

# FINAL PROGRAM



33<sup>rd</sup> International Meeting on Advanced Spine Techniques

## IMAST 2026 TORONTO, ON, CANADA

*Powered by Scoliosis Research Society*



APRIL 15-17, 2026

[WWW.SRS.ORG/IMAST](http://WWW.SRS.ORG/IMAST)

# CORPORATE SUPPORTERS

We are pleased to acknowledge and thank those companies that **provided financial support to SRS in 2025**. 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 (REO) Fund.

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SRS would like to thank the following supporters who provided grant support to the 33<sup>rd</sup> IMAST:

**Atec Spine • DePuy Synthes  
Globus Medical • Highridge Medical  
Medtronic • Orthofix • VB Spine**

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## 33<sup>RD</sup> IMAST VENUE

Metro Toronto Convention Centre (MTCC)  
255 Front Street West  
Toronto, ON M5V 2W6, Canada

## FUTURE EDUCATIONAL EVENTS

### ANNUAL MEETING

61<sup>st</sup> Annual Meeting  
October 6-10, 2026 | Sydney, Australia

62<sup>nd</sup> Annual Meeting  
September 14-18, 2027 | New Orleans, Louisiana, USA

63<sup>rd</sup> Annual Meeting  
September 12-16, 2028 | Vancouver, BC, Canada

### INTERNATIONAL MEETING ON ADVANCED SPINE TECHNIQUES

34<sup>th</sup> IMAST  
April 7-9, 2027 | Copenhagen, Denmark

35<sup>th</sup> IMAST  
April 5-7, 2028 | Seoul, Korea

# WELCOME TO THE 33<sup>RD</sup> IMAST

Dear Delegates and Attendees,

Welcome to Toronto and the 33<sup>rd</sup> International Meeting for Advanced Spine Techniques (IMAST), powered by the Scoliosis Research Society (SRS).

This year's IMAST features the theme: *The Future of Spine: Driving Innovation & Cultivating Leadership*. This theme is strongly represented in the program which features topics such as Design Thinking and Innovation in Spine Surgery, Artificial Intelligence & Emerging Concepts and Understanding the Past and Conquering the Future.

As always, one of the highlights of this meeting is Cases and Cocktails. This year's topics cover Adult, Pediatric and Cervical Deformity. We are also featuring a keynote from Stefan Parent, MD, PhD, on the topic "From Surgeon-Scientist to Surgeon-Entrepreneur: The Unexpected Journey that Led Us to Produce the Top-Ranked Helmet in the NFL".

A don't miss session includes Mastering Early Practice: Lessons Learned with Grey Hair featuring topics like Avoiding the Landmines: Complications I Didn't See Coming and Building Your OR Playbook: Techniques That Saved Me.

The year's Instructional Course Lectures feature future trends in spine surgery and include range of compelling topics such as Innovations in Value Based Care, MIS Deformity: State-of-the-Art, Practical Tips for Using AI to Improve Clinical Care and From Napkin to Commercialization: Device Development.

New this year are the Innovation Updates. Join SRS industry partners for updates on innovations in the Innovation Theatre which is located in the Exhibit Hall.

We offer a special thank you to our industry partners for their continued support. Plan your schedule accordingly so that you can see all of the latest in the exhibit hall and during the Hands-on Workshops. More information on these can be found beginning on page 159.

Close this meeting with the Innovation Celebration on Friday, April 17 from 17:35 - 19:00 in the Azure Lounge at the InterContinental Toronto Centre hotel.

Of note, this is the first IMAST to feature simultaneous translation services for multiple languages via the translation app Wordly. Remember to bring your headphones to use this free service!

Collectively, we have produced what will be a sensational meeting experience that has topics to interest any attendee.



*Amit Jain*

Amit Jain, MD MBA  
IMAST Co-Chair



*Calgar Yilgor*

Calgar Yilgor, MD  
IMAST Co-Chair

General Information

Meeting Agenda

Podium Presentation Abstracts

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## IMAST MEETING APP

A meeting app will be available to all delegates during the 33<sup>rd</sup> IMAST. The meeting app is designed to enhance the attendee experience by providing all the information about IMAST in one convenient location that can be accessed from any smart phone or tablet with an internet connection.

### To download the 33<sup>rd</sup> IMAST Meeting App:

1. Search for IMAST26 in the App Store or Google Play Store and install
2. Open the downloaded app to begin using the app right away
3. To take full advantage of the app, login with your email address

Once downloaded, delegates can access all static content on the app without an internet connection, including:

- A detailed IMAST agenda, which allows delegates to create a personalized schedule (must login with an email address).
- Sort sessions by content tags to plan your meeting experience. Session tags include **PEDIATRICS/ADOLESCENT**, **ADULT SPINAL DEFORMITY**, **NEUROSURGERY** and **EARLY CAREER**
- Exhibitor information including exhibit floor plan, company descriptions and the Hands-On Workshop schedule.
- Maps of meeting space
- An alert system for real-time updates from SRS.
- Session and overall meeting evaluations
- Abstracts

*Please remember to activate your wireless access on your mobile device or tablet to utilize the meeting app without incurring international fees and charges!*

### ASK A QUESTION IN THE APP

Delegates will be able to ask questions, directly through the meeting app, during all sessions at IMAST

To ask a question:

1. Click on "Agenda" and select the session you are in with the "Ask a Question" feature enabled.
2. Scroll to the bottom of the session information and click "Ask a Question" under Session Engagement. Questions already asked by attendees will be listed.
3. Click "Ask a Question" again and a text box will appear.
4. Type your question in the text box and click "Submit Question". Your question will appear within the question list.
5. If someone has asked a question you would also like answered, you can "up vote" the question by clicking the circular up arrow button to the right of the question in the list. When questions get up voted they will be pushed higher up on the page as the number of votes rise.



Join the conversation surrounding IMAST by including **#SRSIMAST26** in your social media posts.



@ScoliosisResearchSociety



@srs\_org



@Scoliosis Research Society



@srs\_org



@srs\_org



@srs\_org

# GENERAL MEETING INFORMATION

## MEETING DESCRIPTION

The 33<sup>rd</sup> IMAST will offer an experience where leading spine surgeons, innovative researchers and the most advanced spine technologies come together in an international forum to demonstrate and discuss recent advances in spine surgery.

## IMAST MISSION & VISION STATEMENT

### Mission

To freely present, discuss and debate emerging technologies used for the treatment and care of patients with complex spine conditions.

### Vision

To be the premier global forum where professionals treating complex spinal conditions meet to share, discuss and demonstrate groundbreaking research with a focus on innovation.

## LEARNING OBJECTIVES

Upon completion of IMAST, participants should be able to:

1. Assess the strategic integration and clinical applicability of emerging technologies, such as advanced diagnostics and enabling platforms to drive innovation in complex spinal deformity management.
2. Formulate leadership strategies for effectively evaluating and implementing evidence-based practices and novel techniques to improve outcomes, minimize complications, and avoid pitfalls during the learning curve across diverse spinal pathologies.
3. Evaluate the next-generation minimally invasive and motion-preservation techniques, including endoscopic and robotic applications, to guide patient-centered decision-making and foster surgical excellence.
4. Cultivate impactful framework focused on building multidisciplinary spinal deformity teams for advancing global best practices in spinal care and enhancing innovations in education and training.

## TARGET AUDIENCE

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

## ATTIRE

Business casual (polo or dress shirts, sport coats) are appropriate for IMAST sessions.

## CASES & COCKTAILS

Cases will be presented by faculty in three concurrent sessions on Wednesday, April 15 from 16:00 - 18:00. Attendees will have the opportunity to discuss cases in small groups with an IMAST faculty member present at each table. Each case presentation will be followed by small group discussions in which each table will debate the various treatment options and determine their action plan. Libations will continue to be served during this time so that all may continue to enjoy a relaxed atmosphere while discussing cases. registered delegates are welcome and encouraged to attend and participate.

Cases & Cocktails session topics:

- Adult Deformity; *supported, in part, by a grant from Highridge Medical*
- Pediatric Deformity; *supported, in part, by a grant from ATEC Spine*
- Cervical Deformity; *supported, in part, by a grant from ATEC Spine*

We encourage delegates to join us for the Welcome Reception, immediately following the Cases & Cocktails sessions, from 18:00 - 20:00. The Welcome Reception will be held in the Exhibit Hall.

## CELL PHONE PROTOCOL

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

## CHARGING TABLES

Delegates are welcome to use the complimentary charging tables located in the sitting area across from the Exhibit Hall on Level 100 to recharge smartphones and small tablets. Please do not leave your electronic devices or any personal belongings at the charging station unattended.

## CME INFORMATION

CME certificates will be available to pre-registered delegates upon the opening of the meeting at <https://apps.srs.org/meetings/imast2026/cme>.

Delegates should log on to the website listed above and enter their last name and the ID# listed on their meeting badge. The system will ask delegates to indicate which sessions they attended and then will generate a PDF certificate which may be printed or saved to the delegate's computer. Session atten-

## GENERAL MEETING INFORMATION

dance is saved in the database, and certificates may be accessed again, in the event the certificate is lost, or another copy is required.

Please note that certificates will not be mailed or emailed after the meeting. The online certificate program is the only source for this documentation. Please contact SRS at [cme@srs.org](mailto:cme@srs.org) for any questions. SRS asks that all CME certificates be claimed no later than December 31, 2026.

### 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 13.5 *AMA PRA Category 1 Credit(s)*<sup>™</sup>. 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.

## EMERGENCY & FIRST AID

The Metro Toronto Convention Centre (MTCC) 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 AWARD SESSIONS

Visit the Innovation Theatre for mini-sessions highlighting the top-scoring E-Points. Listen to live rapid-fire presentations from each nominated paper, followed by a moderated discussion. Voting for award-nominated E-Points can be completed on the IMAST meeting app, and will remain open until Friday, April 17 at 12:00 pm, Eastern Time.

## E-POINT PRESENTATION KIOSKS

There are over 85+ E-Point Presentations to view on the E-Point Presentation kiosks located in the Exhibit Hall.

## IMAST MOMENT WALL

Be sure to capture your IMAST moments at the IMAST moment wall located behind Booth #18 in the Exhibit Hall. Don't forget to tag #SRSIMAST26.

## INNOVATION CELEBRATION

Join your colleagues to close out the 33<sup>rd</sup> IMAST. The celebration takes place Friday, April 17 from 17:35 - 19:00 in the Azure Lounge at the InterContinental Toronto Centre hotel. Open to all registered delegates and guests of registered delegates. Tickets are \$25 USD for registered delegates and \$50 USD for guests and must be purchased in advance. Please stop at the IMAST registration desk to purchase tickets. Dress for the Innovation Celebration is business casual.

### INNOVATION UPDATES

Please join SRS industry partners for updates on innovations by the sponsoring company. Innovation Updates take place in the Innovation Theatre which is located in the Exhibit Hall. Please see page 161 for schedule and descriptions.

## INTERNET ACCESS

Wireless Internet access is available throughout the IMAST meeting space of the MTCC.

To log on select...

Network = SRS Meeting

Password = IMAST2026

## 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 a lost or found an item during the course of IMAST.

## NAME BADGES

Official name badges are required for admission to all IMAST sessions, exhibit hall, and events. 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 activ-

## GENERAL MEETING INFORMATION

ities. 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 IMAST activity or event.

### REGISTRATION DESK

Location: Level 100 Foyer  
 Wednesday, April 15 12:30 - 18:30  
 Thursday, April 16 07:00 - 18:30  
 Friday, April 17 07:00 - 17:30

### SIMULTANEOUS TRANSLATION



Hall 105

Scan the QR code to connect to real-time translation during the sessions.

*Please use your own headphones*





Hall 107

### 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: Room 103 B, Level 100  
 Wednesday, April 15 13:00 - 18:00  
 Thursday, April 16 08:00 - 18:30  
 Friday, April 17 07:00 - 17:00

### 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.

### WELCOME RECEPTION

All registered delegates are invited to attend the IMAST Welcome Reception on Wednesday, April 15 from 18:00 - 20:00. The reception will be hosted in the Exhibit Hall (Constitution Hall 106), where beverages and light hors d'oeuvres will be served. There is no charge for registered delegates. Registered delegates may purchase guest ticket(s) for the Welcome

Reception for \$50 USD, per person, at the IMAST registration desk. Dress for the Welcome Reception is business casual.

### WHO CAN ATTEND IMAST?

IMAST 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."

### INNOVATION ICLs

**NEW:** Check out the Innovation ICL sessions, located in the IMAST Innovation Theatre. These brief sessions will focus on various high-interest topics with opportunities for discussion in a smaller, intimate setting. See pages 4-5 for more details.

Session topics include:

- Innovations in Value Based Care
- MIS Deformity: State-of-the-Art
- Practical Tips for Using AI to Improve Clinical Care
- From Napkin to Commercialization: Device Development

# MEETING OVERVIEW

|           | WEDNESDAY, APRIL 15  | THURSDAY, APRIL 16  | FRIDAY, APRIL 17  |
|-----------|--|---|---|
| MORNING   |  | 07:00 - 18:30<br>Registration Open<br>07:30 - 08:30<br>Hands-On Workshops*<br><i>with breakfast</i><br>08:30 - 08:40<br>Exhibit Viewing*<br>08:40 - 09:30<br>Session 2<br>09:30 - 09:45<br>Exhibit Viewing &<br>Refreshment Break*<br>09:45 - 11:45<br>Abstract Session 3<br>Whitecloud Award<br>Nominated Paper<br>11:45 - 12:00<br>Exhibit Viewing & Lunch Pick-Up* | 07:00 - 17:30<br>Registration Open<br>07:30 - 08:30<br>Session 7<br>08:30 - 09:00<br>Exhibit Viewing & Re-<br>freshment Break*<br>09:00 - 11:30<br>Session 8 & Keynote Address*<br>11:30 - 12:00<br>Exhibit Viewing &<br>Lunch Pick-Up *  |
| AFTERNOON | 12:30 - 18:30<br>Registration Open<br>14:30 - 15:40<br>Session 1<br>16:00 - 18:00<br>Cases & Cocktails | 12:00 - 13:00<br>Hands-On Workshops*<br>13:00 - 13:30<br>Exhibit Viewing*<br>13:30 - 15:00<br>Concurrent Sessions<br>(Sessions 4A & 4B)<br>15:00 - 15:30<br>Exhibit Viewing & Re-<br>freshment Break*<br>15:30 - 17:00<br>Concurrent Sessions<br>(Sessions 5A & 5B*)<br>17:00 - 17:30<br>Exhibit Viewing*<br>17:30 - 18:30<br>Session 6*                              | 12:00 - 13:00<br>Hands-On Workshops*<br>13:00 - 13:15<br>Exhibit Viewing*<br>13:15 - 14:30<br>Concurrent Sessions<br>(Sessions 9A & 9B)<br>14:30 - 15:00<br>Exhibit Viewing & Re-<br>freshment Break*<br>15:00 - 16:15<br>Concurrent Sessions<br>(Sessions 10A & 10B)<br>16:15 - 16:30<br>SRS Membership Info Session*<br>Exhibit Viewing*<br>16:30 - 17:35<br>Session 11 |
| EVENING   | 18:00 - 20:00<br>Welcome Reception &<br>Exhibit Viewing*   |   | 17:35 - 19:00<br>Innovation Celebration*<br><i>Ticket required</i>  |

\*Denotes a non-CME session/event

General Information

Meeting Agenda

Podium Presentation  
Abstracts

E-Point Presentation  
Abstracts

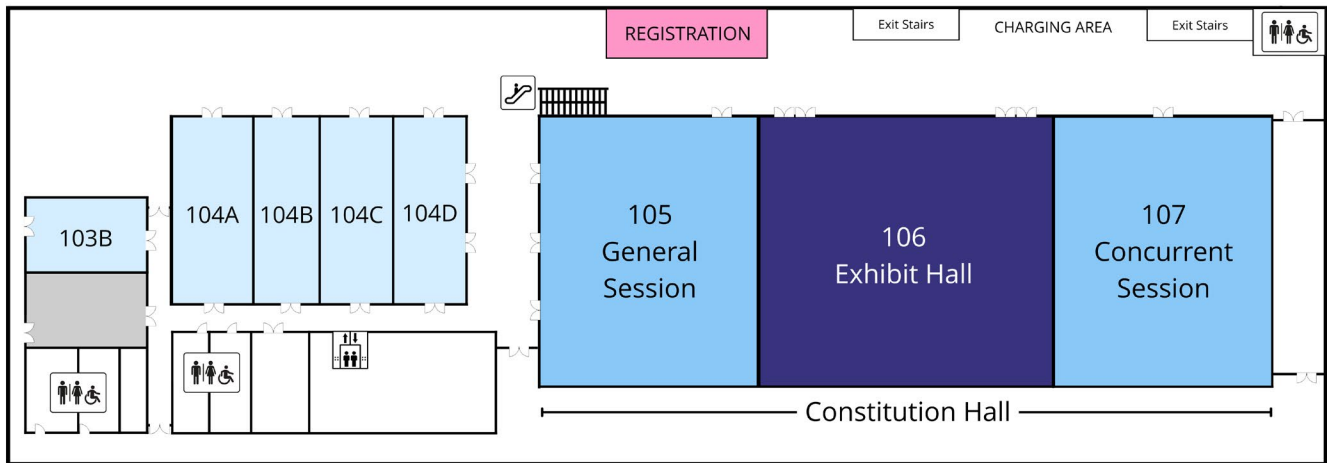
Exhibits & Workshops

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# MEETING LOCATION MAP

## METRO TORONTO CONVENTION CENTRE (MTCC)



|                       | WEDNESDAY         | THURSDAY           | FRIDAY |
|-----------------------|-------------------|--------------------|--------|
| Room 103 B            |                   | Speaker Ready Room |        |
| Room 104 A            |                   | Hands-On Workshop  |        |
| Room 104 B            | Cases & Cocktails | Hands-On Workshop  |        |
| Room 104 C            | Cases & Cocktails | Hands-On Workshop  |        |
| Room 104 D            | Cases & Cocktails | Hands-On Workshop  |        |
| Constitution Hall 105 |                   | General Session    |        |
| Constitution Hall 106 |                   | Exhibit Hall       |        |
| Constitution Hall 107 |                   | Concurrent Session |        |



### WE WANT YOUR FEEDBACK!

Complete the IMAST Meeting Evaluation on the app or online.

