; Patrick J. Cahill, MD; Jason B. Anari, MD; John (Jack) M. Flynn, MD

Hypothesis:
Idiopathic scoliosis patients with good in-brace correction and high brace compliance can achieve significant curve improvement at skeletal maturity.

Design:
Single-center retrospective review

Introduction:
While historically the aim of bracing was to simply halt progression, many patients now complete their treatment with modern 3D bracing with a smaller deformity than at treatment initiation. There is little to no published evidence documenting the frequency of this new outcome, so we lack the information needed to counsel families regarding curve improvement.

Methods:
A retrospective single-center brace compliance database was queried for patients 18y/o and under who completed brace treatment for idiopathic scoliosis and had at least 6 months of post-bracing follow-up. Every patient reached skeletal maturity and had data on their heat-sensitive brace compliance monitor, Cobb angle, and in-brace coronal curve correction. Patients were classified based on if their curve progressed (change≥6º), remained stable (-5º≤change≤5º), or improved (change≤-6º). The data were analyzed using descriptive statistics and Wilcoxon rank sum test.

Results:
170 patients were included. At the most recent follow-up, 42 (25%, 31 F) patients' curves progressed, 89 (52%, 76 F) remained stable, and 39 (23%, 34 F) improved. When comparing patients with curve progression vs. improvement, there was no statistically significant difference in age (12.7 v. 12.9 years, p=0.802), BMI (18.9 v. 18.0, p=0.075), or primary curve magnitude (30 v. 29º, p=0.955) at bracing initiation. Patients whose curves improved had significantly greater in-brace correction (54.7% v. 42.6%, p=0.010) and greater brace compliance (82.5% v. 62.9%, p=0.001) than their peers whose curves worsened. Of patients who braced at least 85% of hours prescribed, 30% ended treatment with a smaller curve.

Conclusion:
23% of idiopathic scoliosis patients treated with a 3D correction brace, and 30% of those who wore their brace at least 85% of the prescribed time, concluded treatment with a deformity smaller than at presentation. Age and major curve magnitude at brace initiation were not significant predictors of curve improvement. We now have evidence to counsel families that a modern 3D correction brace can significantly reduce curve magnitude.

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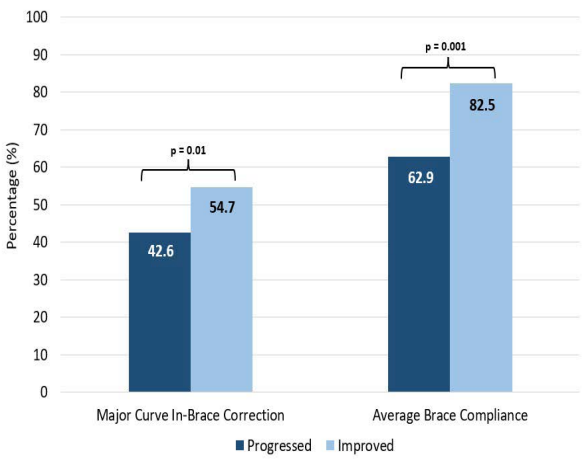


Major curve in-brace correction and average brace compliance in patients with curve progression vs. improvement.

220. Full-time Bracing versus Hybrid Bracing in Adolescent Idiopathic Scoliosis: A Randomized Trial

Adam Yiu Chung Lau, FRCS; Stephanie Tsz Ping Chong; Ho Man Kee, MS; Kenneth Guangpu Yang, PhD, MBBS; Cheuk Kin Kwan, MD; Alec Lik Hang Hung, FRCS; Wayne YW Lee, PhD; M S Wong, PhD; Jack Chun Yiu Cheng, MD; Tsz Ping Lam, FRCS

Hypothesis:
A hybrid bracing protocol combining a daytime underarm brace and a nighttime lateral bending brace can enhance in-brace correction in AIS patients with thoracolumbar or lumbar curves

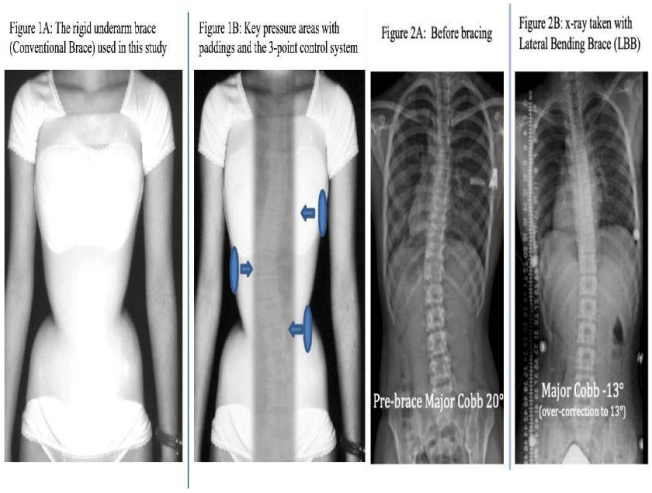
Design:
A prospective randomized parallel-group trial

Introduction:
Fulltime bracing, such as underarm Brace (UAB), is indicated for skeletally immature adolescents with idiopathic scoliosis (AIS) with Cobb angle >20°. Another bracing system is a nighttime Lateral Bending Brace (LBB), which is designed in a bending position opposite to the convexity of the curve, resulting in overcorrection. Previous studies have reported that in-brace correction (IBC) is an important determinant of brace effectiveness. To enhance IBC, we propose a hybrid bracing protocol (HyBP) combining daytime UAB use and nighttime LBB use. The primary objective was to determine whether the HyBP Group achieves superior IBC when compared with the conventional fulltime brace group.

Methods:
102 skeletally immature female AIS patients (baseline mean age 12.3±0.9 years, Cobb angle 25.1±5.0°) with a single thoracolumbar or lumbar curve newly prescribed bracing were randomly allocated to the HyBP Group or the Conventional Brace Group (CB Group) (n = 51 per group). There were no statistically significant baseline differences between the groups in age, BMI, Risser grade, menarche status, or initial Cobb angle. In-brace correction was measured at 2 weeks after first brace fitting and at three and 18 months.

Results:
At first visit, the in-brace correction was comparable between the HyBP and CB group (29.1±27.2% vs 32.2±18.7%, p = 0.503). The hybrid brace group maintained better in-brace correction at three and 18 months (28.4±28.2%, 24.3±22.2%) while the IBC progressively decreased in CB group (22±18.6%, 16.8±24.5%). However, the change in Cobb angle from first fitting to 18 months did not differ significantly between the two groups (HyBP: 5.4±9.5°, CB: 0.44±9°, p=0.09).

Conclusion:
Hybrid bracing enhances in-brace correction compared with conventional fulltime bracing but does not significantly alter Cobb angle at 18 months. Longer follow up until skeletal maturity is required to determine the effect of improved IBC on final curve outcomes.



221. Same-Day In-brace X-rays Result in Better Curve Correction Than Break-in Period X-rays for AIS

Karina A. Zapata, PhD, DPT; Ann Kramer, MS; Grace Dietz, MS; Sara Martinson, MS, CPO; Amy L. McIntosh, MD; Jaysson T. Brooks, MD; *Megan Johnson, MD*

Hypothesis:
In-brace correction (IBC) for adolescent idiopathic scoliosis (AIS) will be equivalent between same-day x-rays and break-in period x-rays.

Design:
retrospective cohort

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Introduction:
It is standard practice to obtain an IB x-ray after brace fitting to evaluate the amount of IBC achieved during brace treatment for AIS, but the ideal timing is unknown. This study compares IBC, brace adherence, curve magnitude changes, and quality-of-life (QOL) changes between patients who undergo IB radiographs the same day as brace fitting and partients who utilize a 1-month break-in period prior to IB radiographs.

Methods:
Single institution review of patients with AIS, Risser 0-2 or Sanders stage <6, curves 20°-45° prescribed custom anterior-opening thoracolumbosacral orthoses from 2022-2024. IBC was calculated by comparing radiographs at brace prescription to IB radiographs. Brace adherence was monitored with temperature sensors. QOL was evaluated with the following PROs: PROMIS Anxiety, Mobility, and Pain Interferences. IBC, brace adherence, QOL changes, and curve magnitude changes were compared between 2 groups (same-day versus break-in) after 6 months.

Results:
118 (same-day=45, break-in=73) patients were included with an average age of 12.4 ± 1.3 and curve magnitude of 29° ± 6° at brace prescription. The groups did not differ by age, sex, curve magnitude, Risser grade, Sanders stage, triradiate cartilage status, and curve pattern. The same-day group required less surgeon clinic visits after brace delivery until their 6-month follow-up visit (1.0 vs. 2.0, p<.001) while receiving more orthotist clinic visits (3.3 vs. 2.8, p=0.002) than the break-in group. The same-day group had significantly greater IBC at 58% ± 30% than the break-in group at 40% ± 23% (p=0.002). There were no significant differences between the same-day and break-in groups for brace adherence (13.8 h vs. 12.8 h, p=0.57), curve progression (-1° vs. 0°, p=0.36), or PROs (p>0.5) after 6 months.

Conclusion:
Same-day IB radiographs show superior IBC compared to IB radiographs taken after a break-in period. Brace adherence, curve magnitude, and PROs are not impacted after 6 months. Same-day IB radiographs also increase clinic availability for providers and improve efficiency by shifting patients' visits to orthotists for brace wear optimization and counseling.

	Nighttime brace	Full-time brace	p-value
Total Sample	n=265	n=255	
Female Sex	78% (n=208)	84% (n=215)	0.088
Initial age (yrs)	12.6±1.3	12.3±1.2	**0.023**
Initial curve type			**<0.001**
Thoracic	14%	86%	
Thoracolumbar/Lumbar	86%	14%	
Initial curve magnitude (°)	24.4±3.3	26.9±4.0	**<0.001**
Initial Risser grade			0.210
0	75%	75%	
1	11%	15%	
2	14%	10%	
Open TRC status	47%	56%	**0.027**
Initial BMI	18.3±2.9	19.2±3.5	**0.003**
Years braced	2.2±0.9	2.0±1.0	**<0.001**
Avg brace wear (h)	7.0±2.3	12.1±5.8	**<0.001**
Growth (cm)	9.7±6.0	9.0±5.8	0.166
Final curve magnitude (°)	26.7±10.8	33.5±12.7	**<0.001**
Total curve progression (°)	2.3±10.1	6.6±11.7	**<0.001**
Curve improvement ≥6°	21%	11%	**0.002**
Curves stable (-5° to 5°)	48%	44%	0.317
Curve progression ≥6°	31%	45%	**<0.001**
Progression to surgery	6%	20%	**<0.001**
Matched thoracic pairs	n=37	n=37	
Open TRC status	51%	51%	1.00
Initial curve magnitude (°)	23.5±2.6	23.5±2.6	0.969
Final curve magnitude (°)	26.2±10.5	27.9±11.9	0.581
Curve improvement ≥6°	17%	13%	0.562
Curve progression ≥6°	24%	32%	0.439
Progression to surgery	5%	11%	0.674
Matched thoracolumbar/lumbar pairs	n=32	n=32	
Open TRC status	59%	59%	1.00
Initial curve magnitude (°)	26.7±3.9	26.7±3.9	1.00
Final curve magnitude (°)	30.5±12.6	31.0±10.3	0.925
Curve improvement ≥6°	14%	7%	0.670
Curve progression ≥6°	31%	28%	0.784
Progression to surgery	13%	9%	1.00

*Bold indicates p<0.05. TRC=triradiate cartilage. Initial=time of brace prescription; Final=skeletal maturity or progression to surgery.

222. Adolescents with Idiopathic Scoliosis Show Less Functional Improvements After Physical Therapy For Low Back Pain

Megan Mendoza, BS; Jason Petrasic, MD; Jaysson T. Brooks, MD; *Brandon A. Ramo, MD;* Karina A. Zapata, PhD, DPT

Hypothesis:
Adolescents with non-specific low back pain (NSLBP) with idiopathic scoliosis (+IS) will have worse functional improvement after outpatient physical therapy (PT) than those without IS (-IS).

Design:
Retrospective cohort

Introduction:
The effectiveness of PT for children with NSLBP +IS compared to -IS is unknown. We compare improvements in functional disability due to outpatient PT between adolescents with NSLBP +IS and NSLBP -IS.

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Methods:
All patients treated with outpatient PT for back pain at a pediatric orthopedic institution from 1/2021-3/2024 were reviewed. Functional disability was assessed using the Oswestry Disability Index (ODI-9); 0-20%=minimal disability and 21-40%=moderate disability. Inclusion criteria were a diagnosis of NSLBP and ODI-9 completion at both PT evaluation and discharge. Secondary diagnoses (e.g. non-IS or spondylolisthesis) were excluded. Patients with NSLBP were grouped by + and - IS. Outcomes were defined by % change in ODI-9 scores: improved (≥50% decrease), stable (change between -49% and +49%), or worsened (≥50% increase).

Results:
76 patients with NSLBP (34 +IS, 42 -IS) ages 15.0±2.4 were included. Median back pain duration was 403 days (IQR: 222–1049), with no differences between groups (p=.52). In the +IS group, curves averaged 27°±16°, and most were near skeletal maturity (94% Risser stage ≥3/80% Sanders stage ≥6). Patients attended an average of 8.1 PT sessions over 11.3 weeks, similar between groups (p>.43). At PT evaluation, mean ODI-9 scores were lower (better) in the +IS group than -IS group (18% vs 24%, p=.029). At PT discharge, ODI-9 scores were similar (13% +IS vs 11% -IS, p=.52). However, functional improvement in the +IS group was smaller than the -IS group (6% vs 13%, p=.009). Fewer in the +IS group achieved ≥50% improvement (35% vs 59%, p=.035) and more experienced ≥50% worsening (18% vs 2%, p=.042), indicating a lower rate of clinically meaningful functional gains among those with IS.

Conclusion:
Patients with NSLBP and IS seek outpatient PT despite having relatively low levels of disability. Although PT generally improves function in NSLBP, children with IS experience smaller gains than their peers without IS. These findings suggest that IS may limit the effectiveness of standard PT approaches, highlighting the need for tailored rehabilitation approaches to optimize outcomes in this population.

	NSLBP + IS	NSLBP - IS	P-value
Age (years)	15.9±2.1	14.6±2.7	**0.035**
Female Sex	79%	76%	0.738
Race			0.677
White	66%	62%	
Black	24%	21%	
Asian	8%	2%	
Other	6%	7%	
Ethnicity			**0.002**
Hispanic	26%	62%	
Non-Hispanic	74%	38%	
Language			**0.024**
English	91%	67%	
Spanish	9%	33%	
Insurance			**0.028**
Private	44%	19%	
Public	29%	57%	
Self-pay	27%	24%	
Body Mass Index (kg/m^2)	21.9±5.3	24.3±6.7	0.934
ADI State Decile	4.4±2.5	5.0±2.4	0.351
Initial PROs			
ODI-9 Total (%)	18.3±11.1	24.3±12.1	**0.029**
PROMIS Pain Score	55.3±8.9	57.1±7.5	0.575
PROMIS Mobility Score	45.7 ±9.5	39.4±7.8	**0.002**
PROMIS Anxiety Score	48.8±10.3	49.5±10.6	0.892
Final PROs			
ODI-9 Total (%)	12.8±9.3	11.4±9.5	0.521
Change ODI-9 %, Initial – Final	-6%	13%	**0.009**
ODI Worse (≥50% increase)	18%	2%	**0.042**
ODI Stable (-49% to +49% change)	47%	39%	0.414
ODI Improved (≥50% decrease)	35%	59%	**0.045**
PROMIS Pain	52.8±9.0	57.5±10.5	0.093
PROMIS Mobility	46.8±9.6	41.9±9.3	0.050
PROMIS Anxiety	45.7±10.5	46.4±10.4	0.769

Pt Characteristics and Outcomes

223. Factors That Influence Pain Trajectories After Anterior Vertebral Tethering (AVT) for AIS

Charles Culata, BS; *John T. Braun, MD;* John T. Braun, MD; Sofia Federico; Brian E. Grottkau, MD

Hypothesis:
Multiple factors will contribute to post-operative pain after AVT.

Design:
Prospective 2021-2024

Introduction:
Though pain is a relatively common complaint in AIS patients, few studies have analyzed pre-operative factors associated with the occurrence, persistence, or resolution of pain after AVT. We prospectively analyzed multiple pre-operative factors in a consecutive series of AIS patients treated with AVT to determine the potential association with post-operative pain.

Methods:
Sixty-seven AIS patients consecutively treated with AVT had ≥ 2 years follow-up. Pain was prospectively evaluated pre-operatively and post-operatively (6 weeks, 12 weeks, 6 months, 12 months, and 24 months) using a Visual Analog Scale, SRS-22r Patient Questionnaire, and patient charts. Pain was categorized by severity, location, duration, and timing. Pain resolution was defined as a VAS of

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0 at 1 and 2 years. Standard X-rays were used for scoliosis analysis.

Results:
Sixty-seven AIS patients with 96 curves (27 T, 11 TL, 29 Double) measuring 50.5° were treated with AVT at 14.2 years and Sanders 5.1. Pain was present in 63% of pre-operative patients and 45% of post-operative patients with 80% of post-operative pain representing persistent pain and 20% new pain ($p \leq 0.04$). Persistent pain was more likely in patients with severe pain and less likely in patients with mild to moderate pain or intermittent pain. New pain was more likely in patients with larger curves (57°) and greater maturity (Sanders 6.5). Pain was absent in 37% of pre-operative patients with 76% of these remaining pain-free post-operatively. The difference in the occurrence of post-operative pain between patients with and without pre-operative pain (36% vs 9%) demonstrated a trend toward significance.

Conclusion:
In this prospective analysis of 67 AIS patients with 63% pre-operative pain, 45% had post-operative pain associated with the presence and severity of pre-operative pain as well as with greater curve magnitude and skeletal maturity.

224. Growth Modulation After Vertebral Body Tethering Results in Similar Axial Correction to a Posterior Spinal Fusion

Melanie E. Boeyer, PhD; Dustin Kress, BS; Stefan Parent, MD, PhD; Peter O. Newton, MD; Burt Yaszay, MD; Harms Study Group; Dan Hoernschemeyer, MD

Hypothesis:
We hypothesize that: (1) postoperative axial rotation correction would be significantly better after Posterior Spinal Fusion (PSF) than Vertebral Body Tethering (VBT), regardless of whether growth modulation occurred postoperatively.

Design:
Retrospective, multi-center.

Introduction:
Adolescent Idiopathic Scoliosis is a complex three-dimensional deformity characterized by significant axial rotation, particularly at the apex. Though PSF has been shown to significantly reduce apical rotation in the axial plane, no studies have conducted a head-to-head comparison with VBT, particularly when accounting for curve type, deformity magnitude, and lowest instrumented vertebra.

Methods:
We included 86 patients treated with either PSF (n = 43) or VBT (n = 43), all of whom had at least two years of follow-up and the required postoperative radiographic data. Patients were matched one- to-one based on sex, curve type (Lenke 1A/B), main thoracic deformity magnitude (±5°), and lowest instrumented vertebra (±1). Those included were required to have three-dimensional full spine reconstructions preoperatively and at all postoperative timepoints. We quantified raw measures of apical vertebral rotation in the axial plane as well as main thoracic cobb angle over time. Clinical axial rotation was evaluated using a scoliometer. We defined postoperative growth modulation as ≥6° of deformity correction from First Erect to Two Years in patients treated with VBT (i.e., VBT-GM). Statistical differences were assessed with either a paired or unpaired, two-sided t-test.

Results:
We observed a significant decrease in main thoracic deformity measures for all patients, with the greatest initial correction being in patients treated with a PSF (11.8±7.3° vs. 29.2±11.0°; $p < 0.001$), followed by continued deformity correction in only VBT-GM (16.3±9.5° [n = 18] vs. 31.8±9.4° [n = 25]; $p < 0.001$). Those treated with a PSF exhibited better three-dimensional axial correction (3.8±8.0° vs. 10.8±8.7°; $p < 0.001$) at Two Years compared to all VBT; however, no differences were observed between PSF and VBT-GM (2.3±8.7° vs. 7.3±9.1°; p = 0.166). We also found no differences in clinical rotation at any timepoint for PSF vs. VBT or PSF vs. VBT-GM.

Conclusion:
Our data indicate that axial correction after VBT is similar to that of PSF when growth modulation occurs. If postoperative growth modulation is unlikely, PSF outcomes are superior.

Table 1. Comparison of Deformity and Axial Rotation Characteristics between VBT vs. PSF and VBT-GM vs. PSF Patients at Relevant Timepoints: values represented as the mean ± standard deviation; statistical comparisons performed using an unpaired or paired two-sided t-test.

Characteristic	Preoperative			First Erect			Two Years		
	VBT	PSF	P-Value	VBT	PSF	P-Value	VBT	PSF	P-Value
N	43	43	---	43	42	---	43	43	---
Proximal Thoracic	24.0 ± 6.9	24.6 ± 7.7	= 0.713	18.9 ± 7.5	10.1 ± 4.4	< 0.001	15.5 ± 9.1	10.6 ± 4.9	= 0.002
Main Thoracic	50.5 ± 11.8	51.5 ± 9.7	= 0.684	29.2 ± 11.0	11.8 ± 7.3	< 0.001	25.3 ± 12.1	16.0 ± 6.1	< 0.001
Thoracolumbar	32.5 ± 8.0	35.3 ± 8.9	= 0.145	21.8 ± 8.3	14.4 ± 7.8	< 0.001	18.5 ± 11.9	14.1 ± 7.2	= 0.068
Apical Axial Rotation	-13.8 ± 8.1	-10.7 ± 10.6	= 0.165	-9.9 ± 7.5	-2.4 ± 8.8	< 0.001	-10.8 ± 8.7	-3.8 ± 8.0	< 0.001
Scoliometer	14.3 ± 3.8	15.3 ± 5.2	= 0.094	9.4 ± 4.6	5.8 ± 3.0	= 0.904	10.5 ± 5.0	6.1 ± 4.1	= 0.348
	VBT-GM	PSF	P-Value	VBT-GM	PSF	P-Value	VBT-GM	PSF	P-Value
N	18	18	---	18	17	---	18	18	---
Proximal Thoracic	23.0 ± 7.2	24.3 ± 6.9	= 0.609	17.9 ± 6.2	10.5 ± 5.5	< 0.001	12.7 ± 7.8	11.3 ± 5.5	= 0.558
Main Thoracic	49.1 ± 9.2	50.3 ± 8.9	= 0.730	29.1 ± 10.6	12.9 ± 5.8	< 0.001	16.3 ± 9.5	14.5 ± 4.8	= 0.538
Thoracolumbar	32.3 ± 7.0	34.3 ± 7.0	= 0.272	22.8 ± 10.3	15.3 ± 8.3	= 0.029	16.0 ± 14.7	12.4 ± 8.1	= 0.398
Apical Axial Rotation	-11.8 ± 9.7	-10.2 ± 13.5	= 0.682	-7.1 ± 8.8	0.8 ± 9.0	= 0.059	-7.3 ± 9.1	-2.3 ± 8.7	= 0.166
Scoliometer	12.6 ± 3.5	14.7 ± 4.8	= 0.231	9.4 ± 6.8	5.2 ± 3.3	= 0.618	7.6 ± 4.1	6.0 ± 3.7	= 0.350

* Note: Scoliometer|Data at First Erect was Missing for a Large Portion of the Sample: 19 PSF and 18 VBT Patients; All Other Relevant Data were Available at this Timepoint.

Table 1.

225. Biomechanically Optimized Intraoperative Correction in Lumbar Vertebral Body Tethering ± ‡

Marine Gay; Nikita Cobetto, PhD; Christiane Caouette, PhD; A Noelle Larson, MD; Isabelle Villemure, PhD; Melanie E. Boeyer, PhD; Dan Hoernschemeyer, MD; Ahmet Alanay, MD; Ron El Hawary, MD, MSc; *Carl Eric Aubin, PhD, P.Eng*

Hypothesis:
Patient specific optimization of intraoperative correction in lumbar vertebral body tethering (VBT) will yield satisfactory scoliosis correction at the end of the clinically meaningful growth period.

Design:
Biomechanical study using a validated patient-specific physics-based finite element model (FEM) of pediatric lumbar scoliosis to include spinal growth.

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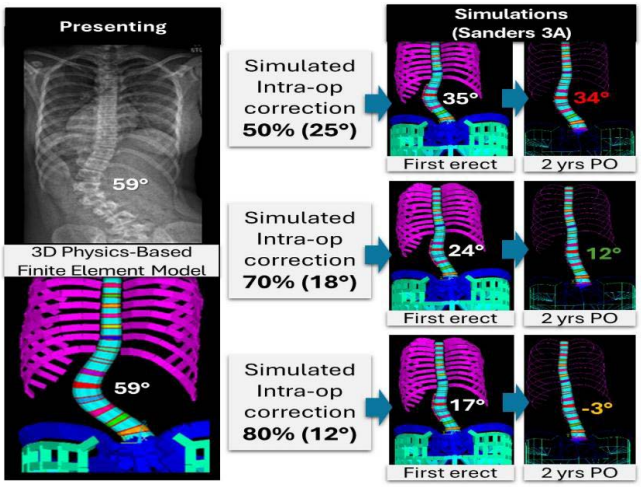
Introduction:
Lumbar VBT is increasingly adopted in adolescent idiopathic scoliosis (AIS) to preserve growth and motion. Surgeons can directly impact intraoperative correction, whereas subsequent growth modulation is biologically driven and challenging to predict. Due to a lack of predictive tools, under and over correction remains a common cause of reoperation and suboptimal results in VBT .

Methods:
Fifteen AIS cases (mean lumbar Cobb 48°, range 40°-59°) were used to build validated 3D patient-specific FEMs (mean 2-yr prediction accuracy: 3°; 90% statistical power). Models were calibrated using preoperative Sanders score (SS), spine flexibility, and body weight. VBT simulations were performed in the lateral decubitus position incorporating actual upper (T10-T12) and lower (L2-L4) instrumented vertebrae. Intra-operative correction levels (50% to 90%) were tested under four alternate growth remaining scenarios (SS 3A, 3B, 4, and 5). Growth and growth modulation were simulated over 2 years. The targeted result was a curve around 10° at 2 year follow-up.

Results:
Achieving a 10 degrees curve at 2 years follow-up required significantly lower intraoperative correction in SS 3A than in all other SS groups ($p<0.01$). No significant difference was found among SS 3B, 4, and 5. Corresponding intraoperative correction targets were 65% (53%–75%), 72% (60%–80%), 73% (60%–80%), and 73% (68%–80%). Spine flexibility, body weight, and their interactions significantly influenced required correction targets in SS 3A and 3B ($p<0.05$).

Conclusion:
Optimal intraoperative correction in lumbar VBT depends on growth remaining, patient weight, and curve flexibility. In skeletally immature patients, spine flexibility and body weight should also guide correction target selection. The planning tool presents a pathway forward to develop precise, individualized intraoperative correction strategies to improve the reliability of VBT surgery.



Example of three simulations for a single case with varying intraoperative correction.

226. Multi-Modal PA and Lateral Whole-Spine Radiographs for Predicting Pulmonary Function in Adolescent Idiopathic Scoliosis

Yuanpeng Zhu, MD; Xiangjie Yin, MD; Guilin Chen, MD; Guozhuang Li, MD; Jianguo T. Zhang, MD; *Nan Wu, MD*

Hypothesis:
A deep learning model that fuses standing PA and lateral whole-spine radiographs can accurately predict spirometric lung function (FEV1 and FVC) in AIS patients, and incorporation of basic clinical covariates will further improve predictive performance compared with imaging-only or clinical-only models.

Design:
Retrospective study

Introduction:
AIS can impair lung function, yet spirometry is not always feasible. Routine standing PA and lateral whole-spine radiographs may enable image-based estimation of FEV1 and FVC for screening and follow-up.

Methods:
We included 1,300 AIS patients with paired standing PA and lateral whole-spine radiographs acquired near the time of spirometry. The dataset was split 8:2 into training and held-out testing sets. Images were standardized with rescaling, centered cropping, and augmentation. A dual-branch convolutional encoder extracted view-specific features from PA and lateral images, followed by attention-based late fusion to generate a unified representation. Age, sex, and BMI were encoded via a small multilayer perceptron and concatenated with fused imaging features. The network was trained as a multi-task regressor to jointly predict FEV1 and FVC . Model performance was evaluated using MAE, RMSE, R^2, and Pearson correlation (r). Comparator models included: (1) imaging-only PA+lateral fusion, (2) single-view models, and (3) clinical-variables-only baselines. Saliency maps (Grad-CAM) were used for interpretability.

Results:
On the test set, the multi-modal fusion model achieved strong agreement with measured spirometry. For FEV1 prediction, MAE was approximately 0.20 L, RMSE 0.27 L, and R^2 0.79 ($r \approx 0.89$). For FVC prediction, MAE was approximately 0.24 L, RMSE 0.33 L, and R^2 0.76 ($r \approx 0.87$). Adding clinical covariates improved R^2 by ~0.04–0.07 over imaging-only fusion. Dual-view fusion outperformed single-view models by ~0.06–0.12 in R^2, while clinical-only baselines showed modest performance ($R^2 \approx 0.45$–0.55). Grad-CAM highlighted the thoracic cage contour, thoracic spine curvature, and costovertebral regions as key contributors to predictions.

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Conclusion:
A deep learning model using paired PA and lateral whole-spine radiographs can predict FEV1 and FVC in AIS, with further improvement from basic clinical covariates. This low-cost tool may support pulmonary risk stratification and follow-up, pending external validation.

227. Integrated Spatial and Single-Nucleus Transcriptomics Uncovers Molecular Drivers of Muscle Fiber Transition: a new player in Adolescent Idiopathic Scoliosis

Gen Tang, PhD; Wayne YW Lee, PhD; Jack Chun Yiu Cheng, MD; Adam Yiu Chung Lau, FRCS; Tsz Ping Lam, FRCS

Hypothesis:
We hypothesized that specific cellular drivers within paraspinal muscles are key regulators of mechanical sensing and muscle fiber transition that drive the initiation and progression of AIS.

Design:
This study integrates human snRNA-seq and spatial transcriptomics with in vitro validation and two in vivo mouse models.

Introduction:
Current AIS therapies target symptoms rather than the unknown etiology. While paraspinal muscle asymmetry is evident in AIS and increased lean mass reduces risk, it remains unclear whether these phenotypes drive deformity. To identify the cellular mechanisms of this remodeling, we integrated single-nucleus RNA sequencing (snRNA-seq) and spatial transcriptomics (ST), aiming to uncover novel diagnostic and therapeutic targets.

Methods:
We constructed a spatially resolved transcriptomic atlas from AIS patient multifidus muscles using snRNA-seq and ST. Validation included in vitro Gene A knockdown and two in vivo models: a mechanical restrainer to simulate loading, and an AAV-mediated Gene A knockdown in wild-type mice to demonstrate independent causality of curvature initiation.

Results:
Trajectory analysis of the transcriptomic atlas identified a novel myogenic precursor population—situated between satellite cells and mature fibers—defined by Gene A and Gene C expression. Clinical validation confirmed significant upregulation of both genes in the convex side. In vitro, Gene A knockdown suppressed Gene C and MYH7, triggering a Type I-to-II fiber transition. In the thoracic restrainer mouse model, we demonstrated that Genes A and C are modulated by mechanical loading, mirroring clinical asymmetry. Crucially, AAV-mediated knockdown of Gene A in wild-type mice was sufficient to induce significant right thoracic curvature by 7 weeks, with mean Cobb angle progression increasing from 2.6° to 15.5°.

Conclusion:
We present the first spatially resolved transcriptomic atlas of AIS paraspinal muscles, identifying 'Gene A+' precursors as regulators of mechanical sensing and fiber transition. Crucially, Gene A knockdown in wild-type mice was sufficient to induce curvature, proving this deficit drives AIS initiation. This finding establishes a new target for non-surgical, biological intervention.

228. Hybrid Fixation is Superior to Bilateral Vertebral Body Tethering for AIS Patients with Double Curves

Amer F. Samdani, MD; Alexander J. Schupper, MD; Joshua M. Pahys, MD; Emily Nice, BS; Sanaa Jackson, BS; Terrence G. Ishmael, MBBS; Steven W. Hwang, MD

Hypothesis:
The hybrid (H) approach (thoracic fusion/contralateral lumbar tether) will provide similar results to bilateral vertebral body tethering (bVBT).

Design:
Retrospective review of prospective single institution data.

Introduction:
In skeletally immature patients with AIS, VBT is a viable option, but with limited correction and a high reoperation rate. The hybrid technique offers a novel approach for patients with double curves but lacks data assessing its efficacy. We sought to determine how the hybrid technique compares with bVBT in patients with AIS.

Methods:
We identified all patients treated with either the hybrid technique or bVBT with a minimum 2-year f/u. Clinical and radiographic data, including reoperations and outcomes, were compared using Student's t-test and Fisher's exact testing where appropriate.

Results:
130 patients were identified (H=27, bVBT=103). Patients were predominantly female (H=70.4%, bVBT=88.3%), with similar age at surgery (H=13.3±1.4 years, bVBT= 12.8±1.3 years, p=0.080). Mean follow-up was H=33.3±8.4 and bVBT=56.5±21.7 months. Both groups were skeletally immature (Sanders median H= 4, bVBT= 3, p<0.01). Hybrid patients had significantly larger pre-op curves compared to bVBT patients (T: 64.0±12.6° vs. 52.9±9.3°, p<0.01; L: 60.1±10.0° vs. 50.9±8.3°, p<0.01). On FE, the hybrid cohort had smaller thoracic curves (15.9±6.5° vs. 29.8±8.7°, p<0.01), and similar lumbar curves (18.1±9.3° vs. 20.7±10.5°, p=0.3). At 2 years, the hybrid cohort had smaller thoracic (17.1±7.0° vs. 23.4±9.7°, p<0.01) and lumbar 12.2±7.3° vs. 17.7±11.6°, p<,01) curves, but with significantly greater % correction (T: H=73.6%, bVBT=55.1%: p<0.01, L: H=79.7%, bVBT= 65.7%, p<0.01). At latest follow-up, all hybrid patients had thoracic curves <30°, with 1 patient (3.7%) having a lumbar curve >30°. In contrast, 56 (54.3%) bVBT patients had a thoracic curve

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>30°, and 26 (25.2%) had a lumbar curve >30°. Both groups had similar reoperation rates (H=33.3%, bVBT= 28.2%, p=0.64), but 17 (16.5%) bVBT patients received a fusion, with none in the hybrid group.

Conclusion:
Hybrid fixation provides markedly better correction than bVBT for AIS patients with double curves. A successful outcome (curve <30°) was achieved in 96% (26/27) of hybrid patients but in only 43.7% (45/103) of bVBT patients. For most patients with double curves, the hybrid approach is the more reliable option.

Demographics	Hybrid	Bilateral	p-value
Total # VBT	27	103	
Female	19 (70.4%)	91 (88.3%)	0.4906
Follow-up (months)	33.3 ± 8.4	56.5 ± 21.7	<0.0001
Age at index procedure (years)	13.3 ± 1.4	12.8 ± 1.3	0.0795
Radiographic Information			
Pre-op thoracic Cobb	64.0 ±12.6	52.9 ± 9.3	<0.0001
Pre-op lumbar Cobb	60.1 ± 10.0	50.9 ± 8.3	<0.0001
Pre-op Sanders score (median)	4	3	<0.0001
Pre-op Risser grade (median)	1	0	<0.0001
First erect thoracic Cobb angle (°)	15.9 ± 6.5	29.8 ± 8.7	<0.0001
First erect lumbar Cobb angle (°)	18.1 ± 9.3	20.7 ± 10.5	0.2756
2-year thoracic Cobb angle (°)	17.1 ± 7.0	23.4 ± 9.7	<0.0001
2-year lumbar Cobb angle (°)	12.2 ± 7.3	17.7 ± 11.6	0.0004
Latest thoracic Cobb angle (°)	13.6 ± 6.3	28.8 ± 11.2	<0.0001
Latest lumbar Cobb angle (°)	12.8 ± 8.4	22.8 ± 12.4	<0.0001
Latest thoracic Cobb angle >30°	0 (0)	56 (54.4)	<0.0001
Latest lumbar Cobb angle >30°	1 (3.7)	26 (25.2)	<0.0001
2-year % correction thoracic	73.6 ± 10.5	55.1± 17.2	<0.0001
2-year % correction lumbar	79.7 ± 11.0	65.7 ± 22.4	0.0087
Reoperations			
Number of patients requiring reoperations	9 (33.3%)	29 (28.2%)	0.6378
Total number of reoperations	9	41	
Months from index	23.6 ± 6.2	33.7 ± 22.7	0.2246
Conversion to fusion	0 (0)	17 (16.5)	<0.0001

229. Automated Alpha Angle Calculation for Adolescent Idiopathic Scoliosis Surgery Planning Using Deep Learning Pose Model

Shun Herng Tan, MBBS; Saturveithan Chandirasegaran, MBBS, MSOrth; Chee Kidd Chiu, MBBS, MSOrth; Chris Yin Wei Chan, MD, MSOrth; Mun Keong Kwan, MBBS, MSOrth

Hypothesis:
An artificial intelligence–based model can accurately and reliably automate Alpha Angle calculation, providing an objective and patient-specific target for LIV tilt.