If you have questions, contact [cme@srs.org](mailto:cme@srs.org)

# MEETING AGENDA: WEDNESDAY, APRIL 15, 2026

14:30 - 15:40 | SESSION 1

Constitution Hall 105

## Mastering Early Practice: Lessons Learned with Grey Hair EARLY CAREER

*This session is supported, in part, by a grant from DePuy Synthes, Globus Medical and Orthofix*

*Moderators: Serena S. Hu, MD & Zeeshan M. Sardar, MD*

14:30 - 14:40 **Optimizing Correction in Adolescent Idiopathic Scoliosis**

*Lawrence G. Lenke, MD*

14:40 - 14:50 **Avoiding Complications in High Grade Spondylolisthesis**

*Munish C. Gupta, MD, MBA*

14:50 - 15:00 **Avoiding the Landmines: Complications I Didn't See Coming**

*Joseph M. Lombardi, MD*

15:00 - 15:10 **Discussion**

15:10 - 15:20 **Make It Perfect or Save the Patient**

*Eric O. Klineberg, MD*

15:20 - 15:30 **Building Your OR Playbook: Techniques That Saved Me**

*Rajiv K. Sethi, MD, PhD*

15:30 - 15:40 **Discussion**

14:30 - 15:40 | CASES & COCKTAILS (concurrent sessions)

## Cases & Cocktails 1: Adult Spinal Deformity ADULT SPINAL DEFORMITY

Room 104 B

*This session is supported, in part, by a grant from Highridge Medical*

*Moderator: Jeffrey L. Gum, MD*

*Table Moderators: Hamid Hassanzadeh, MD; Khaled M. Kebaish, MD; Lawrence G. Lenke, MD; Stephen J. Lewis, MD, FRCS(C); Christopher I. Shaffrey, MD*

## Cases & Cocktails 2: Pediatric Deformity PEDIATRICS/ADOLESCENT

Room 104 C

*This session is supported, in part, by a grant from ATEC Spine*

*Moderator: Ron El-Hawary, MD, MSc*

*Table Moderators: Benny T. Dahl, MD, PhD; Emmanuelle Ferrero, MD, PhD; Steven W. Hwang, MD; Colin Nnadi, FRCS(Orth); James O. Sanders, MD; Michelle C. Welborn, MD*

## Cases & Cocktails 3: Cervical Deformity NEUROSURGERY

Room 104 D

*This session is supported, in part, by a grant from ATEC Spine*

*Moderator: Charles H. Crawford III, MD*

*Table Moderators: Christopher P. Ames, MD; Han Jo Kim, MD; Ronald A. Lehman Jr., MD; Sang Hun Lee, MD, PhD; Peter G. Passias, MD; Jason W. Savage, MD*

18:00 - 20:00 | WELCOME RECEPTION\*

Constitution Hall 106

The 33<sup>rd</sup> IMAST will officially begin with the Welcome Reception, a hosted reception featuring hors d'oeuvres, cocktails, and reunions with colleagues and friends and exhibitor viewing. If you would like to purchase guest ticket(s), you may do so at the Registration Desk.

\*Denotes a non-CME session/event

# MEETING AGENDA: THURSDAY, APRIL 16, 2026

07:30 - 08:30 | HANDS-ON WORKSHOPS\* (breakfast provided)

Rooms 104 B - D

Please see page 159 for schedule and descriptions.

Each workshop will be programmed by a single-supporting company and will feature presentations on topics and technologies selected by the company. Please note: CME credits are not available for Hands-On Workshops.

08:30 - 08:40 | INNOVATION UPDATE\*

Innovation Theatre

Please see page 161 for schedule and descriptions.

Please join SRS industry partners for updates on innovations by the sponsoring company. Innovation Updates take place in the Innovation Theatre which is located in the Exhibit Hall. Please note: CME credits are not available for Innovation Updates.

08:40 - 09:30 | SESSION 2

Constitution Hall 107

## Panel Discussion: Design Thinking and Innovation in Spine Surgery

Moderators: Christopher P. Ames, MD & Suken A. Shah, MD

Panelists: René M. Castelein, MD, PhD; Munish C. Gupta, MD, MBA; A. Noelle Larson, MD; Ronald A. Lehman Jr., MD; Stefan Parent, MD, PhD

09:30 - 09:45 | Exhibit Viewing & Refreshment Break\*

Constitution Hall 106

09:35 - 09:45 | INNOVATION UPDATE\*

Innovation Theatre

Please see page 161 for schedule and descriptions.

Please join SRS industry partners for updates on innovations by the sponsoring company. Innovation Updates take place in the Innovation Theatre which is located in the Exhibit Hall. Please note: CME credits are not available for Innovation Updates.

09:45 - 11:45 | ABSTRACT SESSION 3

Constitution Hall 105

## Whitecloud Award Nominated Papers

Moderators: Amit Jain, MD, MBA & Caglar Yilgor, MD

09:45 - 09:49 **Paper #1: The SRS-Lenke-Aubin 3D Classification: A Structured and Clinically Relevant Extension of the Lenke System to Capture Transverse Plane Deformities in AIS §**  
*Carl-Eric Aubin, PhD, P.Eng; Lawrence G. Lenke, MD; Virginie Lafage, PhD; Michelle C. Welborn, MD; Justin S. Smith, MD, PhD; A Noelle Larson, MD; Michael G. Vitale, MD, MPH; Takashi Kaito, MD, PhD; Peter O. Newton, MD; Jeffrey P. Mullin; Christiane Caouette, PhD; Delphine Aubin, MS; Brice Ilharreborde, MD, PhD*

09:49 - 09:53 **Paper #2: Reliability of Vertebral Pelvic Angles in Pediatric Idiopathic Scoliosis Patients**  
*Nicholas Anton. Collar, MD; Michael Kelly, MD; Miran Stubican, MD; Bryan Menapace, MD, MBA; Ashley Pikero, BS; Chinmay Paranjape, MD, MHSc*

09:53 - 10:02 **Discussion**

10:02 - 10:06 **Paper #4: From Adolescence to Late Adulthood: Quality of Life and Surgical Outcomes in Idiopathic Scoliosis Across the Lifespan §**  
*Susana Núñez Pereira, MD, PhD; Javier Pizones, MD, PhD; Sleiman Haddad, MD, PhD, FRCS; Alejandro Gomez-Rice, MD, PhD; Francisco Javier Sanchez. Perez-Grueso, MD; Lluís Vila Castillo, MD; Yann Phillippe Charles, MD; Anika Pupak, PhD, BS; Ibrahim Obeid, MD; Ahmet Alanay, MD; Frank S. Kleinstueck, MD; Ferran Pellisé, MD, PhD; European Spine Study Group ESSG*

§ = Whitecloud Award Nominee – Best Clinical Paper, † = Whitecloud Award Nominee – Best Basic Science/Translational Paper

\*Denotes a non-CME session/event

# MEETING AGENDA: THURSDAY, APRIL 16, 2026

- 10:06 - 10:10 **Paper #5: What is a Better Predictor of Disability in Adult Spinal Deformity Patients: Gait or Radiographic Parameters? §**  
*Maxmillian Tjauw, BS; Parth Patel, BS; Lauren Rigney, BS; M. Burhan Janjua, MD; John Fred. Burke, MD, PhD*
- 10:10 - 10:14 **Paper #6: C2-UIV Angle Predicts Mechanical Failures in Adult Spinal Deformity Patients §**  
*Karan Joseph, BS; Alexander T. Yahanda, MS; Miguel Ruiz Cardozo, MD; Tim Bui, BS; Samuel Vogl; Nicholas A. Pallotta, MD, MS; Brian J. Neuman, MD; Munish C. Gupta, MD, MBA; Jeffrey M. Hills, MD; Michael P. Kelly, MD; Jacob Greenberg, MD; Wilson Zachary Zach. Ray, MD; Camilo A. Molina, MD*
- 10:14 - 10:25 **Discussion**
- 10:25 - 10:29 **Paper #7: Surgery vs Conservative Management in Adult Spinal Deformity: Propensity-Matched Evidence from a Large Prospective Cohort §**  
*Louis Boissiere, MD; Alice Baroncini, MD, PhD; Daniel Larrieu, PhD; Anouar Bourghli, MD; Javier Pizones, MD, PhD; Ferran Pellisé, MD, PhD; Ahmet Alanay, MD; Yann Phillippe Charles, MD; Frank S. Kleinstueck, MD; Cecile Roscop, MD; Ibrahim Obeid, MD*
- 10:29 - 10:33 **Paper #8: Distal Extension Rates After Lower Instrumented Vertebrae of L4/L5 §**  
*Tejas Subramanian, MD; Francis Lovecchio, MD; Atahan Durbas; Renaud Lafage, MS; Christopher P. Ames, MD; Shay Bess, 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; Frank Schwab; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; Han Jo Kim, MD; International Spine Study Group*
- 10:33 - 10:37 **Paper #9: Not All Returns to the Operating Room Are the Same: A Comparison of Re-operations in Tether Versus Posterior Spinal Fusion §**  
*John S. Vorhies, MD; Jason Brett. Anari, MD; Patrick J. Cahill, MD; Lawrence Lee. Haber, MD; A Noelle Larson, MD; Arun R. Hariharan, MD, MS; Craig R. Louer Jr, MD; Peter O. Newton, MD; Maty Petcharaporn, BS; Stefan Parent, MD, PhD; Harms NonFusion Study Group; Firoz Miyaji, MD, FRCS(C)*
- 10:37 - 10:47 **Discussion**
- 10:47 - 10:51 **Paper #10: Asymmetrical Paravertebral Muscle Fibrosis Causes Progression of Adolescent Idiopathic Scoliosis Via Myostatin Signalling in Fibro-adipogenic Progenitors †**  
*Heng Sun, MD*
- 10:51 - 10:55 **Paper #11: Deep Phenotyping Revolutionizes Genetic Diagnosis of Scoliosis through Nine Strategic Categories †**  
*Nan Wu, MD, PhD; Guozhuang Li, MD; Terry Jianguo Zhang, MD*
- 10:55 - 10:59 **Paper #12: Neuromuscular Adaptations and Shared Neural Drive Imbalance in Adolescent Idiopathic Scoliosis during a Fatiguing Task †**  
*Shao Chen, MD; Chen Liu, MD; Kai-qi Wang, MD; Xiao-min Chen, MD; Hong-gen Du, MD*
- 10:59 - 11:10 **Discussion**
- 11:10 - 11:14 **Paper #13: MRI Perfusion-Ventilation Imaging for Pulmonary Assessment in Scoliosis Patients: Validation Against CT Volumetry and Spirometry †**  
*Junduo Zhao, MD; Jianxiong Shen, MD; Yizhen Huang, MD; Heng Sun, MD*
- 11:14 - 11:18 **Paper #14: Utility of limited sequence "FAST spine MRI" scans as a screening tool in patients with idiopathic scoliosis. †**  
*Anna Johnson Rambo, MD; Aryan Shah; Shah Chetan, MD; John Lovejoy, MD; Vinay Kandula, MD; Brett Shannon, MD; Mona Matthew, PhD; Suken A. Shah, MD; Kevin M. Neal, MD*
- 11:18 - 11:22 **Paper #15: Development of a Radiation-Free Ultrasound Method for Skeletal Maturity Assessment in AIS: A Pilot Study †**  
*Edmond H. Lou, PhD; Tu Pham, PhD; Carlin Canlas; Kathleen Shearer, MN; Eric C. Parent, PhD; Sarah Southon Hryniuk, MN; Kyle Stampe, MD*
- 11:22 - 11:32 **Discussion**

§ = Whitecloud Award Nominee – Best Clinical Paper, † = Whitecloud Award Nominee – Best Basic Science/Translational Paper

\*Denotes a non-CME session/event

# MEETING AGENDA: THURSDAY, APRIL 16, 2026

- 11:32 - 11:35 **Award Voting**  
Cast your vote for the Whitecloud Awards on the Meeting App: Select "Polls & Surveys" from the app home screen and select the Whitecloud Award.
- 11:35 - 11:40 **Annual Meeting 2026 Preview**  
Eric O. Klineberg, MD
- 11:40 - 11:45 **IMAST 2027 Preview**  
Joshua M. Pahys, MD & Zeeshan M. Sardar, MD

11:45 - 11:55 | INNOVATION UPDATE\* Innovation Theatre

**Please see page 161 for schedule and descriptions.**

Please join SRS industry partners for updates on innovations by the sponsoring company. Innovation Updates take place in the Innovation Theatre which is located in the Exhibit Hall. Please note: CME credits are not available for Innovation Updates.

11:45 - 12:00 | Exhibit Viewing\* Constitution Hall 106

11:45 - 12:00 | Lunch Pick-Up\* Room 104 Foyer

12:00 - 13:00 | HANDS-ON WORKSHOPS\* (concurrent sessions) Rooms 104 A - D

**Please see page 159 for schedule and descriptions.**

Each workshop will be programmed by a single-supporting company and will feature presentations on topics and technologies selected by the company. Please note: CME credits are not available for Hands-On Workshops.

13:00 - 13:00 | Exhibit Viewing\* Constitution Hall 106

13:15 - 14:00 | INNOVATION ICL\* Innovation Theatre

## Innovations in Value Based Care\*

Moderators: Eric Klineberg, MD & Rajiv Sethi, MD, PhD

- 13:15 - 13:17 **Introduction**  
Eric Klineberg, MD & Rajiv Sethi, MD, PhD
- 13:17 - 13:22 **Methods Used to Study Value-Based Care Delivery**  
Venu Nemani, MD
- 13:22 - 13:27 **A Sobering Reality: Is Adult Spinal Deformity Surgery Sustainable for the American Medicare Patient in 2026 From a Reimbursement Perspective?**  
Jeffrey Gum, MD
- 13:27 - 13:32 **How Do We Improve Together While Understanding Cost Utility? The Harms Experience**  
Amit Jain, MD, MBA
- 13:32 - 13:37 **Discussion**
- 13:37 - 13:42 **Best Practice Guidelines: How to Form Them and How Can They Increase Value and Safety at the Same Time**  
Michael Vitale, MD
- 13:42 - 13:47 **Canadian Value-Based Health Care in Spine Deformity: What Can the World Learn from Us Regarding the Use of Enabling Technology and Advanced Tools?**  
Jesse Shen, MD
- 13:47 - 14:00 **Discussion**

§ = Whitecloud Award Nominee – Best Clinical Paper, † = Whitecloud Award Nominee – Best Basic Science/Translational Paper

\*Denotes a non-CME session/event

# MEETING AGENDA: THURSDAY, APRIL 16, 2026

13:30 - 15:00 | SESSIONS 4A & 4B (concurrent sessions)

## Abstract Session 4A: Adult Spinal Deformity ADULT SPINAL DEFORMITY

Constitution Hall 105

Moderators: Dong-Gune Chang, MD, PhD & Zeeshan M. Sardar, MD

- 13:30 - 13:34 **Paper #16: Pseudoarthrosis and Rod Breakage in Adult Spinal Deformity Surgery with Minimum 5-Year Follow-Up: Patterns, Predictors, and Machine Learning-Based Risk Analysis**  
*Sleiman Haddad, MD, PhD, FRCS; Lluís Vila Castillo, MD; Leo Mok, MSc; Chuck Lam, BSc; Morgan Jones, FRCS; Susana Núñez Pereira, MD, PhD; Anika Pupak, PhD, BS; Riccardo Raganato, MD; Javier Pizones, MD, PhD; Yann Phillippe Charles, MD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Frank S. Kleinstueck, MD; Francisco Javier Sanchez. Perez-Grueso, MD; Ferran Pellise, MD, PhD; European Spine Study Group ESSG*
- 13:34 - 13:38 **Paper #17: Durability of Adult Spinal Deformity Correction Based on Upper Instrumented Level and Baseline Deformity Severity: A Survival Analysis of a Prospective, 18-Center Study**  
*Peter G. Passias, MD; Francesca Totis, MD; Kyriakos Chatzis, BS; Oluwatobi Onafowokan, MBBS, MS; Max Fisher; Peter Tretiakov, BS; Christopher I. Shaffrey, MD; Virginia Lafage, PhD*
- 13:38 - 13:42 **Paper #18: Seven Years of Safer Surgery: Declining Medical Complications After Adult Spinal Deformity Reconstruction**  
*Atahan Durbas; Han Jo Kim, MD; Andrea Pezzi; Robert N. Uzzo, MBA; Gabrielle Dykhouse, BS; Tejas Subramanian, MD; Stephane OwusuSarpong; Mihir Dekhne; Kasra Araghi; Matthew E. Cunningham, MD, PhD; Francis Lovecchio, MD*
- 13:42 - 13:52 **Discussion**
- 13:52 - 13:56 **Paper #19: Upper Thoracic Spine Alignment: The Missing Piece of the Alignment Puzzle to Improve GAP and T4L1PA Targets**  
*Nuri Demirci, MD; Yasemin Yavuz, PhD; Munish C. Gupta, MD, MBA*
- 13:56 - 14:00 **Paper #20: Transition Rods with or Without Junctional Tethering in the Prevention of Proximal Junctional Kyphosis in Adult Spinal Deformities Surgery**  
*Francesco Lolli, MD; Carmela Altruda, MD; Andrea Baioni, MD; Ilaria Barni, MD; Marco Canceda, MD; Riccardo Draghi, MD; Andrea Messina, MD; Nicolò Regge Gianas, MD; Roberto Ricca, MD; Ignazio Borghesi, MD*
- 14:00 - 14:04 **Paper #21: The Impact of Preoperative Cervical Degeneration on Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery with an Upper Thoracic Upper Instrumented Vertebra.**  
*Josephine R. Coury, MD; Fthimnir Hassan, MPH; Justin L. Reyes, MS; Erik Lewerenz, BS; Joseph M. Lombardi, MD; Zeeshan M. Sardar, MD; Ronald A. Lehman Jr., MD; Lawrence G. Lenke, MD*
- 14:04 - 14:14 **Discussion**
- 14:14 - 14:18 **Paper #22: Marijuana Use and Patient-Reported Outcomes in Spinal Deformity Surgery: Preoperative and Postoperative VAS and ODI Analysis**  
*Srujan Koppurapu, MD; Cesar M. Carballo Cuello, MD; Jay I. Kumar, MD; Puya Alikhani, MD; Sadegh Bagherzadeh, MD; Diego Soto Rubio, MD; Dana Saleh, MD; Mohsen Rostami, MD*
- 14:18 - 14:22 **Paper #23: Four Milligrams Per Level: Defining the BMP Threshold to Prevent Rod Fracture and Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery**  
*Nuri Demirci, MD; Yasemin Yavuz, PhD; Munish C. Gupta, MD, MBA*
- 14:22 - 14:26 **Paper #24: Dynamic Adaptations of the Thoracolumbar Spine: A Cross-Sectional Analysis of Vertebral Pelvic Angle Changes from Standing to Sitting**  
*Atahan Durbas, MD; Han Jo Kim, MD; Robert N. Uzzo, MBA; Gabrielle Dykhouse, BS; Tejas Subramanian, MD; Andrea Pezzi, MD; Michael P. Kelly, MD; Francis Lovecchio, MD*
- 14:26 - 14:36 **Discussion**

\*Denotes a non-CME session/event

# MEETING AGENDA: THURSDAY, APRIL 16, 2026

- 14:36 - 14:40 **Paper #25: Posterior Lumbosacral Tether: A Novel Surgical Approach Preserves Motion at The Lumbosacral Junction in Adult Spinal Deformity Surgery; Early experience**  
*Ahmed Sulieman, MD; Ahmad Alnasser, BS; Brian Tableman, MS; Andrew H. Kim, MD; Goutham Yalla, MD; Yesha Parekh, MD; Tej Azad, MD; Khaled M. Kebaish, MD*
- 14:40 - 14:44 **Paper #26: Which ASD Patients Are at Risk of PJK Despite Posterior Ligament Tether Reconstruction?**  
*Kingsley Ogelle, BS; Fares Ani; Akil Paturi, MD; Themistocles Protopsaltis, MD; Jeffrey P. Mullin, MD; Renaud Lafage, MS; Alex Soroceanu, MD, FRCS(C); Jeffrey Gum, MD; Bassel Diebo, MD; Justin Smith, MD, PhD; Robert Eastlack, MD; Gregory Mundis, Jr., MD; Munish C. Gupta, MD; Han Jo Kim, MD; Eric O. Klineberg, MD; Lawrence G. Lenke, MD; Christopher P. Ames, MD; Christopher Shaffrey, MD; Virginie Lafage, PhD; Frank Schwab, MD; Shay Bess, MD; International Spine Study Group*
- 14:44 - 14:48 **Paper #27: Multiple Fixation, Fewer Failures: A Multicenter Adult Spinal Deformity Analysis**  
*Pawel P. Jankowski, MD; Paritash Tahmasebpour, MD; Spencer Matthews, MS; David C. Ou-Yang, MD; Peter G. Passias, MD; Christopher T. Martin, MD; Jonathan N. Sembrano, MD; Christopher I. Shaffrey, MD; Kari Odland, DAT, ATC; David W. Polly Jr, MD*
- 14:48 - 15:00 **Discussion**

## Abstract Session 4B: Adolescent Idiopathic Scoliosis PEDIATRICS/ADOLESCENT Constitution Hall 107

Moderators: Pawel Grabala, MD, PhD & Steven W. Hwang, MD

- 13:30 - 13:34 **Paper #28: Primary Study for Treatment of Severe Rigid AIS via the Intraoperative Pre-distraction Technique on Concave Side**  
*Xuhong Xue, MD, PhD; Kai Li, MD; Sheng Zhao, MD*
- 13:34 - 13:38 **Paper #29: The Tethering Method in Transpedicular Dynamic Stabilization of Lumbar Secondary Curves in L1C Deformities in Combination With 3D Instrumented Correction and Posterolateral Fusion of the Main Thoracic Curve**  
*Martin Repko, MD, PhD; Milan Filipovic, MD, PhD*
- 13:38 - 13:42 **Paper #30: The Closing Argument: A Randomized Controlled Trial of Three Spinal Wound Closure Methods for Adolescent Idiopathic Scoliosis (AIS)**  
*Alastair Winston. Sterns, BS; Pasha Shakoori, MD, DDS, MEd; John Wyatt, BS; Tishya Wren, PhD; Jasmine Gasca, PA-C; Lori Howell, MD; Kenneth D. Illingworth, MD; Tyler Tetreault, MD; Michael J. Heffernan, MD; Vernon T. Tolo, MD; David L. Skaggs, MD, MMM; Lindsay M. Andras, MD*
- 13:42 - 13:52 **Discussion**
- 13:52 - 13:56 **Paper #31: Thoracic Anterior Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Long-Term Outcomes with Minimum 5-Year Follow-Up**  
*Taemin Oh, MD; Manan Patel, MD; Emily Nice, BS; Sanjana Davuluri; Joshua M. Pahys, MD; Steven W. Hwang, MD; Amer F. Samdani, MD*
- 13:56 - 14:00 **Paper #32: Will the Real Curve Correction Please Stand Up!**  
*John T. Braun, MD; Sofia Federico, BS*
- 14:00 - 14:04 **Paper #33: Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Durability of Outcomes with 5-8 Year Follow-up**  
*Baron S. Lonner, MD; Yazan Alasadi, BA; Olgerta Mucollari, BS; Mark Kurapatti, BS; Charu Jain, BA; Prabhjot Singh, BA; Tariq Issa, MD*
- 14:04 - 14:14 **Discussion**
- 14:14 - 14:18 **Paper #34: Flex on 'em: A Novel Flexibility Index Classification System for AIS**  
*Mackenzie Morris, BS; Margaret L. Sullivan, BS; Chiara Morley-McLaughlin, BA; Shanika De Silva, PhD, MS; David S. Liu, MD; Grant D. Hogue, MD*

\*Denotes a non-CME session/event

## MEETING AGENDA: THURSDAY, APRIL 16, 2026

- 14:18 - 14:22 **Paper #35: Cervical Vertebral Maturation System and Its Correlation with Established Skeletal Maturity Staging in Idiopathic Scoliosis**  
*Talissa O. Generoso, MD; Lorena Floccari, MD; Amishi Jobanputra, MS; Arianne T. Salunga, DO; Hiba Naz, BS; Nicole S. Pham, MPH; Jason Pui Yin Cheung, MD, MBBS, MS, FRCS; Scott Yang, MD; Susan Nelson, MD; Jessica McQuerry, MD; Ron El-Hawary, MD, MSc; James T. Bennett, MD; Craig R. Louer Jr, MD; Kali R. Tileston, MD; John S. Vorhies, MD*
- 14:22 - 14:26 **Paper #36: Beyond Full-Time Bracing: Defining the Minimum Effective Dose of Brace Wear and Synergy of Scoliosis Specific Exercises In Adolescent Idiopathic Scoliosis Treatment**  
*Nikos Karavidas, MSc, PT*
- 14:26 - 14:36 **Discussion**
- 14:36 - 14:40 **Paper #37: Preoperative Paraspinal Muscle Size and Fat Infiltration as Predictors of Postoperative Recovery in Adolescent Idiopathic Scoliosis Patients: A Pilot Study**  
*Paolo Brigato, MD; Sergio De Salvatore, MD; Davide Palombi, MD; Pier Francesco Costici, MD; Leonardo Oggiano, MD*
- 14:40 - 14:44 **Paper #38: Cancer Risk Among Women with Scoliosis: A Nationwide Danish Register-Based Study**  
*Frederik Højsager, MD; Luise Borch, MD, PhD; René M. Castelein, MD, PhD; Steen B. Christensen, MD, PhD; Ane Simony, MD, PhD*
- 14:44 - 14:48 **Paper #39: Is Your Surgical Field as Sterile as You Think When Operating Patients with Adolescent Idiopathic Scoliosis?**  
*Niklas Tondevoid, MD, PhD; Thomas Borbjerg Andersen, MD, PhD; Martin Gehrchen, MD, PhD; Benny T. Dahl, MD, PhD*
- 14:48 - 15:00 **Discussion**
- 15:00 - 15:30 | Exhibit Viewing & Refreshment Break\* Constitution Hall 106
- 15:00 - 15:30 | E-Point Award Nominated Papers 1\* NEUROSURGERY Innovation Theatre  
 Moderator: Brian J. Neuman, MD
- Visit the Innovation Theatre for a mini-session highlighting top-scoring E-Points. Listen to live rapid-fire presentations from each nominated paper, followed by a moderated discussion. Don't forget to also visit the E-Point Kiosks, located in the Exhibit Hall, to view all E-Point presentations. Voting for award-nominated E-Points can be completed on the IMAST meeting app, and will remain open until Friday, April 17 at 12:00pm Eastern Time.
- 15:05 - 15:08 **Paper #222: Clinical Utility of Non-Invasive Hemodynamic Monitoring in Patients Undergoing Multi-Level Posterior Instrumented Fusion**  
*Colson Tomberlin, MD; Steven Glassman, MD; Desiree Chappell; Mladen Djurasovic, MD; Justin Mathew, MD; Jeffrey Gum, MD; Shawn Adams, MD; Leah Carreon, MD*
- 15:08 - 15:11 **Paper #238: Resting State Functional MRI Brain and Effective Connectivity in Chronic Low Back Pain (cLBP)**  
*Dhruv Patel, MS; Saumyajit Basu, MD; Vikas Hanasoge, MBBS, MS; Ayon Ghosh, MS*
- 15:11 - 15:14 **Paper #284: Does Navigation Allow for Placement of Larger S2AI Screws Compared with Freehand Technique?**  
*Kari Odland; Saurabh Rawall, MBBS; David W. Polly, Jr., MD*

\*Denotes a non-CME session/event

# MEETING AGENDA: THURSDAY, APRIL 16, 2026

15:30 - 17:00 | SESSIONS 5A & 5B (concurrent sessions)

## Abstract Session 5A: Artificial Intelligence & Emerging Concepts

Constitution Hall 105

Moderators: Patrick J. Cahill, MD & A. Noelle Larson, MD

- 15:30 - 15:34 **Paper #40: Virtual Reality Training Improves Freehand Pedicle Screw Placement: A High-Fidelity Validation Study in Neurosurgical Trainees**  
*Steve S. Cho, MD; Juan Pedro Giraldo, MD; S. Harrison Farber, MD; Jakub Godzik, MD; Juan S. Uribe, MD*
- 15:34 - 15:38 **Paper #41: Development and Initial Validation of a Free and Open-source Virtual Reality TLIF Surgical Simulator for Resident Training: A Prospective Randomized Study**  
*Léonard Chatelain, MD; Renaud Lafage, MS; Emil Haikal, MD; Blerta Budani, BS; Jonathan Elyse, BS; Max Kohn, BS; Marc Khalifé, MD, MS; Emmanuelle Ferrero, MD, PhD; Virginie Lafage, PhD*
- 15:38 - 15:42 **Paper #42: Spine Reviews: Crowdsourcing Global Spine Experts Knowledge via Digital Ledger Technology**  
*Bassel G. Diebo, MD; Vincent Challier, MD; Virginie Lafage, PhD*
- 15:42 - 15:52 **Discussion**
- 15:52 - 15:56 **Paper #43: A Non-Irradiated Portable 3D Electronic Spine Measurement System for Large-Scale Adolescent Scoliosis Screening: A Diagnostic Accuracy and Implementation Study**  
*Wenjie Wu, MD*
- 15:56 - 16:00 **Paper #44: 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; Kevin Smit, MD; Andrew Tice, MD; Firoz Miyanji, MD, FRCS(C); Stefan Parent, MD, PhD; Thierry A. Odent, MD, PhD; Neil Saran, FRCS(C); Anne Tabard-Fougere, PhD; Natahly Gavira, MD; Romain Dayer, MD; Jean Albert. Ouellet, MD, FRCS(C)*
- 16:00 - 16:04 **Paper #45: Objective Measurement of Post-Operative Recovery Using Smartphone Activity Data in Lumbar and Cervical Spine Surgery**  
*Ryan Turlip, BA; Daksh Chauhan, MD; Mert Marcel Dagli, MD; Richard Chung, BS; Hasan S. Ahmad, BS; Julia Kincaid; Richelle Kim; Akash Verma; Yohannes Ghenbot, MD; Ben Gu, MD; Jang Yoon, MD; Niall Buckley, MD*
- 16:04 - 16:14 **Discussion**
- 16:14 - 16:18 **Paper #46: AP-DADNet: An Anatomical Prior-Driven Framework for 3D Spinal Cord Segmentation and Shape Quantification in CT with Metal Artifacts**  
*Junyu Li, MD; Hanlin Xia, MD; Hanwen Zhang, MD; Zhuoran Sun, MD; Yongqiang Wang, MD; Weishi Li, MD; Duanduan Chen, MD; Miao Yu, MD*
- 16:18 - 16:22 **Paper #47: Automated Computer Vision Model Reveals Hidden Disability Predictors From Standing Radiographs in Adult Spinal Deformity**  
*Tej Azad, MD; Anmol Warman; Swapnil Bhat; Devansh Lalwani; Ahmed Sulieman, MD; Liam Hughes, MD; Amit Jain, MD, MBA; Munish C. Gupta, MD, MBA; Khaled M. Kebaish, MD; Christopher P. Ames, MD*
- 16:22 - 16:26 **Paper #48: Machine Learning (ML) in Intraoperative Neuromonitoring (IONM): Updated Model Integrating Hemodynamic Data Detects Changes 35 Minutes Earlier Than Clinical Teams**  
*Varun Arvind, MD, PhD; Mehdi Elfilali, BA; Madeline C. Monness, BSA; Erik Williams, BS; Miles Bomback, BA, MPH; Alexander Park, BS; Michael W. Brown, BS; Omar Taha, BS; Matthew Weintraub, BS; Teeda Pinyavat, MD; Anil Mendiratta, MD; Michael G. Vitale, MD, MPH*
- 16:26 - 16:36 **Discussion**

\*Denotes a non-CME session/event

# MEETING AGENDA: THURSDAY, APRIL 16, 2026

- 16:36 - 16:40 **Paper #49: Predicting Non-Idiopathic Scoliosis from Plain Radiographs: A Deep Learning Approach**  
Kellen Mulford, PhD; Hans Nugraha, MD; Julia Todderud, BS; Andrew Pumford, BA; Todd A. Milbrandt, MD, MS; [A Noelle Larson, MD](#)
- 16:40 - 16:44 **Paper #50: Development and Validation of an AI Model for Anatomical Structure Detection in Endoscopic Spine Surgery**  
Jung Sub Lee, MD, PhD; [Yoonjae Cho, MD](#); Joonyoung Park, MD; Ki Hun Kim, MD; Hansol Kim, MD; Tae Sik Goh, PhD; Ha Young Jo, MD
- 16:44 - 16:48 **Paper #51: Data-Driven Identification of Spinal Cord Injury Endotypes with Superior Outcomes: Implications for Personalized Care**  
Michael G. Fehlings, MD, PhD, FRCS(C); Karlo M. Pedro, MD; [Mohammed Ali Alvi, MD, PhD, MS](#)
- 16:48 - 15:00 **Discussion**

## Session 5B: The Great Canadian Debates and Controversies\*

Constitution Hall 107

This session is hosted by the Canadian Spine Society

Moderator: John Street, MD, PhD, FRCS(C)

- 15:30 - 15:33 **Introduction & Welcome**  
John Street, MD, PhD, FRCS(C)
- Debate 1: My Priorities in Deformity Correction in AIS**
- 15:33 - 15:39 **I'm All About Coronal Alignment**  
Mark Camp, MD
- 15:39 - 15:45 **I'm All About Sagittal Alignment**  
Fred Nicholls, MD, MA, FRCS(C)
- 15:45 - 15:53 **Rebuttals**  
Mark Camp, MD & Fred Nicholls, MD, MA, FRCS(C)
- 15:53 - 16:01 **Discussion**
- Debate 2: High Grade Isthmic Spondylolisthesis**
- 16:01 - 16:07 **You Should Always Reduce**  
Stefan Parent, MD, PhD
- 16:07 - 16:13 **You Should Never Reduce**  
Stephen Lewis, MD, MSc, FRCS(C)
- 16:13 - 16:21 **Rebuttals**  
Stefan Parent, MD, PhD & Stephen Lewis, MD, MSc, FRCS(C)
- 16:21 - 16:29 **Discussion**
- Debate 3: When to Correct AIS**
- 16:29 - 16:35 **40° and It Gets Fused**  
Firoz Miyanji, MD, FRCS(C)
- 16:35 - 16:41 **70° Is Fine**  
Christopher Nielsen, MD
- 16:41 - 16:49 **Rebuttals**  
Firoz Miyanji, MD, FRCS(C) & Christopher Nielsen, MD
- 16:49 - 16:57 **Discussion**
- 16:57 - 17:00 **Concluding Remarks**  
John Street, MD, PhD, FRCS(C)

\*Denotes a non-CME session/event

# MEETING AGENDA: THURSDAY, APRIL 16, 2026

15:45 - 16:30 | INNOVATION ICL

Innovation Theatre

## MIS Deformity: State-of-the-Art\* NEUROSURGERY

Moderators: Neel Anand, MD, Mch.Orth & Emmanuel Menga, MD

15:45 - 15:53 **How to Wade Through the Jungle of ASD When Considering MIS**

*Praveen Mummaneni, MD*

15:53 - 16:01 **Think Out-of-the-Box when Tackling ASD**

*Emmanuel Menga, MD*

16:01 - 16:07 **Discussion**

16:07 - 16:15 **Can Stand-Alone Lateral Surgery Be Appropriate in Select Cases?**

*Andrew A. Sama, MD*

16:15 - 16:23 **Posterior MIS Surgery is Way More Than Just Putting In MIS Percutaneous Screws**

*Neel Anand, MD, Mch.Orth*

16:23 - 16:30 **Discussion**

17:00 - 17:30 | Exhibit Viewing\*

Constitution Hall 106

17:00 - 17:30 | E-Point Award Nominated Papers 2\* PEDIATRICS/ADOLESCENT

Innovation Theatre

Moderator: Emmanuelle Ferrero, MD, PhD

Visit the Innovation Theatre for a mini-session highlighting top-scoring E-Points. Listen to live rapid-fire presentations from each nominated paper, followed by a moderated discussion. Don't forget to also visit the E-Point Kiosks, located in the Exhibit Hall, to view all E-Point presentations. Voting for award-nominated E-Points can be completed on the IMAST meeting app, and will remain open until Friday, April 17 at 12:00pm Eastern Time.

17:05 - 17:08 **Paper #217: Are Multi-Level Three Column Osteotomies Required in Deformity Surgery?**

*Alexander Schupper, MD; Amer Samdani, MD; Zachary Weingrad, BS; William Purtill; Joshua Pahys, MD; Terrence Ishmael, MBBS; Steven W. Hwang, MD*

17:08 - 17:11 **Paper #273: Pediatric Spinopelvic Fixation: Can We Place Stacked SAI Screws?**

*David W. Polly, Jr., MD; Priya Jayakumar, BS; Christina K. Hardesty, MD*

17:11 - 17:14 **Paper #282: Balancing Rod Contouring and Implant Density to Optimize Correction in Lenke 1 AIS**

*Alexandria Mallinos, PhD; Camille Pillot, MS; Carl-Eric Aubin, PhD, P.Eng; Richard Schwend, MD; Todd Ritzman, MD; Lorena Floccari, MD*

17:14 - 17:20 **Discussion**

\*Denotes a non-CME session/event

# MEETING AGENDA: THURSDAY, APRIL 16, 2026

17:30 - 18:30 | SESSION 6

Constitution Hall 105

## Learning Curve & Master Techniques\*

Moderators: Neel Anand, MD, Mch.Orth & Han Jo Kim, MD

- 17:30 - 17:36 **How I Do the Lateral TransPsoas Approach**  
*Gregory M. Mundis Jr., MD*
- 17:37 - 17:43 **How I Do the Prone TransPsoas Approach**  
*Juan S. Uribe, MD*
- 17:44 - 17:50 **How I Do the Oblique Pre-Psoas Approach**  
*Neel Anand, MD, Mch.Orth*
- 17:51 - 18:01 **Discussion**
- 18:01 - 18:07 **Derotation Techniques in Adolescent Idiopathic Scoliosis**  
*Lindsay M. Andras, MD*
- 18:08 - 18:14 **High Grade Spondy Reduction**  
*Khaled M. Kebaish, MD*
- 18:15 - 18:21 **How to Best Optimize Robotics and Alignment**  
*Ronald A. Lehman Jr., MD*
- 18:22 - 18:30 **Discussion**

\*Denotes a non-CME session/event

# MEETING AGENDA: FRIDAY, APRIL 17, 2026

07:30 - 08:30 | SESSION 7 **ADULT SPINAL DEFORMITY**

Constitution Hall 107

## Making Adult Deformity Correction More Predictable

Moderators: Robert K. Eastlack, MD & Ferran Pellisé, MD, PhD

07:30 - 07:33 **Introduction - The Epidemic of Adult Deformity**

*Ferran Pellisé, MD, PhD*

07:33 - 07:38 **Biomarkers - Molecular Approaches for Adult Spinal Deformity**

*Tej Azad, MD*

07:38 - 07:42 **Bone Health Assessment and Management in Adult Spinal Deformity**

*Elizabeth L. Lord, MD*

07:42 - 07:47 **Sarcopenia - The Critical Muscle Envelope**

*Camilo Molina, MD*

07:47 - 07:55 **Discussion**

## Point-Counterpoint: The Digital Wave

07:55 - 08:00 **Point**

*Christopher P. Ames, MD*

08:00 - 08:05 **Counterpoint**

*Corey T. Walker, MD*

08:05 - 08:13 **Discussion & Live Polling - Are We Ready for the Spine Digital Twin?**

08:13 - 08:30 **Panel Discussion on Digital Health**

*Christopher P. Ames, Kristen E. Jones, MD; Michael P. Kelly, MD; Corey T. Walker, MD*

08:30 - 09:00 | Exhibit Viewing & Refreshment Break\*

Constitution Hall 106

08:30 - 19:00 | E-Point Award Nominated Papers 3\* **PEDIATRICS/ADOLESCENT**

Innovation Theatre

Moderator: Stephen George, Jr., MD

Visit the Innovation Theatre for a mini-session highlighting top-scoring E-Points. Listen to live rapid-fire presentations from each nominated paper, followed by a moderated discussion. Don't forget to also visit the E-Point Kiosks, located in the Exhibit Hall, to view all E-Point presentations. Voting for award-nominated E-Points can be completed on the IMAST meeting app, and will remain open until Friday, April 17 at 12:00pm Eastern Time.