Design:
Retrospective diagnostic validation study.

Introduction:
Accurate selection of lowest instrumented vertebra (LIV) tilt is essential to prevent distal adding-on in adolescent idiopathic scoliosis. We previously showed that achieving an intraoperative LIV tilt (β) ≥ preoperative Alpha Angle (α) from supine left side-bending radiographs reduced adding-on to 10%. This study aimed to develop an AI model to automate Alpha Angle calculation and provide an objective, patient-specific LIV tilt target.

Methods:
This study included 249 AIS patients (Lenke 1–6) undergoing posterior spinal fusion. Supine left side-bending radiographs were divided into training (n=199) and validation (n=50) sets. A YOLOv11-pose CNN was trained to identify T11–L4 vertebrae and the pelvis to calculate the Alpha Angle. Performance was validated against expert consensus using ICC, mean absolute error, clinical success rates (±3° and ±5°), and mean average precision.

Results:
The AI system achieved robust technical performance on the validation set, with a bounding box mAP50 of 99.4% and pose estimation mAP50 of 97.6%. In clinical validation, the model demonstrated excellent reliability with an ICC of 0.931 (95% CI: 0.89–0.96). The Mean Absolute Error was 1.68°, with negligible systematic bias (-0.12°; p=0.78). The AI achieved a clinical success rate of 92.0% within a 5° threshold and 80.0% within a 3° threshold. AI- surgeon agreement rate at 3° was 80.0%, and at 5° was 94.0%. There was no significant difference in X-angle, Alpha angle, and adjusted Alpha angle between surgeon consensus and AI. For the Y-angle, the AI measured a significantly lower displacement (p-value<0.001). Stratified analysis showed robust accuracy from T11 to L1, though reliability decreased at the L2 level (ICC=0.39).

Conclusion:
This study introduces the first AI system to automate Alpha Angle calculation for AIS surgical planning, demonstrating expert-level reliability (ICC >0.93) and accuracy exceeding inter-surgeon variability. With 92% of measurements within 5° of expert consensus, it provides a rapid and consistent alternative to manual measurement, bridging complex modeling and practical clinical application.

230. Effect of Upper Instrumented Vertebra Selection on Sagittal Contour and Proximal Junctional Alignment in Adolescent Idiopathic Scoliosis

Garima Paul, MD; Alexandra N. Yiachos, BS; Matthew Miyasaka, AB; Alexander Kucherina, BS; Mina Eskandar, MS, BS; Constance Maglaras, PhD; Themistocles S. Protopsaltis, MD; Tina Raman, MD; *Juan Carlos Rodriguez-Olaverri, MD*

Hypothesis:
In Adolescent Idiopathic Scoliosis (AIS) patients undergoing posterior spinal fusion, selection of a more proximal upper instrumented vertebra (T3) results in improved postoperative thoracic sagittal contouring and moderation of proximal junctional kyphosis (PJK) magnitude compared with more caudal fixation (T4–T5), even with baseline differences in proximal junctional morphology,

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without a predictable reduction in short-term PJK incidence.

Design:
AIS patients (11–18 years) undergoing primary posterior spinal fusion with UIV at T3 (n=48), T4 (n=62), or T5 (n=35) were retrospectively reviewed.

Introduction:
Selection of the upper instrumented vertebra (UIV) in AIS patients is frequently influenced by concern for PJK and sagittal alignment control. Extension to T3 optimizes thoracic contouring and junctional behavior despite increased surgical extent, yet evidence supporting improved junctional outcomes is limited.

Methods:
Radiographic parameters included thoracic sagittal alignment, shoulder balance, and PJK angle assessed preoperatively, immediately postoperatively, and through 2-year follow-up. PJK was defined as a >10° increase between the lower endplate of the UIV and upper endplate of UIV+2.

Results:
Baseline deformity features were comparable across groups, except for PJK angle, which was significantly greater in T5 constructs than T3 (10.9° vs 5.7°, p<0.001). T3 fixation increased surgical extent: greater fusion length and operative time (p<0.001). Across immediate and early follow-up, more caudal UIV selection displayed consistently higher absolute PJK angles, with T5 constructs exceeding mean values of 13° by 3 months, while T3 constructs maintained lower junctional magnitudes (p<0.05 through 1 year). Although 2-year PJK incidence differed in significantly among groups, junctional kyphosis magnitude and sagittal alignment trajectories favored more proximal fixation.

Conclusion:
More proximal UIVs were associated with improved control of PJK magnitude and early sagittal contouring, despite baseline differences in junctional morphology. While extension to T3 did not significantly reduce 2-year PJK incidence, it moderated junctional kyphosis severity during early and mid-term follow-up. These findings support individualized UIV selection based on sagittal morphology and junctional alignment goals rather than binary prevention of PJK.

231. The Impact of Multiple Indications-related Learning Curves on Complications and Additional Procedures after Anterior Vertebral Tethering (AVT) for AIS

John T. Braun, MD; John T. Braun, MD; Sofia Federico; Charles Culata, BS; Brian E. Grottkau, MD

Hypothesis:
Multiple indications-related learning curves will impact outcomes after AVT for AIS.

Design:
Retrospective 2010-2024

Introduction:
While AVT has been proposed as an alternative to fusion surgery for AIS, the earliest reported outcomes for this new procedure have been disappointing. Though a relatively high rate of complications and additional procedures is likely related to multiple factors, an analysis of the indications-related learning curves necessary to improve outcomes for this novel procedure has yet to be accomplished.

Methods:
One hundred ninety-nine AIS patients consecutively treated with AVT had >2 year F/U. Patients were divided into 3 groups depending on the time period in which they were treated: early (2010-2014), middle (2015-2019), and late (2020-2024). Charts and radiographs were reviewed to identify complications and additional procedures for each of the groups.

Results:
Of 199 AIS patients consecutively treated with AVT over 15 years, 14 were in the early group, 38 in the middle group, and 147 in the late group. Complications in the early group: 42% tether rupture/21% overcorrection/7% kyphosis progression with 7% revision/21% fusion. Complications in the middle group: 39% tether rupture/8% inadequate correction with 8% revision/8% fusion. Complications in the late group: 33% tether rupture/5% inadequate correction/2% overcorrection. Overcorrection and kyphosis progression were essentially eliminated after the early time period due to a change in indications (p<0.05). Inadequate correction decreased after the middle time period due to a change in indications (p<0.05). Tether rupture decreased over time but not significantly. Adding-on and progression of an adjacent curve were not encountered.

Conclusion:
In this study, complications and additional procedures decreased over time due to a better understanding of the indications for AVT. The learning curves for overcorrection and kyphosis progression were short and essentially allowed the elimination of these two complications after the early time period due to the avoidance of small curves, excessive immaturity, and kyphosis. The learning curve for inadequate correction was longer but allowed a significant decrease in this complication after the middle time period due to avoidance of large, stiff curves. Unfortunately, we were unable to identify a learning curve for tether rupture.

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232. Just "A Small Tune-up"? Do VBT Revisions Have More Perioperative Complications Than Index Procedures?

Shelby Meckstroth, MD; Alex R. La Poche, BS; Lawrence L. Haber, MD; Michelle C. Welborn, MD; Laurel C. Blakemore, MD; Craig R. Louer Jr, MD; Pediatric Spine Study Group

Hypothesis:
Revision thoracic vertebral body tethering (VBT) has similar 90-day peri-operative complication rates compared with index VBT procedures.

Design:
Multicenter retrospective cohort study using an international pediatric spine registry

Introduction:
Revision VBT procedures are becoming more common. Surgeons anecdotally report pleural adhesions and scarring during repeat thoracic approaches that may increase perioperative risk; however, outcomes remain poorly defined. This study compared 90-day complications after index and revision thoracic VBT.

Methods:
An international, multicenter pediatric spine registry was queried for scoliosis patients with index or revision thoracic VBT performed between 2013-2025 and ≥ 30 days of follow-up. Revision cases underwent review of case details and radiographs to confirm procedure and approach. Demographics, clinical data, surgical data, and 90-day complications were compared between index and revision cases.

Results:
We identified 362 patients receiving index VBT and 15 that underwent revisions. Surgical approach was confirmed to be repeat endoscopic thoracic approach for 13/15 (87%) of patients, though could not be verified in the remaining 2 patients. Eight patients (53%) underwent selective tether ligation or removal for overcorrection, while 7/15 (47%) underwent tether replacement for curve progression and/or suspected rupture. Revision patients were younger at time of surgery than index (11.4 vs. 12.8 years; p=0.019). Procedure time was shorter for revisions (184 vs 233 min; p=0.047). There was no significant difference in overall 90-day complications between index and revision procedures (24.0% vs 20.0%; p=1.00; Table 1). Pulmonary complications requiring intervention occurred in 9 (2.5%) index and 1 (6.7%) revision (p=0.34). Repeat interventions under anesthesia were required in 15 (4.1%) index vs. 1(6.7%) revision complication patients (p=0.46).

Conclusion:
Complications of revision thoracic approaches for VBT were previously unknown. This study indicates that revision endoscopic thoracic approaches for VBT are feasible and may be performed without increased perioperative complication risk compared with index surgery. This study is limited by a small number of revision procedures. Future analysis with more revisions will further define these risks. This data remains valuable for surgical decision-making and patient counseling.

Surgical Data			
	Index Tether (N= 362)	Revision Tether (N=15)	P-value
LOS (days) (average (SD))	5.1 (1.7)	4.1 (2.1)	p = 0.21
Procedure Time (minutes) (average (SD))	233 (84)	184 (89)	**p = 0.047**
EBL (cc) (average (SD))	183.13 (176.1)	181.40 (113.3)	p = 0.44
Thoracic Approach Endoscopic Open Unknown	 307 (85%) 9 (2.5%) 46 (13%)	 13 (87%) 0 (0%) 2 (13%)	Note: 3 Revisions had additional open lumbar approaches

Complications				
	Index Tether (N= 362)	Revision (N=15)	P-value	Intervention and outcome
All complications n (%)	87 (24.0%)	3 (20%)	p = 1.00	-
Neurologic	6 (1.7%)	1 (6.7%) [a]	p = 0.25	Temporary sensory or motor def. – all resolved
CSF leak	3 (0.83%)	0 (0%)	p = 1.00	Blood patch (2), Lumbar drain, screw revision (1)
Wound	8 (2.2%)	0 (0%)	p = 1.00	Deep SSI: debridement (2) Keloid – scar revision (1)
Pulmonary [b]	9 (2.5%)	1 (6.7%)	p = 0.34	-
Pneumothorax/Hemothorax	5 (1.4%)	1 (6.7%)	p = 0.22	Drain placement (5) Repeat Exploration (1)
Pleural Effusion	4 (1.1%)	0 (0%)	p = 1.00	Drain placement (4) Antibiotics (2)
Other (Pain, GI, prolonged LOS)	62 (17%)	1 (6.7%)	p = 0.48	-
Required intervention under anesthesia	15 (4.1%)	1 (6.7%)	p = 0.48	-

LOS = Length of Stay, EBL = Estimated Blood Loss, CSF = Cerebrospinal Fluid, GI = Gastrointestinal, SSI = Surgical Site Infection. Categorical variables were compared using Fisher's exact test; continuous variables were compared using independent-samples t-tests. [a] *One revision patient experienced thigh numbness/weakness which resolved with time.* [b] *Pulmonary complications (pneumothorax, hemothorax, pleural effusion) were only included if they required additional treatment.*

233. The Law of Diminishing Returns: Is There an Optimal Implant Density for Outcomes in Spinal Fusion for Adolescent Idiopathic Scoliosis?

Suhas Parise, MBA; Charlene W. Cai, BS; Amog Mysore, BS; Ahmad Hudaihed, BA; Victoria Izsa, MS; Alexis Driscoll, BS; Dhruv Mendiratta, MD; Isabel Herzog, MD; Ashok Para, MD; Alice Chu, MD; Michael Vives, MD; *Neil Kaushal, MD*

Hypothesis:
Increasing implant density (ID) will only yield better outcomes up until a certain threshold.

Design:
Single center retrospective

Introduction:
In spinal fusion for adolescent idiopathic scoliosis (AIS), prior literature analyzed if ID affected outcomes in a binary fashion (high ID [HID] vs. low ID [LID]). However, ID was seldom analyzed as a continuous variable, and the type of relationship (linear or quadratic) between ID and outcomes is underexplored. By extension, there is a sparsity in literature on whether an optimal ID (OID) exists. Therefore, we investigated [1] if simply increasing ID yielded better outcomes, [2] if this relationship was linear or quadratic, and [3] if there was an OID.

Methods:
Patients who underwent spinal fusion for AIS from 2019-2025 were reviewed at a single academic center. Demographics, ID, Coronal Cobb Correction at 4 weeks (CC) and estimated blood loss per level fused (EBL) were analyzed. [1] The effect of ID on outcomes was assessed by linear regression in unadjusted and adjusted (con-

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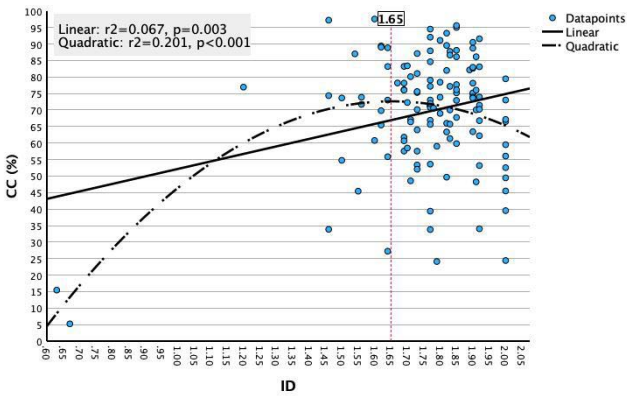
trolling for age, sex, BMI, and pre-op Cobb angle) analysis. [2] For outcomes significantly affected by ID, curve analysis was done to determine if the relationship between ID and outcome was linear or quadratic (whichever had a higher r2 fit the data better). [3] If the relationship was linear, OID of 2 was assumed; if the relationship was quadratic, then vertex analysis was done to calculate OID.

Results:
There were 128 patients (14.4±2.2yo, 66% F, 1.76±0.20 ID). Increasing ID was associated with increased CC (unadjusted and adjusted p<0.031) but not EBL (unadjusted and adjusted p>0.18). For CC, a quadratic curve fit the data better compared to a linear curve (r2 0.20 vs. 0.07). In vertex analysis, OID was 1.65 for CC.

Conclusion:
This is the first study to find ID quadratically affecting CC (with an OID). Increasing ID had better CC up until 1.65 ID. Beyond this, CC slightly declined, suggesting diminishing returns. Though the OID could change with greater sample size, due to the significant quadratic relationship found in this study, we think this diminishing return phenomena will be generalizable. Higher number of implants could be expensive while increasing the total risk of malpositioned screws. Taken together with prior literature showing similarity in outcomes between LID and HID, this study highlights the diminishing returns of using ID beyond 1.65.



234. Patient-Perceived Recovery After Posterior Spinal Fusion: Evaluating Minimum Clinically Important Difference (MCID) in Adolescents with Idiopathic Scoliosis

Leila Mehraban Alvandi, PhD; Joseph N. Charla, BS; Zachariah Samuel, BS; Edina Gjonbalaj, BS; Mohamed Said, MS; Yungtai Lo, PhD; Morgan Roche, BS; Priya Singh, MD; *Jaime A. Gomez, MD*; Jacob F. Schulz, MD; Eric Fornari, MD

Hypothesis:
Lower preoperative SRS-22r scores will predict greater likelihood of achieving anchor-based minimum clinically important difference (MCID) following posterior spinal fusion (PSF) in adolescents with idiopathic scoliosis (AIS).

Design:
Retrospective analysis of a prospectively collected AIS surgical registry

Introduction:
AIS is the most common pediatric spinal deformity requiring surgical correction, yet postoperative recovery varies widely. The SRS-22r assesses multidimensional patient-reported outcomes (PROs), but the ability of preoperative scores to predict clinically meaningful improvement remains unclear. Identifying predictive domains may improve risk stratification and guide targeted perioperative interventions.

Methods:
AIS patients who underwent PSF (2012–2022) with ≥2-year follow-up were included. Exclusions were non-idiopathic scoliosis and anterior fusion. SRS-22r scores were collected preoperatively and at 6 weeks, 6 months, 1 year, and ≥2 years. Anchor-based MCID thresholds (pain 0.6, function 0.3, self-image 1.3, mental health 0.3) were applied. Demographics, surgical variables, and Child Opportunity Index (COI) were recorded. Multivariable logistic regression identified independent predictors of MCID achievement.

Results:
A total of 161 AIS patients were analyzed (mean age 15.3 ± 2.2 years; 65.8% female; 78.9% residing in very low/low COI areas). Median preoperative Cobb angle was 56°. At 1 year, MCID was achieved in 35% (pain), 36% (function), 30% (self-image), and 43% (mental health). By ≥2 years, pain (26%) and self-image (23%) declined, while function (44%) and mental health (35%) were sustained. Lower preoperative SRS-22r scores predicted MCID across all domains ($p < 0.05$). Independent predictors included poorer baseline mental health for pain and mental health MCID, lower baseline function for functional MCID, lower self-image plus male sex for self-image MCID, and younger age for functional recovery.

Conclusion:
Preoperative SRS-22r profiles are strong predictors of clinically meaningful improvement following PSF in AIS. Patients with worse preoperative pain, function, mental health, or self-image demonstrate the greatest capacity for postoperative improvement. Integrating baseline PROs into preoperative counseling and risk stratification may support targeted perioperative interventions and optimize long-term outcomes.

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Table1. Number and Percentage of Patients Who Did and Did Not Pass Bago et al. 's anchor-based MCID thresholds (Across SRS-22r Domains¶ (A indicates anchor based)

SRS22r Domains		MCID Achievement Status n (%)	MCID Threshold
Mental Health (1 Year Postoperative)			0.3
	Not Achieved	47 (56.6)	
	Achieved	36 (43.4)	
Mental Health (≥ 2 Years Postoperative)			0.3
	Not Achieved	39 (65.0)	
	Achieved	21 (35.0)	
Pain (1 Year Postoperative)			0.6
	Not Achieved	53 (65.4)	
	Achieved	28 (34.6)	
Pain (≥ 2 Years Postoperative)			0.6
	Not Achieved	63 (74.1)	
	Achieved	22 (25.9)	
Function and Activity (1 Year Postoperative)			0.3
	Not Achieved	53 (63.9)	
	Achieved	30 (36.1)	
Function and Activity (≥ 2 Years Postoperative)			0.3
	Not Achieved	33 (55.9)	
	Achieved	26 (44.1)	
Self-Image (1 Year Postoperative)			1.3
	Not Achieved	58 (68.9)	
	Achieved	25 (30.1)	
Self-Image (≥ 2 Years Postoperative)			1.3
	Not Achieved	44 (77.2)	
	Achieved	13 (22.8)	

Table 2. Significant Predictors of MCID Achievement Across SRS-22r Domains in AIS Patients Undergoing Posterior Spinal Fusion

SRS-22r Domain	Significant Predictor	Exp(B) [95% CI]	p-value
Mental Health (1 year)	Pre-op Mental Health	0.161 [0.057–0.460]	<0.001
Mental Health (more than 2 years)	Pre-op Mental Health	0.184 [0.070–0.488]	<0.001
Pain (1 year)	Pre-op Pain	0.019 [0.002–0.143]	<0.001
	Pre-op Mental Health	4.813 [1.110–20.843]	0.034
Pain (more than 2 years)	Pre-op Mental Health	0.082 [0.023–0.294]	<0.001
	Sex (M)	0.135 [0.026–0.698]	0.017
Function (1 year)	Pre-op Function	0.060 [0.014–0.255]	<0.001
Function (more than 2 years)	Pre-op Function	0.125 [0.033–0.480]	0.002
	Age	0.640 [0.45–0.909]	0.013
Self-Image (1 year)	Pre-op Self-Image	0.019 [0.003–0.135]	<0.001
	Sex (M)	6.141 [1.018–37.032]	0.048
Self-Image (more than 2 years)	Pre-op Self-Image	0.056 [0.009–0.370]	0.003
	Pre-op Pain	0.235 [0.056–0.992]	0.049

235. The Role of Caudal Screw Fixation in Outcomes of Posterior Dynamic Distraction Device for Adolescent Idiopathic Scoliosis

Gabrielle Rogie, MD, MEng; Hilton C. Braithwaite IV, BS; Daphna Zaaroor-Regev, PhD; *Scott J. Luhmann, MD*

Hypothesis:
Caudal screw parameters influence rates of mechanical failure, revision, and curve correction in patients treated with the Posterior Dynamic Distraction Device (PDDD).

Design:
Retrospective multicenter cohort study

Introduction:
Non-fusion options, such PDDD for adolescent idiopathic scoliosis (AIS), aims to correct deformity and preserve motion. PDDD has 2 pedicle screws cranially but only one caudal screw. This study evaluated caudal screw parameters on mechanical failure, revision surgery, and construct breakage.

Methods:
A review of AIS patients from a multicenter registry who underwent PDDD with ≥2-year follow-up was performed. Caudal screw depth, rod-to-caudal screw angle, and caudal screw-to-upper endplate angle was measured. Mechanical failure was defined as breakage in any component. Revisions for non-mechanical reasons (infection and max actuator length) were excluded.

Results:
A total of 156 patients (mean age 15 yrs, range 10-25 yrs; 75% female) were included, mean f/u of 2.3 years. Mean initial coronal deformity was 45.5°, and 21.5° at final. Construct breakage occurred in 14.4%, and overall mechanical failure in 23.5%. Revisions for mechanical failure occurred in 12.3%. Patients with mechanical failure had a significantly greater final coronal deformity (27.5° vs 19.7°, p = 0.002). Revisions, breakage, and mechanical failure were all correlated with more convergent, negative, initial screw-to-upper endplate angle (2.2° vs -1.4°, p=.009, 2.2 vs –1.7, p=.02, and 2.7° vs –1.6°, p=.0002, respectively). Mechanical failure was also correlated with lower initial and final caudal screw depth (78 vs 72, p=.0331; 75 vs 68.8, p=.0320, respectively), lower initial rod-to-caudal screw angle (87.9 vs 84.4, p=.009), and initial and final convergent screw-to-upper endplate angulation (2.7° vs -1.6° , p<.001; 1.2° vs –2.2°, p=.004, respectively). BMI, Sanders score, and curve flexibility were not correlated with complications. At the final follow-up, 116 patients retained the device, 26 had the device removed, and 14 were converted to PSF.

Conclusion:
PDDD achieved meaningful curve correction, but with notable mechanical failure rates. Caudal screw sagittal position and depth of insertion, but not screw diameter, were associated with suboptimal outcomes, emphasizing the importance of sagittal screw trajectory and depth to maximize outcomes and minimize reoperations.

236. Supercrit-processed allograft reduces pedicle screw loosening at the last instrumented levels in AIS posterior fusion

Othmane Miri, MD; Aren Joe Bizdikian, MD, MS; Anne Laure Simon, MD, PhD; *Brice Ilharreborde, MD, PhD*

Hypothesis:
The addition of supercritical CO2 processed allograft to local autograft enhances distal fusion and reduces the incidence of pedicle screw (PS) loosening at the lowest instrumented levels (LIV) in adolescent idiopathic scoliosis (AIS) surgery.

Design:
Single center retrospective study.

Introduction:
Achieving solid posterior fusion in long constructs remains challenging, even in children, especially at both extremities submitted due to high mechanical loads. The identification of radiolucent halos around distal PS indicate residual micromotion and can lead to revision. Supercritical CO2 sterilization is an innovative process used to prepare allograft, preserving bone matrix's structural integrity, but its safety and efficacy have not been investigated in pediatric PSF.

Methods:
A total of 360 consecutive AIS patients who underwent non-selective PSF (>9 levels) were reviewed, with a minimum 2-year follow-up. Group 1 (n=180, before 2021) received local autograft alone, while a combination of autograft and 250cc of supercrit-processed allograft chips were used in group 2 (n=180, after 2021). Radiological and clinical outcomes were evaluated, and the rates of PS loosening were compared.

Results:
Groups were comparable regarding age, flow-up duration, preoperative deformity magnitude and correction rates (67-69%). The incidence of PS loosening was 6.4% in

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the entire cohort, only located at LIV and LIV-1, and was significantly reduced in group 2 (2.8% vs 10%, p=0.001). All halos appeared progressively and were not visible before 1 year follow-up. In Group 1, loosening led to 2 unplanned revisions and 5 cases of LIV screw fracture, while no complication was reported in group 2.

Conclusion:
The incidence of PS loosening is not negligible after AIS PSF, especially at distal levels. The combination of supercritical CO2 processed allograft with local autograft, associated with thorough distal decortication, significantly reduces the occurrence of distal radiolucency and implant failure.

237. Sagittal Alignment Stabilizes at 3-Months Postopertively in Pediatric Idiopathic Scoliosis

Deniz Kara, MD; Bryan Menapace, MD, MBA; Daniel Bouton, MD; Robert Bernstein, MD; Joseph Ivan Krajbich, MD; Michelle C. Welborn, MD; Jeffrey M. Hills, MD; Rebecca GraceTracey, RN; Cindy Nguyen, PA-C; Michael P. Kelly, MD; *Chinmay Paranjape, MD, MHSc*

Hypothesis:
Sagittal plane maturation occurs by 3 months postoperatively

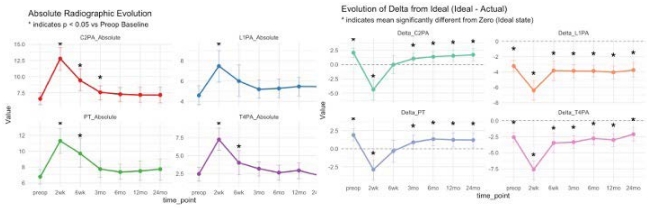
Design:
Retrospective, single institution cohort

Introduction:
In pediatric spinal deformity, postoperative standing alignment emerges from surgically established anatomy and compensatory adaptive responses of the non-instrumented segments. Identifying the point of radiographic maturation—where sagittal alignment reaches a stable, durable state—is critical for postoperative monitoring and determining when further concern regarding sagittal balance is warranted. This study evaluates the longitudinal stability of vertebropelvic angles (VPAs) to define the timeframe of definitive sagittal maturation following surgical intervention for Juvenile and Adolescent Idiopathic Scoliosis (JIS, AIS).

Methods:
251 patients with JIS and AIS who underwent spinal instrumentation and fusion (posterior, anterior, or combined approaches) were reviewed. Standing lateral radiographs were analyzed preoperatively and postoperatively at 2 weeks, 6 weeks, 3 months, 6 months, 1 year and 2 years. VPAs (C2PA, PT, T4PA, L1PA) were plotted absolutely and compared against proposed ideal parameters (ΔVPA = VPAideal – VPAactual); ideal PT was assumed from Le Huec 2019 and ideal VPAs from MEANS results.

Results:
Preoperatively, mean ΔPT and ΔC2PA were positive (+2.0 and +2.1, respectively), indicating a pelvic anteversion relative to the proposed ideal. Following surgery, acute significant shifts occurred at 2 weeks, with mean absolute values peaking (C2PA: 12.8; PT: 11.3) and ΔVPA values crossing zero to reach a nadir (ΔC2PA: -4.3; ΔPT: -2.8), representing initial over-correction/retroversion. Beginning at 3 months, all VPAs demonstrated definitive stabilization. From 3 to 24 months, mean absolute values and ΔVPA deviations remained statistically stable ($p < 0.05$), with final ΔC2PA and ΔPT settling at +1.7 and +1.2.

Conclusion:
In AIS/JIS, the sagittal plane radiographically stabilized at 3 months postoperatively. This was maintained through 24 months, suggesting that radiographs obtained at the 3-month mark accurately reflect the patient's final compensated balance state. While final parameters often deviate from proposed ideals, the system organizes into a stable, patient-specific equilibrium. These findings indicate that surgeons can trust that sagittal alignment has stabilized by 3 months until at least 24 months postoperatively.



VPAs stabilize by 3 months postoperatively up to 2 years

238. Balancing Motion and Correction: Mid-Term Outcomes of Hybrid Fixation in Adolescent Idiopathic Scoliosis

Feyzi Kilic, MD; *Altug Yucekul, MD;* Gokhan Ergene, MD; Sahin Senay, MD; Elif Gizem Carus, MS; Tais Zulemyan, MS; Caglar Yilgor, MD; Ahmet Alanay, MD

Hypothesis:
To report the mid-term radiographic, patient-reported, pulmonary, and implant-survival outcomes for a consecutive cohort of patients undergoing hybrid fixation for scoliosis.

Design:
A retrospective analysis of a single-center, consecutive patient cohort.

Introduction:
Vertebral body tethering (VBT) is a motion- preserving scoliosis treatment. For complex curves, a hybrid approach combining thoracic posterior f usion with thoracolumbar/lumbar VBT balances correction and mobility. This study reports mid-term outcomes for this technique, as comprehensive series are limited.

Methods:
Prospectively maintained data from a single center were retrospectively analyzed. O utcomes included upper thoracic (UT), main thoracic (MT), and thoracolumbar/

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lumbar (TLL) Cobb angles; SRS-22 patient-reported outcomes; and percent-predicted pulmonary f unction tests (FVC, FEV1). Complications and implant survival were also recorded.

Results:
Twenty-five patients (mean age 13.9 ± 2.5 years; 84% female) were analyzed with a median follow- up of 27.2 months [24.2–29.2]. Lenke types were: Type 1: 43.5%, Type 2: 17.4%, Type 4: 4.3%, Type 5: 26.1%, and Type 6: 8.7%; lumbar modifiers: A: 4.3%, B: 26.1%, C: 69.6%. Preoperative flexibility was 48.8 ± 20.5% for UT, 56.8±20.5% for MT, and 80.7±18.9% for TLL. UT, MT, and TLL Cobb angles were 36.0 ± 11.1 °, 61.8 ± 17.3 °, and 50.9 ± 13.9° preoperatively; improved to 8.1 ± 5.0°, 7.8 ± 5.0°, and 12.8 ± 6.6° at first erect; and measured 8.8 ± 6.3 °, 11.0 ± 8.7°, and 12.3 ± 8.3 ° at latest follow-up. SRS-22 self-image improved significantly (Δ +0.84, $p < 0.001$), with 67% of patients achieving MCID. Other SRS-22 domains (Function, Pain, Mental Health) and pulmonary f unction tests remained unchanged (all $p > 0.05$). Two mechanical complications occurred (tether break in 8% of patients), and no readmissions or reoperations were recorded.

Conclusion:
In this cohort with over two years of follow-up, hybrid fixation provided substantial and maintained correction of all curves. Patient self-image improved while pulmonary f unction was preserved. The technique showed a favorable mid-term safety profile with low mechanical complication rates, supporting its use as a promising motion- preserving alternative,warranting confirmation in larger cohorts with longer follow-up.

239. Hybrid Fixation vs Bilateral VBT in AIS: Striking the Balance Between Durability and Motion

Altug Yucekul, MD; Feyzi Kilic, MD; Fedde Weenink, MD; Gokhan Ergene, MD; Sahin Senay, MD; Elif Gizem Carus, MS; Tais Zulemyan, MS; Caglar Yilgor, MD; *Ahmet Alanay, MD*

Hypothesis:
To compare outcomes of hybrid fixation vs. bilateral VBT for AIS in the first matched, follow-up–equalized analysis.

Design:
A retrospective analysis of prospectively collected data for a 1:1 matched cohort.

Introduction:
Hybrid fixation and bilateral VBT are motion- preserving options for adolescent idiopathic scoliosis (AIS). Hybrid constructs provide durable correction in the thoracic spine while preserving lumbar mobility. Bilateral VBT offers flexibility across both regions but may carry higher risks of tether-related complications. To date, no direct comparison between these two approaches has been reported.

Methods:
A 1:1 matched cohort (15 pairs) was created from prospective data based on preoperative Cobb angle and skeletal maturity. Analyses were capped at the shorter follow-up for each pair (median 25.3 months). Cobb angles, SRS-22 scores, pulmonary f unction, complications, and implant survival were compared.

Results:
The matched cohort (15 pairs) had mean ages of 13.3 ± 1.3 yrs (Hybrid) and 12.9 ± 2.0 yrs (Bilateral). Preoperative Cobb angles (Hybrid vs. Bilateral) were: UT 36.8°±10.5° vs 29.9°±9.6° ($p=0.152$); MT 62.1 °±17.5° vs 59.7°±10.2 ° ($p=0.678$); and TLL 50.4°±8.5° vs 49.9°±8.6° ($p=0.080$). At the first- erect, differences in correction were: UT −12.5° ($p=0.0017$), MT −20.0° ($p<0.001$), and TLL −5.5° ($p=0.049$). At the latest follow-up, differences were: UT −10.1 ° ($p=0.020$), MT −17.1 ° ($p<0.001$), and TLL −9.7° ($p=0.014$). The difference in SRS-22 score change (ΔΔ, Hybrid−Bilateral) was significant for the Function domain: −0.47 ($p=0.014$). Other SRS-22 ΔΔ were: Pain −0.17 ($p=0.539$), Self-image +0.39 ($p=0.298$), and Mental Health −0.51 ($p=0.113$). Changes in pulmonary f unction (FVC, FEV1) were not significant: FVC −4.0 ($p=0.561$) and FEV1 −1.5 ($p=0.802$). Tether breaks occurred in 2 Hybrid vs. 9 Bilateral patients ($p=0.023$). Kaplan- Meier survival free of a tether break for Hybrid vs. Bilateral was 1.00 vs. 0.857 at 12 months, and 0.825 vs. 0.455 at 24 months (log-rank $p=0.015$) (Fig 1).

Conclusion:
In this first matched, follow-up–equalized comparison,Hybrid fixation provided better radiographic correction and implant survival. Bilateral VBT showed superior improvement in the SRS-Function domain. Results suggest Hybrid fixation offers greater durability, while Bilateral VBT may have functional advantages. Longer-term studies are needed.

240. Incidence of Proximal Thoracic Major Scoliotic Curves and its Significance: An Analysis of 970 Patients

Chee Kidd Chiu, MBBS, MSOrth; Ying Ying Thum, MBBS; Saturveithan Chandirasegaran, MBBS, MSOrth; Chris Yin Wei Chan, MD, MSOrth; Mun Keong Kwan, MBBS, MSOrth

Hypothesis:
We hypothesized that proximal thoracic major scoliotic curves are significantly associated with a higher prevalence of non-idiopathic scoliosis compared with main thoracic (MT) and thoracolumbar/lumbar (TL/L) major curves.

Design:
Retrospective study

Introduction:
Proximal thoracic major scoliotic curves can be found among individuals with scoliosis. As defined by the Lenke classification, these curves have an apex at T3, T4 or T5.

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E-POINT PRESENTATION ABSTRACTS

The proximal thoracic is major when it had the largest Cobb angle. This study aimed to determine the prevalence and clinical significance of proximal thoracic major curves.

Methods:
We analyzed 970 patients diagnosed with scoliosis in the outpatient clinic from 2012 to 2018. Included were all patients with lateral spine curves exceeding 10° in the coronal plane. Whole spine AP standing radiographs were obtained for major curve and type analysis. Clinical and radiological data of all patients, including age, gender, presenting symptoms and signs, comorbidities, family history and MRI/CT findings, were then collected and analyzed.