08:35 - 08:38 **Paper #300: Outcomes After Vertebral Body Tethering for AIS: A Comparison of Ideal Versus Acceptable Indications**

*John Braun, MD; Sofia Federico, BS*

08:38 - 08:41 **Paper #229: Can Refined Indications for Vertebral Body Tethering Yield Superior Outcomes Similar to Fusion Surgery?**

*John Braun, MD; Sofia Federico, BS*

08:41 - 08:44 **Paper #281: Improving Early Scoliosis Detection with a Low-Dose Mobile Imaging and Automated Measurement Platform: a Cross-Sectional Screening Study**

*Guilin Chen, MD; Terry Jianguo Zhang, MD; Nan Wu, MD*

08:44 - 08:50 **Discussion**

\*Denotes a non-CME session/event

# MEETING AGENDA: FRIDAY, APRIL 17, 2026

09:00 - 11:30 | ABSTRACTION SESSION 8 & KEYNOTE SPEAKER\*

Constitutional Hall 105

## Quality & Safety; Keynote Speaker\*

Moderators: Jeffrey Gum, MD & Kristen E. Jones, MD

- 09:00 - 09:04 **Paper #52: Alignment Factors Associated with the Need for Revision Extension Surgery to the Sacrum After Previous Lumbar Spinal Fusion**  
*Catherine Becker, Hurley, MS; Mingxing Fan, BS; Nicolas Carayannopoulos, BS; Jinseong Kim, MD; Zvipo Chisango, BS; Gabriel Gonzalez, BS; Michael Farias; John Czerwein, MD; Bryce A. Basques; Eren Kuris, MD; Bassel G. Diebo, MD; Alan H. Daniels, MD*
- 09:04 - 09:08 **Paper #53: The Relative Weight of the Most Common Biological Factors in Predicting Adverse Events after Adult Spinal Deformity Surgery**  
*Javier Pizones, MD, PhD; Alejandro Gomez-Rice, MD, PhD; Lucia Moreno-Manzanaro, BS; Susana Núñez Pereira, MD, PhD; Sleiman Haddad, MD, PhD, FRCS; Anika Pupak, PhD, BS; Yann Phillippe Charles, MD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Ferran Pellise, MD, PhD*
- 09:08 - 09:12 **Paper #54: Influence of Active Social Life on patient-reported outcome measures (PROMs) in patients undergoing surgery for complex adult spinal deformity: A Multi-center Propensity Score Matched Analysis**  
*Peter G. Passias, MD; Francesca Totis, MD; Kyriakos Chatzis, BS; Oluwatobi Onafowokan, MBBS, MS; Peter Tretiakov, BS; Max Fisher*
- 09:12 - 09:21 **Discussion**
- 09:21 - 09:25 **Paper #55: Surgeon Cognitive Load While Inserting Pedicle Screws: Results From a Prospective Study**  
*Patrick Cannon; Bruce Robie; Annalisa Michielli; Timothy Minogue; Daniel O'Connor*
- 09:25 - 09:29 **Paper #56: Registration Times Differ Significantly Comparing Two Registration Techniques in Robotic Pediatric Spine Surgery**  
*Robert F. Murphy, MD; Margaret L. Sullivan, BS; Mackenzie Morris, BS; Craig Birch, MD; Roger F. Widmann, MD; Jessica Heyer; Kirsten E. Ross, MD; Dennis P. Devito, MD; Shanika De Silva, PhD, MS; M. Timothy. Hresko, MD; Grant D. Hogue, MD; Daniel J. Hedequist, MD*
- 09:29 - 09:33 **Paper #57: Robotic Pediatric Spinal Fusion with Large Coronal Curves**  
*Margaret L. Sullivan, BS; Mackenzie Morris, BS; Grant D. Hogue, MD; Craig Birch, MD; M. Timothy. Hresko, MD; Mark A. Erickson, MD; Roger F. Widmann, MD; Jessica Heyer; Dennis P. Devito, MD; Robert F. Murphy, MD; Kirsten E. Ross, MD; Shanika De Silva, PhD, MS; Daniel J. Hedequist, MD*
- 09:33 - 09:42 **Discussion**
- 09:42 - 09:46 **Paper #58: Be Careful What You Ask For: Few Patients Meet Mean Arterial Pressure (MAP) Goals After Intraoperative Neuromonitoring (IONM) Changes During Pediatric Scoliosis Surgery**  
*Michaela O'Connor, MD; Michael W. Brown, BS; Mehdi Elfilali; Alexander Park, BS; Joshua Choi, MHA; Josephine R. Coury, MD; Benjamin D. Roye, MD; Michael G. Vitale, MD, MPH*
- 09:46 - 09:50 **Paper #59: Efficacy of Multimodal Intraoperative Neuromonitoring in Pediatric Spinal Deformity Surgery: A 39-Year Comparative Analysis**  
*Gabrielle Rogie, BS; Hilton C. Braithwaite IV, BS; Leah Rakers; Scott John. Luhmann, MD*
- 09:50 - 09:54 **Paper #60: Intraoperative Neuromonitoring (IONM) Alerts in Severe Spinal Deformity Corrections with Baseline Neurodeficit - Are They Different from Those Without - Results from International Multicenter Prospective Spinal Deformity Intraoperative Monitoring (SDIM) Study**  
*Saamyajit Basu, MS (Ortho), DNB (Ortho), FRCS (Ed); Stephen J. Lewis, MD, FRCS(C); Yong Qiu, PhD; Ferran Pellise, MD, PhD; Ahmet Alanay, MD; Justin S. Smith, MD, PhD; Go Yoshida, MD, PhD*
- 09:54 - 10:03 **Discussion**

\*Denotes a non-CME session/event

## MEETING AGENDA: FRIDAY, APRIL 17, 2026

- 10:03 - 10:07 **Paper #61: Impact of GLP-1 Receptor Agonists on Pseudarthrosis Following Spinal Fusion Surgery**  
*Siraj Shaikh, MD; Daniel Coban, MD; George Abdelmalek, MD; Mohammed Taha. Younis, BS; Adam Elkholy, BS; Nikhil Sahai, MD; Kumar Sinha, MD; Ki So. Hwang, MD; Arash Emami, MD*
- 10:07 - 10:11 **Paper #62: Testosterone Replacement Therapy in Transforaminal Lumbar Interbody Fusion Reoperation Rates: A Propensity-Matched Analysis of 1278 Surgical Patients**  
*Puru Sath, BS; Haley Warzecha, BS; Catherine Hurley, BS; Maxwell Dassow, BS; Alexander Lewis, BS; Simbarashe Peresuh, MD; Nicolas Carayannopoulos, BS; Alan H. Daniels, MD; Bryce A. Basques*
- 10:11 - 10:15 **Paper #63: Comparison of Domiciliary Deep Vein Thrombosis (DVT) Pharmacological Prophylaxis in Paraplegic Patients Due to Spinal Cord Injury (SCI): An Exploratory RCT**  
*Pankaj Kandwal, MD, MS; Utsav Anand, MD; Bhaskar Sarkar, MD; Kaustubh Ahuja, MD*
- 10:15 - 10:24 **Discussion**
- 10:24 - 10:28 **Paper #64: Additional Vertebrae are Imaged in 44% of Pediatric Patients when Limited CTs are Ordered**  
*Robert G. Watkins V; Vivien Chan, MD; Christopher Watterson, MD; Elaine Butterworth, RN; Kenneth D. Illingworth, MD; David L. Skaggs, MD, MMM*
- 10:28 - 10:32 **Paper #65: Impact of Preoperative Disc Signal Index-2 Score and Disc Herniation on Cervical Sagittal Alignment following Deformity Correction in Idiopathic Scoliosis**  
*Hong Jin Kim, MD, PhD; Jae Hyuk Yang, MD, PhD; Seung Woo Suh, MD, PhD*
- 10:32 - 10:36 **Paper #66: Measuring Spinopelvic Parameters in Patients with 6 Lumbar Vertebrae: A Matched Comparison of Asymptomatic Volunteers**  
*Chloe Cadieux, MD; Ruheksh Raj, MD; Farbod Moghaddam, BS; May Choi, MD; Fred H. Nicholls, MD*
- 10:36 - 10:45 **Discussion**
- 10:45 - 10:49 **Paper #67: Impact of Different Osteoporosis Treatments on Endplate Changes and Their Correlation with Trabecular Vertebral Bone, as Measured by Hounsfield Units**  
*Abdelrahman Hamouda; Zach Pennington, MD; Derrick Obiri-Yeboah, MD; Anthony L. Mikula, MD; Jeremy L. Fogelson; Benjamin D. Elder, MD, PhD*
- 10:49 - 10:53 **Paper #68: Osteoporosis Screening Gaps Among Patients Undergoing Lumbar Fusion Surgery**  
*Eric Mao, BA; Krystell Ceballos, BS; Jonathan Wang, BS; Amit Jain, MD, MBA*
- 10:53 - 10:57 **Paper #69: Ultra-Early Intervention with Percutaneous Kyphoplasty for Acute Osteoporotic Vertebral Compression Fractures: Efficacy and Safety Outcomes from a High-Volume County Hospital Center**  
*Wenjie Wu, MD*
- 10:57 - 11:05 **Discussion**
- 11:05 - 11:10 **Introduction of the Keynote**  
*Suken A. Shah, MD*
- 11:10 - 11:30 **Keynote Address**  
*Stefan Parent, MD, PhD*

11:30 - 12:00 | Exhibit Viewing\* Constitution Hall 106

11:30 - 12:00 | Lunch Pick-Up\* Room 104 Foyer

\*Denotes a non-CME session/event

# MEETING AGENDA: FRIDAY, APRIL 17, 2026

11:40 - 11:50 | INNOVATION UPDATE\*

Innovation Theatre

Please see page 161 for schedule and descriptions.

Please join SRS industry partners for updates on innovations by the sponsoring company. Innovation Updates take place in the Innovation Theatre which is located in the Exhibit Hall. Please note: CME credits are not available for Innovation Updates.

12:00 - 13:00 | HANDS-ON WORKSHOPS\*(concurrent sessions)

Rooms 104 C & D

Please see page 159 for schedule and descriptions.

Each workshop will be programmed by a single-supporting company and will feature presentations on topics and technologies selected by the company. Please note: CME credits are not available for Hands-On Workshops.

13:00 - 13:15 | Exhibit Viewing\*

Constitution Hall 106

13:15 - 14:30 | SESSIONS 9A & 9B (concurrent sessions)

Abstract Session 9A: Early Onset & Pediatric Scoliosis

PEDIATRICS/ADOLESCENT

Constitution Hall 105

Moderators: Meric Enercan, MD & G Ying Li, MD

- 13:15 - 13:19 **Paper #70: How Does Sacral Slanting Change After Lumbar Hemivertebra Resection in Children**  
*Ziming Yao, PhD; Dong Guo, MD; Xue Jun Zhang, MD*
- 13:19 - 13:23 **Paper #71: A Comparison of Radiographic Sagittal Parameters at 2 Years Follow Up In Paediatric Patients Undergoing Fusion for High Grade Spondylolisthesis Managed Via Fusion In-Situ Vs Reduction and Circumferential Fusion**  
*Karim Aboelmagd, MD; Emma Nadler, MSc; Mark Camp, MD; Reinhard D. Zeller, MD, FRCS(C); David E. Lebel, MD, PhD*
- 13:23 - 13:27 **Paper #72: 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*
- 13:27 - 13:31 **Paper #73: A Novel Surgical Procedure: Selected Muscle Transfer to Correct the Malrotation and Elevation of the Scapula of Sprengel's shoulder deformity in Children and Adult**  
*Xuhong Xue, MD, PhD; Kai Li, MD; Sheng Zhao, MD*
- 13:31 - 13:42 **Discussion**
- 13:42 - 13:46 **Paper #74: Cryoablation Reduces Intraoperative Times, Pain, and Opioid Consumption in AIS Patients Undergoing PSF with Thoracoplasty**  
*Vishal Sarwahi, MD; Anabelle Cohen, BS; Alexander Morledge, BA; Sarah Trent, MD; Brian Li, BS; Yungtai Lo, PhD; Terry D. Amaral, MD*
- 13:46 - 13:50 **Paper #75: Intraoperative Erector Spinae Plane Block with Ropivacaine-Epinephrine-Clonidine-Ketorolac Reduces In-Hospital Opiate Consumption in Idiopathic Scoliosis Patients**  
*Miran Stubican, MD; Bryan Menapace, MD, MBA; Michelle C. Welborn, MD; Daniel Bouton, MD; Ashley Pikero, BS; Robert Bernstein, MD; Rebecca Hall, MD; Chinmay Paranjape, MD, MHSc*
- 13:50 - 13:54 **Paper #76: Does Obesity Enhance the Analgesic Effect of Liposomal Bupivacaine in Pediatric Spinal Fusions?**  
*Emmanuel Ogu, BS; David C. Thornberg, BS; Christopher B. McLeod, MD; Chan-Hee Jo, PhD; Amy Lynn. McIntosh, MD; Brandon A. Ramo, MD; Judy-Mae Lima, BS; Jaysson T. Brooks, MD*

\*Denotes a non-CME session/event

## MEETING AGENDA: FRIDAY, APRIL 17, 2026

- 13:54 - 14:03 **Discussion**
- 14:03 - 14:07 **Paper #77: Comparative Study of Spinal Casting Strategies in Early Onset Scoliosis: Five-year Progression-Free Survival Analysis**  
*Jennifer A. Dermott, PT, PhD candidate; Dorothy Kim, MSc; Lily Switzer; Emma Nadler, MSc; Mark Camp, MD; David E. Lebel, MD, PhD*
- 14:07 - 14:11 **Paper #78: Can Rib Splints Reduce Risk of Proximal Anchor Failure in Distraction-Based Growing Constructs? A Biomechanical Pilot Study**  
*Arianne T. Salunga, DO; Talissa O. Generoso, MD; Calvin Chan, MS; Vivian Ho, BSN; Nicole S. Pham; John S. Vorhies, MD*
- 14:11 - 14:15 **Paper #79: TEG Identifies Altered Intrinsic Pathway Kinetics in CP PSF**  
*Jessica Siragusa, MBA; Sydney Thai, BS; William ElNemer, BS; Paul D. Sponseller, MD*
- 14:15 - 14:19 **Paper #80: Operative Treatment of Severe Scoliosis and Pelvic Obliquity In Patients with Spinal Muscular Atrophy**  
*Heng Sun, MD; Jianxiong Shen, MD*
- 14:19 - 15:00 **Discussion**

### Session 9B: Integrating New Technologies & Techniques\* NEUROSURGERY Constitution Hall 107

*This session is hosted by the AANS/CNS Section on Disorders of the Spine & Peripheral Nerves (DSPN)*

*Moderators: Daniel M. Sciubba, MD & Luis M. Tumlialan, MD*

- 13:15 - 13:18 **Introduction**  
*Daniel M. Sciubba, MD*
- 13:18 - 13:24 **3D Printed Personalized Implants**  
*Praveen V. Mummaneni, MD*
- 13:24 - 13:30 **What is the Role for Sacro-iliac Fusion in Spinal Deformity Surgery?**  
*Benjamin D. Elder, MD, PhD*
- 13:30 - 13:38 **Discussion**
- 13:38 - 13:44 **Prone Lateral - Fad or Here to Stay?**  
*Juan S. Uribe, MD*
- 13:44 - 13:50 **How to Instrument: Free-Hand, Fluoro, Navigation, AR, Robotics, Pre-Contoured Rod & Implants**  
*Charles Sansur, MD, FAANS*
- 13:50 - 13:56 **How Large a Case Can be Done in the ASC/Outpatient Setting**  
*Paul Park, MD*
- 13:56 - 14:04 **Discussion**
- 14:04 - 14:10 **Spinal Endoscopy - How to Learn and Implement**  
*Michael Y. Wang, MD, FAANS*
- 14:10 - 14:16 **How I Use AI as a Spine Surgeon**  
*Amit Jain, MD, MBA*
- 14:16 - 14:22 **How Can Surgeons Improve Limb Function in Spinal Cord Injury Patients?**  
*Wilson Zachary Ray, MD*
- 14:22 - 14:30 **Discussion**

\*Denotes a non-CME session/event

# MEETING AGENDA: FRIDAY, APRIL 17, 2026

13:30 - 14:15 | INNOVATION ICL

Innovation Theatre

## Practical Tips for Using AI to Improve Healthcare\*

Moderators: Addisu Mesfin, MD & Peter G. Passias, MD

- 13:30 - 13:35 **Introduction to AI Principles and Trends in Usage**  
*Venu Nemani, MD, PhD*
- 13:35 - 13:40 **Incorporating AI in Our Data Collection and Analysis**  
*Emmanuelle Ferrero, MD, PhD*
- 13:40 - 13:45 **Employing Wearable Devices in the Diagnostic and Outcomes**  
*Zeeshan Sardar, MD*
- 13:45 - 13:52 **Discussion**
- 13:52 - 13:57 **How Can AI Make Our Practices More Efficient and Less Burdensome?**  
*Ferran Pellisé, MD, PhD*
- 13:57 - 14:02 **The Use of Robotics and Digital Twins**  
*Isador Lieberman, MD, MBA, FRCSC*
- 14:02 - 14:07 **How is AI Changing the Surgical Experience - AR/VR and What Does the Future Hold?**  
*Benjamin Elder, MD*
- 14:07 - 14:15 **Discussion**

14:30 - 15:00 | Exhibit Viewing & Refreshment Break\*

Constitution Hall 106

15:00 - 15:45 | INNOVATION ICL

Innovation Theatre

## From Napkin to Commercialization: Device Development \* EARLY CAREER

Moderators: Patrick Cahill, MD & Stefan Parent, MD, PhD

- 15:00 - 15:10 **Idea**  
*Daniel Sciubba, MD, MBA & John Younger, MD*
- 15:11 - 15:20 **Preclinical Testing**  
*Patrick Cahill, MD & Stefan Parent, MD, PhD*
- 15:21 - 15:30 **Regulatory**  
*Patrick Cahill, MD*
- 15:30 - 15:45 **Funding**  
*Daniel Sciubba, MD, MBA & John Younger, MD*

15:00 - 16:15 | SESSIONS 10A & 10B (concurrent sessions)

## Abstract Session 10A: Cervical Spine NEUROSURGERY

Constitution Hall 105

Moderators: Yashar Javidan, MD & Charles H. Crawford III, MD

- 15:00 - 15:04 **Paper #81: Increased Cumulative Incidence of 10-Year Reoperation and Surgical Complications Following Anterior Cervical Discectomy and Fusion Compared to Cervical Disc Arthroplasty**  
*Theodore Quan, MD; Philip Parel, BS; Jeremy Clements, BS; Adrianna Kowblansky, BS; Sabrina Gill, MD; Tushar Chandrakant Patel, MD; Addisu Mesfin, MD*
- 15:04 - 15:08 **Paper #82: Conservative vs Anterior Cervical Discectomy Fusion (ACDF), and Anterior Cervical Disc Replacement (ACDR) Approaches—Do Management Outcomes Differ in Patients Presenting With Cervical Radiculopathy Without Neurological Deficits?**  
*Vikas Hanasoge, MBBS, MS; Saumyajit Basu, MS (Ortho), DNB (Ortho), FRCS (Ed); Ayon Ghosh, MS; Dhrumilkumar Patel, MBBS, MS; Dhruv Patel, MS; Dr Harsh Patel, MS; Ajay VM, MS*