Results:
Among the 970 patients, aged 2 to 41 years, 779 (80.3%) were females and 191 (19.7%) males. The incidence of proximal thoracic major curves was 2.6%, while the incidence of main thoracic major curves and TL/L major curves were 54.4% and 43%, respectively. Within the proximal thoracic major curve group, 84% had left-sided curves, and 16% had right-sided curves. Notably, the prevalence of non-idiopathic scoliosis was significantly higher in the proximal thoracic major curve group (64%), compared to the MT major group (16.5%) and TL/L major curve group (18.5%). All patients with right-sided proximal thoracic major curve had non-idiopathic scoliosis, while 57.1% of those with left-sided proximal thoracic major curves were non-idiopathic. The proximal thoracic major curves had a higher proportion of males compared to females (72% vs 28%). Neural axis abnormalities (43.8%) were identified as the most common cause of non-idiopathic scoliosis in this group.

Conclusion:
Proximal thoracic major scoliotic curves comprised of 2.6% of cases and show a high prevalence of non-idiopathic causes (64%), with neural axis abnormalities being the most common. Right-sided curves were exclusively non-idiopathic, emphasizing the need for detailed evaluation and imaging in this group.

241. Safety and Efficacy of VBT at 5-year Follow-up: How to Optimize Outcomes

Firoz Miyanji, MD, FRCS(C); Shaina Sim, BS; Amer F. Samdani, MD; Abdullah AlDuwaisan, FRCS(C); Ahmet Alanay, MD; Joshua M. Pahys, MD; Baron S. Lonner, MD; Dan Hoernschemeyer, MD; Stefan Parent, MD, PhD; Peter O. Newton, MD

Hypothesis:
Long term clinical and radiographic outcomes of VBT are favourable at 5-yrs post-op

Design:
Retrospective,multicentre

Introduction:
Vertebral body tethering(VBT) is a growth friendly potential surgical alternative to spinal fusion. Safety and efficacy of VBT has been primarily reported out to 2-yr f/u,however,longer term f/u beyond 2-yrs remains sparce. Our aim was to report on the clinical, radiographic, and complication profile of VBT at min 5-yr f/u.

Methods:
A retrospective,multicentre non-fusion database identified all consecutive patients who underwent a VBT procedure with min 5-yr f/up.Data was collected at preop,first erect(FE),2-yrs,and 5-yrs post-op.Demographic,clinical,radiographic,and complication data were analyzed.Success was defined a priori as major tethered coronal Cobb <30° at most recent f/u.Univariate and multivariate regression attempted to identify predictors of success.

Results:
Total of 84 patients(83.1% female,16.9% male),mean age of 12.2±1.7yrs, and min 5-yr f/u were reviewed.Most curves were Lenke 1(57.4%),2(22.1%) and 5(8.8%).Majority of patients were Sanders 3(53.7%) and 81.2% were Risser 0.Avg preop height was 155.8±10.1cm increasing to avg 169.2±8.5cm at 5 yrs.Median preop major Cobb was 46°[IQR:42,56°;Range:30-81°] correcting to median 27°[IQR:20,33.8°;Range:5-49°] at FE with further correction to median 22.5°[IQR:13.8,31.5°;Range:1-55°] at 5-yr f/u.Thoracic rib hump improved from mean 14±5.3° to 9.5±6.3°and lumbar hump from mean 6.7±4.8° to 4.4±4.3°.72% of patients had clinical success at 5-yr f/u with major tethered coronal Cobb <30°.Univariate analysis identified preop height(p=0.03) and major tethered coronal Cobb at FE(p=0.02) to be predictors of success which remained significant in the multivariate regression model(p=0.04;p=0.01).With each unit increase in preop height,Sanders,Risser, and major tethered Cobb at FE,the odds of successful outcome decreased by 12%,37%,60%,and 19%,respectively.There were 53 reported complications in 29 patients with a reoperation rate of 16.7%: 9.5% conversion to fusion;7.1% revision VBT.

Conclusion:
This is the largest min 5-yr f/u multicenter study showing VBT remains a safe and effective treatment option in idiopathic scoliosis.Success was noted in 72% of patients with the odds of successful outcome strongly associated with preop height,Sanders,Risser,and major tethered Cobb at FE.A 16.7% reoperation rate should alert surgeons to continue to optimize patient selection.

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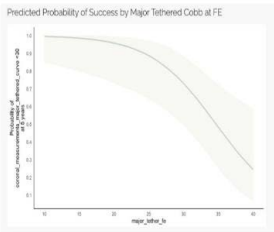
Patient Demographics	Preop	FE	3-yr	5-yr
Mean age(yrs)	12.2+/-1.7			
Gender (%)	M=16.9 F=83.1			
Sanders (%)	1(7.4); 2(18.5); 3(53.7); 4(5.6); 5(5.6); 6(7.4); 7(1.9)			
Mean Height (cm)	155.8+/-10.1	157.1+/-10.4	165.6+/-9.5	166.3+/-21.8)
Mean BMI	18.6+/-3	18.1+/-2.5	20.6+/-3.1	22.1+/-4.1
Risser 0 (%)	81.2	79.4	17.5	1.5
Risser 1 (%)	4.3	7.4	8.8	0
Risser 2 (%)	8.7	7.4	19.3	1.5
Risser 3 (%)	5.8	5.8	31.6	16.2
Risser 4 (%)	0	0	22.8	38.2
Risser 5 (%)	0	0	0	42.6
PertOp Outcomes				
Mean OR T (minutes)	357.1+/-352.8			
Mean EBL (cc)	194.1+/-127.5			
Mean LOS (d)	4.9+/-2.2			
Mean No. of Levels Instrumental	7.7+/-1.8			
Outcome Variable (Median [IQR])	**Preop**	**FE**	**3-yr**	**5-yr**
Thoracic Rib Prominence (°)	14 [10.5,17]	8 [6,11]	7 [5,11.3]	9.5 [5,14]
Lumbar Prominence (°)	5 [4,8.5]	4 [0,5]	4 [1.6,6.5]	4 [1,7]
Major Tethered Cobb (°)	46 [42,56]	27 [20,33.8]	19 [10,31]	22.5 [13.8,31.5]
Upper Thoracic Cobb (°)	26 [22,34]	20 [16,27]	18 [10,24]	17 [9.5,23.5]
Main Thoracic Cobb (°)	45 [42,56]	30 [23.5,35.5]	26.5 [17,39]	28 [21,38.3]
T/L / Lumbar Cobb (°)	33 [24,40]	22 [17,30]	23 [15.8,30]	24 [17,31]
T2-T12 Sagittal Cobb (°)	26 [20,34]	27 [19,33]	27.5[19.3,38.5]	26[19,34]
T5-T12 Sagittal Cobb (°)	10 [4.3,17]	19 [12.3,25]	21 [13.3,28]	21.5 [14,26]
T10-L2 Sagittal Cobb (°)	-2 [-7.5,6]	0 [-6,8.7]	1 [-4,9.8]	-1 [-8.3,8]
Multivariate Regression (Success <30° Major Tethered Cobb at 5yrs)	**Odds Ratio**	**95% CI**	**P-value**	
Age (yrs)	1.28	0.73, 2.35	0.4	
Height (cm)	**0.88**	0.77, 0.98	**0.04***	
Preop Sanders	0.63	0.22, 1.64	0.35	
Preop Risser	0.40	0.07, 1.72	0.24	
Major Tethered Cobb FE (°)	0.81	0.67, 0.92	**0.006***	
Complications N (%)				
Suspected Broken Tether	20 (23.8)			
Overcorrection >10°	4 (4.8)			
Loss of Correction >10°	4 (4.8)			
Reoperation - Fusion	**8 (9.5)**			
Reoperation – Revision VBT	**6 (7.1)**			
Instrumentation	3 (3.6)			
Medical	1 (1.2)			
Pulmonary	1 (1.2)			
Neurologic	1 (1.2)			
Pain	5 (6)			



Paper #242 has been WITHDRAWN from the program.

243. Proximal Femur Maturity Index is a Viable Assessment of Skeletal Maturity in Adolescent Idiopathic Scoliosis

Joshua M. Pahys, MD; Steven W. Hwang, MD; Terrence G. Ishmael, MBBS; Amer F. Samdani, MD; Tracey Bryan, MS; Suken A. Shah, MD; Firoz Miyanji, MD, FRCS(C); Peter O. Newton, MD; Harms Study Group; Michael P. Kelly, MD

Hypothesis:
Proximal femur maturity index (PFMI) can be used to assess skeletal maturity in adolescent idiopathic scoliosis (AIS) patients.

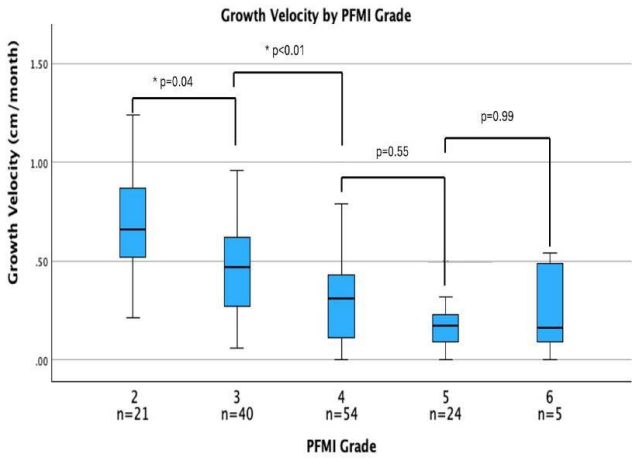
Design:
Retrospective multicenter cohort

Introduction:
Cheung et al (2022) developed PFMI as an alternative assessment of skeletal maturity based on the radiographic appearance of the femoral head, greater trochanter, and triradiate cartilage on full posteroanterior (PA) spine radiographs without the need for additional hand imaging. This study seeks to externally validate the reliability of PFMI and its correlation with Sanders and Risser scoring and peak growth.

Methods:
Longitudinal spine and hand radiographs after thoracic vertebral body tethering (VBT) from first erect (FE: defined baseline standing height) to 2 years postop, were assessed for skeletal maturity with PFMI, Sanders, and Risser. Longitudinal standing heights were recorded in tandem to detect peak growth (cm/month) with minimum 6-month interval between visits. PFMI reliability was graded on 200 PA spine radiographs by three experienced reviewers two weeks apart.

Results:
144 AIS patients (121 females/23 males) were included. PFMI moderately correlated with age (Kendall Tau-b (tb)=0.43) (p<0.001). The largest growth rate occurred at PFMI 2 (0.70+0.26cm/mo) followed by PFMI 3 (0.49+0.31cm/mo) and decreasing to PFMI 6 (0.25+0.24cm/mo) with growth cessation.(Fig 1) Moderate correlations were found between PFMI and Sanders (tb=0.70) and Risser (tb=0.59), p<0.001. Excellent intrarater reliability (weighted kappa: 0.74 to 0.9) and good interrater reliability (weighted kappa=0.66) were observed for PFMI amongst the three reviewers. Mean thoracic curve magnitude decreased from FE to 2 years postop (25º to 20º, p<0.001).

Conclusion:
This is the first study to externally validate the reliability of PFMI and its correlation with traditional maturity markers and peak height growth. PFMI demonstrated good to excellent inter- and intra-rater reliability as well as a moderate correlation with Sanders and Risser scoring comparable to previous reports. Peak height growth was demonstrated at PFMI grade 2 and progressively decelerated to growth cessation at PFMI grade 6. PFMI grades correlated with respective established growth velocity grades for Sanders and Risser. Thus, PFMI is a viable alternative assessment of skeletal maturity that can be measured on routine PA spine radiographs without the need for additional imaging.



244. Risk of Curve Progression Among Children with Positive Scoliosis Screening but Radiographic Cobb Angle Below 10 Degrees

Cheuk Kin Kwan, MD; Kenneth Guangpu Yang, PhD, MBBS; Tsz Ping Lam, FRCS; Adam Yiu Chung Lau, FRCS; Jack

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E-POINT PRESENTATION ABSTRACTS

Chun Yiu Cheng, MD; Alec Lik Hang Hung, FRCS; Wayne YW Lee, PhD

Hypothesis:
Children with positive scoliosis screening but radiographic cobb angle below 10 degrees have a high risk of curve progression to scoliosis

Design:
Cohort study

Introduction:
Screening for scoliosis facilitates early identification and timely intervention. Data from our Student Health Service in Hong Kong indicate approximately 15% of children are screened positive among whom only about 10% are subsequently diagnosed with scoliosis defined by a radiographic Cobb angle of ≥10°. The risk of disease progression for the remaining 90% with Cobb angles <10° remains poorly understood. This study aims to evaluate their risk of subsequent progression to scoliosis (Cobb angle ≥10°) and to the bracing threshold.

Methods:
This retrospective cohort study including children with positive axial trunk rotation (ATR) and Moiré topography screening but initial radiographic Cobb angle <10°. Data included demographics, Cobb angle, and skeletal maturity markers, with follow-up to skeletal maturity. Outcomes were progression to scoliosis threshold (Cobb ≥10°) and bracing initiation. Analyses comprised Kaplan–Meier survival curves and logistic regression modelling.

Results:
Of 218 patients (mean age 12.5 years, mean Cobb angle 7°, mean follow-up 2.0 years), 120 (55.0%) progressed to AIS threshold (Cobb ≥10°), and 11 (5.0%) initiated bracing. Kaplan–Meier analysis showed 50% reaching threshold by age 15 and 55% by final follow-up (Figure 1). Logistic regression identified baseline Cobb angle and Risser grade as predictors for progression to scoliosis (AUC 0.73). No statistically significant predictors were identified for progression to bracing threshold.

Conclusion:
Although 15% of children screen positive for ATR, 90% have initial Cobb angles <10°. This study shows 50% of these children progress to scoliosis (Cobb ≥10°), with 5% requiring bracing. Baseline Cobb angle and skeletal immaturity (Risser grade) independently predicted progression to scoliosis. These findings support targeted monitoring and potential preventive interventions for this high-risk preclinical group. Future research may also focus on identifying additional predictors of scoliosis progression and bracing need.

245. Assessment of Medial Shoulder, Neck, And Lateral Shoulder Balance Following Posterior Spinal Fusion (PSF) in Lenke Type 1 And 2 Adolescent Idiopathic Scoliosis (AIS) Patients: A Multicenter Asia Pacific Spine Society (APSS) Collaborative Study

Chris Yin Wei Chan, MD, MSOrth; Chee Kidd Chiu, MBBS, MSOrth; Saturveithan Chandirasegaran, MBBS, MSOrth; Jason Pui Yin Cheung, MD, MBBS, MS, FRCS; Prudence Wing Hang Cheung, PhD; Victoria Yuk Ting Hui, MBBS; Hideyuki Arima, MD, PhD; Tomohiro Banno, MD, PhD; Yukihiro Matsuyama, MD, PhD; Ajoy Prasad Shetty Tonse, MS; Gnanaprakash Gurusamy, MBBS, MS; Shanmuganathan Rajasekaran, MD, PhD, FRCSA, MCh; Masayoshi Iwamae, MD; Shinji Takahashi, MD, PhD; Leok-Lim Lau, MBBS, FRCS; Gabriel Liu, MBBS, FRCS; Mun Keong Kwan, MBBS, MSOrth

Hypothesis:
Lenke 1 and 2 AIS is associated with postoperative medial shoulder, lateral shoulder, and neck imbalance prior to PSF surgery

Design:
Retrospective study

Introduction:
Few multicentre studies have investigated postoperative medial shoulder, neck, and lateral shoulder balance in patients with Lenke type 1 and 2 adolescent idiopathic scoliosis AIS

Methods:
A total of 253 patients with ≥2-year follow-up from six centers were included. Medial shoulder balance was assessed by T1 tilt (balanced: −3° to 3°), lateral shoulder balance by clavicle angle (−2° to 2°), and neck balance by cervical axis (−3° to 3°)

Results:
The cohort was predominantly female (88.5%), with a mean age of 15.2 ± 3.5 years. 72% of patients were classified as Lenke type 1. The mean main thoracic (MT) Cobb angle was 58.8 ± 14.9°. The prevalence of postoperative positive medial shoulder imbalance (+ve MI) at final follow-up was 36%, with a mean T1 tilt of 2.4 ± 5.1°. The prevalence of positive neck imbalance (+ve NI) was 24% at the final follow-up, with a mean CA of 1.6 ± 3.0°. Positive lateral shoulder imbalance (+ve LI) was observed in 17% at the final follow-up, with a mean Cla-A of 0.7 ± 2.2°. The most significant factors associated with the final follow-up T1 tilt were preoperative T1 tilt, final follow-up PT Cobb angle, and final follow-up UIV tilt angle. For CA, the significant factors were the final follow-up PT Cobb, final follow-up MT Cobb, and preoperative thoracolumbar kyphosis. For Cla-A, the factors included preoperative lumbar Cobb, preoperative MT Cobb, and final follow-up MT Cobb. UIV selection did not significantly influence

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these outcomes. Patients with neck imbalance reported significantly lower postoperative satisfaction (4.27 vs. 4.47, p = 0.031) at the final follow-up

Conclusion:
At final follow-up, medial shoulder, neck, and lateral shoulder imbalance were present in 36%, 24%, and 17% of patients, respectively. Preoperative T1 tilt, postoperative UIV tilt angle, and residual PT and MT Cobb angles were significantly associated with medial shoulder imbalance. Neck imbalance was associated with lower SRS satisfaction scores

246. Screw Trajectory Matters: UIV Screw Angulation as a Modifiable Risk Factor for Proximal Junctional Kyphosis

Nikita Lakomkin, MD; Zach Pennington, MD; Abdelrahman Hamouda, MBBS; Orod Gharibi, MD; Jeremiah Harrison, MD; Michael Martini, MD, PhD; Derrick ObiriYeboah, MD; Mohamed El-Gohary, MBBS; Brett Freedman, MD; Ahmad Nassr, MD; Anthony L. Mikula, MD; Jeremy L. Fogelson, MD; Benjamin D. Elder, MD, PhD

Hypothesis:
Cranially-oriented UIV screw angulation and reduced screw-to-superior endplate distance increase the risk of proximal junctional kyphosis (PJK) following adult spinal deformity surgery

Design:
Retrospective cohort study

Introduction:
PJK is a common complication following adult spinal deformity (ASD) surgery. While implant density and construct stiffness have been implicated, the influence of upper instrumented vertebra (UIV) screw positioning remains poorly characterized. This study evaluates UIV screw trajectory and depth as risk factors for PJK following ASD fusion terminating at the thoracolumbar junction.

Methods:
Adults with ASD undergoing fusion (2010–2017) at a single institution with UIV between T10–L2 and minimum 2-year follow-up were identified. UIV screw position was quantified by screw-to-superior endplate (sEP) distance and screw angle (Cobb angle between screw trajectory and sEP; positive = cranially oriented). PJK was defined as ≥10° increase in proximal junctional angle from immediate postoperative measurements.

Results:
Among 150 patients (median age 68.0 years; 53.3% female), 47 (31.1%) developed PJK at median 24 months. Patients with PJK had lower UIV+1 Hounsfield units (111 vs 150, p<0.001), shorter screw-sEP distance (4.4 vs 7.5 mm, p=0.002), and more cranial screw angulation (3.0° vs 0.8°, p<0.001). ROC analysis identified optimal thresholds: screw angle ≥3.8° (PJK 62.9% vs 21.1%; AUC 0.68; specificity 87%) and screw-sEP <4.6 mm (PJK 52% vs 21%; AUC 0.66). On multivariable Cox regression, higher UIV+1 HU (HR 0.98/HU, p<0.001) and more caudal screw angulation (HR 1.07/degree for cranial angulation, p=0.005) independently predicted PJK risk. Screw-sEP distance was not significant on multivariable analysis (p=0.43).

Conclusion:
More caudal UIV screw angulation and better bone integrity appear protective against PJK following ASD fusion terminating at the thoracolumbar junction. Screw tips positioned closer to the UIV superior endplate may also increase PJK risk, but this was not predictive on multivariable analysis. These findings suggest screw trajectory may represent a more important modifiable factor than screw depth at the proximal junction.

247. Effective Indirect Decompression Despite Psoas Muscle Injury Following Lateral Lumbar Interbody Fusion in Adult Spinal Deformity

Dong-Gune Chang, MD, PhD; Per D. Trobisch, MD

Hypothesis:
The indirect decompression effect following lateral lumbar interbody fusion (LLIF) showed satisfactory radiological results in patients with adult spinal deformity (ASD), despite substantial psoas muscle injury.

Design:
A retrospective cohort study.

Introduction:
Indirect decompression effects after LLIF may be identified by increased intervertebral disc space. However, morphological changes in disc height, spinal canal, intervertebral foramen, and psoas major muscle are unclear in patients with ASD after LLIF.

Methods:
We retrospectively assessed 58 patients with ASD who underwent LLIF comprising 149 lumbar interbody levels. Radiological changes of intervertebral disc height, stenosis grade, and left psoas major muscle were retrospectively evaluated using preoperative and postoperative plain radiographs and magnetic resonance imaging (MRI). The cross-sectional area (CSA) and fatty infiltration (FI) of left psoas muscles were calculated from axial T2-weighted MRI at the involved interbody levels by manual tracing in ImageJ software.

Results:
All radiological parameters including Cobb's angle (12.5° to 4.5°, P < 0.001) and pelvic incidence (PI) – lumbar lordosis (LL) (29.6° to 4.5°, P < 0.001) were significantly improved after LLIF. The mean anterior (Δ = 7.1mm), middle (Δ = 6.0mm), and posterior (Δ = 3.2mm) disc heights were significantly increased after LLIF (all Ps < 0.001). The stenosis grades of the central canal and both foramina were significantly improved after LLIF, and the change in foraminal stenosis grade was significantly

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E-POINT PRESENTATION ABSTRACTS

associated with posterior disc height (P = 0.016). The mean CSA and FI significantly increased by 1.6-fold and 3.2-fold after OLIF, respectively (all Ps < 0.001). Regarding the spinopelvic parameters in LLIF, anterior height at L2-3 was significantly associated with the correction of LL (P = 0.013) and PI– LL mismatch (P = 0.007).

Conclusion:
The indirect decompression effect following LLIF was satisfactory on postoperative MRI in patients with ASD, despite substantial psoas muscle injury. The surgical treatment of ASD through LLIF should focus on posterior disc height to alleviate the stenotic symptoms and the anterior disc height of the upper lumbar lesion to achieve proper correction of the spinopelvic parameters.

248. Ten-Year Outcomes After Elderly Adult Spinal Deformity Surgery: Postoperative Coronal Imbalance Predicts Late Rod Fracture and Reduced Revision-Free Survival

Tomohiro Yamada, MD; Yu Yamato, MD, PhD; Go Yoshida, MD, PhD; Tomohiro Banno, MD, PhD; Hideyuki Arima, MD, PhD; Shin Oe, MD; Hiroki Ushirozako, MD, PhD; Koichiro Ide, MD; Yukihiro Matsuyama, MD, PhD

Hypothesis:
Postoperative coronal imbalance (CIB) after long-segment adult spinal deformity (ASD) correction independently increases the risk of late rod fracture and revision, and satellite-rod reinforcement mitigates this risk.

Design:
Retrospective cohort study with minimum 10-year follow-up.

Introduction:
Residual coronal malalignment is increasingly recognized as a driver of late mechanical complications after ASD surgery, yet its independent contribution to rod fracture—separate from baseline coronal severity—and the potential preventive role of satellite-rod reinforcement remain incompletely defined.

Methods:
Consecutive patients aged ≥65 years who underwent long-segment ASD correction with pelvic fixation (2010–2020) were reviewed. Postoperative CIB was defined as C7 plumb line–CSVL >3 cm on early standing radiographs. Mechanical outcomes included rod fracture and revision surgery. To address baseline confounding, we performed (1) multivariable logistic regression to test whether postoperative CIB was influenced by preoperative coronal parameters (C7–CSVL and coronal Cobb angle), and (2) multivariable logistic regression for rod fracture including postoperative CIB and clinically relevant covariates (age, three-column osteotomy, bone mineral density, and satellite-rod use). Revision-free survival was assessed using Kaplan–Meier and Cox models.

Results:
Postoperative CIB was present in 20.2% of patients. Rod fracture (45.2% vs 28.3%) and revision surgery (37.3% vs 19.8%) occurred more frequently in the CIB group. In the rod-fracture model, postoperative CIB was an independent risk factor (OR 2.95; 95% CI 1.45–11.25; p=0.007), whereas satellite-rod use was independently protective (OR 0.16; 95% CI 0.06–0.39; p<0.001). Revision-free survival was reduced in the CIB group (HR 1.8; 95% CI 1.0–4.0; log-rank p=0.041).

Conclusion:
In elderly ASD correction with pelvic fixation, postoperative CIB is a strong independent predictor of rod fracture and reduced revision-free survival. Satellite-rod reinforcement shows a robust protective association, supporting an actionable strategy: optimize coronal balance and consider reinforcement when residual CIB risk is high.

249. Predictors of Root Level Intraoperative Neuromonitoring (IONM) Changes in Adult Spinal Deformity (ASD) Surgery

Evan Joiner, MD; Amrit Singh, MPH; Colin P. Sperring, MD, MS; Anastasia Ferraro, BS; Erik Lewerenz, BS; Justin L. Reyes, MS; Fthimnir Hassan, MPH; Varun Arvind, MD, PhD; Ted Shi, BS; Nicholas Laskay, MD; Lawal A. Labaran, MD; Matthew E. Simhon, MD; Josephine R. Coury, MD; Earl D. Thuet, CNIM; Nathan J. Lee, MD; Ronald A. Lehman Jr., MD; Lawrence G. Lenke, MD

Hypothesis:
Age, loss of lordosis, PI-LL mismatch, sagittal imbalance, deformity angular ratio, and three-column osteotomy predict root level IONM changes in ASD surgery.

Design:
Retrospective cohort study

Introduction:
Recent studies have clarified risk factors for cord level IONM changes in ASD. Risk factors for root level changes are less well known.

Methods:
A retrospective cohort of ASD patients who underwent posterior only based spine fusion with a single surgeon between 2015 and 2023 was reviewed. Primary outcome was root level IONM change as defined by 75% decrement in motor evoked potential (MEP) in any muscle group. Secondary outcome was new motor deficit on postoperative day (POD) 1. Univariate logistic regression was performed to assess association between clinical variables and root level IONM change. Variables demonstrating univariate p<0.20 were considered potential predictors and entered into an initial multivariable logistic regression model. Predictors with ≤10 events were excluded. Model was refined using backward elimination based on highest p-value with refitting after each removal until remaining predictors demonstrated p<0.05. Key

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demographic variables were retained regardless of p-value due to clinical relevance. Odds ratios (OR) with 95% confidence intervals (CI) were reported. Statistical significance was defined as p<0.05.

Results:
551 ASD patients were included. 116 (21.1%) had root level changes; of these, 29 (25%) developed a new motor deficit. Study-wide, 37 patients (6.7%) experienced new motor deficit. While multiple potential predictors demonstrated statistically significant univariate association with root level change, only body mass index [BMI] (OR 1.072217, CI 1.010072-1.138187, p=0.022), preoperative lower extremity motor deficit (OR 2.712647, CI 1.249272-5.890196, p=0.012), pelvic tilt (OR 1.044434, 1.0165-1.073135, p=0.0021), Type III spinal cord (OR 5.436050, 1.876682-15.746220, p=0.002), and estimated blood loss [liters] (OR 2.182416, 1.307783-3.641994, p=0.003) remained significant in the final multivariable model (Table 1).

Conclusion:
In the largest study of nerve root monitoring to date, we found that BMI, poor baseline nerve and spinal cord health (weakness, Type III cord), evidence of compensation for sagittal imbalance (PT), and intraoperative blood loss (potential ischemia), are predictive of root level IONM changes during ASD surgery.

Univariate logistic regression of potential predictors of root level IONM change				
Potential Predictor	OR	95% CI		p-value
Age	1.005473	0.993889	1.017192	0.356
BMI	1.028047	0.993442	1.063858	0.113
Female gender	0.832225	0.534402	1.296027	0.416
Type of deformity				
Any scoliosis	**2.412376**	**1.006394**	**5.782585**	**0.048***
Kyphosis	1.397617	0.923620	2.114865	0.113
Coronal malalignment	1.382353	0.904747	2.112081	0.134
Sagittal malalignment	**1.752228**	**1.131484**	**2.713518**	**0.012***
Idiopathic scoliosis	**0.603252**	**0.398300**	**0.913667**	**0.017***
Degenerative scoliosis	0.772768	0.511094	1.168414	0.222
Congenital	0.712727	0.266641	1.905107	0.500
Scheuermann kyphosis	0.420000	0.124515	1.416699	0.162
Neuromuscular	**3.714851**	**1.736766**	**7.945873**	**0.001***
Syndromic	1.614425	0.793492	3.284680	0.186
Post XRT	1.458407	0.279254	7.616554	0.655
Post-laminectomy	1.998755	0.825598	4.838945	0.125
Listhesis	1.995780	0.960937	4.145054	0.064
ASA Score				
1	Reference	-	-	-
2	**2.335165**	**1.260987**	**4.324386**	**0.007***
3	1.784257	0.872792	3.647572	0.113
4	**21.857140**	**2.124283**	**224.892200**	**0.010***
Charleston Comorbidity Index				
0	Reference	-	-	-
1	1.576840	0.931225	2.670057	0.090
2	1.116736	0.635165	1.963424	0.701
3	1.114625	0.545210	2.278733	0.766
4	0.743083	0.244557	2.257852	0.600
5	1.424242	0.278043	7.295511	0.671
Comorbidities				
Any cardiac history	1.246142	0.793806	1.956235	0.339
HTN	1.243697	0.782263	1.977320	0.357
HLD	**1.818937**	**1.116588**	**2.963073**	**0.016***
MI	0.747826	0.086514	6.464238	0.792
CHF	1.882610	0.169215	20.945090	0.607
PVD	2.283188	0.537568	9.697287	0.263
Stroke / TIA	1	-	-	-
COPD	**5.142857**	**1.134627**	**23.310720**	**0.034***
Connective tissue disease	0.741071	0.248261	2.212131	0.591
PUD / GERD	0.472728	0.196528	1.137096	0.094
Liver disease	0.618421	0.136456	2.802698	0.533
DM	1.690477	0.511183	5.590393	0.390
Hypothyroidism	1.211560	0.672804	2.181732	0.523
CKD	**2.729360**	**1.015650**	**7.334615**	**0.047***
Cancer	0.721154	0.373941	1.390762	0.329
PE / DVT	0.704082	0.236858	2.092949	0.528
Preop IVC Filter	0.935268	0.259464	3.371281	0.919
Preop lower extremity motor deficit	**2.535750**	**1.621942**	**3.964400**	**<0.001***
Preop myelopathy	**2.927864**	**1.457751**	**5.880559**	**0.003***
Preop radiculopathy	1.424446	0.940786	2.156758	0.095
SVA (cm)	**1.115723**	**1.068911**	**1.164585**	**<0.001***
CVA (absolute value, cm)	1.007929	0.996244	1.019752	0.184
TK (T2-T12)	0.998706	0.990492	1.006987	0.759
Lumbar lordosis	0.998574	0.988342	1.008912	0.786
Pelvic incidence	**1.025827**	**1.010656**	**1.041225**	**0.001***
PI-LL	**1.010492**	**1.001441**	**1.019624**	**0.023***
Pelvic tilt	**1.043576**	**1.023124**	**1.064437**	**<0.001***
Max coronal Cobb angle	1.002399	0.993627	1.011250	0.593
Sagittal DAR	**1.038892**	**1.005387**	**1.073513**	**0.023***
Coronal DAR	**1.054396**	**1.016638**	**1.093557**	**0.004***
Total DAR	**1.032486**	**1.011212**	**1.054208**	**0.003***
Spinal Cord Type				
I	Reference	-	-	-
II	1.195602	0.643294	2.222103	0.572
III	**4.534749**	**2.525911**	**8.141201**	**<0.001***
Preop Hgb	0.990634	0.938775	1.045357	0.732
Lowest intraop Hgb	0.870620	0.761207	0.995761	0.043
Change in Hgb	1.002140	0.967115	1.038434	0.906
Estimated blood loss (L)	**3.164784**	**2.240930**	**4.469511**	**<0.001***
Intraoperative tranfusion (L)	**3.205854**	**2.011358**	**5.109732**	**<0.001***
Durotomy	**2.648829**	**1.517900**	**4.622372**	**0.001***
Three Column Osteotomy				
None	Reference	-	-	-
PSO	**4.347826**	**2.274583**	**8.310794**	**<0.001***
VCR	**2.903226**	**1.544902**	**5.455829**	**0.001***
PSO + VCR	9.999979	0.895411	111.680100	0.061
Number of decompressions	**1.621640**	**1.332686**	**1.973246**	**<0.001***
Number of PCOs	**1.062813**	**1.000447**	**1.129068**	**0.048***
Number of TLIFs	**1.460888**	**1.190675**	**1.792425**	**<0.001***
UIV				
Cervical	1.040000	0.304101	3.556717	0.950
Upper Thoracic	0.626506	0.215064	1.825086	0.391
T5 to T9	1.536364	0.445264	5.301155	0.497
T10 to T12	0.800000	0.236765	2.703098	0.719
Lumbar	Reference	-	-	-
LIV				
Thoracic	-	-	-	-
Lumbar	Reference	-	-	-
Ilium	**1.805555**	**1.085285**	**3.003846**	**0.023***
Multivariable logistic regression of potential predictors of root level IONM change				
Potential Predictor	OR	95% CI		p-value
Age	0.992960	0.968579	1.017954	0.577
BMI	**1.072217**	**1.010072**	**1.138187**	**0.022***
Gender				
Male	Ref	-	-	-
Female	1.028124	0.944000	0.474170	0.474
Preop lower extremity motor deficit	**2.712647**	**1.249272**	**5.890196**	**0.012***
Pelvic tilt	**1.044434**	**1.016500**	**1.073135**	**0.002***
Spinal cord type				
I	Ref	-	-	-
II	0.953874	0.368329	2.470282	0.923
III	**5.436050**	**1.876682**	**15.746220**	**0.002***
Estimated blood loss (L)	**2.182416**	**1.307783**	**3.641994**	**0.003***

Table 1: Logistic regression

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250. Prediction of proximal junctional kyphosis and failure after S2AI fixation in adultspinal deformity Is Pedicle Bone Mineral Density More Critical?

Zezhang Zhu, MD, PhD; Zhen Liu, MD, PhD; Yong Qiu, PhD; Saihu Mao, MD; Xiaodong Qin, PhD; Xing Sun, MD

Hypothesis:
Measuring both pedicle and vertebral bone density simultaneously is more beneficial in providing important guidance for surgical decision-making in patients with DSD.

Design:
Retrospective analysis of medical records of 164 patients with degenerative spinal deformities who underwent pelvic fixation using S2AI screw fixation technique. Patients were divided into a PJK group and a control group based on whether PJK occurred.

Introduction:
Exploring the predictive value of pedicle bone density for postoperative proximal junctional kyphosis (PJK) in patients with degenerative spinal deformities fixed with second sacral iliac screws (S2AI).

Methods:
Retrospective analysis of medical records of 164 patients with degenerative spinal deformities who underwent pelvic fixation using S2AI screw fixation technique in our hospital from March 2017 to November 2022. Patients were divided into a PJK group (38 cases) and a control group (126 cases) based on whether PJK occurred. Measure the HU values of UIV vertebrae and pedicle on preoperative CT, and measure the VBQ scores of UIV vertebrae and pedicle on preoperative MRI. Preoperative and postoperative measurements of the following imaging parameters: thoracic kyphosis (TK), lumbar lordosis (LL), sacral slope (SS), pelvic tilt (PT), pelvic incidence angle (PI), mismatch between PI and LL (PI-LL), sagittal vertical axis (SVA).

Results:
There was no statistically significant difference in the number of fixed segments and follow-up time (P>0.05). The HU values of vertebral bodies and pedicle in the PJK group were significantly lower than those in the control group, while the VBQ scores of vertebral bodies and pedicle were significantly higher than those in the control group. Compared with vertebral HU and VBQ scores, pedicle HU and VBQ scores have higher AUC values in predicting PJK, but the difference is not statistically significant (p>0.05). In patients with low vertebral bone density, the incidence of PJK was significantly lower in patients with higher pedicle bone density than in patients with lower pedicle bone density (15% vs 32%, p<0.05).

Conclusion:
Individual vertebral bone density is not sufficient to accurately assess the risk of PJK occurrence. Therefore, measuring both pedicle and vertebral bone density simultaneously is more beneficial in providing important guidance for surgical decision-making in patients with DSD.