\*Denotes a non-CME session/event

# MEETING AGENDA: FRIDAY, APRIL 17, 2026

- 15:08 - 15:12 **Paper #83: Deep Learning Fusion of Operative Notes with Structured Preoperative Data Improves 2-Year Outcome Prediction for Cervical Spinal Myelopathy Surgery**  
*Eunice Yang, BS; Harrison Howell, BS; Praveen V. Mummaneni, MD; Dean Chou, MD; Mohamad Bydon, MD; Erica F. Bisson, MD; Christopher I. Shaffrey, MD; Oren N. Gottfried, MD; Anthony L. Asher, MD; Domagoj Coric, MD; Eric A. Potts, MD; Kevin T. Foley, MD; Michael Y. Wang, MD; KaiMing G. Fu, MD, PhD; Michael S. Virk, MD, PhD; John J. Knightly, MD; Scott Meyer, MD; Paul Park, MD; Cheerag D. Upadhyaya, MD; Chun Po Yen, MD; Juan S. Uribe, MD; Luis Manuel Tumialan, MD; Jay D. Turner, MD, PhD; Regis W. Haid, MD; Andrew K. Chan, MD*
- 15:12 - 15:16 **Paper #84: Biomechanical Performance of Uniform and Hybrid Screw Constructs in Long-Segment Cervical Spine Fusion: A Finite Element Study**  
*Ataollah Shahbandi, MD; Mohamad Bakhaidar, MD, FRCS(C); Balaji Harinathan, PhD, MS; Abdul Mounnem Yassin Kassab, MD; Pegah Ghamasaei, MD; Narayan Yoganandan, PhD; Saman Shabani, MD; Kevin Wojcik, DO*
- 15:16 - 15:27 **Discussion**
- 15:27 - 15:31 **Paper #85: Extent of Medial Facetectomy Required Varies by Level for Posterior Cervical Foraminotomy: A Radiographic Study**  
*Joshua H. Lee, MD; Tarun Mattikalli, BS; Brian Cho, MD; Daniel Berman, MD; Wesley Bronson, MD; Saad Chaudhary, MD; Andrew C. Hecht, MD; Jeremy Steinberger, MD; James D. Lin, MD, MS*
- 15:31 - 15:35 **Paper #86: Surgical and Clinical Outcomes of French Door vs. Open Door Laminoplasty: A Long-Term Analysis of Neurological Recovery**  
*Alexandra N. Yiachos, BS; Lefko Charalambous, MD; Akil Paturi, MD; Kingsley Ogelle, BS; Constance Maglaras, PhD; Themistocles S. Protopsaltis, MD; Tina Raman, MD*
- 15:35 - 15:39 **Paper #87: Evaluating the Impact of Single or Two-Level Anterior Cervical Surgery on Extensor Neck Muscle Volume in Patients with Degenerative Pathology**  
*Sydney Pattison, BS; Aiyush Bansal, MD, Other; Madison Alessi, BS; Kento Yamanouchi, MD; Kenneth Nguyen, BS; Rakesh Kumar; Jean-Christophe Leveque, MD; Venu Nemani, MD, PhD; Philip Louie, MD*
- 15:39 - 15:48 **Discussion**
- 15:48 - 15:52 **Paper #88: Transient Skeletal Muscle Loss After Cervical Decompression for Myelopathy**  
*Isaiah Gritters, BA; Reagan Grieser-Yoder, BS; Natalie Glass, PhD; Bradley Hindman, MD; Andrea Strayer, PhD; Matthew Howard, MD; Catherine Olinger, MD, MS*
- 15:52 - 15:56 **Paper #89: Personalizing the Approach to Degenerative Cervical Myelopathy (DCM): Multivariable Trajectory Models to Define Precise Clinical Recovery Patterns**  
*Michael G. Fehlings, MD, PhD, FRCS(C); Karlo M. Pedro, MD; Mohammed Ali Alvi, MD, PhD, MS*
- 15:56 - 16:00 **Paper #90: Does Surgery Reduce Neck Pain and Restore Independence 5 years After Surgery for Cervical Spondylotic Myelopathy (CSM)? A SpineCORE QOD Study**  
*Vardhaan Ambati, MS; Hunter S. Yamada, BS; Arati Patel, MD; Catherine Ravikumar, MS; Andrew K. Chan, MD; Erica F. Bisson, MD; Mohamad Bydon, MD; Anthony L. Asher, MD; Domagoj Coric, MD; Eric A. Potts, MD; Kevin T. Foley, MD; Michael Y. Wang, MD; Michael S. Virk, MD, PhD; John J. Knightly, MD; Scott Meyer, MD; Paul Park, MD; Cheerag D. Upadhyaya, MD; Chun Po Yen, MD; Jay D. Turner, MD, PhD; Luis Manuel. Tumialan, MD; Juan S. Uribe, MD; Oren N. Gottfried, MD; Christopher I. Shaffrey, MD; Regis W. Haid, MD; Dean Chou, MD; Praveen V. Mummaneni, MD*
- 16:00 - 16:04 **Paper #91: Does Timing Matter? Impact of Early Surgery for Cervical Spondylotic Myelopathy on 5-Year Patient-Reported Outcomes**  
*Eunice Yang, BS; Harrison Howell, BS; Praveen V. Mummaneni, MD; Dean Chou, MD; Mohamad Bydon, MD; Erica F. Bisson, MD; Christopher I. Shaffrey, MD; Oren N. Gottfried, MD; Anthony L. Asher, MD; Domagoj Coric, MD; Eric A. Potts, MD; Kevin T. Foley, MD; Michael Y. Wang, MD; KaiMing G. Fu, MD, PhD; Michael S. Virk, MD, PhD; John J. Knightly, MD; Scott Meyer, MD; Paul Park, MD; Cheerag D. Upadhyaya, MD; Chun Po Yen, MD; Juan S. Uribe, MD; Luis Manuel. Tumialan, MD; Jay D. Turner, MD, PhD; Regis W. Haid, MD; Andrew K. Chan, MD*
- 16:04 - 16:15 **Discussion**

\*Denotes a non-CME session/event

# MEETING AGENDA: FRIDAY, APRIL 17, 2026

## Abstract Session 10B: Tumors, Infection, & Miscellaneous

Constitution Hall 107

Moderators: Ronald Lehman Jr. MD & Addisu Mesfin, MD

- 15:00 - 15:04 **Paper #92: Clinical Validation of a Novel Psoas Classification for Optimal L4-L5 Access: OLIF vs LLIF**  
*Harjot Uppal, MD; George Abdelmalek, MD; Daniel Coban, MD; Siraj Shaikh, MD; Nikhil Sahai, MD; Kumar Sinha, MD; Ki So. Hwang, MD; Arash Emami, MD*
- 15:04 - 15:08 **Paper #93: Revision Anterior Lumbar Spine Access Surgery: Is It Safe?**  
*Karim A. Shafi, MD; Sree Vemu, MD; Rajeev Rao, MD; Todd H. Lanman, MD; Hyun W. Bae, MD; Willis Wagner, MD*
- 15:08 - 15:12 **Paper #94: Impact of Screw Diameter on the Mechanical Performance of Cement-Augmented Lumbar Spinal Fusion Constructs**  
*Akar Jigna. Jani, BS; Nicole DeVries Watson, PhD; Douglas C. Fredericks, BS; Catherine Olinger, MD, MS*
- 15:12 - 15:27 **Discussion**
- 15:27 - 15:31 **Paper #95: Development and Validation of a Novel Survey Measuring Lumbar Activity Levels: Core Health Evaluation - Lumbar Activity Rating Scale (CHEV-LARS)**  
*Francis Lovecchio, MD; Eric Zhao, BS; Gregory Kazarian, MD; Jung Mok, MD; Mihir Dekhne, MD; Tomoyuki Asada, MD; Atahan Durbas; Sereen Halayqeh, MD; Adrian Lui, MBBS; Sheeraz Qureshi, MD; Todd J. Albert, MD; Sravisht Iyer, MD*
- 15:31 - 15:35 **Paper #96: Tranexamic Acid Does Not Significantly Change Thromboembolic Risk in Spinal Metastasis Tumor Patients**  
*Braxton Morrison, MS; Jay Kumar, MD; Vardhaan Ambati, MS; Hunter S. Yamada, BS; Abraham Dada, BA; Rithvik Ramesh, BS; Parisa Jahangirizadeh, BA; Paul McMillan Villalobos, BE; Christopher P. Ames, MD; Vedat Deviren, MD; Sigurd H. Berven, MD; Alekos A. Theologis, MD; Dean Chou, MD; Aaron J. Clark, MD, PhD; Praveen V. Mummaneni, MD; Nima Alan, MD*
- 15:35 - 15:39 **Paper #97: Does Preoperative Embolization Lower Surgical Blood Loss in Nonvascular Metastatic Spine Tumor Surgery?**  
*Hunter S. Yamada, BS; Vardhaan Ambati, MS; Danielle Nieto, BA; Paul McMillan Villalobos, BE; Parisa Jahangirizadeh, BA; Braxton Morrison, MS; Abraham Dada, BA; Rithvik Ramesh, BS; Christopher P. Ames, MD; Sigurd H. Berven, MD; Alekos A. Theologis, MD; Dean Chou, MD; Aaron J. Clark, MD, PhD; Lee A. Tan, MD; Praveen V. Mummaneni, MD; Nima Alan, MD*
- Paper #98 has been WITHDRAWN**
- 15:39 - 15:54 **Discussion**
- Paper #99 has been WITHDRAWN**
- 15:54 - 15:58 **Paper #100: Expandable Cage versus Mesh Cage in the Treatment of Vertebral Osteomyelitis**  
*Mitsuhiro Nishizawa, MD; Mladen Djurasovic, MD; Steven D. Glassman, MD; John R. Dimar, II, MD; Charles H. Crawford III, MD; Benjamin Kostic, BS; Leah Y. Carreon, MD*
- 15:58 - 16:02 **Paper #101: Tuberculosis of the Spine in Children- Is Conservative Treatment Effective?**  
*Bhushan Sagade, MS; Alaric Aroojis, MD; Ira Shah, MD; Rujuta Mehta, MD; Tausif Ahmed Aslam Shikalgar, MD, MBBS, D.Ortho, DNB Ortho; Arjun Dhawale, MD; Abhay Nene, MS*
- 16:02 - 16:15 **Discussion**

16:15 - 16:30 | Exhibit Viewing\*

Constitution Hall 106

16:15 - 16:30 | SRS MEMBER INFORMATION SESSION\*

Innovation Theatre

Join Fellowship Committee Chair, Gregory M. Mundis, MD to learn more about becoming a member of SRS.

\*Denotes a non-CME session/event

# MEETING AGENDA: FRIDAY, APRIL 17, 2026

16:30 - 17:35 | SESSION 11

Constitution Hall 105

## Understanding the Past and Conquering the Future EARLY CAREER

Moderators: Meric Enercan, MD & Joshua M. Pahys, MD

- 16:30 - 16:35 **Presentation of the Whitecloud, E-Point, and Innovation Award Winning Papers**  
*Amit Jain, MD, MBA & Caglar Yilgor, MD*
- 16:35 - 16:42 **The Early Years: From the Animal Lab to Staples and the First VBT Cases**  
*A. Noelle Larson, MD*
- 16:42 - 16:49 **Evolution of VBT to Thoracolumbar Spine, Double Row, and Non-AIS Patients**  
*Patrick J. Cahill, MD*
- 16:49 - 16:56 **The Future of Growth Modulation: Apical Fusion, Hybrid Technique, and Beyond**  
*Amer F. Samdani, MD*
- 16:56 - 17:05 **Discussion**
- 17:05 - 17:12 **Advancements in Revision Adult Deformity: How to Fix a Harrington Rod Patient**  
*Dong-Gune Chang, MD, PhD*
- 17:12 - 17:19 **Innovations in Primary Adult Spinal Deformity: Restoration of the Sagittal Plane and 3D Alignment**  
*Addisu Mesfin, MD*
- 17:19 - 17:26 **Evolution of Surgical Planning: From an Educated Guess to AI/Machine Learning**  
*Michael P. Kelly, MD*
- 17:26 - 17:35 **Discussion**

17:35 - 19:00 | INNOVATION CELEBRATION\*

Azure (InterContinental)

Join your colleagues to close out the 33<sup>rd</sup> IMAST. The celebration takes place at the InterContinental Toronto Centre hotel in Azure. Open to all registered delegates and guests of registered delegates. Tickets are \$25 USD for registered delegates and \$50 USD for guests and must be purchased in advance. Please stop at the IMAST registration desk to purchase tickets. Dress for the Innovation Celebration is business casual.

\*Denotes a non-CME session/event

## PODIUM PRESENTATION ABSTRACTS

### Paper #1. The SRS-Lenke-Aubin 3D Classification: A Structured and Clinically Relevant Extension of the Lenke System to Capture Transverse Plane Deformities in AIS §

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

#### Hypothesis:

Regional and local transverse plane modifiers provide clinically meaningful information, independent from conventional 2D parameters, and enhance 3D characterization of adolescent idiopathic scoliosis (AIS).

#### Design:

Proposal of new transverse plane modifiers for a 3D Lenke-based classification, supported by a retrospective cohort study using patient-specific 3D spinal reconstructions.

#### Introduction:

AIS is a 3D deformity increasingly treated with multiplanar strategies, yet clinical classification remains anchored in 2D coronal and sagittal metrics. To address this gap, the SRS 3D Classification Task Force extended the Lenke system by introducing two new transverse plane descriptors: orientation of the regional plane of deformation (ORPD) and apical vertebral rotation (AVR).

#### Methods:

A representative cohort of 285 AIS surgical cases was reconstructed in 3D using calibrated biplanar radiographs. ORPD and AVR were measured independently for the proximal thoracic (PT), main thoracic (MT), and thoracolumbar/lumbar (TL/L) regions and categorized using clinically relevant thresholds. Correlation and multivariate analyses assessed their independence and their relationships with Cobb angle, thoracic kyphosis, and lumbar lordosis.

#### Results:

Building upon the existing Lenke classification, the new system integrates two transverse plane modifiers per region—ORPD (1–3) and AVR (s, m, l)—within a 3-tiered, 4-modifier framework. A wide range of ORPD–AVR combinations was observed. ORPD and AVR were independent in PT and MT but moderately correlated in TL/L ( $r=0.69$ ). Cobb angle correlated moderately to strongly with ORPD in MT ( $r=0.43$ ) and TL/L ( $r=0.67$ ). Over 55% of ORPD variability remained unexplained by 2D parameters, demonstrating the added value of the 3D descriptors.

#### Conclusion:

The SRS-Lenke-Aubin 3D classification enriches the Lenke system with structured transverse plane modifiers that are clinically applicable and largely independent of conventional parameters. It provides a practical framework for comprehensive 3D characterization of AIS, intended to better inform surgical planning and outcome evaluation.

### Paper #2. Reliability of Vertebral Pelvic Angles in Pediatric Idiopathic Scoliosis Patients §

*Nicholas A. Collar, MD; Miran Stubican, MD; Michael P. Kelly, MD; Bryan Menapace, MD, MBA; Ashley Pikero, BS; Chinmay Paranjape, MD, MHSc*

#### Hypothesis:

Vertebral pelvic angles (VPAs) provide more reliable and reproducible measures of sagittal alignment than conventional sagittal Cobb angles in juvenile and adolescent idiopathic scoliosis, owing to their reduced susceptibility to rotational distortion and endplate ambiguity.

#### Design:

Retrospective radiographic reliability study.

#### Introduction:

Vertebral pelvic angles have demonstrated utility in assessing sagittal alignment in adult spinal deformity due to their relative insensitivity to rotational distortion and inconsistent visualization of endplates. Their reliability in juvenile and adolescent idiopathic scoliosis (JIS/AIS) has not been established, despite potential advantages over conventional Cobb-based parameters.

#### Methods:

Seventy-three patients aged 10–21 years with JIS or AIS undergoing posterior spinal fusion were included. Three independent raters measured pre- and postoperative VPAs (C2PA, T4PA, L1PA, pelvic incidence [PI], pelvic tilt [PT]) and conventional sagittal Cobb angles (L1–L4 lordosis, L4–S1 lordosis, T4–T12 kyphosis, and C2–C7 lordosis) using standardized EOS lateral radiographs. Interobserver reliability was assessed using intraclass correlation coefficients (ICCs). SEM was calculated for each parameter using standard error of measurement.

#### Results:

Seventy-three patients (mean age  $15 \pm 2.4$  years, 78% female) were included. Most patients were skeletally mature, with 83% at Risser stage  $\geq 4$  and 71% at Sanders stage  $\geq 7$ . Lenke type 1 (38.9%) and type 2 (26.4%) curves were most common. VPAs demonstrated good to excellent interrater reliability: T4PA and C2PA had excellent ICCs (0.92 and 0.90), while L1PA, PT, and PI showed good agreement (ICCs 0.83,

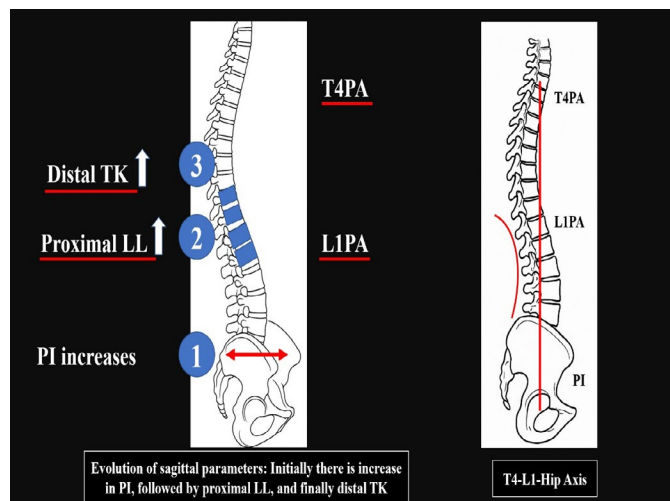
§ = Whitecloud Award Nominee – Best Clinical Paper

## PODIUM PRESENTATION ABSTRACTS

0.84, and 0.78). Corresponding SEMs ranged from 2.2° to 4.9°. In contrast, sagittal Cobb angles showed moderate (T4–T12 kyphosis, ICC 0.72) to poor reliability (L1–L4 and L4–S1 lordosis, ICCs 0.31 and 0.29) with substantially higher SEMs (up to 7.4°).

### Conclusion:

VPA provides more reliable and reproducible measurements of sagittal alignment in pediatric idiopathic scoliosis than conventional Cobb methods, particularly in regions affected by rotational deformity. Their use may improve radiographic assessment and surgical planning in this population.