251. Artificial Intelligence-Based Quantification of Total Paraspinal Muscle Fatty Infiltration Predicts Proximal Junctional Failure following Thoracolumbar Spinal Fusion for Adult Spinal Deformity

Pearce B. Haldeman, MD; Thaddeus Woodard, MD, BS; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Bahar Shahidi, PhD

Hypothesis:
Total lumbar paraspinal muscle fatty infiltration (FI) measured using artificial intelligence is associated with proximal junctional failure (PJF).

Design:
Retrospective analysis of a prospective cohort.

Introduction:
PJF remains a significant complication following long-segment posterior spinal fusion (PSF) for adult spinal deformity (ASD). Prior studies have linked paraspinal muscle quality to PJF risk; however, most rely on manual segmentation and extrapolate global lumbar muscle quality from single-level measurements. This study evaluates automated, multi-level paraspinal muscle FI in patients with and without PJF following thoracolumbar PSF.

Methods:
A prospective ASD cohort was queried for patients undergoing PSF to the pelvis with available preoperative thoracolumbar MRI. Demographics, surgical variables, and 3-month postoperative sagittal alignment parameters were collected. L1PA error was calculated as measured L1PA minus goal L1PA (goal L1PA=0.5*PI-19). PJF was defined as revision surgery for pathology at the proximal junction. Automated MRI analysis quantified FI of the erector spinae (ES), multifidus (M), psoas (P), and quadratus lumborum (QL). Multivariate regression assessed the association between FI and PJF, adjusting for sagittal alignment. Significance was set at p<0.05.

Results:
Forty-five patients met inclusion criteria with a minimum 2-year follow-up (mean=41 months); 10 patients (22%) developed PJF. Mean time to PJF was 12±8.6 months. There were no differences in age, sex, BMI, DEXA T-score, or number of levels fused between groups. Postoperative L1PA, T4PA, and C2PA were greater in the PJF group (p<0.03), though L1PA error and T4PA–L1PA mismatch did not differ. M FI was greater in the PJF group (p=0.043). Multivariate analysis adjusting for C2PA, T4PA, and L1PA demonstrated that increased M FI was independently associated with PJF (OR=1.09, 95% CI 1.02–1.16).

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Conclusion:
Increased lumbar multifidus FI is independently associated with PJF after long-segment PSF, with an approximately 9% increased risk per 1% FI increase after accounting for sagittal alignment. These findings support the validity of single-level lumbar FI as a surrogate for global lumbar muscle quality in the ASD population and highlight the utility of high-throughput, AI-based muscle characterization in ASD risk stratification.

Variable	No PJF (n=35)	PJF (n=10)	p-value
Demographics / Clinical			
Age (years)	67.9±8.9	72.2±5.1	0.064
Female Sex	18 (51%)	8 (80%)	0.154
BMI (kg/m²)	26.4±4.8	26.7±7.6	0.916
DEXA T-score	−1.66±0.9	−1.66±0.9	0.989
Primary surgery	20 (57%)	6 (60%)	1
Levels fused	8.5±1.0	8.7±1.0	0.544
Sagittal Alignment (3-month postop)			
L1PA (°)	6.4±6.6	10.7±4.5	**0.03**
T4PA (°)	10.4±7.5	17.2±3.4	**<0.001**
C2PA (°)	17.5±7.9	25.3±3.9	**<0.001**
L1PA Error	-1.5±4.7	0.7±5.0	0.221
T4PA-L1PA mismatch	3.9±3.9	6.6±3.9	0.082
Paraspinal Muscle Fatty Infiltration (%)			
Multifidus FI	40.7±10.3	50.3±12.4	**0.043**
Erector spinae FI	29.0±8.7	36.0±13.5	0.149
Psoas FI	15.3±5.3	18.2±13.6	0.521
Quadratus lumborum FI	27.4±8.2	30±8.7	0.431

252. Weakness Of Trunk And Knee Extensors Might Hinder the Ability To Maintain Compensatory Mechanisms While Walking

Abir Massaad, PhD; Rami Rachkidi, MD, MS; Jean-Pierre Saad; Yamen Beyh; Josef Lattouf; Michel Al Ammouri; Frederic Maatouk; Mohamad Hajj Youssef; Ibrahim Hamati; Moustapha Rteil; *Virginie Lafage, PhD;* Ismat Ghanem, MD, MS; Ayman Assi, PhD

Hypothesis:
ASD with increased pelvic tilt and weak trunk and knee extensors fail to maintain pelvic retroversion while walking.

Design:
Retrospective study on prospectively collected data.

Introduction:
Recent findings in the functional evaluation of ASD have shown that some patients maintain pelvic retroversion during walking, while others adopt a normal or anteverted pelvis. Therefore, the aim was to investigate the underlying mechanisms that enable certain patients to maintain compensatory mechanisms while walking.

Methods:
96 ASD patients, presenting with sagittal malalignment and PT>25°, underwent biplanar X-rays with the calculation of 3D spinopelvic parameters and filled QOL questionnaires (SF36, VAS for pain). Trunk and lower limb muscle forces were captured using a handheld dynamometer. They all underwent 3D gait analysis from which spine, pelvis and lower limbs kinematics were calculated. Patients were classified depending on their dynamic pelvic tilt behavior relatively to a normative database of 150 controls: anteverted (Antev-dynPT <-17°), normal (-17 to -6°) or retroverted (Retro-dynPT >-6°, Fig1.A). Comparisons were computed between groups.

Results:
19 ASD were classified as Antev-dynPT (-20°), 44 as normal-dynPT (-10°) and 33 as Retro-dynPT (1°). Radiographic spinopelvic parameters were similar between the 3 groups (PI:54°, PT:31°, SVA:75mm). Patients in the Antev-dynPT group walked with a forward shifted trunk (dynSVA: 177 vs 122mm) and exhibited a reduced trunk and knee extensors forces compared to the Retro-dynPT group (108 vs 235N, 157 vs 265N resp., all p<0.001; Fig1.B). Patients in the Antev-dynPT group reported more deteriorated QOL scores (VAS: 8.2 vs 6.5, physical component SF36: 32 vs 37 in the Retro-dynPT group, both p<0.05).

Conclusion:
Despite comparable radiographic sagittal malalignment, ASD patients with weak trunk and knee extensors tend to walk with an anteverted pelvis and increased trunk flexion. In contrast, patients with preserved muscle capacity appear to maintain their static compensatory mechanisms during gait. Personalized muscle strengthening programs may restore patients' ability to utilize compensatory mechanisms while walking, thereby enhancing surgical and non-surgical outcomes.

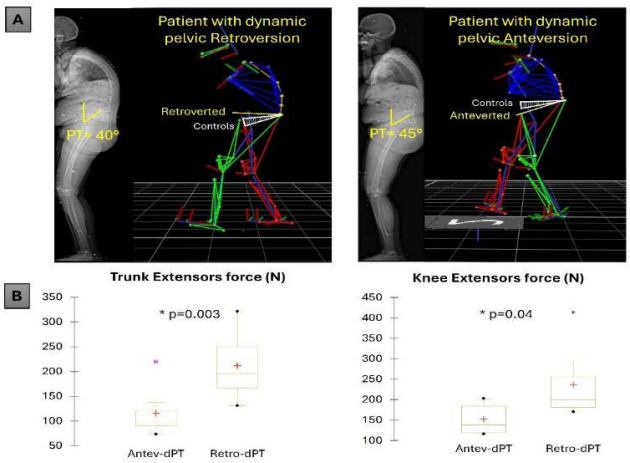

Fig.1: A) examples of patients with retroverted and anteverted dynamic pelvic tilt and comparable radiographic profiles. B) Trunk and knee extensors force.

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E-POINT PRESENTATION ABSTRACTS

253. Putting to Use A New Classification System for Distal Junctional Failure After Adult Spinal Deformity Surgery: An In-Depth Dual Institution Study

Benjamin D. Elder, MD, PhD; Scott Zuckerman, MD; Pawel P. Jankowski, MD; Byron F. Stephens, MD; *Harsh Jain, MBBS;* Advith Sarikonda, BS, BA; Robert K. Eastlack, MD; Peter G. Passias, MD; Kari Odland, DAT, ATC; David W. Polly Jr, MD

Hypothesis:
A new classification system of distal junctional failure (DJF) after adult spinal deformity surgery (ASD) will help predict reoperation for spinopelvic complications.

Design:
Retrospective cohort

Introduction:
DJF and spinopelvic complications after ASD surgery total $1 billion over 5-years and occur in approximately 25% cases. In a dual-institution study, we sought to use the classification system to: 1) describe spinopelvic complications from two centers and 2) determine which complications require reoperation.

Methods:
A dual-institution, retrospective cohort study (2009-23) was undertaken for patients undergoing ASD surgery. Inclusion criteria were: ≥5-level fusion, fused to pelvis, sagittal/coronal deformity, and 2-year follow-up. Primary outcome was spinopelvic failure, defined as L4-S1 rod fractures/pseudarthrosis, S1/iliac screw failure, iliac set plug dislodgment, iliac screw loosening/prominence, and sacroiliac joint (SIJ) pain. The classification system trichotomized failures into: 1) instrumentation, 2) osseous and 3) clinical failure. Descriptive/bivariate statistics were performed.

Results:
Of 311 patients, spinopelvic failure occurred in 74 (23.8%) patients, with 60/74 (81.1%) requiring reoperation. The classification was successfully implemented; 45 (60.8%) had one complication mode only, whereas 19 (25.7%) had 2 failure modes, and 10 (13.5%) had all 3 failure modes. Instrumentation failure was most common (62, 83.7%), followed by bony (28, 37.8%) and clinical (23, 31.1%). Rod fractures occurred in 39 (52.7%), most commonly at L4/5 (28, 71.8%), followed by L5/S1 (10, 25.6%), and S1/ilium (2, 5.1%). Pelvic screw haloing occurred in 33 (44.6%), S1 screw haloing occurred in 7 (9.5%), distal bone fracture occurred in 3 (4.1%), painful screw prominence in 3 (4.1%), and SIJ pain in 16 (21.6%). Patients with bony failures had the highest reoperation rates (89.2%), followed by clinical (87.0%) and instrumentation failures (77.4%). Rod fracture was significantly associated with reoperation compared to patients without rod fracture (91.4% vs. 71.8%, p=0.031).

Conclusion:
Using the novel classification system to report spinopelvic failures, a more granular description can be utilized to gain additional insight into DJF and spinopelvic complications after ASD surgery. Rod fractures from L4-ilium were significantly associated with reoperation.

254. Routine Practices in Anesthesiology for Spine Deformity Surgery: A Multi-Centre Comparison

Chloe Cadieux, MD, FRCS(C); Kyle Rogan, MD, FRCS(C); So Kato, MD, PhD; Saumyajit Basu, MS (Ortho), DNB (Ortho), FRCS (Ed); Yashar Javidan, MD; Sultan Aldebeyan, MD; Eric O. Klineberg, MD; Jeffrey M. Hills, MD; Sigurd H. Berven, MD; Serena S. Hu, MD; Zeeshan M. Sardar, MD; Brian J. Neuman, MD; Alisson R. Teles, MD; Anastasios Charalampidis, MD; Robert Ravinsky, MD, FRCSA, MPH; Kenny Y. Kwan, BMBCh(Oxon), FRCSEd; Kristen E. Jones, MD; Ahmed Shawky Abdelgawaad, MD, PhD; Jonathan N. Sembrano, MD; Mauricio Campos Daziano, MD; Reuben CC Soh, MBBS, FRCS; Arthur Sackeyfio, MD; Bhavuk Garg, MS; Aaron J. Buckland, MBBS, FRCSA; Nelson Astur, MD; Stephen J. Lewis, MD, FRCS(C); Michael P. Kelly, MD; Justin S. Smith, MD, PhD; *Fred H. Nicholls, MD*

Hypothesis:
Agreement will be seen in anesthesia practices across deformity centres.

Design:
Survey

Introduction:
Despite the critical role anaesthesiologists play in the care of spinal deformity patients, there remains vast variability in practice patterns. We compared routine perioperative practices in anesthesiology across high volume deformity centres to help highlight best-practice protocols specific for spinal deformity surgery.

Methods:
A 103 question survey was designed in collaboration between surgeons and anesthesiologists to assess routine perioperative anesthesia practices in spinal deformity surgery. Basic demographic and professional characteristics were collected. Subsequent sections focused on anesthesia practices in pre-operative, intra-operative, and post-operative care. The survey was distributed to the AO Spine Knowledge Forum Deformity membership for completion by either an adult or pediatric anesthesiologist at their home centre.

Results:
Thirty-six survey responses were collected, representing 15 different countries. Of these, 63% were based on adult and 37% were based on paediatric practices. The majority of respondents had additional fellowship training (67%) and 53% worked at centres that performed >100 major deformity cases per year. Vast differences in routine practices were seen between centres in all phases of care. Considerable variation was seen in pre operative evaluation and optimization; only 56% of sites had a

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dedicated subspecialty anaesthesia team and only 39% referred patients to a local blood management program. On the day of surgery, significant differences were seen in routine medications prescribed pre-operatively. Intra-operatively, MAP targets used during surgery ranged greatly between 60-80 mmHg and Hb transfusion thresholds between 60-110. Fluid management was highly variable, with only 39% of respondents indicating an attempt to limit crystalloid usage for volume replacement. Post-operatively, major differences included analgesia modalities commonly used and routine involvement of an acute pain service.

Conclusion:
Despite strong evidence in the literature, substantial heterogeneity in nearly all aspects of peri-operative anesthesia care in spinal deformity surgery persists. The variability in this international survey highlights the need for standardized protocols and guidelines, and the results provide insight into simple targets for optimization.

Question	% Respondents
Strong agreement across survey responses	
Do you routinely use tranexamic acid?	97.2% reported "yes"
How do you routinely administer antibiotics for SSI prophylaxis?	91.7% reported intermittent bolus
What do you routinely use to maintain anesthesia during deformity procedures when evoked potentials are being used?	88.8% reported TIVA with propofol
What thromboprophylaxis strategies do you use intra-operatively, if any?	75% reported sequential compressive devices (SCDs)
Strong disagreement across survey responses	
Does your program routinely pursue pre-operative opiate reduction?	30.5% reported "yes"
Are patients routinely screened for malnutrition (low BMI or muscle mass)?	38.8% reported "yes"
Does your anesthesia group have a standardized anesthetic protocol for major spine deformity procedures?	42% reported "no"
What is the routine disposition for patients undergoing major deformity procedures?	50% reported ICU (extubated)
Are patients who smoke routinely counselled on smoking cessation without nicotine replacement?	58.3% reported "yes"
Is intra-operative cell salvage routinely used at your institution?	52.7% reported "yes"
Do you attempt to limit crystalloid administration during cases (i.e. additional volume replacement done via colloid and/or blood product administration)?	61.2% reported "no"

Example summary of practice agreement

255. Postoperative Bracing following Adult Thoracolumbar Spinal Deformity Surgery

Anthony L. Mikula, MD; Nikita Lakomkin, MD; Justin K. Scheer, MD; Scott Zuckerman, MD; Jay D. Turner, MD, PhD; Jeffrey Mullin, MD; Breton Line; Renaud Lafage, MS; Virginie Lafage, PhD; Khaled M. Kebaish, MD; Eric O. Klineberg, MD; Gregory M. Mundis Jr, MD; Alan H. Daniels, MD; Robert K. Eastlack, MD; Stephen J. Lewis, MD, FRCS(C); Richard Hostin, MD; Jeffrey Gum, MD; Byron F. Stephens, MD; Brandon B. Carlson, MD; Thomas Buell, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Munish C. Gupta, MD, MBA; Han Jo Kim, MD; Michael P. Kelly, MD; Lawrence G. Lenke, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Shay Bess, MD; International Spine Study Group

Hypothesis:
Postoperative bracing is protective against reoperation for mechanical complications following adult thoracolumbar spinal deformity surgery.

Design:
Retrospective review of a prospective multicenter adult spinal deformity (ASD) database.

Introduction:
The benefits of postoperative bracing in preventing mechanical complications following adult spinal deformity surgery are not well understood.

Methods:
Patients undergoing adult spinal deformity surgery with constructs extending from the thoracic spine to the pelvis were included. Minimum follow up was one year to maximize study power as the benefits of short duration postoperative bracing in preventing mechanical complications >1 year is unlikely. Patients who underwent postoperative bracing were compared against those who did not, using two primary outcome measures: radiographic complications and reoperation for mechanical complications. Multivariable logistic regression analysis controlled for factors significant on the univariable analysis, including number of rods, rod configuration, rod material, and body mass index.

Results:
A total of 520 patients were included, with a mean age of 65 years and 72% of the cohort was female. Postoperative bracing was utilized by 293 patients (56%), with a thoracolumbar sacral orthosis being the most common (n=211, 72%), with a median brace duration of 12 weeks. Radiographic complications occurred in 257 patients (49%), including PJK (n=224), rod fracture (n=18), and pseudarthrosis (n=15). Reoperation for mechanical complications occurred in 45 patients (9%), with indications including proximal junctional kyphosis (n=22), pseudarthrosis (n=17), implant failure (n=16), junctional fracture (n=10), and distal junctional failure (n=2). On the multivariable analyses, the use of postoperative bracing was not protective against radiographic complications (p=0.82), but it was independently protective against reoperation for mechanical complications (p=0.02, OR = 0.39) in addition to four rod constructs (p=0.04, OR = 0.38).

Conclusion:
The use of postoperative bracing was independently associated with decreased odds of reoperation for mechanical failure following adult thoracolumbar spinal deformity surgery. Surgeons should consider the use of postoperative bracing following adult thoracolumbar deformity surgery.

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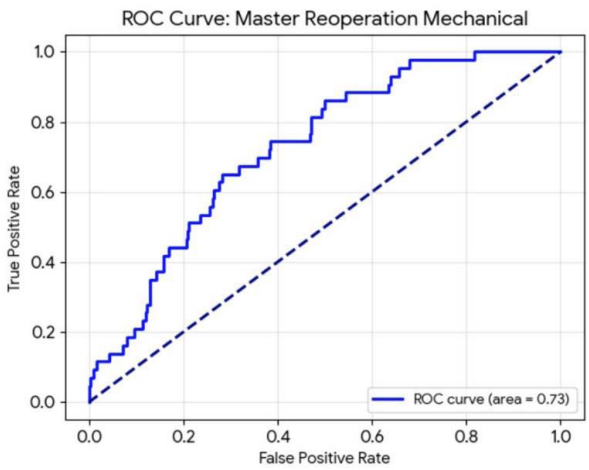


256. A Nomogram for Predicting Postoperative Neurological Deficits in Spinal Deformity Surgery: A Multicenter Study.

Jiahao Zhang, MD; Jiale Zhu, MS; Yan Zeng, MD

Hypothesis:
A nomogram integrating key preoperative radiographic and clinical factors including preoperative neurological status, apex location, sagittal Cobb angle, and total deformity angular ratio (T-DAR) can effectively predict the risk of postoperative neurological deficits (PONDs) in patients underwent spinal deformity surgeries.

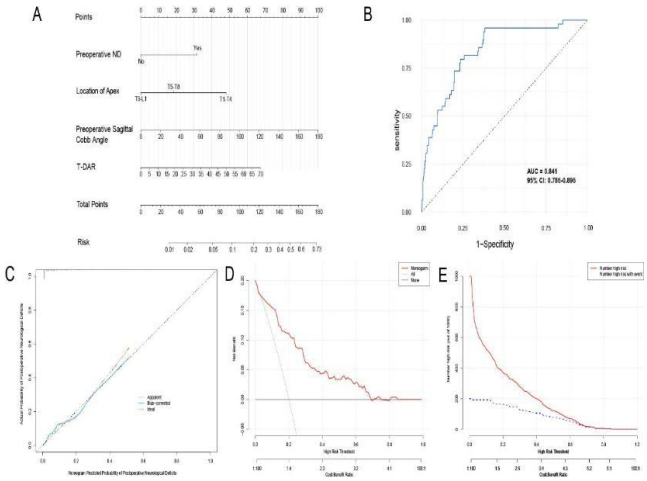
Design:
Retrospective multicenter comparative analysis.

Introduction:
Corrective surgery for spinal deformity carries a significant risk of PONDs, a serious complication that impacts patient outcomes. Current risk assessment relies on individual surgeon experience and isolated radiographic parameters, lacking a comprehensive, quantitative predictive tool. This study aimed to develop and validate a clinically practical nomogram model to predict the probability of PONDs.

Methods:
A consecutive series of 598 patients from three centers with spinal deformity who underwent corrective surgery between April 2010 and June 2025 were included in our study. Relevant measurements, including the Cobb angle, deformity angular ratio, and location of the apex were assessed and calculated using x-ray imaging. To identify independent risk factors associated with PONDs, we employed univariate analysis, followed by stepwise multivariate logistic regression analysis. A nomogram was established based on the identified independent risk factors to predict the likelihood of PONDs in patients underwent spinal deformity surgeries.

Results:
The mean age of the 598 patients was 26.0 (14.0–53.0) years, with an observed incidence of PONDs at 8.2%. The stepwise multivariate logistic regression analysis indicated that preoperative neurological deficits, location of apex, preoperative sagittal Cobb angle, andT-DAR were independent predictors of PONDs. Utilizing these independent risk factors, we constructed a nomogram model to estimate the probability of PONDs. The concordance index of the model was 0.841 (95% CI: 0.786–0.896), indicating a satisfactory level of accuracy in predicting the likelihood of PONDs.

Conclusion:
The predictive factors for PONDs include preoperative neurological deficits, location of apex, preoperative sagittal Cobb angle, and T-DAR. We developed a nomogram model to predict PONDs, which could be useful for patient counseling and facilitating treatment-related decision-making.



A: the nomogram; B: ROC curve for the model; C: calibration curve; D: DCA curve; E: CIC curve.

257. What Do Patients Hope to Regain from Adult Spinal Deformity Surgery? Cross-Cultural Differences in Expectations and Patient-Reported Outcomes Between the United States and Japan

JeanChristophe A. Leveque, MD; *Takeshi Fujii, MD, PhD;* Philip K. Louie, MD; Aiyush Bansal, MD, MASc; Venu M. Nemani, MD, PhD; JeanChristophe Leveque, MD; Kento Yamanouchi, MD; Kazuki Takeda, MD, PhD; Satoshi Suzuki, MD, PhD; Rajiv K. Sethi, MD, PhD; Kota Watanabe, MD, PhD

Hypothesis:
Expectations and baseline patient-reported outcomes (PROs) for adult spinal deformity (ASD) surgery differ

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between the United States (US) and Japan (JP) and are associated with self-image.

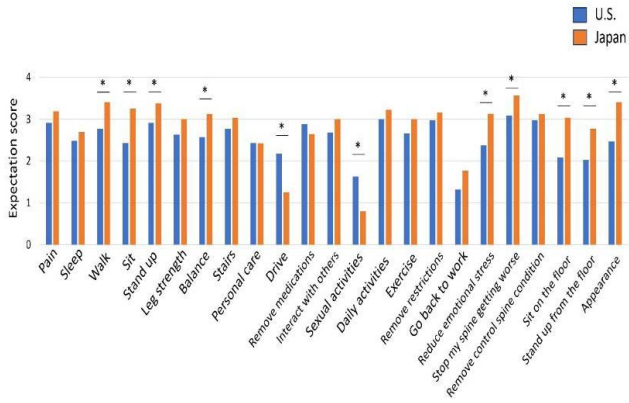
Design:
Prospective cohort study.

Introduction:
Patient expectations may potentially influence a patient's perception of their clinical outcomes. In addition, cultural differences in daily activities may shape what patients hope to regain following ASD surgery. This study aims to evaluate cross-cultural differences in patient expectations for ASD surgery and to assess the association between expectations and baseline PROs.

Methods:
Patients ≥ 50 years undergoing ASD correction with ≥ 5-level fusion were prospectively enrolled (2024-2025). Expectations were measured using a modified Hospital for Special Surgery Lumbar Spine Surgery Expectations Survey. PROs were assessed with SRS-22 and the Lumbar Stiffness Disability Index (LSDI). Preoperative expectations, PROs, and radiographic deformity were compared between surgical patients in the US and JP, and correlations between expectations and SRS-22 domains were analyzed.

Results:
Eighty-two patients were included (67.3 ± 8.1 years; 41 US, 41 JP); age and fused levels were similar. Overall expectations were comparable; JP patients more strongly expected improvement in walking (p=0.01) and floor-sitting (p=0.03), whereas US patients prioritized driving (p=0.04). JP had worse deformity: coronal balance 42.6 ± 35.6 vs 20.8 ± 25.2 mm, SVA 51.0 ± 14.9 vs 35.8 ± 14.3 mm, and PI-LL mismatch 33.6 ± 17.0° vs 21.1 ± 15.0° (all p<0.01). Despite this, LSDI was lower in JP (18.7 ± 17.8 vs 34.2 ± 20.3, p=0.01). SRS-22 function and pain scores were higher, while self-image and mental health scores were lower in JP. Expectations correlated negatively with SRS-22 self-image (p<0.01).

Conclusion:
Japanese ASD surgical patients showed greater radiographic severity yet lower stiffness-related disability and better function/pain, with worse self-image/mental health and culture-specific expectations. These findings indicate that patient-centered targets for ASD surgery differ across cultures (walking/floor-sitting vs driving) and that expectations are linked to self-image. Culturally informed counseling and studies linking expectations to postoperative satisfaction and PRO change are warranted.



Preoperative Patient Expectations

258. Machine Learning–Based Prediction of Rod Fracture After Long-Segment Fusion: The Role of Construct Design and Segmental Lordosis Distribution

JungHee Lee, MD, PhD; Ki Young Lee, MD; Hong-Sik Park, MD; Woo-Jae Jang, MD

Hypothesis:
We hypothesized that predictive performance would differ among machine learning (ML) models for rod fracture (RF) after long-segment fusion for adult spinal deformity (ASD) surgery and that surgical construct design and segmental lordosis distribution would contribute more substantially to RF risk.

Design:
Retrospective cohort study.

Introduction:
RF remains a frequent mechanical complication after long-segment fusion for ASD. Although global sagittal alignment has been emphasized, RF is influenced by multiple interacting anatomical and surgical factors. ML techniques may improve risk prediction; however, comparative model performance and the relative importance of contributing variables remain unclear. This study aimed to compare ML models for RF prediction and to clarify the roles of construct strategy and alignment parameters using SHapley Additive exPlanations (SHAP).

Methods:
Patients who underwent lateral lumbar interbody fusion combined with posterior column osteotomy for ASD were retrospectively reviewed. Patients were classified into RF (n=29) and non-RF (n=122) groups. Logistic regression (LR), random forest, XGBoost, and LightGBM models were developed. Model performance was evaluated using AUROC, accuracy, sensitivity, and specificity. SHAP analysis was used to quantify the contribution and directionality of anatomical, surgical, and radiographic variables.

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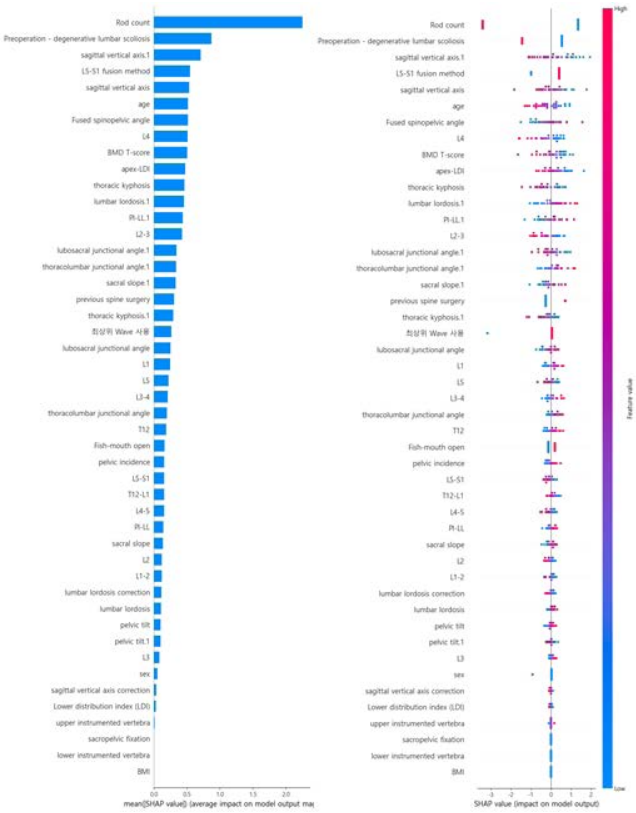
Results:
LR demonstrated the most consistent predictive performance, showing superior AUROC and balanced accuracy compared with tree-based ensemble models. SHAP analysis identified surgical construct design and segmental alignment distribution as the primary contributors to RF prediction. Use of a four-rod construct showed a strong protective effect. Larger L2–3 intervertebral angles, higher apex lordosis distribution index, and greater postoperative lumbar lordosis (LL) were also associated with reduced RF risk. Global alignment parameters showed comparatively lower contributions.

Conclusion:
LR provided the most reliable and interpretable model for predicting RF after long-segment fusion for ASD. Surgical construct design and segmental alignment distribution play a more important role in RF risk than global alignment parameters alone. Emphasizing multi-rod constructs and a harmonious distribution of LL with a more proximal apex may help reduce mechanical failure after long-segment fusion for ASD.



SHAP plot

259. Synthetic CT from Diagnostic Spine MRI: a Multi-Center Approach for Radiation-Free Bone Visualization *

Ryan Pollitt; Tom P. Schlosser, MD, PhD; Marijn van Stralen, PhD; *René M. Castelein, MD, PhD*; Wilbert Bartels, PhD; Peter R. Seevinck, PhD

Hypothesis:
An AI model trained on a large multi-center dataset can generalize to new, unseen centers, generating synthetic CT from routine diagnostic spine MRI with performance equivalent to models trained on the new center's data.

Design:
In this prospective, multicenter study, paired spinal MR and CT scans were collected in nine different centers and used in a technical validation.

Introduction:
Synthetic CT (sCT) generation from MRI promises radiation-free 3D bone visualization. Current methods are limited by single-center validation, a need for dedicated scans, or low-resolution outputs. This study aimed to develop and validate an sCT method from diagnostic spine MRI that overcomes these limitations.

Methods:
Using paired MRI/CT scans from 199 patients across nine centers spanning a wide range of spinal pathologies, anatomical regions and MRI sequences, we trained a Multi-Center Network on data from eight centers. Its performance on an unseen ninth center was compared to two benchmarks: a Single-Center Network (trained only on that center's data) and an All-Centers Network (trained on all center's data). The sCTs and CTs were compared using image intensity-based metrics and the mean surface distance between automatic vertebra segmentations.

Results:
The Multi-Center Networks (trained without the test center's data) performed equally to the Single-Center Networks (trained with the test center's data) as shown qualitatively in Fig. 1. The Multi-Center Networks also achieved similar performance to the All-Centers Network with non-significant differences in 74% of comparisons and an average of only 1.5% difference in metric values. This performance was consistent across different MRI scan types and all three test centers.

Conclusion:
An AI model trained on a large, diverse multi-center dataset, can successfully generate (sub)millimeter resolution 3D sCTs from diagnostic MRI from new unseen centers, performing similarly to networks trained on data from that center. This demonstrates an important step towards radiation-free bone visualization from diagnostic MR scans across diverse imaging centers, supporting broader clinical and surgical applications.

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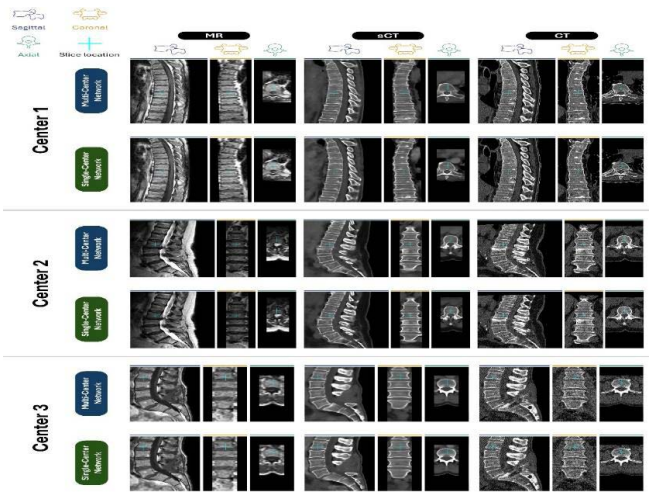

Qualitative examples of sCTs predicted by the Multi-Center Networks and Single-Center Networks per center. The MR inputs were sagittal 2D acquired scans with original slice spacings of 3.3-4.4 mm.

260. Lactoferrin-Anchored Tannylated Mesoporous Silica Nanomaterials-Induced Bone Fusion in a Rat Model of Lumbar Spinal Fusion *

Sung Hyeon Noh, MD, PhD

Hypothesis:
We suggest that TA-MSN-LF is a potent material for spinal bone fusion.

Design:
Prospective study

Introduction:
Lactoferrin (LF) is a potent antiviral, anti-inflammatory, and antibacterial agent found in cow and human colostrum which acts as an osteogenic growth factor. This study aimed to investigate whether LF-anchored tannylated mesoporous silica nanomaterials (TA-MSN-LF) function as a bone fusion material in a rat model.

Methods:
In this study, we created TA-MSN-LF and measured the effects of low (1 μg) and high (100 μg) TA-MSN-LF concentrations in a spinal fusion animal model. Rats were assigned to four groups in this study: defect, MSN, TA-MSN-LF-low (1 μg/mL), and TA-MSN-LF-high (100 μg/mL).

Results:
Eight weeks after surgery, a greater amount of radiological fusion was identified in the TA-MSN-LF groups than in the other groups. Hematoxylin and eosin staining showed that new bone fusion was induced in the TA-MSN-LF groups. Additionally, osteocalcin, a marker of bone formation, was detected by immunohistochemistry, and its intensity was induced in the TA-MSN-LF groups. The formation of new vessels was induced in the TA-MSN-LF-high group. We also confirmed an increase in the serum osteocalcin level and the mRNA expression of osteocalcin and osteopontin in the TA-MSN-LF groups. TA-MSN-LF showed effective bone fusion and angiogenesis in rats.

Conclusion:
We suggest that TA-MSN-LF is a potent material for spinal bone fusion.

261. Radiological Features and Postoperative Outcomes in Patients of Degenerative Lumbar Scoliosis with Pelvic Obliquity: the Application of a Novel Classification *

Junyu Li, MD; Liangyuan Wang; Yongqiang Wang, MD; Zhuoran Sun, MD; Miao Yu, MD; Weishi Li, MD

Hypothesis:
A novel classification system for pelvic obliquity (PO) in degenerative lumbar scoliosis (DLS) can distinguish between two distinct types with different biomechanical implications. The preoperative categorization can guide surgical strategy and predict outcomes for pelvic balance restoration.

Design:
Retrospective cohort study

Introduction:
Pelvic obliquity (PO) is common in Degenerative Lumbar Scoliosis (DLS) and significantly impacts quality of life. However, its definition and impact on surgical planning are poorly studied. This study proposes and evaluates a novel classification of PO to guide corrective surgery.

Methods:
Patients with DLS and PO (Pelvic Obliquity Angle, POA ≥3°) were classified into two types based on the relationship between the C7 Plumb Line (C7PL) and the higher iliac crest: Type I: The C7PL deviates toward the higher side of the pelvis. Type II: The C7PL deviates toward the lower side of the pelvis. Radiological parameters (Cobb angle, C7PL-CSVL distance [CVA], Apical Vertebral Translation [AVT], Sacral Obliquity Angle [SOA], POA) and surgical outcomes (fixation levels, PO persistence/recurrence) were compared pre- and post-operatively and between types.

Results:
90/290 patients (31%) had significant PO (48 Type I, 42 Type II). Type I PO Recovery: Associated with better correction of coronal deformity (lower postoperative AVT). Sacral fixation was not mandatory for PO correction. Type II PO Recovery: Dependent on adequate intraoperative SOA correction. Sacral fixation was crucial for preventing long-term PO recurrence. Poor Outcomes: Persistent/recurrent PO was linked to insufficient correction of the primary deformity (AVT in Type I) or failure to address sacral obliquity/fuse to the sacrum (in Type II).

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Conclusion:
The proposed PO classification (Type I vs. Type II) is clinically relevant. It suggests distinct surgical strategies: Type I PO correction focuses on overall coronal balance (Cobb, AVT), while Type II PO correction requires specific attention to the sacrum (SOA correction, sacropelvic fixation). This classification can help tailor surgery, potentially avoiding unnecessary fusion to the sacrum in Type I cases.

Fig.1: Methods for measuring radiological parameters. Fig.2: Type I pelvic obliquity in a DLS patient, pre- and post-op. Fig.3: Type II pelvic obliquity in a DLS patient, pre- and post-op.

262. The Two Distinct Functional Lordoses of the Lumbar Spine *

David Gadoin, MD; Ayman Assi, PhD; Claudio Vergari, PhD; Anas Venard, MD; Pierre Guigui, MD, PhD; Olivier Gille, MD, PhD; Wafa Skalli, PhD; Virginie Lafage, PhD; Emmanuelle Ferrero, MD, PhD; *Marc Khalife, MD, PhD, MS*

Hypothesis:
Lumbar lordosis may consist of two distinct functional arcs (proximal and distal), each with its own set of contributing spinopelvic parameters, challenging current uniform curvature models

Design:
Prospective observational and analytical study

Introduction:
Lumbar lordosis (LL) is a key component of sagittal spinal balance, yet its definition and measurement remain debated. Recent evidence suggests that LL is not a uniform curvature but a composite structure with proximal and distal arcs exhibiting distinct biomechanical roles. This study aimed to analyze the relationships of these arcs with spinopelvic parameters and determine how their distribution varies with pelvic incidence (PI).

Methods:
This multicentric study included 642 healthy volunteers (mean age 37.6±16.3 years) without spinal deformities. Full-body stereoradiographs were used to measure spinopelvic parameters, including maximum lumbar lordosis (LLmax), proximal lordosis (LLprox, from the thoracolumbar inflection point to the lumbar apex), and distal lordosis (LLdist, from the lumbar apex to the sacral plateau). Correlations between these arcs and spinopelvic parameters were sought. Subjects were stratified into five PI groups using Jenks' natural breaks optimization method, to determine lordosis distribution variation with PI in terms of angle and number of vertebrae included in curvature.

Results:
LLdist strongly correlated with pelvic parameters, particularly sacral slope (SS, r=-0.83, p<0.001) and PI (r=-0.54, p<0.001), but not with thoracic alignment. In contrast, LLprox correlated with both pelvic and thoracic parameters, including SS (r=-0.31, p<0.001) and thoracic kyphosis (TKmax, r=-0.35, p<0.001). As PI increased, the contribution of LLdist to LLmax rose from 55±12% to 66±8% (p<0.001), while the number of vertebrae in the distal arc increased from 1.52±0.50 to 2.32±0.59 (p<0.001). LLprox's proportional contribution decreased from 45±12% to 34±8% (p<0.001), despite a stable vertebral extent.

Conclusion:
Lumbar lordosis comprises two functionally distinct arcs: a pelvic-driven distal arc and a compensatory proximal arc influenced by thoracic alignment. As PI increases, the distal arc of LL becomes preponderant. These findings advocate for a segmental approach in clinical assessment and surgical planning, emphasizing the need to consider both arcs independently to optimize sagittal balance and reduce complications such as PJK.

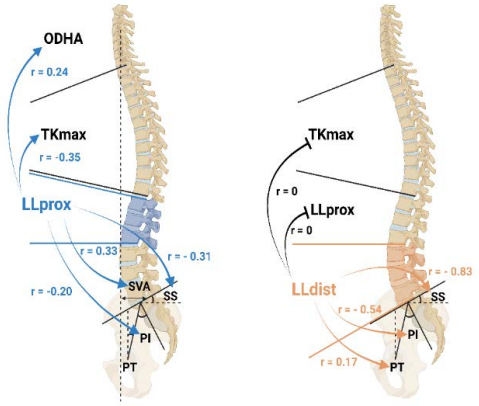

Figure : Functional Duality of Lumbar Lordosis

263. Unilateral Segmental Artery Ligation Induces Asymmetric Vertebral Growth and Vertebral Wedging in Immature Swine

Jie Xiao, MD; Jingming Xie; Jin Zhou, MD; Yingsong Wang, MD; Zhi Zhao, MD; Tao Li, MD; Zhiyue Shi, MD; Tingbiao Zhu, MD; Wei Zhao, MD; Xiaobing Tian, MD

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Hypothesis:
Unilateral segmental artery ligation in immature swine diminishes ipsilateral vertebral growth plate perfusion, resulting in asymmetric vertebral growth, increasing vertebral wedging, and scoliosis.

Design:
Prospective randomized controlled study.

Introduction:
Vascular injury to one side of a limb growth plate can disrupt symmetric growth and produce angular deformity, but whether targeted vascular disruption can modulate vertebral growth is not well defined. We investigated unilateral segmental artery disruption as a growth-modulating stimulus, hypothesizing that reduced unilateral vertebral blood supply alters the local growth environment and induces asymmetric vertebral development and scoliosis.

Methods:
Thirty 6-week-old piglets (9–11 kg) were randomized to Experimental (n=10), Sham (n=10), or Control (n=10). Left segmental arteries from T12 to L1 were ligated at their origin and intervertebral foramina and electrocoagulated in the Experimental group. A left paramedian approach exposed the rib bed and costotransverse joints, ligated posterior intercostal vessels/nerves, and removed a 2cm segment of T12–15 ribs and the L1 transverse process to expose target arteries. Sham animals underwent identical exposure without ligation; Controls had no surgery. Monthly radiographs assessed curve progression; axial CT at 4, 8, and 12 weeks quantified vertebral morphology and side-to-side height asymmetry using vertebral height ratio (VHR = ligation-side height/non-ligation-side height).

Results:
The Experimental group developed scoliosis with convexity contralateral to the surgical side, progressing Cobb angles of 11.87±2.07° (4 W), 13.94±2.59° (8 W), and 16.49±2.22° (12 W). Sham group had milder scoliosis with ipsilateral convexity and Cobb angles of 9.62±1.47°, 11.23±1.34°, and 12.48±1.64° at the same time points. CT demonstrated wedge-shaped vertebral deformation in the Experimental group, with early T12–L1 side-to-side height asymmetry at 1 month (VHR 0.929–0.951) that progressed by 3 months (VHR 0.856–0.868), indicating increasing growth imbalance on the ligated side.

Conclusion:
Unilateral disruption of segmental arterial supply induces asymmetric vertebral growth and progressive vertebral wedging, producing scoliosis in immature swine. These results suggest a vascular role in spinal growth modulation and offer a platform to research targeted vascular treatments to reduce asymmetric growth in EOS.

264. Does Adding Uncovertebral Foraminotomy to Anterior Cervical Discectomy and Fusion Improve Patient Outcomes? A 5-Year Propensity Score–Matched Analysis of MCID and Mechanical Complications

San Kim, MD; Hyuk-joon Sohn, MD; Kihyun Kwon, MD; Dong-Ho Lee, MD, PhD; Dong Ki Ahn, MD, PhD; ByungSuk Kim, MD; Jiseon Ahn, MD

Hypothesis:
The study investigated whether adding uncovertebral foraminotomy (UVF) to anterior cervical discectomy and fusion (ACDF) affects long-term patient outcomes, specifically the achievement of the minimum clinically important difference (MCID) and the incidence of mechanical complications

Design:
A 5-Year Propensity Score–Matched (PSM) Analysis

Introduction:
The study aimed to evaluate long-term patient outcomes and mechanical complications over a minimum five-year follow-up in patients undergoing ACDF with or without UVF

Methods:
From a pool of 253 patients who underwent one- to three-level ACDF between 2006 and 2020, a propensity score-matched (PSM) analysis was conducted. Patients were matched 1:1 into UVF (n = 85) and No UVF (n = 85) groups based on variables including age, sex, BMI, bone quality (CT HU), and surgical levels. Outcome measures included the Neck Disability Index (NDI), visual analogue scale (VAS) for neck and arm pain, and radiographic assessments for pseudarthrosis, cage subsidence, and loss of lordosis. Both absolute and relative MCID achievement rates were analyzed

Results:
In the matched cohort, NDI and neck pain VAS showed no significant differences between the two groups at any time point. While the UVF group reported significantly higher arm pain VAS at the two-year mark compared to the No UVF group (3.54 ± 2.91 vs. 2.35 ± 2.57; p = 0.006), this difference was no longer significant at the final follow-up. There were no statistical differences in MCID achievement rates for any clinical metric between groups. Radiographically, C2–C7 lordosis and SVA were similar between the groups. Although the overall rate of mechanical complications did not differ significantly in the matched cohort, subanalysis revealed that bilateral UVF was associated with a higher incidence of pseudarthrosis compared to the No UVF group (17.9% vs. 5.5%; p = 0.017)

Conclusion:
Adding UVF to ACDF does not provide additional long-term clinical benefits or improve MCID achievement.

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Furthermore, it may increase early postoperative arm pain and the risk of pseudarthrosis, particularly when performed bilaterally. Surgeons should carefully weigh the potential for increased mechanical complications against the lack of long-term clinical superiority when considering UVF

Characteristics		UVF (n = 85)	No UVF (n = 85)	*P*-value
Radiographic outcomes				
C2–7 lordosis	Preoperative	5.43 ± 12.37	5.66 ± 10.89	0.897
	Postoperative	7.05 ± 10.94	6.90 ± 8.04	0.914
	Final	9.88 ± 10.21†,‡	8.90 ± 10.13†,‡	0.529
C2–7 SVA	Preoperative	17.78 ± 10.08	19.62 ± 9.53	0.223
	Postoperative	18.46 ± 8.14	20.07 ± 9.16	0.228
	Final	18.35 ± 10.21	20.09 ± 9.41	0.250
Complications				
Pseudarthrosis	Final	6 (7.1%)	6 (7.1%)	1.000
Subsidence	Final	1 (1.2%)	6 (7.1%)	0.117
Loss of lordosis	Final	13 (15.3%)	17 (20.0%)	0.547
Revision	After final	4 (4.7%)	5 (5.9%)	1.000
Patients with any mechanical complication		20 (23.5%)	25 (29.4%)	0.487

UVF, uncovertebral foraminotomy; SVA, sagittal vertical axis;

* Statistically significant difference between the two groups (p <0.05).

† Statistically significant change compared to the preoperative measurement.

‡ Statistically significant change compared to the postoperative measurement.

Radiographic outcomes

265. Comparison of Clinical and Radiographic Outcomes between Subaxial Pedicle Screws and Lateral Mass Screws in Cervical Deformity Surgery

Anthony L. Mikula, MD; Rahul Kumar, MD, PhD; Darryl Lau, MD; Jeffrey Mullin, MD; Nikita Lakomkin, MD; Justin K. Scheer, MD; Renaud Lafage, MS; Virginie Lafage, PhD; Khaled M. Kebaish, MD; Eric O. Klineberg, MD; Gregory M. Mundis Jr, MD; Alan H. Daniels, MD; Robert K. Eastlack, MD; Richard Hostin, MD; Jeffrey Gum, MD; Brandon B. Carlson, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Munish C. Gupta, MD, MBA; Han Jo Kim, MD; Michael P. Kelly, MD; Lawrence G. Lenke, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; International Spine Study Group

Hypothesis:
Subaxial pedicle screws are associated with a greater magnitude of radiographic correction compared to lateral mass screws without a difference in perioperative complications.

Design:
Retrospective review of a prospective multicenter cervical adult spinal deformity database.

Introduction:
The impact of subaxial pedicle screws on radiographic outcomes and perioperative complications compared to lateral mass screws for cervical deformity surgery is not well understood.

Methods:
Patients undergoing cervical deformity surgery with subaxial pedicle screws placed at the C3-C6 levels were compared to those who had lateral mass screws. Patients who had a mix of both screw types from C3-C6 were excluded. The primary outcome measures were radiographic parameters at first follow up and complications. Analysis of covariance controlled for key covariates to isolate the impact of subaxial pedicle screws versus lateral mass screws. No minimum follow-up period was required to capture all screw-placement related complications.

Results:
A total of 232 patients were included, with a median age of 65 and 55% were female. Fifty-one patients (22%) underwent subaxial pedicle screw placement. After controlling for baseline radiographic parameter value, construct length, three column osteotomy, posterior column osteotomy, previous cervical spine surgery, and surgical approach, subaxial pedicle screws resulted in a greater degree of radiographic correction including C2 tilt by 2° (p=0.02), C2-C7 sagittal vertical axis (SVA) by 6mm (p=0.01), C2-T3 SVA by 10mm (p=0.01), C7-S1 SVA by 20mm (p=0.03), and T1 slope by 6° (p=0.01). There was no difference between subaxial pedicle screw and lateral mass screw patients in any of the complications, including instrumentation failure, neurologic deficit, operative complications, and radiographic complications. Specifically, subaxial pedicle screw placement did not cause any strokes or vascular injuries.

Conclusion:
Subaxial pedicle screws are associated with a greater magnitude of radiographic correction compared to lateral mass screws without a difference in complication rate. Cervical deformity surgeons should consider subaxial pedicle screws for cases that demand a high degree of sagittal plane correction.

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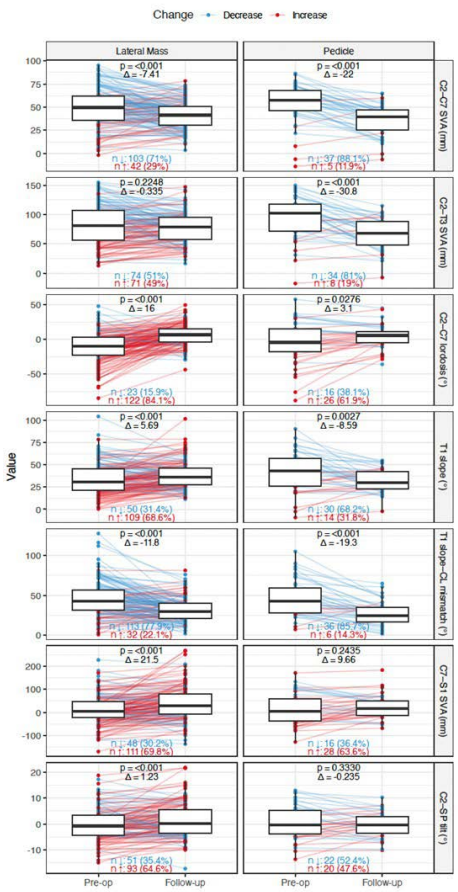

266. Clinical Efficacy of Concave-Side Distraction in the Treatment of Congenital Cervical Scoliosis

Dazhao Tie, MD; Feifei Zhou, MD

Hypothesis:
Concave-side distraction (CSD) provides effective, durable correction of congenital cervical scoliosis (CCS) while reducing neurovascular risk; corrective efficiency is highest at the craniovertebral junction (CVJ).

Design:
Retrospective study of CSD-based strategies applied at two anatomic regions (CVJ and subaxial/CTJ)

Introduction:
CCS correction is limited by vertebral artery proximity and the morbidity of extensive osteotomy or hemivertebra resection. We developed a "valley-fill" strategy that restores concave-side length using patient-specific spacers. This represents the largest known surgical cohort of congenital cervical scoliosis worldwide.

Methods:
We retrospectively reviewed 69 consecutive patients who underwent surgical correction for congenital cervical scoliosis (CCS) at a single tertiary referral center between December 2009 and January 2023. Inclusion criteria were CCS with a coronal Cobb angle >10° and definitive surgery. The CVJ cohort included 25 patients who underwent concave-side distraction (CSD)–based procedures, with outcomes focused on the CVJ structural Cobb angle (SCA). The subaxial/cervicothoracic (CTJ) cohort comprised 44 patients treated with subaxial CSD.

Results:
In the CVJ cohort, concave-side distraction achieved substantial and durable coronal correction, with the structural Cobb angle (SCA) improving from 30.75°±13.09° preoperatively to 4.30° early postoperatively (84% correction) and to 3.00° at final follow-up (88% correction). Mean operative time was 473.74±134.29 minutes, and mean estimated blood loss was 336.11±166.52 mL. In the subaxial and cervicothoracic (CTJ) cohort, mean SCA improved from 33.7°±14.1° to 12.8°±11.4° postoperatively (66.7% correction) and was maintained at final follow-up (12.5°±11.0°). Mean operative time and estimated blood loss were 466.6±118.5 minutes and 321.1±209.8 mL, respectively. Across both cohorts, the most common complication was transient C5 palsy (CVJ: 5; subaxial/CTJ: 4), with full recovery within six months. Two cases of CVJ spacer subsidence occurred without neurological sequelae and were managed conservatively, with no impact on final radiographic outcomes.

Conclusion:
Concave-side distraction offers a reconstructive alternative to resection-based CCS correction, enabling concave-side length restoration and coronal realignment with low catastrophic neurovascular risk.

267. The Improvement of 3D-printed Titanium Cage Used in Atlantoaxial Lateral Joints on Cervical Realignment in Atlantoaxial Dislocation

Qixin Liu, MS; Junlong Zhong, MD, PhD; Zhenhai Zhou, MD, PhD; Qin Wu, MS; *Kai Cao, MD, PhD*

Hypothesis:
Three D-printed cage used in the atlantoaxial lateral joint can improve the cervical sagittal realignment in atlantoaxial dislocation.

Design:
Cohort study.

Introduction:
This study is to investigate the effects of using 3D-printed titanium cage in the atlantoaxial lateral joints on cervical sagittal realignment in atlantoaxial dislocation surgery compared with conventional Harms rod-screw system without cage.

Methods:
Seventeen atlantoaxial dislocation Pts treated with

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3D-printed cage (Cage group) with a 1:1 matched Pts without cage (Non-cage group) were collected during the same period. Preoperative, last follow-up cervical upright lateral radiographs were collected. Cervical sagittal parameters including slope of Frankfort horizontal line (sFH), orbital tilt (OrT), occipital incidence (OI), occipital slope (OS), cervical sagittal vertical axis (cSVA), occiput-C1 Cobb angle (O-C1 CA), occiput-C2 Cobb angle (O-C2 CA), C1-C2 Cobb angle (C1-C2 CA), C2-7 Cobb angle (C2-7 CA), T1 slope (T1s), thoracic inlet angle (TIA), and neck tilt (NT) were measured and compared between two groups.

Results:
Total 34 Pts were included in this study with 1:1 matched in two groups. The average operative time and blood loss were more in cage group but with no significant difference. The gender, age, hospital stay, all preoperative cervical sagittal parameters and intraoperative complications were not significant different between two groups. Solid bone fusion could be observed in all Pts in 3 mons after surgery. Cervical alignments were improved in all Pts at two groups after surgery, However, OrT, O-C1 CA, O-C2 CA, C2-7 CA and T1S were significantly improved more in cage group. The values of ΔsFH, ΔOrT, ΔO-C1 CA, ΔO-C2 CA, ΔC2-7 CA reflecting the postoperative improvement of cervical alignments compared with the preoperative also significantly changed more in cage group.

Conclusion:
In the surgical treatment of atlantoaxial dislocation, the placement of a 3D-printed titanium cage between the atlantoaxial lateral mass joints did not increase the surgery related complications. However, it did significantly realign the cervical spine better compared to the conventional Harm screw-rod system without cage through improving the value of atlantoaxial regional alignment.

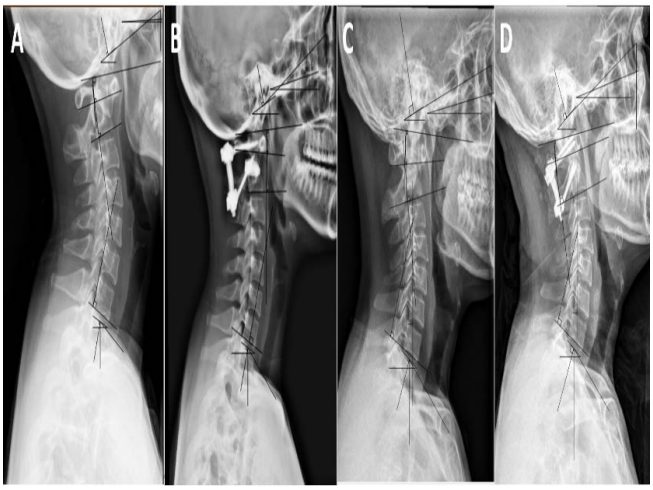

Fig.1, Lateral X-rays of Pts with atlantoaxial dislocation at preop. (A,C) and at final F/U with 3D-printed cage (B) or without (D).

268. Beyond the Cervicothoracic Junction: Proximal Thoracic Lower Instrumented Vertebra Optimizes Sagittal Balance in Adult Cervical Deformity Patients

James Y. Chen, BA; Justin L. Reyes, MS; Thomas Hunt, BA; Jacob Okulewicz, BS; Demetrius Bryson, BS; Shonik Ganjoo, BS; Hamzah Abbas, BS; Kenji Kaproth, BS; Joseph M. Lombardi, MD; Ronald Lehman Jr, MD; Daniel Riew, MD; Zeeshan M. Sardar, MD

Hypothesis:
Compared to patients fused to the cervicothoracic junction (CTJ), those fused to the proximal thoracic spine (PTS) have more significant baseline deformities but comparable outcomes.

Design:
Retrospective comparative cohort

Introduction:
Prior studies on the selection of the lowest instrumented vertebra (LIV) in adult cervical deformity have primarily compared fusion lengths with respect to the CTJ (C7-T1). Few studies have characterized the factors influencing LIV selection, particularly to the CTJ or the PTS.

Methods:
We reviewed all adult cervical deformity patients with 2+ year follow-up who underwent 4+ levels of posterior cervical fusion (PCF, with or without anterior fusion) at a single center. We included patients with: C2-C7 sagittal vertical axis (cSVA) > 30 mm, T1 slope (T1S) > 30°, and/or cervical mismatch (T1S+CSA [cervical sagittal angle]) > 25°. Patients were divided into CTJ (C7-T1 LIV) and PTS (T2-T4 LIV) groups. Wilcoxon rank-sum test and Fisher's exact tests were used with significance set to P<0.05.

Results:
26 patients were included (mean age 58.5±15.4 years; 35% female), with 13 in the CTJ group and 13 in the PT group. Compared to the CTJ group, preoperatively, the PTS group had more kyphotic cervical spines (CK; CSA +18.8° vs. -3.0°, P=0.046), greater C2 slope (C2S; 51.9° vs. 33.1°, P=0.016), and greater cSVA (59.9 vs. 42.9 mm, P=0.040). Immediate post-operative T1S was greater in the CTJ group (35.6° vs. 24.8°, P=0.027), while the PTS group had greater correction in C2S (-33.1° vs. -11.3°, P=0.018) and cSVA (-27.3 vs. -6.1 mm, P=0.006). At final follow-up, cSVA correction remained greater in the PTS group while the CTJ group had slight worsening of alignment (-19.4 vs. 2.0 mm, P=0.012). Rates of complications, mechanical failures, and revisions were similar post-operatively.

Conclusion:
Patients fused to the proximal thoracic spine (PTS) had greater pre-operative cervical kyphosis (CK) and greater cervical sagittal imbalance than those fused to the cervicothoracic junction (CTJ), yet the PTS group achieved better maintenance of cervical alignment at final fol-

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low-up. This is the first single-center study supporting longer fusion constructs terminating in the PTS for these complex cervical deformities.

	LIV Anatomical Region		
	CTJ (C7-T1) N = 13	PTS (T2-T4) N = 13	*P*-value
Age (years, mean ± SD)	62.7 ± 9.2	54.2 ± 19.3	0.46
Female (N, %)	5 (38%)	4 (31%)	1.00
BMI (kg/m², mean ± SD)	29.5 ± 7.8	28.3 ± 6.5	0.83
Comorbidities (N, %)			
Osteoporosis	1 (7.7%)	1 (7.7%)	1.00
Smoking History	8 (62%)	4 (31%)	0.24
Prior Cervical Fusion (N, %)	9 (69%)	5 (38%)	0.24
Posterior Levels Fused (mean ± SD)	5.2 ± 0.9	6.5 ± 1.6	**0.021**
Anterior-Posterior Fusion (N, %)	8 (62%)	8 (62%)	1.00
Surgical Time (minutes, mean ± SD)	248.3 ± 82.6	309.2 ± 162.1	**0.031**
Estimated Blood Loss (mL, mean ± SD)	175.0 ± 77.7	309.2 ± 110.0	**0.003**
Complications (N, %)			
Wound Complications	0	1 (7.7%)	1.00
Any Mechanical Complications	0	2 (15%)	0.48
Proximal Junctional Kyphosis (PJK)	0	0	1.00
Distal Junctional Kyphosis (DJK)	0	0	1.00
Pseudoarthrosis	1 (7.7%)	1 (7.7%)	1.00
Revision	2 (15%)	1 (7.7%)	1.00
Radiographic Parameters (mean ± SD)			
Baseline Pre-Operative			
C2-C7 Cervical Sagittal Angle (CSA, °)	-3.0 ± 14.6	18.8 ± 27.8	**0.046**
C2 Slope (C2S, °)	33.1 ± 15.5	51.9 ± 21.6	**0.016**
T1 Slope (T1S, °)	34.8 ± 10.0	30.8 ± 13.3	0.58
T1S+CSA (°)	34.8 ± 15.3	48.4 ± 22.0	0.11
C2-C7 Sagittal Vertical Axis (cSVA, mm)	42.9 ± 15.3	59.9 ± 20.3	**0.040**
Immediate Post-Operative			
CSA (°)	-9.4 ± 13.7	-6.8 ± 15.1	0.81
Δ CSA (°)	-9.4 ± 18.1	-24.9 ± 26.4	0.15
C2S (°)	22.2 ± 12.0	18.8 ± 13.7	0.72
Δ C2S (°)	-11.3 ± 14.2	-33.1 ± 24.0	**0.018**
T1S (°)	35.6 ± 10.5	24.8 ± 11.0	**0.027**
Δ T1S (°)	0.7 ± 11.1	-3.3 ± 10.1	0.31
T1S+CSA (°)	24.5 ± 11.7	18.4 ± 12.6	0.37
Δ T1S+CSA (°)	-13.3 ± 15.6	-27.7 ± 29.3	0.22
cSVA (mm)	37.9 ± 12.6	32.3 ± 19.0	0.57
Δ cSVA (mm)	-6.1 ± 12.8	-27.3 ± 18.2	**0.006**
Final (2+ Year) Follow-up			
CSA (°)	-11.9 ± 13.9	-4.6 ± 9.7	0.22
Δ CSA (°)	-11.6 ± 17.6	-22.7 ± 27.9	0.47
C2S (°)	25.3 ± 12.2	24.0 ± 15.1	0.94
Δ C2S (°)	-8.1 ± 14.6	-27.8 ± 28.6	0.05
T1S (°)	36.6 ± 6.8	32.0 ± 16.3	0.77
Δ T1S (°)	2.2 ± 9.5	3.0 ± 13.3	0.98
T1S+CSA (°)	24.7 ± 10.8	26.3 ± 15.4	0.25
Δ T1S+CSA (°)	-7.5 ± 16.9	-22.4 ± 32.1	0.36
cSVA (mm)	45.9 ± 13.9	40.2 ± 19.5	0.76
Δ cSVA (mm)	2.0 ± 12.3	-19.4 ± 23.5	**0.012**

Table 1: Patient Characteristics and Outcomes Stratified by LIV Anatomical Region

269. A Novel Morphology-Based Classification for Congenital Cervical Scoliosis: Development, Reliability, and Surgical Application

Feifei Zhou, MD

Hypothesis:
A classification system based on deformity-driving anatomical units can reliably characterize congenital cervical scoliosis (CCS) and guide surgical strategy.

Design:
Retrospective cohort study with reliability analysis.

Introduction:
Congenital cervical scoliosis (CCS) is a rare and surgically challenging deformity. Unlike thoracolumbar congenital scoliosis, CCS lacks a dedicated classification that reflects its unique anatomy and informs surgical planning. Existing systems are not designed for the cervical spine and provide limited guidance for operative decision-making. Using the largest surgical CCS cohort to date, we developed a morphology-based classification focused on deformity-driving units and evaluated its reliability and clinical utility.

Methods:
Seventy-five patients undergoing surgical correction for CCS were retrospectively reviewed. A deformity-driving unit was defined as a malformed vertebra or fused vertebral complex responsible for a coronal Cobb angle >10°. Based on the number and composition of these units, CCS was classified into three types and five subtypes. Ten fellowship-trained spine surgeons independently classified all cases twice, with a three-week interval. Interobserver and intraobserver reliability were assessed using Fleiss' and Cohen's kappa, respectively. Surgical strategies included convex-side resection or concave-side distraction. Radiographic correction, operative data, and complications were analyzed.

Results:
Thirteen patients were classified as Type 1, 17 as Type 2a, 25 as Type 2b, 9 as Type 3a, and 11 as Type 3b. Interobserver reliability was substantial (mean κ = 0.79), as was intraobserver repeatability (mean κ = 0.81). Mean operative time was 472 ± 126 minutes, longest in Type 3b ($P < 0.05$). Median estimated blood loss was 400 mL without significant intergroup differences. Median Cobb angle improved from 27.5° preoperatively to 8.3° postoperatively and 8.1° at final follow-up ($P < 0.001$). Correction rates differed significantly among subtypes, with Type 1 achieving the highest correction.

Conclusion:
The PUTH classification is the first morphology-based system specifically developed for CCS. It demonstrates high reproducibility and provides a practical framework for surgical decision-making based on deformity-driving anatomy.

270. Difference of Characteristics and Outcomes Between the Advanced Cervical Deformity: Global Cervical Kyphosis vs. Preserved Cervical Lordosis Morphotypes based on the Subaxial Cervical Alignment

Ahmed Sulieman, MD; Tej Azad, MD; Virginie Lafage, PhD; Robert K. Eastlack, MD; Jeffrey Gum, MD; Munish C. Gupta, MD, MBA; Richard Hostin, MD; Michael P. Kelly, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Darryl Lau, MD; Gregory M. Mundis Jr, MD; Peter G. Passias, MD; Paul Park, MD; Frank Schwab, MD; Themistocles S. Protopsaltis, MD; Christopher P. Ames, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Khaled M. Kebaish, MD; Sang Hun Lee, MD, PhD; International Spine Study Group

Hypothesis:
Advanced cervical deformity (CD) has different clinical

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characteristics and surgical outcomes depending on the subaxial cervical spine alignment.

Design:
Retrospective analysis of a multicenter prospective CD database.

Introduction:
Subaxial cervical spine is not always kyphotic in advanced CD. Global Cervical Kyphosis (GK) and Preserved Lordosis (PL) type are distinct morphotypes but comparative data remain limited.

Methods:
Adults undergoing CD surgery were grouped as PL(T1 slope(T1S) > C2 Slope(C2S), T1S> 35°) vs GK(T1S < C2S). Focal or compensated deformity with C2-7 SVA <4cm were excluded. Demographics, surgical characteristics, radiographic parameters, patient reported outcomes (PROs), and complications were compared.

Results:
The cohort included 110 patients (PL n=55; GK n=55). At baseline, PL showed preserved cervical lordosis (CL:18 vs −22°), higher thoracic kyphosis (TK:54 vs 38°), higher T1S (56 vs 23°), more prior thoracolumbar (TL) fusion (51 vs. 25%) and greater sagittal malalignment (C2–7 SVA 54 vs 46 mm; C2 pelvic angle 26 vs 20°; all p<0.01), but lower T1S–CL (38 vs 44°, p=0.04) than GK. GK more often had upper cervical UIVs (65 vs 94%) and PL more often had mid or lower thoracic LIVs (81 vs 23%, both p<0.01). PL also had more three-column osteotomies (55 vs 25%, p<0.01) and higher EBL (1000 vs 400mL, p=0.01). There was no significant differences in baseline, 6-month, or 1-year PROs. Overall surgical complications and revision rates were similar, while distal junctional kyphosis (DJK) was higher in GK (38vs 15%, p<0.01) after excluding cases fused to the pelvis. On multivariable analysis, deformity type was not associated with surgical complications (OR 1.3, p=0.71) or revisions (OR 1.5, p=0.63).

Conclusion:
Advanced CD can be categorized with subaxial cervical alignment. GK and PL are distinct subtypes with different baseline alignment and operative strategies. The PL demonstrated greater baseline TL malalignment and surgical magnitude, and the GK showed greater cervical malalignment. Revisions and complications were similar, while DJK was more common in GK. These findings need to be considered in preoperative planning and patient counselling.

Table 1: Comparison of baseline radiographic data, surgical characteristics and complications between patients with Preserved Lordosis deformity versus Global Cervical Kyphosis deformity

Baseline	Preserved Lordosis (n=55)	Global Cervical Kyphosis (n=55)	P value
C2-C7 Coronal Cobb	3.51 ± 8.8	2.06 ± 10.5	0.459
PI-LL Mismatch	4.07 ± 17.1	3.12 ± 13.7	0.755
T4-T12 Kyphosis	-53.62 ± 18.1	-37.70 ± 13.8	**<0.001**
C7-S1 SVA	37.16 ± 72.7	-19.57 ± 58.6	**<0.001**
T4 Pelvic Angle	14.13 ± 11.7	11.28 ± 9.1	0.166
T1 Pelvic Angle	19.15 ± 11.8	14.33 ± 9.3	**0.024**
C2 Pelvic Angle	26.49 ± 11.7	20.26 ± 9.0	**0.005**
C2-C7 Sagittal Cobb Angle	18.26 ± 16.3	-21.54 ± 18.7	**<0.001**
T1S-CL mismatch	37.96 ± 13.8	44.06 ± 17.0	**0.041**
C2-C7 SVA	54.07 ± 13.2	46.48 ± 14.3	**0.005**
T1 Slope	56.22 ± 13.6	22.52 ± 9.0	**<0.001**
C2 Slope	37.66 ± 13.9	44.28 ± 16.3	**0.024**
McGregor Slope	5.00 ± 13.9	2.66 ± 10.4	0.395
Surgical Variables	**Preserved Lordosis (n=55)**	**Global Cervical Kyphosis (n=55)**	**P value**
Estimated Blood Loss, cc	1000 (375–1400)	400 (200–1200)	0.014
Operative time, minutes	352 (245–520)	368 (247–473)	0.507
Levels fused	11 (8–15)	7 (7–9)	<0.001
Length of stay, days	6 (4–9)	6 (4–8)	0.569
Approach			<0.001
Posterior only	44 (80.00)	21 (38.18)	
Anterior - posterior	8 (14.55)	27 (49.09)	
Three column osteotomy	30 (54.55%)	14 (25.45%)	0.003
Complications	**Preserved Lordosis (n=55)**	**Global Cervical Kyphosis (n=55)**	**P value**
Surgical Complications	18 (32.73)	23 (41.82)	0.324
Medical Complications	13 (23.64)	7 (12.73)	0.138
Neurologic Complications	11 (20.00)	9 (16.36)	0.621
Revision Surgery	7 (12.73)	8 (14.55)	0.781
Deep Surgical Site Infection	2 (3.64)	1 (1.82)	>0.99
Superficial Surgical Site Infection	2 (3.64)	1 (1.82)	>0.99
C5 Motor Deficit	0 (0.00)	3 (5.45)	0.243
Sensory Deficit	3 (5.45)	2 (3.64)	>0.99
Radiculopathy	2 (3.64)	3 (5.45)	>0.99
Spinal Cord Injury	1 (1.82)	0 (0.00)	>0.99
Motor Deficit	7 (12.73)	4 (7.27)	0.527
Dural Tear	0 (0.00)	3 (5.45)	0.243
Adjacent Segment Disease	1 (1.82)	0 (0.00)	>0.99
Distal Junctional Kyphosis	8 (14.55)	21 (38.18)	0.005

Values represent mean ± SD, median (IQR) or n (%). PI-LL: Pelvic Incidence -Lumbar Lordosis; SVA: Sagittal Vertical Axis; T1S-CL: T1 Slope-Cervical Lordosis.

271. Cervical Motion Imbalance Is Associated with Postoperative Cervical Kyphosis Progression After Posterior Decompression: A Prospective Cohort Study

Kazuki Takeda, MD, PhD; Satoshi Suzuki, MD, PhD; Takahito Iga, MD, PhD; Toshiki Okubo, MD, PhD; Masahiro Ozaki, MD, PhD; Narihito Nagoshi, MD, PhD; Morio Matsumoto, MD, PhD; Masaya Nakamura, MD, PhD; Kota Watanabe, MD, PhD

Hypothesis:
Preoperative flexion-extension imbalance and anterior sagittal translation (C2-C7 and C7-S1 SVA) increase the risk of postoperative cervical kyphosis progression.