### Paper #3 has been WITHDRAWN

### Paper #4. From Adolescence to Late Adulthood: Quality of Life and Surgical Outcomes in Idiopathic Scoliosis Across the Lifespan §

Susana Nunez Pereira, MD, PhD; Javier Pizones, MD, PhD; Sleiman Haddad, MD, PhD, FRCS; Alejandro Gomez-Rice, MD, PhD; Francisco Javier S. Perez-Gruoso, MD; Lluis Vila Castillo, MD; Yann Phillippe Charles, MD, PhD; Anika Pupak, PhD, BS; Ibrahim Obeid, MD; Ahmet Alanay, MD; Frank S. Kleinstueck, MD; Ferran Pellise, MD, PhD; European Spine Study Group ESSG

### Hypothesis:

The impact of idiopathic scoliosis (IS) on health-related quality of life (HRQoL) and the outcomes of surgery vary across age groups.

### Design:

Cross-sectional study from a prospectively collected database with 2 years follow-up

### Introduction:

Idiopathic scoliosis (IS) will accompany patients throughout their lives from diagnosis. Even if most studies show a relatively benign natural history, a subset of patients still pursue surgery during adult-

hood, reflecting a greater symptom burden compared to their peers.

### Methods:

Surgically treated IS patients with >2 years of follow-up from a multicenter prospective database stratified by age. Preoperative SRS-22 scores—including pain (P), function (F), self-image (SI), and mental health (MH)—were compared across seven decades using the Kruskal-Wallis test with post hoc Bonferroni correction. Correlations were analyzed using Spearman's test (r).

### Results:

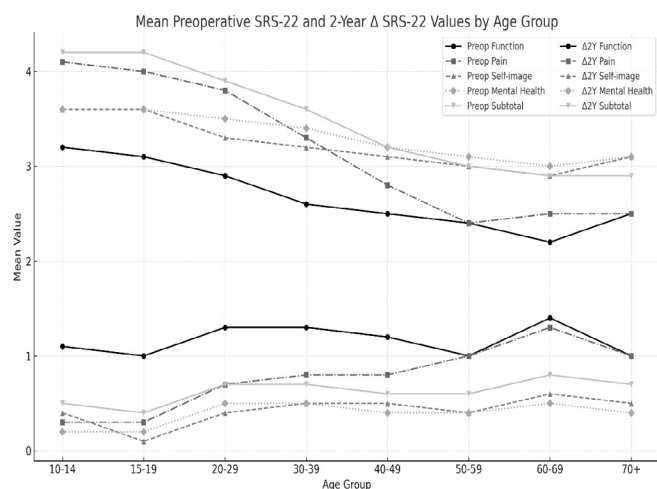
761 patients (85.5% female, ages 10–83), age distribution: 10–14 (n=62), 15–19 (n=151), 20–29 (n=247), 30–39 (n=80), 40–49 (n=72), 50–59 (n=79), 60–69 (n=47), and >70 (n=23). Significant negative correlations with age were observed in all preop SRS-22 domains (P: r=-0.52, F: r=-0.60, SI: r=-0.46, MH: r=-0.38, all p<0.0001). The oldest group had baseline P and F scores 1.22 and 1.5 points lower, compared to the youngest. SI and MH showed smaller differences (0.68 and 0.58). Patients over 50 had less thoracic curve severity. Lumbar curve severity increased after age 30. Global tilt and lumbar lordosis progressively worsened with age. Postoperatively, SI had the greatest improvement across all age groups (p=0.106). Older patients exhibited significantly greater improvements in P and MH (p<0.001). Correlations for 2-year improvements were significant only for P, MH, and subtotal scores, all <0.4.

### Conclusion:

This study is the first to describe the full spectrum of IS surgery across the lifespan. Preoperative SRS-22 domain scores are lower in elder surgical candidates, particularly P and F. SI is the most affected domain across all age groups and demonstrates the greatest postoperative improvement. Pain and function become increasingly relevant in older patients. Patients were responsive to surgery across the entire age spectrum although improvements in P, MH, and subtotal scores remain age-dependent.

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SRS-22 values: Above preop, below 2 years postop increase

### Paper #5. What is a Better Predictor of Disability in Adult Spinal Deformity Patients: Gait or Radiographic Parameters? §

Maxmillian Tjauw, BS; Parth Patel, BS; Lauren Rigney, BS; M. Burhan Janjua, MD; John F. Burke, MD, PhD

#### Hypothesis:

Spatial temporal gait parameters are a better predictor of disability compared to radiographic metrics in Adult Spinal Deformity (ASD) patients.

#### Design:

Retrospective cohort study

#### Introduction:

Previous studies have demonstrated that radiographic parameters of sagittal alignment predict disability in ASD patients. More recently, quantitative metrics of gait have been shown to correlate with the degree of sagittal plane deformity. It remains unclear whether radiographic or gait parameters are better predictors of disability in ASD.

#### Methods:

67 ASD patients presenting to a single center over a 12 month period were included. Patient reported outcome measures (PROMs) were collected and included ODI and SRS-22 pain (P), function (F), self-image (SI) and mental health (MH) sub-components. Three gait spatial temporal parameters (velocity, cadence, percentage of swing time within the step cycle) were collected from a 9-meter walk using a computerized gait analysis system. Radiographic parameters were collected and included: pelvic tilt (PT), pelvic incidence minus the lumbar lordosis (PI-LL), T4-L1 pelvic angle (T4-L1PA), and the C2 tilt (C2T). Univariate and multivariate regressions were used to correlate gait and radiographic data with PROMs. Using a multivariate classifier, we predicted severe

disability using (1) radiographic metrics alone, (2) gait metrics alone, and (3) gait and radiographic metrics.

#### Results:

On univariate regression, all three gait parameters were significantly correlated with ODI and SRS-F; gait velocity was also correlated with SRS-SI. For the radiographic parameters, PT, PI-LL, and C2T correlated with ODI, PI-LL correlated with SRS-F, and PI-LL and PT correlated SRS-SI. On multivariate analysis, gait velocity, gait swing time percentage, and PI-LL correlated with ODI, and only gait velocity and cadence correlated with SRS-P. Using the multivariate classifier, radiographic metrics alone predicted severe disability with an area under the curve (AUC) of 0.75, whereas gait metrics yielded an AUC of 0.84. The combined gait and radiographic data predicted disability with an AUC of 0.92.

#### Conclusion:

Gait data was more predictive of disability than radiographic information in a cohort of ASD patients. These data suggest that gait information can be combined with radiographic information for improved classification of disease severity in ASD.

### Paper #6. C2-UIV Angle Predicts Mechanical Failures in Adult Spinal Deformity Patients §

Karan Joseph, BS; Alexander T. Yahanda, MS; Miguel Ruiz Cardozo, MD; Tim Bui, BS; Samuel Vogl; Nicholas A. Pallotta, MD, MS; Brian J. Neuman, MD; Munish C. Gupta, MD, MBA; Jeffrey M. Hills, MD; Michael P. Kelly, MD; Jacob Greenberg, MD; Wilson Zachary Ray, MD; Camilo A. Molina, MD

#### Hypothesis:

Preoperative C2-UIV angle is associated with mechanical failures.

#### Design:

Retrospective case-control study

#### Introduction:

Multiple measures of spinopelvic alignment have been identified for adult spinal deformity (ASD). Malalignment in multiple of these metrics has been associated with increased odds of postoperative mechanical failure. However, few studies have examined the relationship between the angle formed by C2 and the upper instrumented vertebra (UIV) and how this may impact mechanical failures. This study assessed the prognostic value of the C2-UIV angle and its relationship to postoperative outcomes.

#### Methods:

This was a retrospective case-control study of patients undergoing spinal fusions for ASD. Patients with mechanical failures (n=69) were compared to a sample of non-failure patients (n=178). Preop-

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## PODIUM PRESENTATION ABSTRACTS

erative C2-UIV angles were assessed on standing radiographs. Mechanical failure was defined as development of proximal junctional kyphosis (PJK) or hardware-related instrumentation failure. Uni- and multivariable logistic regression analyses were used to identify predictors of failure, controlling for age, sex, BMI, and preoperative C2 tilt. A maximally selected rank statistic was used to identify an optimal threshold for preoperative C2-UIV angle. The cutoff was subsequently converted into a binary variable and tested in a multivariable logistic regression model.

### Results:

242 patients were included (mean age = 66.4, 67% female). In multivariable regression, preoperative C2-UIV was independently predictive of mechanical failure (OR=1.09, p=0.006), after adjusting for age, sex, BMI and global alignment. A maximally selected rank statistic identified an optimal cutoff of 6°. A second multivariable model using a binary variable confirmed the threshold's predictive value (OR=3.93, p=0.004), even when controlling for the same covariates. The threshold demonstrated high sensitivity (91.3%) and negative predictive value (88.2%).

### Conclusion:

Preoperative C2-UIV angle is a robust independent predictor of mechanical failures in ASD patients, even after accounting for preoperative global alignment. A threshold of 6° identifies patients at significantly elevated risk, supporting its use as a surgical planning goal when selecting UIV level. These findings highlight the clinical utility of incorporating C2-UIV angle into preoperative assessments to improve construct stability and reduce postoperative complications.

### Paper #7. Surgery vs Conservative Management in Adult Spinal Deformity: Propensity-Matched Evidence from a Large Prospective Cohort §

*Louis Boissiere, MD; Alice Baroncini, MD, PhD; Daniel Larrieu, PhD; Anouar Bourghli, MD; Javier Pizones, MD, PhD; Ferran Pellise, MD, PhD; Ahmet Alanay, MD; Yann Phillippe Charles, MD, PhD; Frank S. Kleinstueck, MD; Cecile Roscop, MD; Ibrahim Obeid, MD*

### Hypothesis:

Surgical management yields superior 2-year clinical outcomes versus conservative care, including in patients without severe sagittal imbalance or disability.

### Design:

Retrospective analysis of a large prospective ASD database with 1:1 propensity score (PS) matching.

### Introduction:

Choosing between surgery and non-surgical care for adult spinal deformity (ASD) remains challeng-

ing. In the absence of randomized trials, we tested whether surgery confers better outcomes than conservative treatment using PS matching to reduce selection bias.

### Methods:

ASD patients treated surgically or conservatively with ≥2-year follow-up were eligible. PS matching used demographics (age, sex, BMI), radiographic parameters (Cobb angle, global tilt [GT]), pelvic parameters including PI-LL, and baseline quality-of-life scores (ODI, SRS-22). Patients were matched 1:1 by PS. Balance after matching showed mean absolute differences <0.2 for each variable (P>0.05). Notably, PS matching tended to select surgical patients without sagittal imbalance, yielding profiles more comparable to conservative patients.

### Results:

Three hundred twenty patients were analyzed (surgery n=160; conservative n=160). Before matching, groups differed in age (45.5±17.4 vs 54.3±18.2 years), radiography (Cobb 51.7±19.8° vs 43.9±22.9°; GT 19.2±14.6° vs 27.2±17.5°), and disability (ODI 20.8±16.7 vs 40.7±20), indicating baseline selection bias. After PS matching, between-group differences were minimized. At 2 years, surgical treatment achieved significantly better SRS sub-scores versus conservative care—pain, function, aesthetics, and mental health—and this advantage persisted in patients without sagittal imbalance (reported values: pain 17±16.9 vs 23.9±17.7; function 3.9±0.9 vs 3.8±0.8; aesthetics 3.9±0.7 vs 3.1±0.9; mental health 3.8±0.7 vs 3.4±0.8).

### Conclusion:

In a propensity-matched comparison, surgery for ASD provides superior 2-year clinical outcomes relative to conservative management, including among patients without marked sagittal imbalance or disability. These findings support surgical consideration when durable symptom relief and functional gains are prioritized.

### Paper #8. Distal Extension Rates After Lower Instrumented Vertebrae of L4/L5 §

*Tejas Subramanian, MD; Francis Lovecchio, MD; Atahan Durbas, MD; Renaud Lafage, MS; Christopher P. Ames, MD; Shay Bess, MD; Robert K. Eastlack, MD; Munish C. Gupta, MD, MBA; Richard Hostin, MD; Khaled M. Keibaish, MD; Eric O. Klineberg, MD; Gregory M. Mundis Jr., MD; David O. Okonkwo, MD, PhD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; Han Jo Kim, MD; International Spine Study Group*

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## PODIUM PRESENTATION ABSTRACTS

### Hypothesis:

Lower instrumented vertebra (LIV) at L4/L5 might not require distal extension to the pelvis within 2 years.

### Design:

Retrospective cohort study.

### Introduction:

LIV choice in adult spinal deformity (ASD) surgery is challenging. Stopping at L4/L5 preserves lumbosacral motion but may lead to distal degeneration and revisions. The balance between preserving motion and mechanical durability remains unresolved. This study aimed to understand the incidence, risk factors, and radiographic signs of distal extension after long fusions to the pelvis.

### Methods:

ASD patients (aged  $\geq 18$ ) undergoing  $\geq 4$ -level fusion with L4/L5 LIV and 2-year follow-up were included. The primary outcome was the rate, timing, and reason for distal fusion extension (extended cohort [EC] vs non-extended cohort [NEC]). Demographics, alignment parameters, lumbar disc sizes, and patient-reported outcomes were compared at baseline and subsequent time points, up to pre-revision for EC or 2 years for NEC.

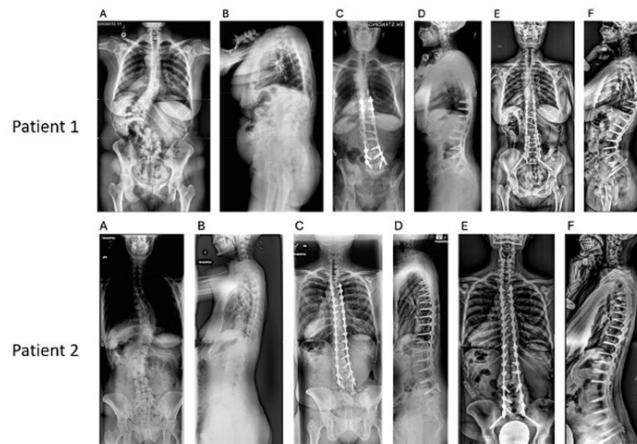
### Results:

65 patients (52F, 13M), mean age 47.9 years, BMI 25.3 kg/m<sup>2</sup>, and 8.7 fused levels met the criteria. 41 fusions ended at L4, 24 at L5. 16.9% (11/65) required distal extension to pelvis at median 517 days (IQR 226–770). Extension-free survival at a mean of 4.27 years was 83.1%. Extension risk was similar for L4 and L5 LIV (13.9% vs 33.3%,  $p=0.3$ ). Reasons for extension included sagittal malalignment with distal kyphotic change ( $n=2$ ; Patient 1), without distal kyphotic change ( $n=3$ ; Patient 2), adjacent segment disease without sagittal malalignment ( $n=4$ ), and distal mechanical failure (screw pullout, pseudarthrosis) ( $n=2$ ). Demographic and radiographic data at baseline and 6W were comparable. However, EC showed more anterior translation at L5–S1 (6W:  $-2.1$  vs  $-0.8$  mm,  $p=0.049$ ), and increased PT (1Y:  $23.6^\circ$  vs  $16.4^\circ$ ,  $p=0.02$ ; 2Y:  $24.7^\circ$  vs  $16.9^\circ$ ;  $p=0.01$ ). Early disability worsening (ODI at 6M:  $47.3$  vs  $30.3$ ,  $p=0.047$ ), decreased L5–S1 anterior disc height (10.6 mm vs 15.2 mm,  $p=0.03$ ), higher L1PA offset ( $4.9^\circ$  vs  $12.5^\circ$ ,  $p=0.01$ ), and T4–L1PA mismatch ( $1.1^\circ$  vs  $4.6^\circ$ ;  $p=0.03$ ) at final follow-up were observed in EC.

### Conclusion:

Stopping at L4/L5 shows an 83.1% 2-year extension-free survival. Failures mainly occur in the first year due to malalignment or distal fixation issues, indicated by changes in distal segment and disc height. Pre-op listhesis  $\geq 0.5$  mm at L5–S1 increased

the extension risk; spondylolisthesis  $<0.1$  mm was protective (0% extension).



A–B: Pre-op, C–D: Pre-revision, E–F: Post-revision.

### Paper #9. Not All Returns to the Operating Room Are the Same: A Comparison of Re-operations in Tether Versus Posterior Spinal Fusion §

*John S. Vorhies, MD; Jason B. Anari, MD; Patrick J. Cahill, MD; Lawrence L. Haber, MD; A Noelle Larson, MD; Arun R. Hariharan, MD, MS; Craig R. Louer Jr, MD; Peter O. Newton, MD; Maty Petcharaporn, BS; Stefan Parent, MD, PhD; Harms NonFusion Study Group; Firoz Miyanji, MD, FRCS(C)*

### Hypothesis:

For this study, we the nature and morbidity associated with re-operations also differs.

### Design:

Retrospective, multicenter

### Introduction:

Re-operation rates differ markedly between anterior vertebral body tethering (AVBT) and posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS).

### Methods:

This study reviewed a multicenter database of patients with AIS undergoing PSF and AVBT. We included all returns to the operating room for spine-related surgery, for patients with at least two years of follow-up from their index operation. The rates and types of re-operations were compared.

### Results:

3816 PSF patients were included from 1996–2022 with a mean follow-up of 2.35 years and a reoperation rate of 6.8% ( $n=261$ ). 462 AVBT patients were included from 2011–2021 with a mean follow-up of 3.09yrs and a reoperation rate of 12.6% ( $n=58$ ). Among re-operations after PSF, cause were: Surgical Site/Incision 36.9% ( $n=96$ ), Instrumentation 31.2% ( $n=81$ ), Pseudoarthrosis 9.6% ( $n=25$ ), Adding on/Junc-

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## PODIUM PRESENTATION ABSTRACTS

tional failure 8.1% (n=21), Neurologic 5.4% (n=14), Pain (hardware removal, secondary spine pathology) 5.0% (n=13), Pulmonary (Chest tube) 1.9% (n=5), Dural tear/Leak – 1.2% (n=3), and Medical/Aborted Primary – 0.8% (n=2). Among the re-operations that occurred after AVBT, 41% (n=24) resulted in continuation of AVBT at the same levels (tether release, replacement, chest tube) and 29% (n=17) occurred at different levels (extension of tether, new tether for a secondary curve), 29% (n=17) were converted to PSF and 2% (n=1) had another spinal pathology. No re-operations for infection were recorded in the AVBT group.

### Conclusion:

The nature and rate of re-operation differs between AVBT and PSF, suggesting distinct morbidity profiles and impacts on quality of life. Future studies should further quantify these differences to improve patient counseling and informed surgical decision-making.

### Paper #10. Asymmetrical Paravertebral Muscle Fibrosis Causes Progression of Adolescent Idiopathic Scoliosis Via Myostatin Signalling in Fibro-adipogenic Progenitors †

*Heng Sun, MD*

### Hypothesis:

Myostatin asymmetry underlies the observed ECM fibrosis imbalance between the concave and convex sides of paravertebral muscle in AIS.

### Design:

Basic research

### Introduction:

Adolescent idiopathic scoliosis (AIS) is characterized by progressive spinal deformity; however, its underlying mechanisms are poorly understood. While asymmetry of the paravertebral muscles (PVMs) has been linked to AIS progression, its molecular basis remains unclear.

### Methods:

PVMs biopsies from the concave and convex sides of 10 patients with AIS (Cobb angle > 45°, aged 14 – 18 years) were collected during corrective surgery for histological and gene expression analyses. Bulk RNA sequencing data (GSE254300) from five paired PVMs samples were reanalysed to identify differentially expressed genes, followed by Gene Ontology enrichment and Gene Set Enrichment Analysis. Single-cell RNA sequencing data (PRJNA722100) were used to examine the pathway activation in fibro-adipogenic progenitors (FAPs). In vitro, mouse skeletal muscle-derived FAPs were cultured with or without myostatin and assessed for fibrogenic and adipogenic differentiation. In vivo, unilateral myostatin injec-

tions were administered to the PVMs of bipedal mice to induce scoliotic deformities, which were evaluated using radiography and histological analysis.