Design:
Prospective cohort study

Introduction:
Posterior decompression is effective for degenerative cervical disease, yet postoperative cervical kyphosis progression remains a clinically relevant complication. The contribution of whole-spine sagittal alignment, beyond cervical alignment and motion, remains unclear.

Methods:
A total of 131 patients who underwent posterior decompression with ≥2-year follow-up were prospectively enrolled. Kyphotic deformity progression was defined as a ≥5° decrease in the neutral C2–7 angle at 2 years postoperatively. Preoperative cervical parameters included the C2–7 angle, flexion and extension range of motion (ROM), C2–7 SVA, and T1 slope. Global sagittal

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parameters included T2-5 TK□T5-12 TK□T2-12 TK□SS□PT□PI□LL□PI-LL□C7 SVA. Patients were divided into progression (K) and non-progression (N) groups. Radiographic parameters were compared, and multivariate logistic regression was performed.

Results:
Kyphotic deformity progression was observed in 31 patients (24%); one patient required revision surgery for kyphosis correction. There were no differences in age, sex, diagnosis, surgical procedure, or number of decompressed levels between two groups. The K group showed greater preoperative flexion ROM (27±9° vs. 23±10°, p=0.03), smaller extension ROM (11±6° vs. 14±8°, p=0.01), and larger C2–7 SVA (33±18 mm vs. 24±14 mm, p<0.01). The K group also demonstrated a larger preoperative C7 SVA (44±46 mm vs. 25±46 mm, p=0.049), while other global sagittal parameters were not different between two groups. Multivariate analysis identified flexion and extension ROM as independent risk factors.

Conclusion:
In this prospective cohort, cervical kyphosis progression occurred in 24% at 2 years after posterior decompression. A flexion-dominant, extension-limited preoperative motion pattern independently predicted progression; adding dynamic cervical radiographs to standing full-length sagittal assessment may improve risk stratification and surgical planning.

272. Early Treatment of Cervical Myelopathy with Multilevel Fusion Achieves a Greater Clinically Meaningful Improvement Compared to Delayed Treatment

Gracie Garcia, MD; Izza Tahir, MBBS; Catherine Ravikumar, MS; Erica F. Bisson, MD; Mohamad Bydon, MD; Anthony L. Asher, MD; Paul Kim, MD; Eric A. Potts, MD; Vincent J. Alentado, MD; Kevin T. Foley, MD; Michael Y. Wang, MD; KaiMing G. Fu, MD, PhD; Michael S. Virk, MD, PhD; Christopher I. Shaffrey, MD; Oren N. Gottfried, MD; John J. Knightly, MD; Scott Meyer, MD; Paul Park, MD; Cheerag D. Upadhyaya, MD; Andrew K. Chan, MD; Luis M. Tumialan, MD; Dean Chou, MD; Juan S. Uribe, MD; Jay D. Turner, MD, PhD; Timothy J. Yee, MD; Regis W. Haid, MD; Praveen V. Mummaneni, MD; Chun-Po Yen, MD

Hypothesis:
Longer preoperative symptom duration is associated with delayed achievement of clinically meaningful improvement after ≥3-level fusion for cervical spondylotic myelopathy (CSM).

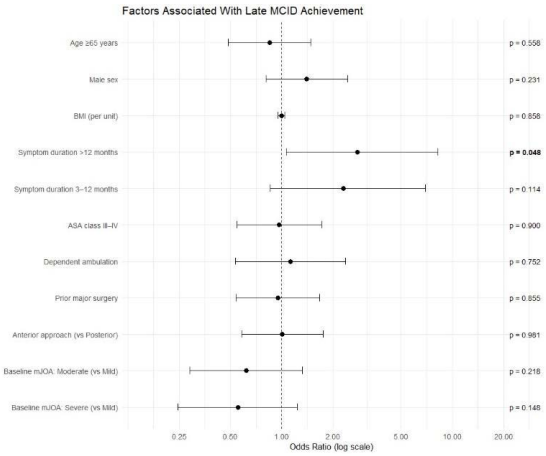
Design:
Post hoc analysis of a prospective multicenter study involving 1,085 patients with >80% follow-up at 5 years.

Introduction:
Multilevel cervical fusion for CSM improves patient-reported outcomes; however, recovery timing varies. While many patients improve early, others experience delayed recovery. Identifying determinants of recovery kinetics may inform counseling and operative decision-making.

Methods:
We prospectively collected data on 1,085 patients undergoing surgical treatment for CSM through a multicenter study group. Patients undergoing ≥3-level cervical fusion (anterior and/or posterior) with baseline and longitudinal Neck Disability Index (NDI) follow-up were included (N=267, 98.6% follow-up at 5 years). Meaningful improvement was defined using established NDI minimal clinically important difference (MCID) thresholds. Early improvement was defined as MCID attainment by 3 months postoperatively and late improvement as attainment between 3 months and 5 years. Multivariable logistic regression identified factors independently associated with late improvement.

Results:
Among patients achieving MCID after ≥3-level cervical fusion (N=267), early (≤3 months) and late (>3 months through 5 years) recovery patterns were observed. Baseline demographic, clinical, and surgical characteristics were similar between groups. On multivariable analysis, myelopathy symptoms ≤12 months was associated with reaching MCID for NDI by 3 months postoperatively whereas symptom duration >12 months was associated with delayed improvement (mean 25 ±18 months; OR 2.77, 95% CI 1.06-8.22; p=0.048). Age, baseline mJOA, ambulatory status, comorbidity burden, and surgical approach were not associated with delayed recovery.

Conclusion:
Among patients achieving clinically meaningful improvement following multilevel cervical fusion for CSM, intervention within 12 months of myelopathy symptoms is associated with earlier recovery (MCID for NDI by 3 months postop). Patients with symptoms for >12 months required, on average, 2 years to reach MCID. Surgery soon after myelopathy symptom onset improves recovery kinetics.



Factors Associated with Late MCID Achievement

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273. Benefits to Subaxial Cervical Pedicle Screws for Cervical Deformity Surgery: Assessment of Correction, Mechanical Failure and Revision Surgery

Darryl Lau, MD; Sean N. Neifert, MD; Hammad Khan, MD; Justin S. Smith, MD, PhD; Anthony L. Mikula, MD; Justin K. Scheer, MD; Khaled M. Kebaish, MD; Sang Hun Lee, MD, PhD; Munish C. Gupta, MD, MBA; Shay Bess, MD; Virginie Lafage, PhD; Christopher I. Shaffrey, MD; Eric O. Klineberg, MD; Themistocles S. Protopsaltis, MD; Peter G. Passias, MD; Gregory M. Mundis Jr, MD; Robert K. Eastlack, MD; Frank Schwab, MD; Han Jo Kim, MD; Christopher P. Ames, MD; International Spine Study Group

Hypothesis:
Use of subaxial cervical pedicle screws in cervical deformity (CD) is associated with improved correction and lower revision rates

Design:
Retrospective review

Introduction:
Strength of posterior cervical fixation is often the limiting factor when trying to perform corrective maneuvers especially with lateral mass screws. Pedicles screws have proven to be stronger but there are inherent risks. This study aims to assess the utility of subaxial pedicle screws for primary CD and multiregional CD.

Methods:
A multicenter prospective database of adult CD patients was queried. Patients were split into two groups: primary CD (T1 slope<30° and C2 slope>20°) and multiregional CD (C2 slope>20° and T1 slope≥30°). The utility of subaxial pedicle screw utilization on correction, mechanical failure (pseudarthrosis, junctional or instrumentation), and revision surgery was examined using univariate analysis.

Results:
A total of 201 patients were identified: 75 (37.3%) primary CD and 126 (62.7%) multiregional CD, 50 (24.9%) with pedicle screws and 151 (75.1%) with lateral mass screws. Primary CD preoperative alignment: cSVA (4.1 cm), CL (24.8°), C2-slope (40°), and T1-slope (18.7°) and multiregional CD preoperative alignment: cSVA (6.0 cm), CL (4.8°), C2-slope (53.6°), and T1-slope (49.3°). With similar preoperative deformity, use of pedicle screws (vs. lateral mass screws) for both CD subtypes was significantly associated with shorter operative time (primary CD: 260 vs 459 min, p<0.001 and multiregional CD: 280 vs 471 min, p<0.001), less anterior surgery (primary CD: 18.8% vs. 72.9%, p<0.001 and multiregional CD: 0.0% vs. 33.7%, p<0.001), and fewer anterior interbodies (primary CD: 0.5 vs 2.5, p=0.003 and multiregional CD: 0 vs 1.6, p<0.001). Similar correction was achieved when comparing anterior-posterior surgery vs. posterior-only with pedicle screws. Overall rate of mechanical failure and revision at 1-year were as follows: primary CD (10.7% and 6.7%) and multiregional CD (5.6% and 6.3%). Pedicle screws were not associated with mechanical complications or revision surgery for both groups.

Conclusion:
Regardless of CD subtype, subaxial cervical pedicle screws may offer the ability to achieve adequate correction with decreased need for additional anterior approaches and without compromise of long-term outcomes.

274. PROMIS Anxiety Scale is Reflective of Suicide Risk in Adolescents with Spine Concerns

Karina A. Zapata, PhD, DPT; Emily Gale, PhD; Caroline Roberts, PhD; Paloma Merida, BA; Chan-Hee Jo, PhD; Megan Johnson, MD; Jaysson T. Brooks, MD; *Brandon A. Ramo, MD*

Hypothesis:
Elevated Patient-Reported Outcomes Measurement Information System (PROMIS) Anxiety is associated with a positive Ask-Suicide Screening Questions (ASQ) score.

Design:
cross-sectional survey

Introduction:
The relationship of suicide risk with anxiety in adolescents with spine concerns is unknown. The 4-item ASQ assesses suicide risk in youth. We evaluated 1) the responsiveness of PROMIS Anxiety with the ASQ and 2) predictors of suicide risk in adolescents with spine concerns.

Methods:
8,089 adolescents (5,068 girls, 3,021 boys) ages 10-18 referred to a pediatric orthopedic institution for spine concerns who completed both the ASQ and PROMIS Pediatric Anxiety were retrospectively reviewed from 4/2021-6/2023. Positive ASQ scores (+ASQ: ≥1 yes response for suicide risk) were compared to negative ASQ scores (-ASQ). Elevated PROMIS anxiety was defined as scores ≥51 indicating ≥mild severity, a clinically meaningful distinction. Logistic regression followed by ROC analysis determined the PROMIS Anxiety threshold.

Results:
4.2% of adolescents with spine concerns had +ASQs (338/8,089). PROMIS Anxiety averaged mild severity (54) for +ASQs versus within normal limits (41) for -ASQs. Children with elevated (≥mild severity) PROMIS Anxiety scores had a 6-fold risk of a +ASQ than those with PROMIS Anxiety scores within normal limits (OR 6.35, 95% CI 5.07-7.99). Scoliosis was not associated with a +ASQ (4.4% with scoliosis [196/4,489]; 3.9% [98/2,528] with no structural diagnosis). However, larger coronal curves were associated with a +ASQ (OR 1.010, 95% CI 1.003-1.017). Multivariate analysis revealed older age (OR 1.09, 95% CI 1.03-1.15), female sex (OR 1.61, 95% CI 1.22-2.14), English vs Spanish speakers (OR 2.30, 95% CI 1.48-3.74), public vs private insurance type (OR 1.42, 95% CI 1.10-

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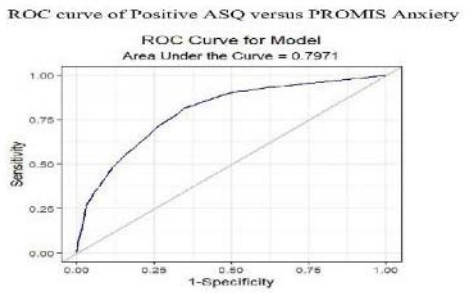
1.84), and increased PROMIS Anxiety scores (OR 1.11, 95% CI 1.10-1.12) were associated with a +ASQ. A PROMIS anxiety threshold of 44.5 (AUC=0.80) was associated with a +ASQ.

Conclusion:
Increased anxiety is clearly associated with suicide risk in youth with spine concerns, resulting in an acceptable AUC. PROMIS anxiety may be a readily available and useful clinical predictor of suicide risk in clinical settings that don't routinely screen for suicide risk, especially for girls who are disproportionately affected by scoliosis and stressful life events. Early intervention can potentially improve PROMIS anxiety scores, reflecting lower suicide risk.



275. Home-Based Halo Gravity Traction for Severe Pediatric Spinal Deformities Using a Novel Protocol

Lucas Piantoni, MD, PhD; Carlos A. Tello, MD, PhD; Eduardo Galaretto, MD; Rodrigo G. Remondino, MD

Hypothesis:
A home-based HGT management protocol would facilitate this preoperative stage without increasing complication rates, while achieving satisfactory correction and reducing costs.

Design:
Prospective cohort study

Introduction:
Conventional halo-gravity traction (HGT) for severe pediatric spinal deformities is usually performed in the hospital setting. After developing a structured protocol for preoperative home-based traction, we evaluated the safety and efficacy of this home HGT approach in children with severe spinal deformity.

Methods:
A treatment protocol for preoperative home-based HGT was developed for children with severe spinal deformity submitted to posterior spinal fusion. The protocol comprises two phases. Phase 1 (hospital, 3–5 days) includes halo placement and structured family training on pin-site care, weight progression, and neurological monitoring. Phase 2 (home) involves a gradual traction increase of weight, weekly clinical, neurological, nutritional, respiratory, and radiological assessments. We assessed: duration of traction, Cobb angle, complications, and adherence to the protocol. All variables were recorded by two specialist spine surgeons. The protocol was implemented and evaluated in a prospective cohort of patients with kyphoscoliosis > 90° (2020-2024). Inclusion criteria were age 5 to 18 years, adequate cultural and economic family support, and the ability to attend scheduled follow-up visits at the hospital.

Results:
Forty-three patients were initially evaluated; 40 completed the home-based HGT protocol. The mean age at the start of HGT was 12 years ± 2 months (5-18), and 67.5% were female. The mean pre-HGT scoliosis angle was 106°, with a mean angular correction of 25°. The mean duration of HGT was 14.7 weeks. Complications occurred in seven patients (17.5%), including six cases requiring halo or pin repositioning procedures (15%) and one superficial infection (2.5%). All patients were able to maintain their usual educational and social activities, and families continued their work routines.

Conclusion:
The home-based HGT protocol proved effectiveness, achieving results comparable to those in literature. It appears to be safe, and may provide psychosocial advantages together with a potential reduction in both hospital and family-associated costs. We recommend its use in carefully selected patients with adequate family support and sufficient educational and cultural resources.

276. Single-Stage En Bloc Spondylectomy via Rotated Prone Lateral Surgery: Bridging Anterior-Posterior Access Without Repositioning

Yu-Cheng Yeh, MD; Yung-Hsueh Hu, MD; Tsung-Ting Tsai, MD, PhD; Po-Liang Lai, MD

Hypothesis:
Rotated prone lateral surgery (RPLS) allows for a seamless transition from staged surgeries to a single-stage en bloc spondylectomy by bridging the anterior and posterior corridors without patient repositioning.

Design:
Retrospective case series and technical note.

Introduction:
En bloc spondylectomy for complex thoracolumbar tumors (WBB type 3/5) traditionally requires staged procedures or cumbersome intraoperative repositioning to manage the diaphragm, great vessels, and nerve roots. This study demonstrates how the rotated prone lateral technique bridges the gap between anterior release and posterior reconstruction, facilitating a transition toward a more efficient, single-stage surgical paradigm.

Methods:
We retrospectively reviewed 10 consecutive patients who

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underwent en bloc spondylectomy for metastatic thoracolumbar tumors (L1-L4) using the RPLS approach. Patients were positioned prone on a radiolucent Jackson table rotated 45 degrees, utilizing gravity to retract peritoneal contents. This orientation provides simultaneous access to the retroperitoneal corridor for vessel mobilization and the posterior column for instrumentation. Surgical metrics, margins, and complications were analyzed.

Results:
he cohort included 10 patients (mean age: 59.7 ± 9.3 years) with oligoprogression metastatic thoracolumbar tumors. The procedures involved levels from L1 to L4, requiring WBB type 3 or 5 resections. All patients successfully underwent single-stage en bloc resection without intraoperative repositioning. The mean operative time was 7 hours 19 minutes ± 2 hours 55 minutes, and the mean estimated blood loss was 1117 ± 899 ml. The rotated prone position allowed for simultaneous approach and manipulation for en bloc resection of the spinal tumor. No major approach-related complications (e.g., bowel injury, major vascular injury) occurred, though one patient experienced root injury.

Conclusion:
Rotated prone lateral surgery represents a significant transition in complex tumor surgery. By bridging the anterior and posterior surgical corridors in a single stage, this technique eliminates the risks associated with repositioning and staged procedures. It offers a safe and ergonomic alternative for WBB type 3 and 5 tumors, reflecting the evolution toward integrated, simultaneous access in oncological spine surgery.

277. Robotic-Assisted Direct Pars Repair: An Innovative Minimally Invasive Technique

Vivien Chan, MD, MS; Samantha Snyder, BS; Paal Nilssen, BS; Prudhvi Kodali, BA; James Caruso, MD; Christopher Mikhail, MD; Kenneth D. Illingworth, MD; Corey T. Walker, MD; David L. Skaggs, MD, MMM

Hypothesis:
Robotic-assisted direct pars repair is safe and effective technique for treating spondylolysis

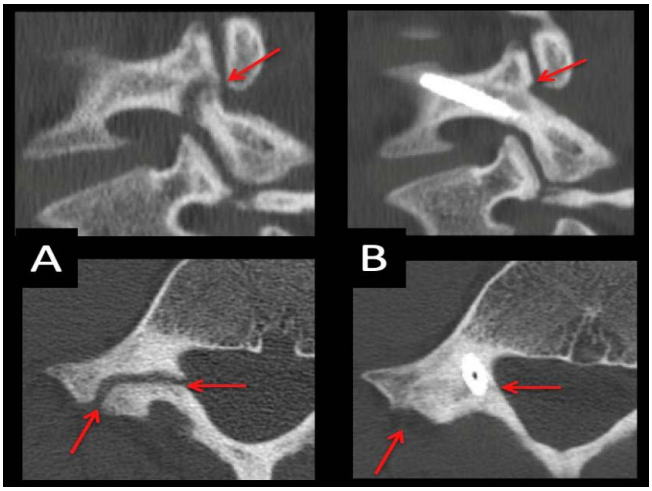
Design:
Case Series

Introduction:
Spondylolysis is the most common cause of low back pain in young athletes. Direct repair with robotic-assisted surgery could be less invasive and more precise than traditional techniques.

Methods:
We performed a single-center retrospective review of all patients with spondylolysis who underwent robotic-assisted direct pars repair from 2023-2025. The technique evolved to placing a reference array on the spinous process of the affected vertebra through a <2 cm midline incision, and screws were placed through a separate <2cm midline incision. Hydroxyapatite screws, usually 4.5mm x 40mm, were planned with navigation software. Screw position was confirmed with intra-operative fluoroscopy and EMG, and postoperative CT.

Results:
There were 32 patients (mean age 16 years, range 10-23) with 63 pars fractures. Mean spondylolysis gap size was 1.5 mm (range 0.0-7.7). Mean bilateral repair operative time was 138 minutes, and 28 patients (84%) were discharged same-day. Ten patients had bone grafting at initial surgery, and three patients (T2 STIR negative) underwent reoperation with bone grafting. Four cases (13%) had minor perioperative complications which resolved without intervention (guidewire breakage, anterior thigh pain/tightness, bilateral numbness/tingling/pain, seroma). There were no major complications or neurological injuries. At first post-operative follow-up (mean 22 days), 27 (84%) patients had resolution of pre-operative pain, 4 (12%) had improved pain, and 1(3%) had persistent pain. CT demonstrated complete union in 35 (60%), partial union in 23 (40%), no case of non-union, and correct screw location as planned 100%. Excluding one patient with an endplate fracture, 29 of 30 patients who were at least 10 weeks post-op were pain free and allowed to return to sports.

Conclusion:
This represents the largest reported case series of robotic-assisted direct pars repair for spondylolysis. The technique appears safe and effective, with high rates of pain resolution, accurate screw placement, and early return to athletics.



CT Scans: A. Pre-op, pars fracture (red arrows) B. 12 weeks post-op healed fracture. Professional dancer returned to dance, shared with patient consent.

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278. Evaluation of the Subaxial Cervical Spine Injury Classification Score in a Pediatric Population

Satchi Metaxas, BA; Mohammed Abbas, MD; Ian Fletcher, MD; Jacquelyn N. Valenzuela-Moss, MPH; Tyler Tetreault, MD; Michael J. Heffernan, MD; *Lindsay M. Andras, MD*

Hypothesis:
SLIC treatment recommendations for pediatric spinal injuries will closely predict treatment decisions in a spinal practice.

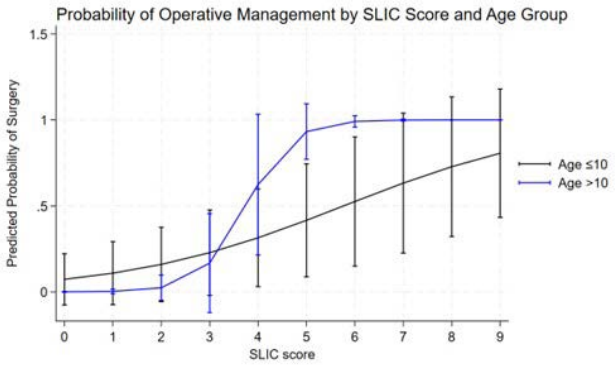
Design:
Single center, retrospective

Introduction:
The Subaxial Cervical Spine Injuries Classification (SLIC) score is commonly used to provide guidance on surgical versus conservative treatment in adults but remains largely unvalidated in the pediatric population.

Methods:
Retrospective study of patients under the age of 18 at a pediatric level one trauma center evaluated for traumatic subaxial cervical spinal injury between January 1, 2012, and June 1, 2025. Injuries were graded using the SLIC score. Agreement between SLIC score recommendations and management patients received was assessed. Overall agreement was calculated using misclassification rate, defined as the proportion of discordant cases. Median SLIC scores were compared between treatment groups using Wilcoxon rank-sum tests.

Results:
70 patients with mean age of 13.5 met the inclusion criteria. 20/70 (28.6%) were treated operatively, and 50/70(71.4%) were treated nonoperatively. The overall median SLIC score was 1.5 (IQR 5), with the operative cohort showing a median of 6 (IQR 2) and the nonoperative cohort showing a median of 1 (IQR 2) (p<0.001). There was a misclassification rate of 5.7%. Overall agreement was high at 94.3%. SLIC sensitivity was 94.4% (95% CI, 72.7-99.9%) and specificity was 94.2% (95% CI [84.1–98.8%]), with strong rule-in and rule-out performance (LR+=16.4; LR-=0.06; OR = 277.7). The PPV was 85.0% (95% CI, 62.1–96.8%) and the NPV was 92.5% (95% CI, 81.8–97.9%). For the patients aged >10 years (54/70), operative management closely aligned with SLIC recommendations, with sensitivity of 100% (95% CI, 75.3-100%) specificity of 95% (95% CI, 83.5-99.4%), and 96.3% accuracy. Discordance more often reflected SLIC recommending operative management when nonoperative treatment was ultimately chosen (3/5 cases). For the patients ≤10 years (16/70), SLIC sensitivity was 80% (95% CI, 28.4-99.5%), with a specificity of 91% (95% CI, 58.7-99.8%), and 87.5% accuracy. Discordance was uncommon in this group (2 cases) and split between one over-recommendation of surgery and one under-recommendation.

Conclusion:
The SLIC scoring system demonstrated strong concordance with treatment decisions made at a major pediatric spine center and supports the use of SLIC as an adjunct in guiding management of pediatric patients.



279. Robotic-Assisted Revision Spinal Deformity Surgery in Adult and Paediatric Patients: Accuracy, Safety, and Early Outcomes

Vidyadhara Srinivasa, MD, MS; Balamurugan Thirugnanam, MS; Abhishek Soni, MD, MS; Dinesh Iyer, MS

Hypothesis:
The established accuracy of robotic guidance in primary spine surgery extends to the more complex scenario of revision spinal deformity surgery in both adult and paediatric populations.

Design:
Prospective observational study

Introduction:
Revision spinal deformity surgery is complicated by distorted anatomy, prior instrumentation, and abnormal pedicle morphology. Robotic guidance has proven accurate in primary cases, but its utility in revision deformity involving both adults and children is not well established.

Methods:
Twenty-six consecutive patients (18 adults, 8 paediatric) undergoing revision spinal deformity surgery with robotic-assisted instrumentation were prospectively enrolled. Pedicle screw accuracy was evaluated using the Gertzbein–Robbins classification. Secondary outcomes included screw-related reoperation, 90-day complications, and three-month functional outcomes (ODI/VAS for adults; SRS-22/VAS for paediatric patients).

Results:
A total of 342 pedicle screws were placed. Clinically acceptable accuracy (Grade A+B) was achieved in 97.7% of screws. Two screws (0.58%) required revision; no permanent neurological injury occurred. The 90-day

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complication rate was 15.4%. At three months, adults demonstrated significant improvement in ODI (54.3% to 30.2%) and VAS (7.1 to 3.3), while paediatric patients improved in SRS-22 (2.8 to 4.0) and VAS (6.3 to 2.9) (all p<0.001).

Conclusion:
Robotic guidance provides excellent screw accuracy with minimal revision rates in revision spinal deformity surgery, supporting its role as a valuable adjunct in complex deformity reconstruction across all age groups.

Parameter	Result
Total patients	26
Adults / Paediatric	18 / 8
Mean age (years)	42.3 ± 19.6
Female / Male	15 / 11
Total screws placed	342
Screws per patient	13.1 ± 3.2
Clinically acceptable accuracy (Grade A+B)	97.7%
Screw-related revision rate	0.58%
Permanent neurological injury	0
Mean operative time (minutes)	331 ± 62
Blood loss – adults (mL)	880 ± 310
Blood loss – paediatric (mL)	580 ± 190
Fluoroscopy time (seconds)	18.4 ± 5.9
90-day complication rate	15.4%
Adult ODI (pre → post)	54.3% → 30.2% (p<0.001)
Adult VAS (pre → post)	7.1 → 3.3 (p<0.001)
Paediatric SRS-22 (pre → post)	2.8 → 4.0 (p<0.001)
Paediatric VAS (pre → post)	6.3 → 2.9 (p<0.001)

Table: Summary of Key Findings

280. Lost in Translation: Interpreter Need Identifies Socioeconomic Risk in Pediatric Spinal Deformity

Judy-Mae Lima, BS; David C. Thornberg, BS; John Patrick Rathbun, BS; Aisha Analil, BSA; Hannah Shreiner, BA; Brandon A. Ramo, MD; Amy L. McIntosh, MD; Megan Johnson, MD; Jaysson T. Brooks, MD

Hypothesis:
Hispanic/Latino pediatric spinal deformity patients requiring interpreters will have worse socioeconomic indicators and PROMIS scores.

Design:
Retrospective Study

Introduction:
Hispanic/Latino (H/L) children are a rapidly growing US population while encountering barriers to care. Although disparities across ethnic groups are documented, less is known about how primary language shapes disparities within the same ethnic community. This study evaluates how language and interpreter request affects socioeconomic status using both self-reported and proxy-reported measures among patients within the same ethnic background.

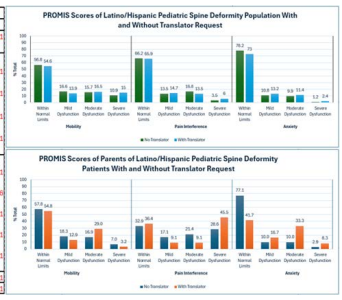
Methods:
An IRB-approved review identified spine deformity patients seen over 1 year at a pediatric orthopedic hospital. Included patients identified as H/L and Caucasian, spoke Spanish or English, had a geocodable address, and completed a Social Determinants of Health (SDOH) survey. Addresses were used to assign Area Deprivation Index (ADI) and Child Opportunity Index (COI) scores. COI domains (Overall, Education, Health/Environment (H/E), and Social/Economic (S/E)) were categorized as Low or High Risk. Lower ADI and higher COI scores represent less disadvantage. SDOH subdomains included Food Insecurity (FI), Housing Stability (HS), Caregiver Education/Work (CEW), Transportation Needs (TN), and Financial Resource Strain (FRS). PROMIS scores were collected when available.

Results:
Of 1667 patients, 561 (37%) required an interpreter. Interpreter need was associated with lower COI scores and higher High-Risk proportions in Education (40% v 24%), H/E (82% v 62%), and S/E subdomains (50% v 29%) (all p<0.0001). Interpreter-using families had higher SDOH risk across CEW (72% v 17%), FRS (24% v 6.6%), HS (24% v 16.7%), TN(10.8% v 6.1%), and FI (51% v 24%)(all p<0.01). ADI was worse among interpreter users (65 ±19 v 57 ±22, p<0.0001). However, PROMIS mobility, pain interference, and anxiety scores did not clinically differ.

Conclusion:
Despite similar ethnic backgrounds, families requiring interpreter services had worse self-reported and proxy SES markers as measured by SDOH, ADI, and COI. Despite these disparities, PROMIS domain scores were similar, suggesting comparable patient-reported health status at presentation. Acknowledging interpreter requirements may help clinics identify at-risk families and connect them to supportive resources to improve equity.

Table 1: Interpreter Use in the Latino/Hispanic Pediatric Spine Deformity Population (n=1667)

		Interpreter Use	No Interpreter Use	p-value
Preferred Language	English	0 (0%)	1106 (100%)	<0.0001
	Spanish	561 (100%)	0 (0%)	
COI National				
Overall National	Low Risk	222 (40.7%)	711 (65.5%)	<0.0001
	High Risk	**323 (59.3%)**	374 (34.5%)	
Education	Low Risk	328 (60.2%)	825 (76.0%)	<0.0001
	High Risk	**217 (39.8%)**	260 (24.0%)	
Health & Education	Low Risk	98 (18.0%)	411 (37.9%)	<0.0001
	High Risk	**447 (82.0%)**	674 (62.1%)	
Social & Economic	Low Risk	273 (50.1%)	775 (71.4%)	<0.0001
	High Risk	**272 (49.9%)**	310 (28.6%)	
SDOH				
Caregiver Education/Work	Low Risk	148 (28.5%)	839 (82.7%)	<0.0001
	High Risk	**372 (71.5%)**	175 (17.3%)	
Housing Stability	Low Risk	396 (76.0%)	849 (83.4%)	0.0006
	High Risk	**125 (24.0%)**	169 (16.6%)	
Financial Resource Strain	Low Risk	376 (76.0%)	920 (93.4%)	<0.0001
	High Risk	**119 (24.0%)**	65 (6.6%)	
Transportation Needs	Low Risk	456 (89.2%)	933 (93.9%)	0.0021
	High Risk	**55 (10.8%)**	61 (6.1%)	
Food Insecurity	Low Risk	247 (49.3%)	736 (76.2%)	<0.0001
	High Risk	**254 (50.7%)**	230 (23.8%)	
% of SDOH as High Risk		36.1% ± 24.2%	14.1 ±20.2%	<0.0001
National ADI	N= 3395	64.9 ±19.3	57.0 ± 22.3	<0.0001



Interpreter Use in Latino/Hispanic Spine Deformity Pop.

281. TiLiPA - Towards a Universal Spinal Alignment Metric: Regional Landmarks Outperform Fixed Vertebral Points Across the Pelvic Incidence Spectrum *

Sleiman Haddad, MD, PhD, FRCS; Lluis Vila Castillo, MD; Anika Pupak, PhD, BS; Susana Nunez Pereira, MD, PhD; Michael P. Kelly, MD; Jeffrey M. Hills, MD; Javier Pizones, MD, PhD; Alejandro Gomez-Rice, MD, PhD; Frank Klein-

± Louis A. Goldstein Best Clinical Research E-Point Presentation
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stuck, MD; Ahmet Alanay, MD; Ibrahim Obeid, MD; Ferran Pellise, MD, PhD; Yann Phillippe Charles, MD, PhD; European Spine Study Group ESSG

Hypothesis:
While the fixed T4-L1 model remains a valid tool for spinal assessment, a regional approach based on individual anatomical inflection points will demonstrate superior stability and predictive accuracy across the pelvic incidence (PI) spectrum

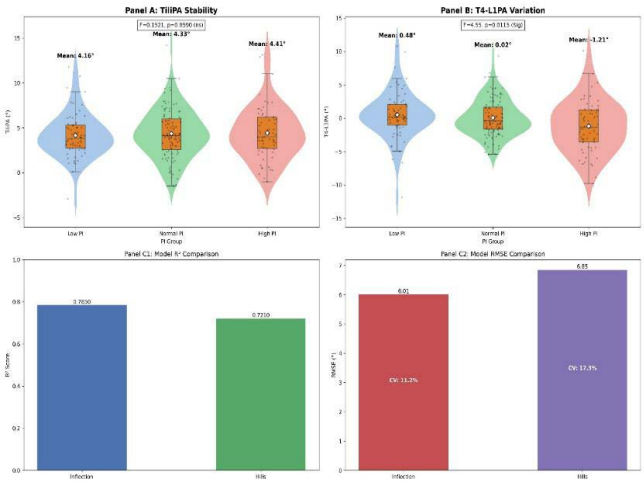
Design:
Cross-sectional analytical study of 236 asymptomatic adults

Introduction:
The T4-L1 Hip axis model (Hills) is a validated and effective method for assessing global spinal alignment. However, its reliance on fixed vertebral landmarks (T4, L1) may reduce precision in patients with significant anatomical variations. This study evaluates whether determining regional landmarks based on individual curve inflection points offers a more stable and accurate alternative to fixed vertebral references.

Methods:
We analyzed 236 asymptomatic adults (35.7±10.1 years) with complete EOS imaging. Patients were stratified by PI: Low (<45°, n=67), Normal (45-60°, n=108), and High (>60°, n=61). The primary outcome was the stability of TiLiPA (Thoracic - Lumbar Inflection pelvic angle) across groups. Secondary outcomes included validation of the Hills model (T4L1PA), predictive modeling for lumbar lordosis (LL), and correlation analyses using ANOVA, Pearson correlations, linear regression, and Bland-Altman tests.

Results:
TiLiPA demonstrated remarkable stability across PI groups (p=0.864), with mean values ranging only from 4.17° (Low PI) to 4.42° (High PI), unlike fixed vertebral parameters which showed significant variation (p<0.001). Although the T4-L1PA model predicted LL well (R^2=0.721), it suffered from systematic bias (1.15°) and significant proportional error (p<0.001) in PI extremes. Conversely, the inflection-based approach offered superior lumbar predictive accuracy (R^2=0.785, RMSE=6.01°) and greater stability across the PI spectrum (CV=6.3% vs. 11.7% for Hills).

Conclusion:
This study confirms the validity of the T4-L1 fixed landmark model for general assessment but provides evidence that a regional, inflection point-based approach offers superior precision. While the Hills model remains a useful standard, TiLiPA demonstrates universal applicability without the systematic bias found in fixed models. These findings support utilizing valid fixed models for general screening while adopting regional inflection points for personalized, high-precision surgical planning



282. Development, Calibration, and Clinical Validation of a Deployable PROMIS-Based Adaptive Assessment Tool (PROMIS-CAT) for Real-Time Patient-Reported Outcomes in Spine Care ±

Devender Singh, PhD; Eeric Truumees, MD; Matthew Geck, MD; *Aiyana Adams, BS;* Swara Kale, BS; John Stokes, MD

Hypothesis:
A locally deployable Patient-Reported Outcomes Measurement Information System-computer (PROMIS)-based computer adaptive testing engine can accurately reproduce standard PROMIS T-scores across physical, pain, fatigue, and psychosocial domains using fewer questions, without requiring server connectivity, while maintaining clinical interchangeability with PROMIS Short Forms.

Design:
Instrument development & validation

Introduction:
To develop a Patient-Reported Outcomes Measurement Information System-computer adaptive test (PROMIS-CAT) capable of estimating PROMIS T-scores using fewer questions by applying adaptive item selection & machine-learning–based calibration.

Methods:
Three sequential datasets (development n = 2,000; calibration n = 900; validation n = 887) were used. The final system adaptively measured six PROMIS domains (Physical Function, Pain Interference, Fatigue, Anxiety, Depression, & Ability to Participate in Social Roles). After each response, the tool computes a provisional ability estimate (θ) using a graded response model & selects the next question predicted to produce maximal statistical information at θ. The adaptive loop continues until measurement precision meets the PROMIS-CAT thresh-

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E-POINT PRESENTATION ABSTRACTS

old. To convert θ into standard PROMIS T-scores, linear calibration models were applied to Physical Function, Pain Interference, Fatigue, & Social Roles. For Anxiety & Depression, isotonic monotonic regression calibration was required to eliminate systematic underestimation in emotional health.

Results:
In the 887-patient validation cohort, our PROMIS-CAT engine demonstrated high accuracy relative to PROMIS Short Forms. Physical Function, Pain Interference, Fatigue, & Social Roles met all a priori interchangeability criteria, achieving mean absolute errors (MAEs) less than 3 T-score points & negligible bias. Anxiety & Depression, initially inaccurate (MAE ~ 12), improved dramatically after isotonic calibration (MAE ~ 4), with bias eliminated.

Conclusion:
Our PROMIS-CAT engine estimates PROMIS T-scores with dramatically fewer questions without relying on PROMIS servers, enabling real-time scoring within mobile apps, patient portals, & EMR environments. This instrument supports efficient, accurate, & clinically actionable outcome measurement in routine spine care.

283. Intraoperative Wound Bed Cultures in Pediatric Spinal Deformity Surgery: Incidence, Risk Factors, and Clinical Implications of Cutibacterium acnes

Gabriel Piza Vallespir, MD, PhD; *Ignacio Sanpera Trigueros, MD, PhD*

Hypothesis:
Positive intraoperative wound bed cultures (IWBCs) are common and are not independently associated with deep surgical site infection (SSI); frequent Cutibacterium acnes recovery may guide prophylactic strategies.

Design:
Single-center retrospective cohort study.

Introduction:
The incidence, microbiology, and clinical significance of IWBCs in pediatric spinal deformity surgery remain unclear, particularly when results suggest contamination.

Methods:
We reviewed pediatric spinal deformity procedures in which IWBCs were obtained. At our center, when a heterologous graft is used, a wound bed specimen (and a separate graft specimen) is routinely collected to monitor potential graft contamination. Organisms and growth were recorded; scant growth or growth only in enrichment broth was considered probable contamination. Demographic and surgical variables were collected. Superficial and deep SSIs were identified clinically. Associations were evaluated with univariate analyses.

Results:
115 patients were included (76% female; mean age 15.7 years). IWBCs were positive in 53/115 cases (46.1%), yielding 61 isolates, most commonly C. acnes and coagulase-negative staphylococci; 79% were classified as probable contaminants. IWBC positivity was not associated with demographics, diagnosis, or surgical variables. Eight infections occurred (7.0%), including six deep SSIs requiring debridement (5.2%). Deep SSI was more frequent in neuromuscular/syndromic deformity and in older patients, but was not associated with IWBC positivity, even after excluding probable contaminants. C. acnes was recovered in 2/6 deep SSI debridement cultures (both polymicrobial) and was present in the IWBC in 2 cases, although not in the same patients.

Conclusion:
Positive IWBCs are frequent, and most isolates show low-burden growth consistent with contamination rather than true infection. IWBC positivity was not independently associated with deep SSI. However, frequent C. acnes isolation and its recovery in some polymicrobial deep infections suggest considering this organism when refining perioperative prevention strategies (systemic prophylaxis selection, skin preparation and/or topical antibiotics).

284. Comparative Analysis of Patient Radiation Exposure Across Five CT-based Imaging Systems Used in Spinal Surgery

Matthew C. Gernon, BS; Nicholas Swarts, BA; Damon Mar, PhD, MS, BS; Brandon B. Carlson, MD

Hypothesis:
We hypothesize that different intraoperative CT-based imaging systems differ significantly in radiation exposure under controlled conditions.

Design:
Controlled, phantom-based dosimetry study.

Introduction:
Intraoperative computed tomography (CT) imaging is increasingly used in spinal surgery to enable navigation platforms and facilitate minimally invasive instrumentation techniques. The radiation profiles remain an important concern due to dose-dependent risks associated with ionizing radiation (IR), which has been linked to an increased risk of malignancy. Although prior studies have reported radiation exposure for individual intraoperative CT systems, direct comparisons among multiple imaging platforms in a controlled setting are limited.

Methods:
Radiation exposure was measured in a controlled operating room (OR) environment at a university hospital using an anthropomorphic phantom positioned prone on a radiolucent Jackson table. Calibrated Thermoluminescent Dosimeters (TLDs) were placed on the posterior surface of the phantom centered at the L3 vertebral level. Environmental radiation exposure was simultaneously measured using pressurized-ion-chamber dosimeters

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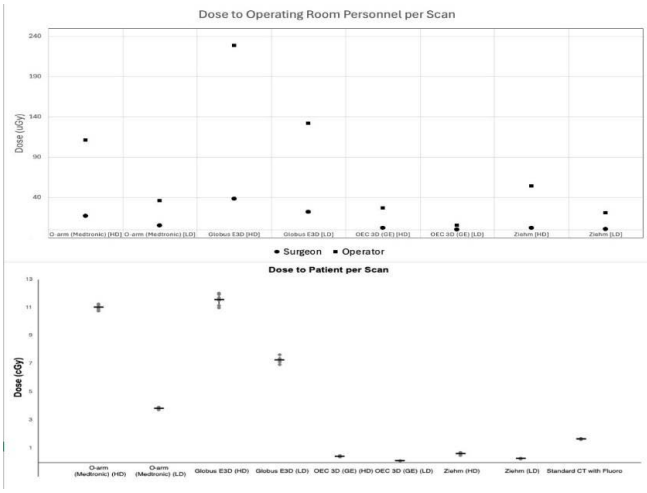
positioned at standardized surgeon and radiology technologist positions. Intraoperative CT systems with both high- and low-dose exposure protocols were evaluated in comparison with a standard CT. One-way analysis of variance (ANOVA) was used to compare the different mean radiation doses.

Results:
Significant differences were seen in patient and OR personnel radiation exposure across imaging systems under high and low-dose protocols ($p < .001$). Post-hoc pairwise comparisons identified multiple significant differences. Across all imaging systems, OR personnel radiation exposure scaled proportionally to patient radiation dose (Figure 1).

Conclusion:
In a controlled setting, radiation exposure to patient and OR personnel differed significantly across CT-based navigation systems in spine surgery. Given the cumulative dose-dependent risk factors surrounding IR, the inter-system differences observed in this study are clinically meaningful for understanding occupational risk exposure. These findings emphasize that system selection and dose-protocol optimization provide opportunities to reduce radiation exposure without compromising intraoperative navigation.



Radiation dose to OR personnel and patient.

285. Bridging The Gap Between Patient Priorities And Clinical Outcome Measures: A Qualitative Analysis Of The Reddit Scoliosis Community

Chuck H. Lam, BSc; Conor T. Boylan, MBChB, MSc, BSc, MRCS Ed; David S. Marks, MBBS, FRCS; Morgan Jones, FRCS, MBChB; David L. Skaggs, MD, MMM

Hypothesis:
Patients' priorities expressed in an online scoliosis community extend beyond domains captured by commonly used PROMs (e.g., SRS-22), particularly around navigating care, understanding diagnosis, and exercise safety.

Design:
Cross-sectional qualitative content analysis of an online health community.

Introduction:
Patient-reported outcome measures (PROMs) such as the SRS-22 are widely used to assess quality of life in scoliosis, and these instruments were developed through expert consensus rather than direct patient input. Online health communities offer an unfiltered window into what patients themselves prioritise. This study analysed patient-generated content from the Reddit scoliosis community (r/scoliosis) to characterise patient concerns and evaluate their alignment with existing outcome measures.

Methods:
We conducted a cross-sectional qualitative analysis of posts from r/scoliosis over 12 months (May 2024–May 2025). Question-type posts were extracted and coded using a 14-category codebook developed through iterative review of 300 posts. Categories included diagnosis and severity assessment, pain experiences, treatment decisions, mental health and emotional impact, body image, healthcare navigation, exercise and physical therapy, and daily function.

Results:
A total of 4,683 posts met the inclusion criteria. The most prevalent themes were diagnosis and severity assessment (53.6%), pain experiences (39.0%), healthcare navigation (37.6%), peer support (30.6%), and exercise safety guidance (29.7%). Exercise safety guidance and healthcare navigation were discussed more frequently than mental health (21.4%) and body image (21.3%). Posts frequently addressed multiple concerns, with a mean of 3.4 themes per post. Diagnosis and healthcare navigation commonly co-occurred (25.1%), suggesting patients simultaneously struggle to understand their condition and access appropriate care.

Conclusion:
Patient-generated content reveals patient priorities that are incompletely captured by current scoliosis outcome measures. While mental health and body image are incorporated into commonly used PROMs, concerns such as healthcare navigation, exercise safety guidance, and diagnostic understanding—which were frequently discussed in patient forums—are not. These findings support the development of more patient-centred outcome measures and targeted educational resources.

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286. Does Surgeon Gender and Size Affect Muscle Exertion During Spine Surgery?

Joshua Abrams, BS; Zoe Cauthen, BS; Lyles Addy, BS; Robert F. Murphy, MD; Sara Van Nortwick, MD

Hypothesis:
Standard spinal instrumentation disproportionately increases muscle exertion and ergonomic strain among surgeons of smaller stature, particularly female surgeons, during spinal fusion tasks.

Design:
Prospective cross-sectional experimental study

Introduction:
Work-related musculoskeletal injuries are common among spine surgeons, yet ergonomic research in spine surgery remains limited compared to other surgical fields. As the surgical workforce becomes increasingly diverse in gender and body size, reliance on one-size-fits-all instrumentation may contribute to ergonomic inequities. This study evaluates muscle activation and perceived exertion during simulated posterior spinal fusion tasks to assess whether surgeon gender and size influence ergonomic burden.

Methods:
Participants included PGY3–7 residents and attending spine surgeons with prior spinal fusion experience. No exclusions were made based on gender, hand size, height, or weight. A simulated posterior spinal fusion was performed using a model spine, adjustable table, and standard instruments. Participants placed pedicle screws using manual and power screwdrivers, performed rod bending with a French bender, and completed tasks at both optimal and non-optimal table heights. Surface EMG sensors were placed on seven muscles of the dominant arm. Muscle activation was normalized to maximal voluntary contraction. Surveys assessed demographics, perceived exertion, pain, and instrument difficulty. EMG and survey data were analyzed using amplitude analysis and independent samples t-tests.

Results:
Female surgeons demonstrated significantly higher flexor carpi radialis activation during rod bending ($p = 0.005$) and power screwdriver use ($p = 0.024$), indicating increased forearm strain. No other muscles showed statistically significant gender differences, though EMG amplitudes generally trended higher among women. Survey results mirrored EMG findings: female participants reported greater perceived exertion, increased difficulty using the French bender, and lower comfort with standard instruments. Neck pain was the most commonly reported symptom (55%), followed by lower back (27%) and hand pain (18%).

Conclusion:
Standard spinal instrumentation may place disproportionate ergonomic demands on female and smaller-stature surgeons. These findings support the need for ergonomically adaptive tools to reduce injury risk and improve accessibility and longevity in spine surgery.

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REGIONAL SCIENTIFIC MEETING ABSTRACTS

The inaugural Regional Scientific Meeting was held on February 6-7, 2026 in Fukuoka, Japan. This meeting was regionally focused from the presenters to the location. Regional authorship and faculty requirements helped to ensure that this meeting was for the region, by the region. Seven of the top-scoring abstracts were nominated for the first-ever "Regional Scientific Meeting Award".

SRS partnered with 13 regional societies to hold a "Best Of" session, where each partner society presented a society introduction, followed by the best paper from their most recent meeting. This section includes the Regional Scientific Meeting Award-winning abstract, as well as the abstracts features in the "Best Of" session.

SRS Regional Scientific Meeting Award Winning Paper: Risk Factors Associated with Degeneration of Unfused Lumbar Intervertebral Disc Over Ten Years After Posterior Spinal Fusion for Thoracic Idiopathic Scoliosis

Satoshi Suzuki, MD, PhD; Kazuki Takeda, MD, PhD; Takahito Iga, MD, PhD; Toshiki Okubo, MD, PhD; Masahiro Ozaki, MD, PhD; Narihito Nagoshi, MD, PhD; Morio Matsumoto, MD, PhD; Masaya Nakamura, MD, PhD; Kota Watanabe, MD, PhD

Hypothesis
Distal adding-on after posterior spinal fusion (PSF) for thoracic adolescent idiopathic scoliosis (AIS) could be a risk factor for degeneration of unfused intervertebral lumbar disc (IVDD) over time.

Design
Prospectively collected, retrospective analyzed cohort study

Introduction
While several studies have investigated IVDD following PSF for AIS, there are no studies that focus exclusively on thoracic main curves. This study aims to identify factors contributing to IVDD progression over a ten-year postoperative period.

Methods
A total of 92 patients with thoracic AIS (7 males, 85 females; mean age of 27.0 years) who underwent PSF and had a follow-up period of over 10 years were included in this study. Lumbar MRI and standing radiographs were obtained preoperatively and at the 10-year follow-up. IVDD was evaluated using a modified Matsumoto classification. Based on the progression of IVDD, patients were divided into two groups: the degenerated group (Group D), comprising patients with progression of disc degeneration, and the non-degenerated group (Group ND), comprising those without. Demographic characteristics, surgical variables, radiographic parameters, and SRS-22 scores were compared between the two groups using both univariate and multivariate analyses. A p-value of <0.05 was considered statistically significant.

Results
A total of 400 lumbar discs were evaluated. IVDD deterioration was observed in 38 discs (9.5%) among 31 patients in Group D. No significant differences were found between groups in Demographic characteristics and curve correction parameters. Significant differences were observed in distal adding-on (68.0% vs 20.9%, p<0.01), and L4 translation (3.8mm vs 2.1mm, p=0.03). Logistic regression analysis also identified distal adding-on (B 2.1, Odds ratio 8.13, 95%CI 2.84-23.3), and L4 translation (B 0.13, OR 1.14, 95%CI 1.001-1.30) as significant risk factors for IVDD progression. All SRS-22 domains demonstrated comparable scores between the two groups, with no significant differences.

Conclusion
Distal adding-on and increased L4 translation were significant risk factors for the progression of unfused lumbar IVDD ten years after PSF for thoracic AIS. Preventing the occurrence of distal adding-on could contribute to reducing the risk of intervertebral disc degeneration in unfused lumbar segments.

Best Paper - Australian Spine Society: Ultrasound as a Tool to Objectively Assess the Injured Spinal Cord in a Porcine Model of Thoracic Contusion Spinal Cord Injury

Madeleine Bessen, PhD; Oana Marian, MD; Ryan O'Hare Doig, PhD, BSc (Hons); Annabel Sorby-Adams, PhD; Christine Gayen; Lola Kaukas, BHlthSci (Hons), GradCert; Anna Leonard, PhD, BHlthSci (Hons); Claire Jones, PhD

Hypothesis
Quantitative ultrasound (US) measures can detect and track changes to the spinal cord over time following traumatic spinal cord injury (SCI).

Design
Experimental large animal study

Introduction
Tools for monitoring traumatic spinal cord injury (SCI) severity and progression are limited. Ultrasound (US) imaging may be suitable but requires improved understanding of tissue changes observed with the modality post-injury. Using serial US images, this study: (1) determined temporal changes to the spinal cord and subarachnoid space over 24-hours post-SCI; and, (2) quantitatively compared US to magnetic resonance imaging (MRI) and histology at 24-hours post-SCI, in a porcine model.

Methods
Thoracic contusion SCI was induced in anaesthetised female pigs (N=10 across three injury groups). Midsagittal B-mode US images were obtained hourly from baseline to 24-hours post-SCI. At 24-hours, T2-weighted MRI and histology specimens were obtained. Injury-site spinal cord and dura sagittal diameters were measured on US images. Greyscale distribution measures (median, interquartile range [IQR]) of parenchymal signal were assessed on US and MRI. Tissue loss and intraparenchymal haemorrhage (IPH) were quantified on histological sections. Association of US parenchymal changes with MRI and histology outcomes were assessed by Pearson's correlation.

REGIONAL SCIENTIFIC MEETING ABSTRACTS

Results
Spinal cord swelling caused apparent subarachnoid occlusion by 13-hours; maximum spinal cord diameter occurred at 20-hours, accompanied by dura distension ≤10%. US parenchymal greyscale median and IQR increased rapidly from baseline to 2-hours (median: 37.4–197.4%; IQR: 37.5–132.9%) and slowly and/or inconsistently from 2- to 24-hours (median: -37.9–80.04%; IQR: -46.3–32.33%) post-SCI. At 24-hours, increased US median greyscale was moderately-to-strongly associated with IPH (r=0.69; p=0.035) and tissue loss (r=0.74; p=0.015), and increased IQR was strongly associated with tissue loss (r=0.70; p=0.024); but greyscale median and IQR from US and MRI were not associated.

Conclusion
US can objectively assess spinal cord swelling and dura distension, and parenchymal echogenicity appears related to IPH and tissue loss, in a porcine SCI model. This study supports continued investigation of US as a tool to assess injury progression and therapeutic outcomes.

Best Paper - Asia Pacific Spine Society: Unlocking the IVD: Unveiling Its Microbial Landscape with Shotgun Metagenomics

Ajoy Prasad Shetty Tonse, MS Orth; Karthik Ramachandran, MBBS, MS, DNB(Orth); Shanmuganathan Rajasekaran, MBBS, PhD, FRCSA, MCh; Sharon M. Nayagam, MSc; Chitra Thangavel, BSc

Hypothesis
The main objective of the study is to explore the bacterial diversity in patients with IVDD using shotgun metagenome sequencing.

Design
Prospective Cohort Study

Introduction
The intervertebral disc disease (IVDD) leading to degeneration is multifactorial, and one such factor is subclinical infection. As evidenced earlier, the disc harbours a unique microbiome, and this study proposes to explore the abundance of the entire microbial community using shotgun metagenomics.

Methods
Shotgun metagenomics was used to identify the diverse microbial species in IVD. The IVD control tissue samples were collected from brain-dead organ donors (n=20), while diseased tissue from patients undergoing microdiscectomy with both modic changes (MC) (n=18) and non-modic (NMC) (n=22). DNA was extracted, and shotgun sequencing was performed using the Illumina Novaseq platform. Alpha and beta diversity analyses were conducted with statistical tests, including the Mann-Whitney U test and PERMANOVA (permutational multivariate analysis of variance).

Results
With a median relative abundance of over 1%, a total of 202 species was identified in the control IVD tissue, whereas 116 and 146 species were found in the diseased MC and NMC tissue samples, respectively. The alpha diversity revealed a rich species diversity, with a significant difference between the control and NMC samples (p=0.03). The beta diversity analysis using PCoA showed a significant difference (p=0.002) between the control and diseased (MC & NMC) populations. Across all samples (Control, MC & NMC), the most abundant bacterial species were Klebsiella pneumoniae, Pseudomonas aeruginosa, Corynebacterium amycolatum, and Acidovorax sp. BLS4. The bacterial diversity in diseased samples (MC & NMC) was lower. The presence of Pseudomonas aeruginosa phages supports P. aeruginosa as a natural inhabitant of IVD.

Conclusion
The study strengthened our hypothesis that IVDD is caused by infection, as evidenced by the abundance of P. aeruginosa. As it facilitates co-bacterial species to polymicrobial infection, which may influence the disease progression by modulating the host immunity and the IVD microbiome. Further richness of Pseudomonas phages in the disease group strongly supports the presence of P. aeruginosa in IVD and its possible role in IVDD.

Best Paper - Association of Spine Surgeons of India: Non Fusion Anterior Scoliosis Correction in Lenke 5 AIS patients- surgical outcomes, AVR, AVT & coronal balance correction- a single centre, single surgeon experience

Sajan K. Hegde, MBBS, MS; Dr K Appaji Krishnan, DO, DNB; Dr Vigneshwara Badikkillaya, MBBS, MS, Ortho,FASSI; *Sharan T. Achar, MS;* Harith B. Reddy, MS; A Akshyaraj, MD

Hypothesis
To analyse the efficacy of NFASC for Lenke 5 AIS patients in terms of cobbs, rotation & translation correction with a look into complications at 2year follow up (FU).

Design
Prospective Cohort Study

Introduction
Non Fusion Anterior Scoliosis Correction (NFASC) as Vertebral Body Tethering (VBT) was introduced as a growth modulating scoliosis surgery. With advancing recent innovations, it has now been used as a motion preserving corrective procedure in Adolescent Idiopathic Scoliosis (AIS). But there has been varied results and complications among the centres world-wide especially in the lumbar Lenke 5 curves, which account for 12-20% of AIS.

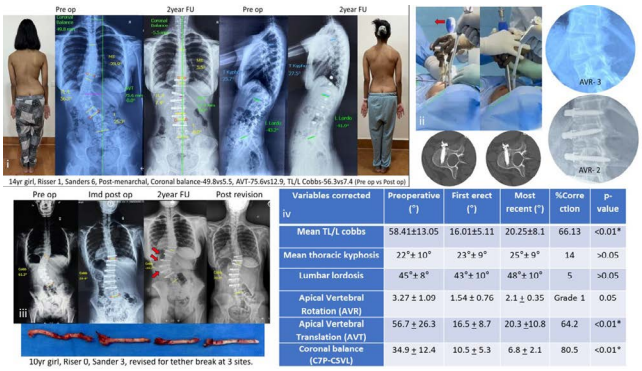
Methods
42 patients of Lenke 5 curve with coronal cobbs angle of 40-80o showing >50% flexibility on awake traction radiographs who underwent NFASC between 2019-2023 were included. 36 girls & 6 boys were assessed clinically & radiologically with skeletal-maturity parameters, curve type, Cobb angle, Apical vertebral rotation (AVR), Apical vertebral translation (AVT), Coronal balance (C7P-CSVL), intra-operative details and Scoliosis Research Society-22 revised (SRS-22r) questionnaire.

Results
The mean FU was 28.1months (24-60months) with mean age 14+3.43yrs, risser stage of 4.12+0.56 and sanders stage of 6.91+0.54.The instrumented levels were from

T10-L4 (T9-9.7%, T10- 41.9%, T11- 32.3%, T12- 12.9%, L3- 54.8%, L4- 45.1%). 72.6% curve correction post-surgery was maintained at 66.13% correction at 2year FU (loss of correction of 6.35+4.05o in 60% of patients) (p=0.001). The coronal balance improved significantly (C7P-CSVL from pre op 34.9+12.4 to 6.8+2.1mm at 2yr FU- 80% correction) (P=0.001) along with maintenance of the sagittal profile. The AVR improved by grade 1.2+0.43 and AVT by 36.4+15.5mm (p<0.01). The median SRS 22r sub-score was 4.3 (3.5-4.8). Tether breakage was encountered in 8 patients (19.04%) but with no significant clinical (minor increase in flank crease) and radiological (loss of correction was 12.87+5.8o) decompensation except in 1 where revision was mandated. No other approach related/ post-operative complications were noted unlike those reported in literature.

Conclusion

NFASC achieves and maintains successful good cobbs correction (66% at 2yr FU) with significant AVT, coronal balance correction, though there was 19% tether breaks without significant decompensation.



Variables corrected	Preoperative (°)	First erect (°)	Most recent (°)	%Correction	p-value
Mean TL/L cobbs	58.41±13.05	16.01±5.11	20.25±8.1	66.13	<0.01*
Mean thoracic kyphosis	22°± 10°	23°± 9°	25°± 9°	14	>0.05
Lumbar lordosis	45°± 8°	43°± 10°	48°± 10°	5	>0.05
Apical Vertebral Rotation (AVR)	3.27 ± 1.09	1.54 ± 0.76	2.1 ± 0.35	Grade 1	0.05
Apical Vertebral Translation (AVT)	56.7 ± 26.3	16.5 ± 8.7	20.3 ±10.8	64.2	<0.01*
Coronal balance (C7P-CSVL)	34.9 ± 12.4	10.5 ± 5.3	6.8 ± 2.1	80.5	<0.01*

Best Paper - Chinese Association of Spine CAS: Etiological classification of major cervicothoracic/upper thoracic scoliosis

Saihu Mao, PhD; Shuqi Sun; Kai Sun, No; Song Li, MD, PhD; Zezhang Zhu, MD, PhD; Zhren Lui, PhD; Yong Qiu, MD

Hypothesis

A clinical etiological classification system for cervicothoracic scoliosis, established based on retrospective summary of clinical data, can effectively distinguish different etiological subtypes of cervicothoracic scoliosis, and is expected to guide individualized clinical management and prognosis evaluation.

Design

Retrospective Cohort Study

Introduction

At present, the clinical etiology of cervicothoracic scoliosis remains unclear, and the disease characteristics and therapeutic challenges associated with different etiologies require further investigation. This study aims to analyze, categorize, and summarize the clinical etiologies of cervicothoracic scoliosis.

Methods

We retrospectively reviewed patients with cervicothoracic scoliosis treated surgically or with bracing at our institution from January 2017 to September 2025. Inclusion criteria were a primary curve in the C6–T4 region with a Cobb angle >10°. Patient demographics, clinical etiology, and curve direction were recorded, and disease characteristics were compared among etiological subtypes.

Results

A total of 184 patients (79 males, 105 females) with a mean age of 12.3 ± 5.1 years (range, 3–34) were included. Congenital scoliosis was most common (52.1%), comprising failures of formation (14.7%), failures of segmentation (6.0%), and mixed-type (31.5%). Other etiologies included idiopathic (26.6%), neurofibromatosis-associated (17.4%), Chiari malformation-related (2.2%), myogenic (1.1%), and tumor-related (0.5%). Among patients younger than 12 years, congenital scoliosis accounted for 71.4%. In idiopathic cases, 63.2% were female and all primary curves were left-sided, whereas no clear sex or curve-direction pattern was observed in other etiological subtypes.

Conclusion

Among patients with cervicothoracic scoliosis and a Cobb angle >10°, congenital scoliosis was the most common etiology, particularly in younger children, followed by idiopathic, neurofibromatosis-associated, and other neuromuscular causes. The findings of this study provide reference data to aid in the clinical diagnosis and differential assessment of cervicothoracic scoliosis.

Best Paper - Indonesian Orthopaedic Spine Surgeon Association (IOSSA): A Cost-Effective Approach to Severe Rigid Scoliosis Correction using Low-Density Pedicle Screw Constructs based on Radiographic Parameters

Greesea Dinamaria, MD; *Abdul Kadir Hadar, MD*

Hypothesis

What is the efficacy of low density pedicle screw constructs in the surgical correction of severe rigid scoliosis by radiographic parameters?

Design

Retrospective Study

Introduction

Severe rigid scoliosis presents significant surgical challenges due to its marked curvature and limited flexibility. Traditional high-density pedicle screw constructs provide strong biomechanical stability but are associated with increased operative time, blood loss, cost and risk of screw related complication. Low-density pedicle screw constructs, employing selective screw placement as critical vertebrae levels have emerged as a promising alternative. This approach aims to maintain adequate correction and stability while reducing surgical morbidity and resource utilization.

Methods

A prospective cohort of patient diagnosed with severe rigid scoliosis underwent posterior spinal fusion utilizing a low-density pedicle screw technique. Surgery performed by single orthopaedic surgeon involved selective screw placement at key vertebral levels to optimize correction forces while minimizing hardware density. Data collected included preoperative and post operative radiographic parameters (Cobb angle, sagittal and

coronal balance), operative time, intraoperative blood loss and perioperative complications.

Results
Low-density pedicle screw constructs achieved significant correction of coronal and sagittal deformities, with postoperative Cobb angle reductions. Operative time and intraoperative blood loss were significantly reduced, contributing to decreased surgical morbidity. The incidence of screw malposition and neurovascular complications was minimized, reflecting the benefits of fewer fixation points.

Conclusion
Low-density pedicle screws provide efficient, safe scoliosis correction with fewer implants— success hinges on meticulous planning, appropriate patient selection, and continual clinical validation.

Best Paper - Japanese Scoliosis Society: Early Brace-Related Stress, Not Wear Time, Correlates with One-Year QOL Change in AIS: A Retrospective Cohort Study

Kotaro Sakashita, MD; Tomoyuki Asada, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Yasushi Iijima, MD, PhD; Shohei Minami, PhD; Tsutomu Akazawa, MD, PhD; Seiji Ohtori, MD; Toshiaki Kotani, MD, PhD

Hypothesis
Early brace-related stress at 1 month, assessed by the JBSSQ-brace, is independently associated with 1-year change in SRS-22r health-related quality of life, whereas objectively measured brace wear time is not.

Design
Retrospective Cohort Study

Introduction
Brace treatment for adolescent idiopathic scoliosis (AIS) can prevent curve progression, but may adversely affect quality of life (QOL). Few studies have evaluated QOL using objectively measured brace wear time, and it remains unclear whether brace-related stress or prolonged wear time has the greater impact on QOL. We evaluated factors related to 1-year change in QOL during brace treatment.

Methods
In this retrospective cohort, 133 AIS patients treated with Boston braces (7 males; mean age 12.4 years) were analyzed. The primary outcome was change in SRS-22r total score from baseline to 1 year. Braces were prescribed for ≥20 h/day. Independent variables included the major Cobb angle, Risser sign, baseline SRS-22r, JBSSQ-brace at 1 month (evaluating brace-related stress; lower scores indicated higher stress), and objectively measured wear time (using a temperature logger). Missing data were handled using multiple imputation. Multiple linear regression was used to identify associated factors.

Results
Model fit was acceptable (adjusted $R^2 = 0.38$; all VIF < 2). Higher JBSSQ-brace scores (i.e., lower stress) were independently associated with greater improvement in SRS-22r total score ($\beta = 0.014$; 95% CI, 0.002 to 0.026; $p = 0.027$). Baseline SRS-22r was inversely associated with improvement ($\beta = -0.632$; 95% CI, −0.812 to −0.452; $p < 0.01$). Objectively measured wear time was not associated with QOL change ($\beta = -0.003$; 95% CI, −0.013 to 0.008; $p = 0.63$), nor was major Cobb angle ($\beta = 0.009$; 95% CI, −0.004 to 0.022; $p = 0.18$).

Conclusion
Brace-related stress at 1 month, captured by JBSSQ-brace, was a key correlate of 1-year QOL change, whereas objective wear time and curve magnitude were not. Because lower JBSSQ-brace scores indicate higher stress, greater early stress was associated with worse QOL trajectories. Stratifying patients by 1-month JBSSQ-brace and introducing early psychological support may be a pragmatic strategy to mitigate QOL decline during brace treatment.

Best Paper - Korean Society of Spine Surgery: Pelvic Inclination Angle as a Novel Sagittal Parameter: Clinical Applications in Adult Spinal Deformity Surgery

Se-Jun Park, MD, PhD; Jin-Sung Park, MD, PhD; Dong-Ho Kang, MD; Chong-Suh Lee, MD, PhD; Yunjin Nam, MD

Hypothesis
We hypothesized that pelvic inclination angle (PIA) would better correlate with clinical outcomes than pelvic tilt (PT) in patients undergoing adult spinal deformity (ASD) surgery.

Design
Retrospective Study

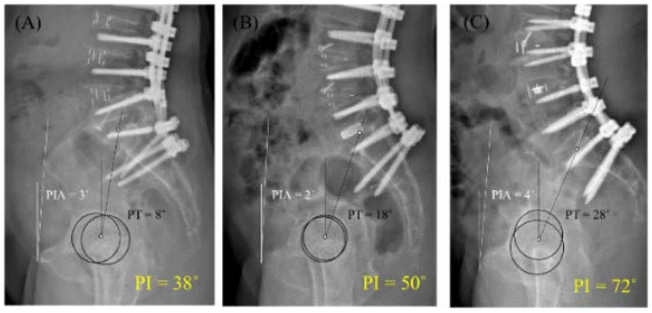
Introduction
Restoring PT to "normal range" is an essential goal in ASD surgery; however, normal PT values vary among individuals due to differences in pelvic incidence (PI). Recently, PIA was introduced as a novel sagittal parameter to evaluate pelvic compensation. This study aim to evaluate the clinical utility of PIA in assessing postsurgical outcomes after ASD surgery.

Methods
We retrospectively analyzed consecutive patients who underwent ≥ 6-level fusion, including the sacrum/pelvic for ASD. Sagittal parameters—including PIA, PI−lumbar lordosis (LL), PT, T1 pelvic angle (T1PA), and sagittal vertical axis (SVA)—and clinical outcomes [Oswestry disability index (ODI) and Scoliosis Research Society-22r (SRS-22r) scores], were evaluated preoperatively and at 2 years postoperatively. Pearson's correlation analysis was performed to examine the relationship among sagittal parameters and between sagittal parameters and ODI. Linear regression analysis was used to define the relationship between postoperative ODI and PIA.

Results
A total of 211 patients were included in the study (mean age, 69.6 years; female, 88.2%; and mean fusion length, 8.0 levels). PIA showed moderate-to-strong correlations with PI−LL, PT, and T1PA, both pre- and postoperatively, indicating that PIA well reflects sagittal deformity severity. Postoperative ODI correlated most strongly with PIA ($r = 0.427$), significantly higher than correlations with PI−LL ($r = 0.218$, $P < 0.001$) and PT ($r = 0.233$, $P < 0.001$). Additionally, ΔODI was also most strongly correlated with ΔPIA ($r = 0.242$) compared with ΔPI−LL ($r = 0.055$, $P = 0.014$), ΔPT (r

= 0.117, P = 0.048), ΔT1PA (r = 0.075, P = 0.021), and ΔSVA (r = 0.020, P = 0.017). Linear regression analysis demonstrated the equation: PIA (°) = 4.0° + 0.2 × ODI (%). The postoperative PIA thresholds corresponding to mild (ODI = 20) and severe (ODI = 40) disability were 8.0° and 12.0°, respectively. Postoperative PIA was significantly influenced by the postoperative LL and PT, but not by PI.

Conclusion
PIA is a reliable parameter that reflects sagittal deformity severity and demonstrates stronger correlations with clinical outcomes than conventional sagittal measures. It may serve as a practical reference for evaluating pelvic compensation and guiding surgical alignment targets in ASD correction.



Best Paper - Korean Spinal Neurosurgery Society: Revision Surgery Following Primary Adult Spine Deformity Surgery

Dae Jean Jo, MD, PhD; Yong Ahn, MD, PhD; Sungsoo Bae, MD

Hypothesis
We hypothesized on various techniques to suggest another treatment option for deformity revisions based on experience of a single-institution, high-volume center.

Design
Retrospective Cohort Study, and Case Series Using Data from a Single Institution

Introduction
Adult deformity surgery is technically demanding, due to patient and implant-related factors. Clinical data supports the effectiveness of surgery in huge deformities with clear sagittal malalignment, but conversely face the increasing problem of surgical revisions. Frequently reported failures are: proximal or distal failure, junctional disease, non-union with rod breakage and clinically relevant loss of correction. Posterior osteotomies, combined anterior and posterior approaches, single-level lordotic cages or multi-level interbody cages and multi-rod complexes are some of the rescue techniques that surgeons can apply to effectively perform revisions. There is a lack of consensus on which technique should be adopted in revision surgery and it still remains a case-by-case decision.

Methods
Revision surgeries via a modified extratransforaminal lumbar interbody fusion(ExTLIF) by using conventional ALIF cages were performed on patients with complications after deformity surgery.

Results
51 patients underwent ExTLIF procedure. Mean lumbar lordosis, segmental lumbar lordosis, and mean disc space increased significantly during the last follow-up. Significant correlation existed between subsidence and cage height.

Conclusion
In revision surgery, the source of the problem indicates different techniques. In proximal junction failures, decompression of the cord with extension to about 3 level higher and using hooks are necessary. In distal junction failures, L5S1 OLIF with iliac extension may be recommended. In cases of both proximal and distal complications in fixed deformities, posterior decompression with osteotomy has high correctional versatility. If there are more than 2 levels of motion segments, anterior column support is preferred, with or without anterior column realignment. Lateral lumbar interbody fusion is recommended in any type of revisions except in fixed deformities and contraindications (i.e. vascular variations, morbid obesities, prior abdominal surgeries, intraperitoneal or retroperitoneal infection or tumor). Posterior only approaches are possible with osteotomy combined with exTLIF technique.