### Results:

Histological and transcriptomic analyses revealed increased collagen deposition and extracellular matrix (ECM) remodelling on the concave side of PVMs. Single-cell RNA sequencing identified FAPs with enhanced myostatin pathway activation on the concave side of PVMs. In vitro, myostatin promoted FAPs proliferation and fibro-differentiation via SMAD3 signalling. In vivo, unilateral myostatin overexpression induced asymmetric PVMs fibrosis and spinal curvature in bipedal mice, which were alleviated by pharmacological inhibition of myostatin or SMAD3.

### Conclusion:

This study revealed increased ECM fibrosis was more pronounced on the concave side of PVMs than on the convex side in patients with AIS. Asymmetrical myostatin-driven fibrogenesis in FAPs was a significant mechanism underlying asymmetrical PVMs fibrosis and scoliosis progression, highlighting the therapeutic potential of targeting the myostatin-SMAD3 axis in AIS.

### Paper #11. Deep Phenotyping Revolutionizes Genetic Diagnosis of Scoliosis through Nine Strategic Categories †

*Nan Wu, MD; Guozhuang Li, MD; Terry Jianguo Zhang, MD*

### Hypothesis:

Integrating deep phenotyping with next-generation sequencing (NGS) significantly enhances the genetic diagnosis of scoliosis.

### Design:

Retrospective study.

### Introduction:

Scoliosis is diagnostically challenging due to heterogeneous etiologies, especially in rare bone diseases. While NGS has advanced variant detection, inconsistent phenotyping hampers accuracy. Deep phenotyping—capturing subtle features beyond spinal curvature (skin, joint, ocular, prenatal)—offers a more precise path to uncovering genetic causes.

### Methods:

We analyzed records of 600+ scoliosis patients with NGS, applying deep phenotyping from clinical and family data to link traits with variants, with case examples showing how targeted phenotyping improved genetic testing.

### Results:

Nine key aspects emerged, highlighting the impor-

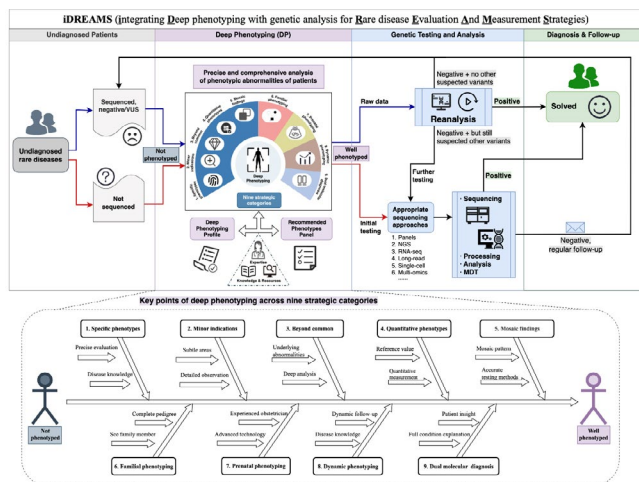
† = Whitecloud Award Nominee – Best Basic Science/Translational Paper

# PODIUM PRESENTATION ABSTRACTS

tance of deep phenotyping in scoliosis diagnoses: 1. Minor Indications: Subtle features (e.g., mild blue sclera) clarified conditions like osteogenesis imperfecta. 2. Quantitative Phenotyping: Precise measurements (e.g., kidney size) confirmed renal hypoplasia in congenital scoliosis linked to 16p11.2 microdeletion. 3. Specific Phenotypes: Overlooked traits such as skin laxity identified Ehlers-Danlos syndrome with COL5A1 variants. 4. Beyond Common Phenotypes: Joint pain assessments led to uncovering CCN6 variants in progressive pseudorheumatoid dysplasia. 5. Dual Molecular Diagnosis: Comprehensive evaluations revealed pathogenic variants in both NF1 and EGR2 in a single patient. 6. Prenatal Phenotyping: Major prenatal anomalies suggested Kabuki syndrome (KMT2D), distinct from later facial and spinal manifestations. 7. Familial Phenotyping: Examining relatives clarified inherited NF1 variants contributing to scoliosis. 8. Mosaic Findings: Conspicuous cutaneous features (e.g., multiple congenital melanocytic nevi) prompted somatic testing of NRAS. 9. Dynamic Phenotyping: Monitoring emerging features (e.g., kyphoscoliosis) confirmed SELENON-related congenital myopathy.

### Conclusion:

Our findings underscore that NGS alone, though powerful, often falls short without parallel deep phenotyping. Detailed clinical assessments—encompassing subtle, familial, prenatal, and evolving traits—significantly bolster diagnostic yield. This comprehensive approach not only guides molecular testing but also refines management strategies, ultimately improving patient outcomes in scoliosis and associated rare bone disorders.



A systematic framework.

## Paper #12. Neuromuscular Adaptations and Shared Neural Drive Imbalance in Adolescent Idiopathic Scoliosis during a Fatiguing Task †

Shao Chen, MD; Chen Liu, MD; Kai-qi Wang, MD; Xiaomin Chen, MD; Honggen Du, MD

### Hypothesis:

We hypothesize that during an isometric back extension fatiguing task, adolescents with idiopathic scoliosis (AIS) will exhibit distinct neuromuscular adaptations compared to healthy adolescent controls (HAC).

### Design:

This is cross-sectional study.

### Introduction:

Paraspinal muscle asymmetry is a key clinical feature of AIS: convex side shows increased activation in symmetric tasks, while dominant side has reduced activation in asymmetric tasks. However, existing findings focus on non-fatiguing tasks, with limited exploration of AIS bilateral paraspinal muscle adaptations to fatigue, lacking data on sEMG characteristics like MPF, %DET, FD, and intermuscular coherence. This study investigates these during an isometric back extension fatiguing task, comparing AIS with healthy controls to clarify neuromuscular mechanisms.

### Methods:

High-density sEMG signals were recorded from the bilateral paraspinal muscles (L1–L5 levels) in 18 patients with AIS and 18 HAC during an 80-s isometric back extension fatiguing task. Neuromuscular adaptations were assessed using sEMG parameters, including root mean square (RMS), mean power frequency (MPF), percentage of determinism (%DET), and fractal dimension (FD), to evaluate fatigue-related asymmetry. Share neural drive to force output was quantified through intermuscular coherence in the delta band.

### Results:

Patients with AIS exhibited significant neuromuscular asymmetry, characterized by greater fatigue-related changes on the convex side (higher RMS and %DET, lower MPF and FD) compared to the concave side. Both groups showed increased intermuscular coherence during the final 40 s contractions. However, AIS patients demonstrated significantly higher delta-band coherence than HAC, indicating a greater reliance on shared neural input to maintain force output.

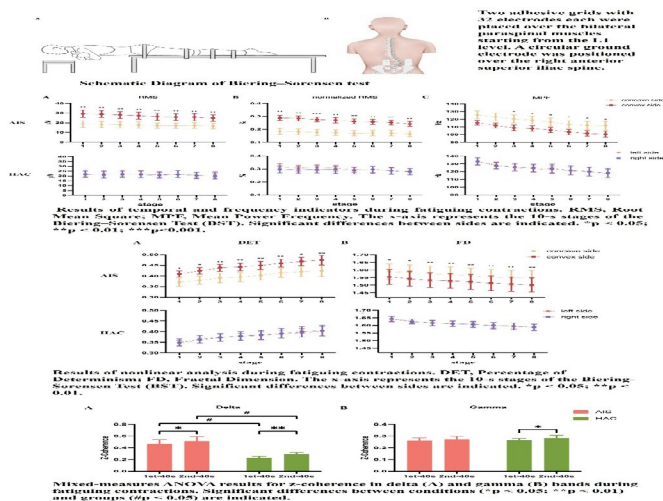
### Conclusion:

Our findings highlights AIS-specific neuromuscular adaptations, including fatigue-related asymmetry and increased dependence on shared neural input for force control. Rehabilitation strategies should

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focus on strengthening the neuromuscular control on the concave side and improving bilateral force coordination to reduce asymmetry and reliance on shared neural input.



Characteristics of bilateral paraspinal muscles activity during fatiguing contractions

## Paper #13. MRI Perfusion-Ventilation Imaging for Pulmonary Assessment in Scoliosis Patients: Validation Against CT Volumetry and Spirometry †

Junduo Zhao, MD; Jianxiang Shen, MD; Yizhen Huang, MD; Heng Sun, MD

### Hypothesis:

Non-contrast phase-resolved functional lung (PREFUL) MRI-derived perfusion-ventilation parameters correlate significantly with spirometry and CT volumetry in scoliosis patients, providing radiation-free lung function assessment.

### Design:

Prospective Study

### Introduction:

Pulmonary function impairment significantly impacts scoliosis patients, particularly those with severe deformities. Traditional pulmonary function tests include CT volumetry and spirometry. Non-contrast PREFUL MRI is a radiation-free, non-invasive strategy mapping lung function. This study aims at validating PREFUL MRI in assessment of pulmonary function in scoliosis patients against Spirometry and CT volumetry.

### Methods:

22 consecutive patients (mean age 13.1±5.6 yrs, mean Cobb angle 52±17°) including idiopathic scoliosis (n=12), congenital scoliosis (n=8), Neurofibromatosis-associated scoliosis (n=1), and Scheuermann kyphosis (n=1) were prospectively enrolled between

March 2024 and September 2025. All patients underwent: 1. Non-contrast PREFUL MRI during free breathing at 1.5T; 2. Volumetric chest CT end-inspiration; 3. Comprehensive spirometry including FEV1, FVC, and FEV1/FVC ratio. 4. MRI volumetry performed at end-inspiration and end-expiration. PREFUL MRI data were processed to generate quantitative perfusion defect percentage (QDP), ventilation defect percentage (VDP), and flow-volume-loop correlation coefficient (FVL). CT and MRI images were reconstructed for lung volumes.

### Results:

Mean VDP was 18.3±7.1%, QDP 20.1±7.4%. VDP demonstrated strong inverse correlation with FEV1% predicted (r=-0.68, p<0.05) and moderate correlation with FVC% predicted (r=-0.61, p<0.05). QDP correlated significantly with CT-based lung volume asymmetry ratio (r=0.64, p<0.05). MRI inspiratory volumes showed agreement with CT measurements (r=0.82, p<0.05).

### Conclusion:

PREFUL MRI accurately assesses lung function in scoliosis patients, correlating strongly with spirometry and CT. This radiation-free technique is ideal for scoliosis longitudinal monitoring and preoperative evaluation.

### Non-Contrast PREFUL MRI Analysis 12-year-old Female, Idiopathic Scoliosis, Cobb 48°



Representative 12-year-old patient with idiopathic scoliosis imaged with non-contrast PREFUL MRI during free breathing. Multi-parametric maps show morphology, perfusion, ventilation, FVL correlation, and V/Q defects. Quantitative metrics: VDP 19.5%, QDP 21.6%, FVL 0.89; spirometry: FEV1 82.1%, FVC 70.9% predicted.

† = Whitecloud Award Nominee – Best Basic Science/Translational Paper

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### Paper #14. Utility of Limited Sequence “FAST spine MRI” Scans as a Screening Tool in Patients with Idiopathic Scoliosis †

*Anna J. Rambo, MD; Aryan Shah; Shah Chetan, MD; John Lovejoy, MD; Vinay Kandula, MD; Brett Shannon, MD; Mona Matthew, PhD; Suken A. Shah, MD; Kevin M. Neal, MD*

#### Hypothesis:

Limited spine MRI will detect neural axis abnormalities at the same rate as full sequence spine MRIs.

#### Design:

Retrospective with control group.

#### Introduction:

Full sequence cervical, thoracic, and lumbar magnetic resonance imaging (MRI) is often performed as a routine screening study in patients with idiopathic scoliosis (IS). Full sequence MRIs may take up to 60 minutes, and pediatric patients often require sedation or anesthesia. Limited sequence MRI (IsMRI) scans require less time and need for sedation than full sequence MRIs but may decrease diagnostic accuracy. The purpose of this study is to investigate the feasibility and safety of IsMRI scans as an effective screening tool in patients with IS.

#### Methods:

A single institutional multisite cohort of patients with IS that had IsMRI or full MRI ordered from 2023-2025 was retrospectively reviewed. Full sequence MRIs from institutional AIS surgical database were used as a control group. Data collection included the MRI sequence type, need for sedation, scan time, neural axis abnormalities (NAA) detected, neurosurgery (NSGY) consult or intervention, need for repeat full sequence MRI, major Cobb angle. Intraoperative neuromonitoring (IONM) events and new neurological deficits were assessed for IS patients that underwent posterior spinal fusion (PSF). Mann-Whitney U and Fisher exact tests were used for statistical analysis.

#### Results:

389 patients met inclusion criteria: 218 IsMRI and 171 full MRI. IsMRI had a lower average scan time [23.9 min(8-89, SD 10.8)] than full MRI [45.3 min (20-151, SD 20.3),  $P < 0.0001$ ](Table 1). IsMRI and full MRI detected NAA at similar rates, 5.96% and 5.26% respectively. There were no differences in NSGY consult, need for repeat full MRI, NSGY intervention, or IONM between the two groups. Need for sedation was similar between the two groups. In a subgroup analysis in patients  $< 10$  years, full MRI was more likely to require sedation [ $F < 0.0001$ ,  $p < 0.05$ ]. 2 IONM events occurred in each group: IsMRI (1.98%), full MRI (1.43%).

#### Conclusion:

IsMRI significantly decreased scan time and detected NAA at the same rate as full sequence MRI, without increasing the need for repeat scanning. IsMRI decreased need for sedation in patients  $< 10$  years. Limited sequence MRI is a reliable, safe screening tool for the detection of neural axis abnormalities in idiopathic scoliosis patients.

### Paper #15. Development of a Radiation-Free Ultrasound Method for Skeletal Maturity Assessment in AIS: A Pilot Study †

*Edmond H. Lou, PhD; Tu Pham, PhD; Carlin Canlas; Kathleen Shearer, MN; Eric C. Parent, PhD; Sarah Southon Hryniuk, MN; Kyle Stampe, MD*

#### Hypothesis:

An ultrasound-derived Ossification Ratio Index (ORI) from finger joints can accurately estimate skeletal maturity in children with AIS.

#### Design:

Prospective pilot study

#### Introduction:

Skeletal maturity is a critical prognostic factor for curve progression in AIS, guiding decisions on observation, bracing, and surgery. Hand-wrist radiography is more reliable than the iliac crest-based Risser sign, yet many centers avoid its use to reduce cumulative radiation exposure in children who already undergo frequent spinal radiographs. This trade-off between accuracy and safety highlights the need for non-ionizing alternatives. We developed a portable ultrasound-based method for hand imaging and assessment of skeletal maturity and evaluated its feasibility and accuracy in a pilot study.

#### Methods:

Ethical approval (Pro00154110) was obtained. Hand ultrasound was standardized using a custom 3D-printed fixture with finger partitions and a glider holder to ensure reproducible probe motion. Water was used as the coupling medium. Because the probe's scanning window was limited to 5 cm, three sweeps were performed across the hand, capturing 13 joints and 17 bones. The ORI was defined as the proportion of ossified bone relative to the joint region. Twenty-seven children (15 F, 12 M; ages 7–16 years) were recruited. Multiple linear regression models were developed using the 13 ORI values, with 5-fold cross-validation for optimization.

#### Results:

The best model showed strong agreement between actual and ultrasound-estimated chronological age ( $r^2 = 0.993$ ). The mean chronological age was  $11.0 \pm 2.7$  years, compared with an estimated  $11.9 \pm 3.1$

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years by ORI. In most cases, ultrasound estimates were within one year of chronological age. The scanning plus the reporting procedures required less than one minute.

### Conclusion:

This pilot study establishes proof of concept for a novel ultrasound-based method to estimate skeletal maturity in AIS. Although limited by a small sample size, these findings support further validation on a larger scale and comparison with established skeletal maturity systems, such as Sanders' stages. The next step will be to train predictive models to directly correlate ORI values with skeletal maturity staging, enabling ultrasound to serve as a true radiation-free alternative to radiography in routine scoliosis care.

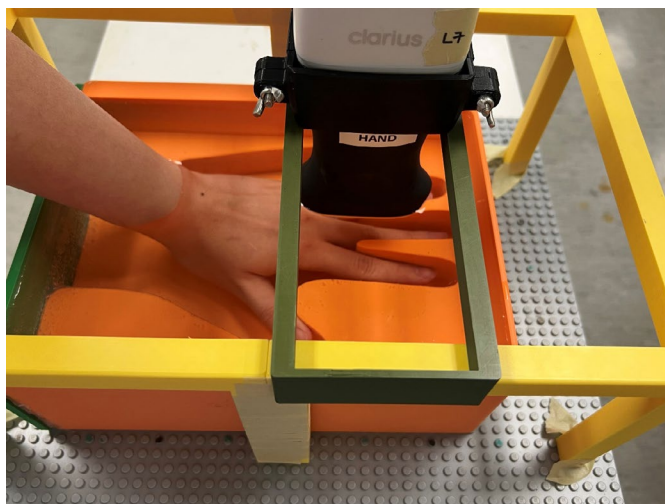


Figure 1. Standardized hand ultrasound setup with 3D-printed fixture and probe guide.

### Paper #16. Pseudoarthrosis and Rod Breakage in Adult Spinal Deformity Surgery with Minimum 5-Year Follow-Up: Patterns, Predictors, and Machine Learning-Based Risk Analysis

Sleiman Haddad, MD, PhD, FRCS; Lluís Vila Castillo, MD; Leo Mok, MSc; Chuck H. Lam, BSc; Morgan Jones, FRCS, MBChB; Susana Nunez Pereira, MD, PhD; Anika Pupak, PhD, BS; Riccardo Raganato, MD; Javier Pizones, MD, PhD; Yann Phillippe Charles, MD, PhD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Frank S. Kleinstueck, MD; Francisco Javier S. Perez-Grueso, MD; Ferran Pellise, MD, PhD; European Spine Study Group ESSG

### Hypothesis:

When alignment is controlled and follow-up time increases, the prevalence of rod fracture rises. Factors other than alignment play an important role in the development of pseudoarthrosis, especially mechanical and surgical factors, as well as patient-specific characteristics.

### Design:

Retrospective analysis of a prospective multi-centre ASD registry.

### Introduction:

Pseudoarthrosis and rod breakage are prevalent complications in adult spinal deformity (ASD) surgery, even in well-aligned patients. As surgical techniques evolve to reduce junctional failures, mechanical issues have gained attention. This study evaluates the incidence of pseudoarthrosis, identifies associated risk factors, and compares predictive models using traditional statistics and machine learning models (MLMs).

### Methods:

A retrospective analysis of 1965 ASD patients from a multicenter registry was conducted, with Kaplan-Meier curves used to estimate pseudoarthrosis incidence including patients who developed pseudoarthrosis within 5 years of follow-up. Predictive modeling included logistic regression and random forest analysis in a subset of 651 patients with  $\geq 5$  years of follow-up. Preprocessing addressed missing data and excluded highly correlated variables ( $r > 0.9$ ).