Best Paper - Malaysia Spine Society: International Multicenter Validation of Growth Velocity and Scoliosis Progression Prediction Using the Distal Radius and Ulna (DRU) Classification: An APSS Scoliosis Focus Group Study

Hideyuki Arima, MD, PhD; Yu Yamato, MD, PhD; Chris Yin Wei Chan, MSOrth; Chee Kidd Chiu, MBBS, MSOrth; Mun Keong Kwan, MBBS, MS Orth; Shinji Takahashi, MD, PhD; Yusuke Hori, MD, PhD; Hideki Sudo, MD; Katsuhisa Yamada, MD, PhD; Shu-Hua Yang, MD, PhD; Ming-Hsiao Hu, MD; Chih-Wei Chen, MD; Jason Pui Yin Cheung, MD, MBBS, MS, FRCS; Yat Wa Wong, MD, MBBS, FRCS; Keith Dip Kei Luk, MD; Daisuke Sakai, MD, PhD; Daisuke Kudo, MD, PhD; Wataru Saito, MD, PhD; Gabriel KP Liu, MD; Leok-Lim Lau, FRCS; Ajoy Prasad Shetty Tonse, MS Orth; Hideki Shigematsu, MD, PhD

Hypothesis
Growth velocity and scoliosis curve progression vary according to distal radius and ulna (DRU) classification stages, and the DRU classification is a valid and reliable predictor of growth potential and scoliosis progression across different ethnic populations in patients with idiopathic scoliosis.

Design
Prospective International Multicenter Cohort Study

Introduction
The distal radius and ulna (DRU) classification, which evaluates bone maturity using wrist radiograph, is recognized for its clinical utility. However, its validity across cross-ethnic cohorts remains unexplored. Objective: This study aims to investigate growth velocity and scoliosis progression in idiopathic scoliosis patients across DRU classifications in an international multicenter study.

REGIONAL SCIENTIFIC MEETING ABSTRACTS

Methods
Idiopathic scoliosis patients aged 9 to 18 years, enrolled in a prospective multicenter study at Asian scoliosis centers (October 2020–December 2023), were examined every 4 to 6 months for height, arm span, Cobb angle, DRU classification, and Risser stage. The rate of change in height, arm span, and scoliosis curve was calculated based on DRU classification and Risser stage at the previous visit. Data from the first registration to the start of brace or surgery were analyzed. Data collected after the initiation of brace or surgery were excluded from the analysis to minimize confounding due to these interventions.

Results
Of 329 enrolled idiopathic scoliosis patients, 191 (mean age 13.5 ± 1.6 years, 84.8% female) (119 Japanese, 40 Malaysian, 20 Taiwanese, 12 Hong Kong) were analyzed. The baseline Cobb angle of the scoliosis curve was 22.6° ± 9.8°. Peak growth in body height occurred at radius grade (R) 5 (0.74 ± 0.31 cm/month), ulna grade (U) 4 (0.78 ± 0.29 cm/month), and Risser stage 0 (0.53 ± 0.35 cm/month). Peak change in arm span occurred at R5 (0.88 ± 0.29 cm/month), U4 (0.91 ± 0.41 cm/month), and Risser stage 0 (0.62 ± 0.50 cm/month). In contrast, progression of the maximum scoliosis curve was most pronounced at R6 (0.20 ± 0.60 degrees/month), U5 (0.33 ± 0.57 degrees/month), and Risser stage 0 (0.12 ± 0.79 degrees/month). Scoliosis curve progression was less likely to occur at or after R9 (0.04 ± 0.85 degrees/month) and U7 (0.05 ± 0.69 degrees/month).

Conclusion
The results from this Asian multicenter study demonstrate that R7 and U5 are associated with a high risk of scoliosis curve progression, which is consistent with previous reports. The DRU classification has been confirmed as a practical method for evaluating scoliosis curve progression across different ethnicities.

Best Paper - Philippine Spine Society: Early Outcomes on the Combined Halo-Pelvic Traction and Kyphectomy from an All-Posterior Approach for Severe Kyphotic Deformity

Leo F. Rebato, MD, DPOA; Mary Ruth A. Padua, MD, FPOA FPSS; Gracia Cielo E. Balce, MD, FPOA; Frederick Patrick I. Nicomedez, MD, FPOA, FPSS; Samuel Arsenio M. Grozman, MD, FPOA FPSS

Hypothesis
The use of halo-pelvic traction and an all-posterior approach surgical approach is a viable option in the management of severe kyphotic deformity in young children

Design
Case Report

Introduction
Severe kyphotic deformity is one of the sequelae of tuberculosis of the spine. When left untreated, patients may develop restrictive lung and heart disease and even neurologic deficits. Surgical management of severe kyphotic deformity is complex and high risk especially in young children. Halo-pelvic traction is a technique reported to decrease complexity, blood loss, operative time and complication rate in definitive fixation, however, the technique has not been used locally in correction of severe deformities.

Methods
This is a case report on a 6-year-old with severe kyphotic deformity secondary to tuberculosis of the spine. The aim is to provide novel insights into the design and application of the halo-pelvic traction construct, combined with an all posterior surgical technique to achieve deformity correction.

Results
The halo-pelvic traction was able to achieve 26 degrees (35.13%) correction over 35 days with an average daily angular correction at 0.72 degrees per day and daily lengthening at 1.52mm per day. The patient was able to ambulate with assistance at 2 weeks and ambulate without assistance at 3 weeks on the traction construct. At 6 weeks, vertebral column resection and definitive fixation through an all-posterior approach was done with final angular correction of 49 deg (66.21%). Halo-pelvic construct was maintained as an adjunct to fixation and is to be maintained until with fusion

Conclusion
The combined two-staged approach of halo-pelvic traction and vertebral column resection through an all-posterior approach has proven to be effective in this pediatric patient with severe kyphotic deformity.

Best Paper - Singapore Spine Society: The Impact of Smoking on Anterior Cervical Discectomy and Fusion with Standalone Cages: Radiological and Functional Outcomes.

Cassie Yang, MBBS; Reuben CC Soh, MBBS, FRCS, MMedOrth; Yeong Huei Ng, FRCS (Ortho); Li Tat John Li Tat Chen, MBBS (NUI), BAO, LRCSI, FRCS (Edin); Youheng Ou Yang, MBBS, MMed

Hypothesis
Smoking causes increased subsidence after anterior cervical discectomy and fusion with anchored standalone cages, leading to poorer functional outcomes.

Design
Retrospective Cohort Study

Introduction
Standalone cages for anterior cervical discectomy and fusion (SA-ACDF) are simpler to implant but exhibit higher subsidence rates than traditional plate and screw constructs. Smoking is a recognized risk factor for subsidence, though several studies suggest functional outcomes remain unaffected. We hypothesized that smoking exacerbates subsidence after SA-ACDF, resulting in worse functional outcomes.

Methods
A retrospective review of patients who underwent primary single (SL) and double-level (DL) SA-ACDF from 2015–2022 was performed. Patients were categorized as Non-Smokers (NS) or Current/Ex-Smokers (CES). Patients with diagnosis of cervical myelopathy, radiculopathy, or myeloradiculopathy, age range 40–90 years were includ-

ed. Patients with prior cervical spine surgery, tumor, or infection diagnosis were excluded. Data collected included patient biodata (age, gender, number of operated levels), radiological outcomes (1-year postoperative subsidence rates, 1-year Δtotal intervertebral height (TIH), 1-year Δlordotic angle), and functional outcomes (Japanese Orthopedic Association Score (JOAS), Neck Disability Index (NDI), Visual Analogue Scores for Neck Pain (VASNP) and Upper Limb Pain (VASLP) preoperatively, at 6 months, and at 2 years).

Results
23 CES and 48 NS were identified. Between the groups, there were no significant differences in age or levels operated (p>0.05). A higher proportion of the CES group were males (p=0.001). Radiological Outcomes of CES vs NS: Subsidence rate at 1 year was 60.9% (n=14) vs 35.4% (n=17) (p=0.043). The ΔTIH was 2.4mm vs -1.7mm (p=0.038), ΔLordotic Angle was -4.1° vs -3.8° (p=0.78) and fusion rate was 91.3% (n=21) Vs 89.5% (n=43) (p=0.82). Functional Outcomes of CES vs NS: Preoperative JOAS was 11.4 vs 11.8, NDI 45.9 vs 35.4, VASNP 6.1 vs 4.1, and VASLP: 4.3 vs 2.3. At two years postoperatively, JOAS was 15.0 vs 14.8, NDI 19.8 vs 9.6, VASNP 2.4 vs 1.0 and VASLP was 2.1 vs 0.5. Improvement in all functional scores were found after surgery (p<0.05). The rate of functional improvements were similar (p>0.05). CES demonstrated persistently worse NDI, VASNP and VASLP scores (p<0.05) at all time periods. Smoking did not affect JOA scores.

Conclusion
In SA-ACDF, smoking is linked to significantly worse radiological and functional outcomes. Subsidence rates are almost twice as high in smokers. NDI, VASNP, and VASLP scores improve post-surgery but remain about twice as elevated in smokers at 2 years postoperatively.

Best Paper - Spine Society of Thailand: Prediction of Postoperative Coronal Trunk Shift in Adolescent Idiopathic Scoliosis Surgery Using Intraoperative Crossbar Measurement Technique

Tinnakorn Pluemvitayaporn, MD; Suttinont Surapuchong, MD; Mahisaun Tongin; Charnchai Jongtaweesathapon; Piyabuth Kittithamvongs, MD, MSc; Warot Ratanakoosakul; Kitjapat Tiracharnvut, MD; Chaiwat Piyasakulkaew, MD; Sombat Kunakornsawat, MD

Hypothesis
To use the intraoperative crossbar measurement technique to assess and predict the postoperative coronal trunk shift following corrective spinal deformity through posterior fusion and instrumentation in adolescent idiopathic scoliosis.

Design
Prospective Cohort Study

Introduction
Adolescent idiopathic scoliosis (AIS) surgery aims to achieve spinal balance while minimizing complications. Numerous studies focus on the selection of instrumented levels, the prevention of shoulder imbalance, and the avoidance of the adding-on phenomenon. However, there exists a paucity of studies addressing postoperative coronal trunk shift and its intraoperative detection.

Methods
The study enrolled all individuals diagnosed with adolescent idiopathic scoliosis (AIS) and indicated for surgery between 2023 and 2025, based on the Lenke classification system. The fusion levels were chosen following Lenke's recommendations. Radiographic parameters assessed included C7-CSVL distance, major Cobb angle, T1 tilt angle, UIV tilt angle, and LIV tilt angle, both pre- and postoperatively. The postoperative coronal trunk shift was predicted utilizing the distance proportion derived from the intraoperative crossbar measurement technique

Results
The study included 50 AIS patients (45 females and 5 males) with an average age of 16.4 ± 4.5 years. The preoperative proximal thoracic curve averaged 57.7 degrees, reducing to 28.6 degrees postoperatively (50.4% correction). The main thoracic curve decreased from 48.9 degrees to 15.2 degrees (68.9% correction), and the thoracolumbar/lumbar curve dropped from 46.8 degrees to 11.3 degrees (75.9% correction). Intraoperative C7-CSVL distance after the deformity correction was 0.27 times the C7 vertebral body width, with postoperative distance at 0.55 times.

Conclusion
The intraoperative measurement of C7-CSVL using the crossbar technique accurately predicts 0.5 times the postoperative C7-CSVL distance. Our study shows that this technique effectively predicts postoperative trunk shift in adolescent idiopathic scoliosis (AIS) patients undergoing surgery. It is straightforward, reliable, accurate, and easily accessible.

Best Paper - Taiwan Spine Society: An Innovative 3D-360° Scanning Camera Radiation-Free Device for Assessing the trend of Adolescent Idiopathic Scoliosis curve

Pang Hsuan Hsiao, MD; Chun Tseng, MD, PhD; Chien Chung Chang, MD, PhD; Hsien Te Chen, MD, PhD

Hypothesis
We hypothesize that a radiation-free 3D-360° scanning device can assess scoliosis curves and monitor curve progression in AIS patients.

Design
Prospective Validation Study

Introduction
Adolescent idiopathic scoliosis (AIS) requires regular whole spine X-ray follow-up before reaching the indication for surgical intervention. However, prolonged monitoring with spinal X-rays results in cumulative radiation exposure, which may increase the risk of cancer in adolescent. Therefore, tracking the progression of scoliosis while reducing radiation exposure has always been a challenging task. This study will introduce a new radiation-free device for evaluation the curve trend and comparing with traditional X-rays in AIS patients.

Methods
From August 2023 to September 2024, we collected data

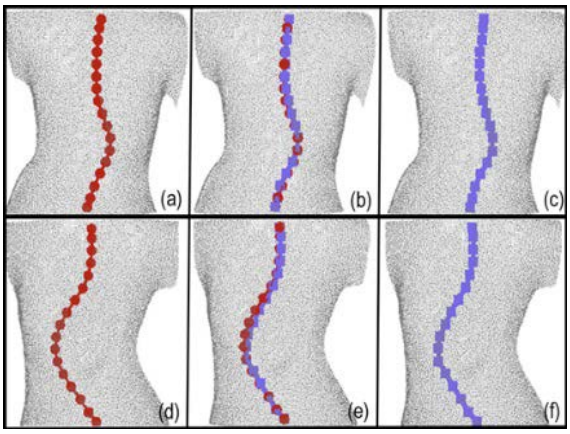
from a total of 55 patients diagnosed with adolescent idiopathic scoliosis, ranging in age from 14 to 30 years. All patients underwent whole segment spine X-ray anterior-posterior and sagittal view imaging and scanning with the new device. The results were analyzed using deep learning, comparing point cloud data generated by the device with the corresponding conventional X-ray findings. The two sets of extracted data are appropriately scaled and analyzed using Jaccard Index and Mean Square Error (MSE) to calculate the degree of alignment.

Results

The average Jaccard Index across the 55 patients is 0.91. The MSE has an average value of 1.96×10^{5}. The red curve represents the trend of the X-ray. The blue curve indicates the trend predicted by the machine. Figure (a), (b) and (c) is the same subject. Figure (d), (e) and (f) is another subject. The overlap between the two is figure (b) and (e).

Conclusion

This new device can be considered as an alternative to traditional X-rays for adolescent idiopathic scoliosis patients who have not reached the surgical indication.



INDUSTRY

The Scoliosis Research Society gratefully acknowledges Globus Medical, Orthofix and OrthoPediatrics for their support of the Hibbs Society Meeting.

Industry Workshops 240

INDUSTRY WORKSHOPS

Annual Meeting delegates are encouraged to attend the Industry Workshops. Each workshop is programmed by a single-supporting company and will feature presentations on topics selected by the company.

Please note: CME credits are not available for Industry Workshops.

Thursday, October 8 | 07:00-08:00

Hot breakfast will be provided

Room	Company
Room C2.1	VB Spine
Room C2.2	SI-BONE
Room C2.3	Highridge Medical
Room C2.4	Arthrex
Room C2.5	Australian Pacific Medical

Thursday, October 8 | 12:30-14:00

Hot lunch will be provided

Room	Company
Room C2.1	DePuy Synthes
Room C2.2	Orthofix
Room C2.3	Medtronic
Room C2.4	Globus Medical
Room C2.5	Carlsmed
Room C2.6	ATEC Spine

07:00-08:00

Arthrex | Room C2.4

Percutaneous Pars Fracture Repair—Arthrex Fully Threaded Headless Compression Screws
Faculty: Corey T. Walker, MD

Description: Utilization of robotics, uni-portal endoscopy and Arthrex fully threaded compression screws and instrumentation through a percutaneous approach

Australian Pacific Medical Pty Ltd | Room C2.5

Innovative technologies in spine surgery and real world experience
Speaker: Brian Hsu, MD; Wang Yu, MD; Alvin Pun, MBBS, FRACS, FAOrthA

Description: Join Dr. Hsu and invited experts to explore innovative spine technologies — and interact with all three products in a dedicated hands-on experience.

Highridge Medical | Room C2.3

The Tether® 2.0 Evolution of a Revolution
Faculty: Amer F. Samdani, MD; Baron S. Lonner, MD; Firoz Miyanji, MD, FRCSC; John T. Braun, MD

Description: Learn how a revolutionary, non-fusion approach to AIS has evolved since FDA HDE approval in 2019. An expert panel with 50+ years of combined experience with VBT will share their clinical framework for patient indications. The event will culminate with an introduction of The Tether 2.0, the next generation VBT system designed and developed for AIS applications. The Tether 2.0 is currently under FDA review.

SI-BONE | Room C2.2

When the Ends Fail: The Need for 3D Printed Osseointegrative Fixation
Faculty: Isador Lieberman, MD, MBA, FRCSC; Robert K. Eastlack, MD; Gregory M. Mundis Jr, MD; Alp Ozpinar, MD

Description:

- Recognize the clinical impact of compromised bone in spinal deformity surgery
- Understand the biomechanical rationale and clinical evidence supporting 3D-printed osseointegrative implant solutions
- Examine real world applications with case presentation from the panel

VB Spine | Room C2.1

From Biology to Prediction: Decoding the Molecular Drivers of Scoliosis Progression with ScolimiR-3D
Faculty: Alain Moreau, PhD

INDUSTRY WORKSHOPS

12:30-14:00

ATEC Spine | Room C2.6

EOS Insight for Surgical Decision Making: Aligning Clinical Judgment and Data Science
Moderator: Pat Miles, Chairman & CEO

Faculty: Andrew Chan, MD; Vedat Deviren, MD; Lawrence G. Lenke, MD; Juan S. Uribe, MD; and Kevin Vincent, PhD

Description: As interest in artificial intelligence accelerates across spine care, surgeons are asking practical questions: What problems can AI meaningfully solve today? What data is required to make these tools reliable? And how should they be validated for clinical use? This multidisciplinary fireside discussion brings together spine surgeons and data scientists to explore the real-world application of AI in alignment assessment, surgical planning, and clinical workflow. Through real case examples, the panel will examine the opportunities and challenges of translating emerging technologies into everyday practice. The session concludes with a forward-looking discussion on data collaboration, standardization, and the role surgeons can play in shaping the responsible integration of AI into spine care.

Carlsmed | Room C2.5

The aprevo® Technology Platform AI-Enabled 3D Surgical Planning and Patient-Specific Devices: Clinical Evidence, Expanding Applications, and What›s Next
Faculty: Christopher P. Ames, MD; Sigurd H. Berven, MD; Alex Cruz, MD; Zeeshan M. Sardar, MD; Sharon Schulzki

Description: aprevo® is reshaping spine surgery by enabling treatment strategies tailored to achieve the goals of each patient's anatomical 3D virtual correction plan. A growing body of evidence continues to demonstrate the value of the aprevo® Technology Platform in supporting improved outcomes across an expanding range of applications, from complex adult spinal deformity to degenerative lumbar disease and patients with compromised bone quality.

This workshop will explore the aprevo® Technology Platform through the lens of current clinical evidence and surgeon experience. Faculty will discuss the role of aprevo® in adult spinal deformity, degenerative lumbar surgery, and patients with poor bone quality, highlighting patient selection, case examples, and published data. The session will conclude with early clinical experience and results in cervical applications.

DePuy Synthes | Room C2.1

DePuy Synthes Presents: Bridges to a New Era in Spinal Deformity
Moderator: Amer F. Samdani, MD & Isador Lieberman, MD, MBA, FRCSC

Faculty: Jennifer M. Bauer, MD, MS; Eric O. Klinberg, MD; W.G. Stuart Mackenzie, MD; Alexos A. Theologis, MD

Description: Join leading pediatric and adult spine surgeons for a high-impact, debate-driven workshop tackling the toughest challenges in deformity surgery. Through dynamic discussion and expert insight, you'll gain practical strategies on fusion decisions, alignment goals, and managing complex surgical environments. Explore how cutting-edge technologies, robotics, navigation, and predictive analytics will transform the way surgeons plan and execute deformity procedures.

Globus Medical | Room C2.4

From Early Onset to Adult Deformity: Complex Case-Based Insights, Cutting Edge Techniques, and Panel Debate
Moderators: Suken A. Shah, MD & Gregory M. Mundis Jr, MD

Faculty: Michelle C. Welborn, MD; Ferran Pellisé, MD, PhD; Aaron J. Buckland, MBBS, FRACS; Joshua M. Pahys, MD

Description: Explore the full spectrum of deformity care from early-onset to complex adult conditions in this dynamic, case-based workshop. Attendees will gain meaningful insights into advanced techniques, evolving treatment strategies, and decision-making challenges across all age groups. Interactive panel discussions and expert debates will highlight controversies, complications, and varying approaches.

INDUSTRY WORKSHOPS

12:30-14:00

Medtronic | Room C2.3

Treating Complex Pathologies Utilizing the Full Spectrum of Planning, Hardware and Segmental Tracking

Moderator: Marinus de Kleuver, MD, PhD

Panel: Jeffrey L. Gum, MD; Christopher J. Kleck, MD; Ronald A. Lehman Jr., MD

Description: Join a panel of experts, moderated by Prof. Marinus de Kleuver, as they share their clinical experiences with the AiBLE Ecosystem and its role in the treatment of complex deformity. Dr. Jeff Gum, Dr. Christopher Kleck, and Dr. Ron Lehman will highlight how planning, robotics, and optimized implants can be used together to support surgical decision-making and improve the management of challenging complex cases

Orthofix | Room C2.2

Continuous Precision: Personalized Alignment to Machine Vision Surgery

Faculty: Robert K. Eastlack, MD; Jeffrey Hills; Michael D. Selby MBBS, FRACS, FAOrthA; Rajiv K. Sethi, MD, PhD

Description: Achieving optimal alignment requires precision from start to finish. By bringing together preoperative planning, radiation-free Machine Vision navigation, and patient-specific rod execution, surgeons can apply a comprehensive digital approach to deformity correction. Discover how aligning these tools across the care continuum helps personalize treatment while maximizing accuracy, OR efficiency, and patient care.

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Rajiv K. Sethi, MD, PhD	United States	Alphatec Spine (g); Globus Medical (b, g); Orthofix (b, g); Highridge Medical (April 2024 to Present) (b)
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Francis Lovecchio, MD	United States	SI Bone (b); Seaspine (b); Alphatec Spine (a, b); Highridge Medical (April 2024 to Present) (d)
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Robert H. Cho, MD	United States	DePuy Synthes (b); Globus Medical (b, e, g); OrthoPediatrics (b, e); Pacira Pharmaceuticals (b); Ergobaby Inc. (b, e)
Samuel K. Cho, MD	United States	Alphatec Spine (b); Globus Medical (g); Medtronic (b); SI Bone (g)
Romain Dayer, MD	Switzerland	DePuy Synthes (a, b, d)
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Jeffrey Gum, MD	United States	Acuity (b, e, g); Globus Medical (b, g); Medtronic (b, e, g); VB Spine (b, e); FYR Medical (b, e); Norton Healthcare, Inc (f); Expanding Innovations (b, c); Pacira Pharmaceutical , Baxter, Broadwater, NASS, Fischer Owen Fund (g); Cingulate Therapeutics (c); Alan L. & Jacqueline B. Stuart Spine Center, Biom'Up, Cerapedics, Inc., Empirical Spine, Inc. Medtronic, National Spine Health Foundation, Scoliosis Research Society, Stryker, The International Spine Study Group, Edwards LifeSciences (a)
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Craig R. Louer Jr, MD	United States	Globus Medical (a, d); Highridge Medical (April 2024 to Present) (d); DePuy Synthes (b, d); OrthoPediatrics (e)
W.G. Stuart Mackenzie, MD	United States	DePuy Synthes (b)
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Alekos A. Theologis, MD	United States	DePuy Synthes (b); Alphatec Spine (a, g); Restor3D (g); Ulrich Medical USA (b, g); SI Bone (a, b); Globus Medical (a, b); Smart Step Surgical (b); Surgeon Design Center (b); VB Spine (a, b); SpineArt (b); SRI (b); Medtronic (b)
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Eren Kuris, MD	United States	Orthofix (b); Medtronic (a)
Venu M. Nemani, MD, PhD	United States	Medtronic (b, d); Orthofix (b, d); Alphatec Spine (a, b); Carlsmed (b, d); Highridge Medical (April 2024 to Present) (b, d, g)
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May Choi, MD	Canada	AstraZeneca (b); Celltrion (b); Organon (b); Werfen (b); MitogenDx (b); Biogen (b)
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Full Name	Country	Disclosure
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Christopher J. Nielsen, MD	Canada	DePuy Synthes (d)
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International Spine Study Group	United States	DePuy Synthes (a); Medtronic (a); NuVasive (a); Stryker Spine (a); Alphatec Spine (a); Globus Medical (a); Bioventus (g); Cerapedics (g); HCA Healthcare Inc. (g); Implanet (g); Pacira (g); SI Bone (g); SMAIO (g); Amplify (g); Astura Medical (g); Highridge Medical (April 2024 to Present) (g); Icotec Medical (g); Implanet (g); Induce Biologics (g); Neo Spine USA (g); Spinal Elements, Inc. (g); TrackX (g)
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2026 RESEARCH GRANTS

SRS Research funds are dedicated solely to research seeking improved treatments, the causes and possible prevention of spinal deformities. Since 1994, SRS has provided more than $8.6 million for 244 spinal deformity research projects from the institutions all over the world, including the United States, Australia, Canada, Hong Kong, Spain and the Netherlands. These have included studies on improved spinal cord monitoring during surgery, brace treatment effectiveness, methods to improve fusion rates, and studies looking for the cause of idiopathic scoliosis.

In 2026, SRS received 84 grant applications, requesting over $6.1 million. The following 13 projects were selected for funding.

2026 RESEARCH GRANTS

Title of Project	Primary Investigator/ Location	Grant Duration	Type of Grant
SpineRAG: A Retrieval-Augmented Generation System for AI-Assisted Consensus in Spinal Deformity	Chuck Lam / Birmingham, United Kingdom	1 year	Exploratory Micro
Time-Dependent Stiffening 4D-Printed Braces to Improve Compliance in AIS	Weichen Qi / Hong Kong	1 year	Exploratory Micro
Morphological Apical Intervertebral Disc and Vertebral Characteristics as Predictors of Curve Progression in AIS	Conor Boylan / Birmingham, United Kingdom	1 year	Resident/Fellow
The Neurobiology of Deformity Correction: imaging neurovascular dynamics during reduction maneuvers	TJ Florence / San Diego, United States	1 year	Resident/Fellow
Patient-Specific Vertebral Strength Estimation from Preoperative CT Predicts Proximal Junctional Failure After Adult Spinal Deformity Surgery	Syed Khalid / Philadelphia, United States	1 year	Resident/Fellow
Noninvasive Auricular Vagal Nerve Stimulation for Reducing Inflammation After Long-Segment Fusion for Adult Spinal Deformity	Alexander Yahanda / St. Louis, United States	1 year	Resident/Fellow
What Does the Cell Saver Give Back? Characterizing Inflammatory Contaminants in Salvaged Blood During Spinal Deformity Surgery	Byron Stephens / Nashville, United States	2 year	Biedermann Innovation
Using a novel scoliosis mouse model to investigate hormonal regulation of spinal growth during scoliosis development	Joe Kodama / Baltimore, United States	2 year	SRS-Cotrel Foundation Basic Science
Mechanisms of Spinal Stiffening After Growing Rod Insertion	Blake Montgomery / Philadelphia, United States	2 year	New Investigator
A Wearable-Based Gait Index for Monitoring Functional Recovery After Spinal Arthrodesis for Adult Spinal Deformity	Theo Cojean / Sainte-Foy-lès-Lyon, France	2 year	New Investigator
Prospective Validation of an Artificial Intelligence Platform for Real-Time Intraoperative Neuromonitoring (IONM) in Spine Surgery	Michael Vitale / New York, United States	2 year	Standard
Epigenetic Aging in Adult Spinal Deformity: Longitudinal Effects of Surgical Correction on Biological Age and Recovery	Brian Neuman / St. Louis, United States	2 year	Standard
Deterministic Patient-Specific Biomechanical Simulation of Posterior Fusion Strategies in Lenke 5 AIS	Alexandria Mallinos / Akron, United States	2 year	Standard

ABOUT SRS

SRS OVERVIEW

Founded in 1966, the Scoliosis Research Society is an organization of medical professionals and researchers dedicated to improving care for patients with spinal deformities. Over the years, it has grown from a group of 37 orthopaedic surgeons to an international organization of more than 1,800 health care professionals.

MISSION STATEMENT

The purpose of the Scoliosis Research Society is to foster the optimal care of all patients with spinal deformities.

DEI STATEMENT

The SRS recognizes the benefit of bringing the knowledge, perspectives, experiences, and insights of a diverse membership to our society. We are committed to including outstanding members from the broad spectrum of human ethnicities, genders, sexual orientations, national origins, geographic backgrounds, abilities, disabilities, religious beliefs, and ages. We will create a culture that is equitable and inclusive, where everyone has a voice and differences are celebrated. By building a membership and leadership who better reflect the diverse communities we study and care for, we foster better and more equitable care for patients with spinal disorders.

MEMBERSHIP

SRS is open to orthopaedic surgeons, neurosurgeons, researchers, and allied health professionals who have a practice that focuses on spinal deformity. Visit www.srs.org/membership for more information on membership types, requirement details, and to apply online.

PROGRAMS AND ACTIVITIES

SRS is focused primarily on education and research that includes the Annual Meeting, the International Meeting on Advanced Spine Techniques (IMAST), Worldwide Courses, the Research Education Outreach (REO) Fund, which provides grants for spine deformity research, and development of patient education materials.

WEBSITE INFORMATION

For the latest information on SRS meetings, programs, activities, and membership please visit http://www.srs.org. The SRS Website Committee works to ensure that the website information is accurate, accessible, and tailored for target audiences. Site content is varied and frequently uses graphics to stimulate ideas and interest. Content categories include information for medical professionals, patients/public, and SRS members.

SOCIETY OFFICE STAFF

Ashtin Neuschaefer, CAE - Executive Director
Grace Abrahamson - Meetings Manager
Rachel Davis - Administrative Manager
Erica Ems - Membership Manager
Sammie Farrall - Digital Communications Manager
Rachel Johnston - Program Manager, Education
Laura Pizur, CAE - Research Program Manager
Kelly Rabolt - Major Gifts Officer
Kate Reed - Website Manager
Rebecca Scardino - Senior Education Manager
Michele Sewart, PMP - Senior Communications Manager
Leah Skogman, CMP - Senior Meetings Manager

SCOLIOSIS RESEARCH SOCIETY

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http://www.srs.org

Join the conversation surrounding the SRS Annual Meeting by including **#SRSAM26** in your social media posts.

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April 7–9, 2027 | Powered by the Scoliosis Research Society

34TH IMAST

Copenhagen, Denmark

62ND ANNUAL MEETING

NEW ORLEANS, LOUISIANA

SEPTEMBER 14–18, 2027

SRS
Scoliosis Research Society

SPINE DEFORMITY SOLUTIONS:
A HANDS-ON COURSE
FROM THE SCOLIOSIS RESEARCH SOCIETY

JUNE 23-25, 2027

Nijmegen, Netherlands

SRS
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SPINE Next
A HANDS-ON COURSE FOR EARLY CAREER SURGEONS
Powered by the SRS | Denver, Colorado, USA

SRS
Scoliosis Research Society

MAY 20–22, 2027

MEETING OUTLINE

TUESDAY, OCTOBER 6, 2026		
07:00 - 08:00	Committee Chair Breakfast* (*by invitation only*)	Room C2.3
08:00 - 16:30	Committee and Council Meetings*	Varied: C2-Rooms
10:30 - 17:00	Registration Open	Ground Level
12:00 - 17:00	Speaker Ready Room Open	Speaker Prep Centre
13:00 - 17:00	Hibbs Society Meeting ● ■ ○	Parkside Ballroom
18:00 - 21:30	SRS Leadership Dinner* (*by invitation only*)	Offsite
WEDNESDAY, OCTOBER 7, 2026		
06:30 - 19:00	Registration Open	Ground Level
07:00 - 18:30	Speaker Ready Room Open	Speaker Prep Centre
07:00 - 08:00	Women In Spine Breakfast	Parkside Ballroom
08:00 – 09:50	Pre-Meeting Course ●	Darling Harbour Theatre
09:50 - 10:15	Refreshment Break ●	The Gallery
10:15 – 12:00	Pre-Meeting Course	Parkside Ballroom
12:00 - 12:15	Lunch Pick-Up	The Gallery
12:15 - 13:15	Lunchtime Symposia 1 ● ■ Lunchtime Symposia 2 ● ■ Lunchtime Symposia 3 ● ■	Darling Harbour Theatre Parkside Ballroom Pyrmont Theatre
13:15 - 13:30	Break	
13:30 - 15:00	Abstract Session 1 ●	Darling Harbour Theatre
15:00 - 15:20	Refreshment Break	The Gallery
15:20 - 17:05	Abstract Session 2 ■	Darling Harbour Theatre
17:05 - 17:20	Break	
17:20 - 19:00	Opening Ceremonies*	Darling Harbour Theatre
19:00 - 21:00	Welcome Reception*	The Gallery
THURSDAY, OCTOBER 8, 2026		
06:30 - 16:00	Registration Open	Ground Level
07:00 - 16:00	Speaker Ready Room Open	Speaker Prep Centre
07:00 - 08:00	L.E.A.D. Breakfast* (*by invitation only*)	Parkside Ballroom
07:00 - 08:00	Industry Workshops* (*5 Concurrent Sessions*)	Varied: see Meeting App
08:00 - 09:50	Abstract Session 3A ○ Abstract Session 3B ■	Darling Harbour Theatre Pyrmont Theatre
09:50 - 10:10	Refreshment Break	The Gallery
10:10 - 12:15	Abstract Session 4; Harrington Lecture & Lifetime Achievement Award	Darling Harbour Theatre
12:15 - 12:30	Lunch Pick-Up	The Gallery
12:30 - 14:00	Industry Workshops* (*6 Concurrent Sessions*)	Varied: see Meeting App
14:00 - 14:10	Refreshment Break	The Gallery
14:10 - 15:55	L.E.A.D. SRS Cohort Session* (*by invitation only*)	Parkside Ballroom
14:10 - 15:55	Half-Day Course 1 ■ ○ ▲ Abstract Session 5 ■	Darling Harbour Theatre Pyrmont Theatre
16:00 - 17:30	SRS Traveling Fellows Alumni Reception* (*by invitation only*)	Room C2.6
FRIDAY, OCTOBER 9, 2026		
06:30 - 07:30	Past Presidents' Breakfast* (*by invitation only*)	Room C2.3
07:00 - 17:30	Registration Open	Ground Level
07:00 - 18:00	Speaker Ready Room Open	Speaker Prep Centre
08:00 - 09:50	Abstract Session 6	Darling Harbour Theatre
09:50 - 10:10	Refreshment Break	The Gallery
10:10 - 11:50	Abstract Session 7 ■ ▲ & Presidential Address	Darling Harbour Theatre
12:15 - 13:30	Member Business Meeting* (*lunch pick-up at 11:50*)	Parkside Ballroom
12:15 - 13:30	Membership Information Session for Non-Members** (*lunch pick-up at 11:50*)	Room C2.2-3
13:30 - 13:45	Break	
13:45 - 15:30	Half-Day Course 2 ■ ○ Abstract Session 8 ○	Darling Harbour Theatre Pyrmont Theatre
15:30 - 15:50	Refreshment Break	The Gallery
15:50 - 18:00	Abstract Session 9A Abstract Session 9B ■	Darling Harbour Theatre Pyrmont Theatre
18:30 - 19:30	President's Reception* (*by invitation only*)	Offsite
19:30 - 22:00	Farewell Reception* (*ticket required*)	Offsite
SATURDAY, OCTOBER 10, 2026		
07:00 - 08:00	SRS Board of Directors Meeting*	Room C2.3
07:30 - 11:30	Registration Open	Ground Level
07:30 - 11:30	Speaker Ready Room Open	Speaker Prep Centre
08:00 - 10:10	Abstract Session 10 ■, Award Presentation & Transfer of the Presidency	Darling Harbour Theatre
10:10 - 10:30	Refreshment Break	Darling Harbour Theatre Foyer
10:30 - 12:15	Abstract Session 11 ▲	Darling Harbour Theatre
12:15	SRS 61st Annual Meeting Concludes	

● **Early Career** ■ **Pediatric/Adolescent** ○ **Adult Spinal Deformity** ▲ **Neurosurgery**

**denotes a non-CME session/activity*

WIRELESS INTERNET

Network: SRS Annual Meeting | Password: 61SRS2026