### Results:

Pseudoarthrosis incidence was 25% by 10 years, increasing by 4.5% annually until the fourth year and 1.2% thereafter (mean time to pseudoarthrosis: 4.8 years). Pelvic fixation was a key risk factor, mitigated using interbody cages, multiple rods, and BMP. The random forest model (F1: 0.89; Accuracy: 0.94) outperformed logistic regression (F1: 0.62; Accuracy: 0.78). Key predictors included pelvic fixation (9.5%), sagittal balance, blood loss, age, and the Charlson Comorbidity Index. Radiological parameters contributed 50.2% of the predictive weight of the MLM.

### Conclusion:

Mechanical factors such as alignment and construct design are primary predictors of pseudoarthrosis. Protective strategies, including optimized fixation techniques and BMP use, reduce pseudoarthrosis. Future research should refine predictive models and explore less-studied biological factors.

### Paper #17. Durability of Adult Spinal Deformity Correction Based on Upper Instrumented Level and Baseline Deformity Severity: A Survival Analysis of a Prospective, 18-Center Study

Peter G. Passias, MD; Francesca Totis, MD; Kyriakos Chatzis, BS; Oluwatobi Onafowokan, MBBS, MS; Max Fisher; Peter Tretiakov, BS; Christopher I. Shaffrey, MD; Virginie Lafage, PhD

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## Hypothesis:

Time to revision will vary based on UIV and severity of BL deformity

## Design:

Retrospective analysis of a prospectively enrolled clinical trial

## Introduction:

The need for revision surgery and extension of fusion constructs remains a lingering burden in adult spinal deformity (ASD) surgery for patients and surgeons

## Methods:

Operative ASD patients  $\geq 18Y$  with a LIV of  $S1 \geq S1$ , complete BL, and 2Y data included. Revision w/in 90D of index procedure or revisions for wound/infectious/neurological complications excluded. C2PA stratified to assess BL deformity severity: Severe=top quartile; moderate=2nd/3rd quartiles. Kaplan-Meier curves plotted survival time to first revision surgery. Cox Proportional Hazard models and multivariate logistic regression analysis assessed revision risk associated with the following groups: G1:L3-Pelvis, G2:L1/2-Pelvis, G3:T8/12-Pelvis, G4:T1/8-Pelvis, G5:-Cervical-Pelvis. Each group assessed based on similar deformity. Subanalyses assessed survival time based on deformity severity

## Results:

1008 patients were included (mean age 64.1, BMI 28.4, CCI 1.9). On Cox analysis, severe C2PA increased revision risk 3.4-fold (HR 3.43,  $p=.017$ ), but extending the UIV above the lumbar region reduced this risk threefold (HR 0.33,  $p=.042$ ). Severe TK or C2PA with lumbar UIVs shortened survival times (1.55 vs 2.34y; 1.04 vs 2.30y, both  $p<.05$ ). ROC analysis identified a C2PA threshold of  $31.5^\circ$  for lumbar UIVs, above which revisions were more common (62.5% vs 36.6%,  $p=.003$ ). In frail/osteoporotic patients, UIVs at T3 or proximal prolonged revision-free survival by  $\sim 12$  months (29.5 vs 17.9m,  $p=.041$ ). Fusion length ( $\leq 7$  vs  $>7$  levels) was not associated with survival time ( $p=.723$ )

## Conclusion:

Survival time to reoperation in ASD surgeries varies based on UIV and BL deformity. Caution is warranted when selecting UIVs in the upper lumbar region in the setting of severely elevated TK, global malalignment, or significant frailty

| Groups | Moderate Deformity (C2PA) |                         |                          | Severe Deformity (C2PA) |                         |                                 |
|--------|---------------------------|-------------------------|--------------------------|-------------------------|-------------------------|---------------------------------|
|        | n                         | Number of Revisions (%) | Survival (Mean $\pm$ SE) | n                       | Number of Revisions (%) | Survival months (mean $\pm$ SE) |
| G1     | 12                        | 1 (8.3%)                | 39.0 $\pm$ 0.0           | 6                       | 4 (66.7%)               | 12.8 $\pm$ 3.9                  |
| G2     | 54                        | 10 (18.5%)              | 27.1 $\pm$ 4.5           | 9                       | 0 (0%)                  | -                               |
| G3     | 253                       | 37 (14.6%)              | 25.2 $\pm$ 2.7           | 121                     | 21 (17.4%)              | 22.1 $\pm$ 3.8                  |
| G4     | 105                       | 24 (22.9%)              | 21.1 $\pm$ 2.9           | 71                      | 14 (19.7%)              | 17.8 $\pm$ 2.2                  |
| G5     | 2                         | 0 (0%)                  | -                        | 1                       | 0 (0%)                  | -                               |
| Total  | 426                       | 72 (16.9%)              | 24.3 $\pm$ 1.8           | 208                     | 39 (18.8%)              | 19.6 $\pm$ 2.2                  |

## Paper #18. Seven Years of Safer Surgery: Declining Medical Complications After Adult Spinal Deformity Reconstruction

Atahan Durbas, MD; Han Jo Kim, MD; Andrea Pezzi, MD; Robert N. Uzzo, MBA; Gabrielle Dykhouse, BS; Tejas Subramanian, MD; Stephane OwusuSarpong, MD; Mihir Dekhne, MD; Kasra Araghi, BS; Matthew E. Cunningham, MD, PhD; Francis Lovecchio, MD

## Hypothesis:

Continual advances in perioperative management have reduced the risk of post-op medical complications in adult spinal deformity (ASD) surgery across all levels of surgical invasiveness.

## Design:

Retrospective cohort study.

## Introduction:

Over the last decade, institutions have prioritized pre-op optimization and multidisciplinary perioperative protocols to decrease morbidity after ASD reconstruction. Our purpose was to evaluate trends in medical complications after ASD surgery at a tertiary referral center.

## Methods:

Adults (aged  $\geq 18$ ) undergoing  $\geq 5$  levels of fusion to pelvis for spinal deformity between 2017-2023 were retrospectively reviewed, excluding those with trauma, tumor, or infection. Primary outcome was post-op medical complications, classified by ISSG-AO. Surgical invasiveness was measured using the ASD-Surgical and Radiographical (ASD-SR) score, stratified into low/high groups by median. We analyzed annual complication rates with linear regression and Cochran-Armitage test. Multivariable logistic regression was used to identify factors associated with medical complications.

## Results:

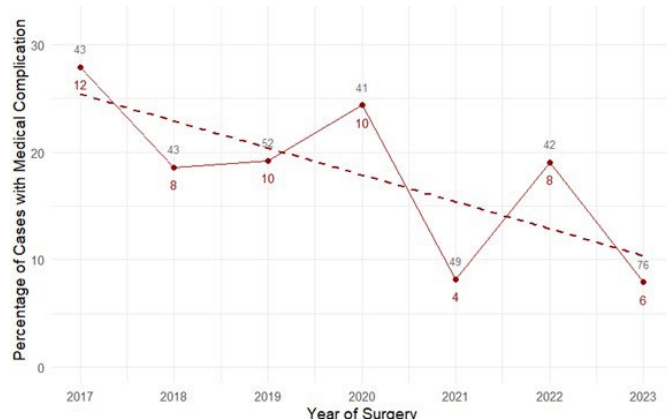
311 patients were analyzed (median: 68; Low ASD-SR:  $n=157$ , High ASD-SR:  $n=154$ ). Demographics, BMI, and CCI were similar, though patients in the high ASD-SR group had more fusion levels (10.8 vs 8.1), more osteotomies (92.7% vs 48.3%), and higher blood loss (1302.2 vs 937.4 mL) (all  $p<0.001$ ). Primary surgery rates were similar (46.8% vs 49%,  $p=0.8$ ). Medical complication rates didn't differ (16.2% vs 18.5%,  $p=0.7$ ), regardless of type or timing. Mean annual medical complication rate was 16.7%, with GI events being the most common subtype (43%), followed by cardiopulmonary (34%), and renal (6%). The overall medical complication rate decreased by 2.5% annually ( $p=0.01$ ), mainly driven by reductions in cardiopulmonary events ( $-1.3\%$ ,  $p=0.01$ ), while GI and renal remained stable ( $p>0.05$ ). CNS, infectious, and MSK complications were rare. After adjusting for

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ASD-SR score, demographics, and surgical factors, only the year of surgery (OR=0.8, p=0.005) and age (OR=0.97 per year, p=0.03) remained significant.

## Conclusion:

Medical complication rates after ASD surgery have decreased over the past 7 years, regardless of invasiveness level. This shows ongoing improvements in perioperative care and mitigation strategies have effectively lowered medical complications.



Trend of medical complication rates: total cases above, complications below.

## Paper #19. Upper Thoracic Spine Alignment: The Missing Piece of the Alignment Puzzle to Improve GAP and T4L1PA Targets

Nuri Demirci, MD; Yasemin Yavuz, PhD; Munish C. Gupta, MD, MBA

### Hypothesis:

We hypothesized that upper thoracic alignment, measured by T1-T9 pelvic angle mismatch (T1T9PA), provides added predictive value for proximal junctional kyphosis (PJK) beyond Global Alignment and Proportion (GAP) score and T4-L1 pelvic angle mismatch (T4L1PA).

### Design:

Prospective cohort of 207 adult spinal deformity patients undergoing thoracic-to-pelvis fusion with ≥7 levels and pelvic fixation, ≥2-year follow-up.

### Introduction:

PJK remains a common complication after adult spinal deformity (ASD) surgery. Despite advances, maintaining alignment is difficult. GAP score and T4L1PA have been proposed to reduce risk, but their predictive ability is limited, likely from underassessment of upper thoracic alignment. We evaluated T1T9PA, hypothesizing it improves PJK prediction.

### Methods:

PJK was defined as ≥20° increase in proximal junctional angle or revision for PJK. Six-week postoper-

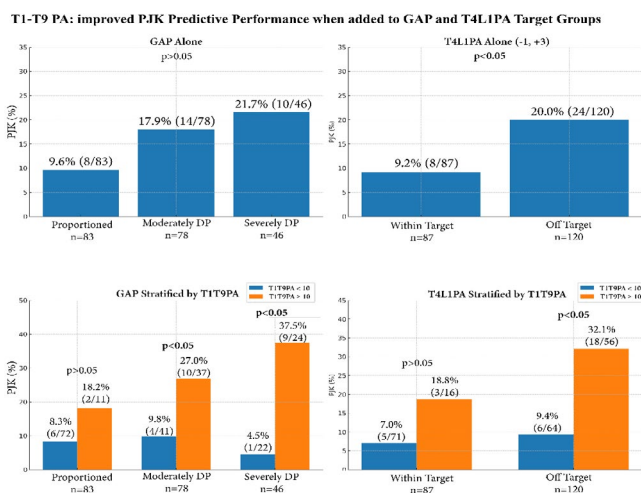
ative radiographs were assessed for GAP, T4L1PA, and T1T9PA. GAP was classified as proportioned (≤2), moderately disproportionate (3–6), or severely disproportionate (≥7). T4L1PA was within (−1° to +3°) or off target. ROC analysis defined the optimal T1T9PA cutoff. Associations with PJK were tested with chi-square and logistic regression.

### Results:

Mean age 62.1±11.1 years, BMI 29.7±5.7, 78% female. UIVs ≤T6 in 72.9%, PSO 20.8%, VCR 6.3%. Over 46 months mean follow-up, 32 patients (15.5%) developed PJK. PJK incidence rose with GAP: 9.6% (proportioned), 17.9% (moderate), 21.7% (severe), though not significant. ROC identified T1T9PA <10° as optimal. Mismatch ≥10° was linked to higher PJK in moderate (27.0% vs. 9.8%, p<0.05) and severe groups (37.5% vs. 4.5%, p<0.05), was not in proportioned patients (18.2% vs. 8.3%, p>0.05). T4L1PA within target was associated with lower PJK (9.2%) than off-target (20%). Among off-target patients, PJK risk increased from 9.4% with mismatch <10° to 32.1% with mismatch ≥10° (p<0.05). Among those within target T4L1PA, the difference between mismatch <10° (7%) and ≥10° (18.8%) did not reach statistical significance.

### Conclusion:

In long fusion ASD, PJK occurred in 15.5%. GAP and T4L1PA showed limited predictive ability, whereas T1T9PA ≥10° independently predicted risk, especially with disproportionate GAP and off-target T4L1PA. Upper thoracic alignment is critical for sagittal balance, and T1T9PA may serve as a target to reduce PJK complication.



T1T9PA: Enhancing PJK Prediction Beyond GAP and T4L1PA

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### Paper #20. Transition Rods with or Without Junctional Tethering in the Prevention of Proximal Junctional Kyphosis in Adult Spinal Deformities Surgery

Francesco Lolli, MD; Carmela Altruda, MD; Andrea Baioni, MD; Ilaria Barni, MD; Marco Cancedda, MD; Riccardo Draghi, MD; Andrea Messina, MD; Nicolò Regge Gianas, MD; Roberto Ricca, MD; Ignazio Borghesi, MD

#### Hypothesis:

To evaluate the effectiveness of transition rods with or without junctional tethering in the prevention of proximal junctional kyphosis

#### Design:

Retrospective

#### Introduction:

Proximal junctional kyphosis (PJK) is one of the most problematic complications in the field of spinal deformities surgery. Aim of the study is to evaluate the effectiveness of transition rods with or without junctional tethering to prevent this complication in adult patients

#### Methods:

97 consecutive patients were included in the study. All patients had been treated by "long" posterior instrumented fusion (screws only construct, with or without anterior lumbar support), extended from the proximal thoracic segment (T1-T5) to the pelvis, for an adult spinal deformity in the coronal or sagittal plane. Exclusion criteria were: oncological or infective spinal diseases, neurologic diseases (like Parkinson). Patients were divided in 3 groups. In 38 cases (R Group) regular 5.5 mm rods were used in the upper part of the instrumentation. In 32 cases (TR Group) transition rods (3.5 mm, titanium or cobalt chrome) were used in the proximal thoracic segments (1 or 2 levels), in 27 cases (TRJ) transition rods were associated with junctional tethering (UIV + 2). The 3 groups were comparable in terms of age (69.8 vs 67.2 vs 68.5 years), prevalence of female sex (81.5 vs 84.3 vs 77.8%), underlying pathology (adult idiopathic scoliosis 24 vs 15 vs 12 cases, failed back surgery 11 vs 12 vs 11 cases, degenerative malalignment 3 vs 5 vs 4 cases)

#### Results:

At a mean follow up of 31 months (range 24 to 40), PJK occurred in 18 cases in R Group (47.4%), in 3 cases in TR group (9.4%), in 2 cases in TRJ group (7.4%). In R Group, PJK always occurred in first 3 months after surgery; in TR/TRJ Groups PJK occurred in 3 cases in first 3 months, in 2 cases later. Neurological impairment was present in 3 cases in R Group, in no case in TR/TRJ Groups. Revision surgery was performed in 11 cases in R Group, in 1 case in TR Group.

Clinical results, evaluated with VAS and Oswestry questionnaires, were similar in TR and TRJ groups, statistically worst in R Group ( $p < 0.05$ )

#### Conclusion:

The use of transition rods has been shown to be effective in adult spinal deformities surgery, with a statistically significant reduction of PJK if compared to 5.5 mm rods. The association with junctional tethering has not shown significant advantages in PJK prevention

### Paper #21. The Impact of Preoperative Cervical Degeneration on Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery with an Upper Thoracic Upper Instrumented Vertebra

Josephine R. Coury, MD; Fthimnir Hassan, MPH; Justin L. Reyes, MS; Erik Lewerenz, BS; Joseph M. Lombardi, MD; Zeeshan M. Sardar, MD; Ronald Lehman Jr, MD; Lawrence G. Lenke, MD

#### Hypothesis:

Adult Spinal Deformity patients with preoperative MRI-detected severe cervical degeneration are at increased risk of proximal junctional kyphosis following thoracolumbar deformity correction.

#### Design:

Retrospective Cohort

#### Introduction:

PJK is a common complication after thoracolumbar (TL) correction. Prior work links cervical sagittal vertical axis (SVA) and proximal junctional angle (PJA) to PJK risk, but the impact of cervical degeneration is unclear. We evaluated whether MRI-defined cervical degeneration predicts PJK.

#### Methods:

Retrospective review of ASD patients with preoperative cervical MRI who underwent TL correction and fusion from an upper thoracic upper instrumented vertebra (UIV C7-T4) to a lumbosacral lower instrumented vertebra (L1-S1/Ilum). One hundred eighty-one patients had  $\geq 2$ -year follow-up. Degeneration was graded per Wang et al.; grades 4-5 were "severe" (collapsed disc height, hypointense nucleus, loss of annulus-nucleus distinction). PJK was defined as PJA (UIV to UIV+2)  $\geq 10^\circ$  and  $\geq 10^\circ$  greater than preoperative.

#### Results:

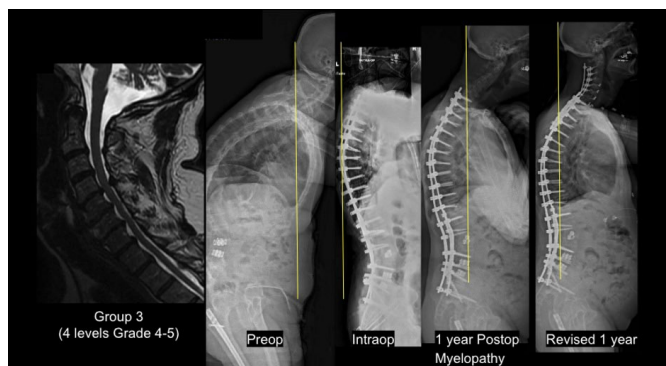
Patients without severe cervical degeneration showed no significant PJA change at 2 years. With 1-2 grade  $\geq 4$  discs, mean PJA increased  $3.3^\circ$  ( $p = 0.008$ ); with  $\geq 3$  severely degenerated discs,  $4.0^\circ$  ( $p = 0.04$ ). None of 105 patients with minimal degeneration developed radiographic PJK. Among those with 1-2 degenerated levels ( $n = 44$ ), 4 (9.1%) developed PJK

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( $p < 0.0001$ ). Among those with  $\geq 3$  levels ( $n=32$ ), 13 (40.6%) developed PJK; 10 were symptomatic and 4 had acute cervical myelopathy ( $p < 0.0001$ ). On multi-variable analysis adjusting for age, baseline cervical alignment, T1 slope, postoperative TL alignment, and postoperative T4–L1 pelvic angle, severe cervical degeneration remained the strongest independent predictor of PJK: OR 2.99 ( $p=0.0001$ ) in stepwise and OR 4.42 ( $p=0.0022$ ) in standard models (AUC 0.95–0.97;  $p < 0.0001$ ).

### Conclusion:

Severe cervical degeneration on preoperative MRI markedly increases PJK risk—nearly 200%—after TL correction with an upper thoracic UIV. Preoperative cervical MRI should be strongly considered in ASD surgical planning; when multiple severely degenerated discs are present, risk counseling and potential staged or concomitant cervical treatment may be warranted.



62M with 4 levels of severe cervical degeneration, his postop course was complicated by PJK and new cervical myelopathy at 1 year.

### Paper #22. Marijuana Use and Patient-Reported Outcomes in Spinal Deformity Surgery: Preoperative and Postoperative VAS and ODI Analysis

*Srujan Kopparapu, MD; Cesar M. Carballo Cuello, MD; Jay I. Kumar, MD; Puya Alikhani, MD; Sadeh Bagherzadeh, MD; Diego Soto Rubio, MD; Dana Saleh, MD; Mohsen Rostami, MD*

### Hypothesis:

We hypothesized that marijuana users would demonstrate less favorable postoperative improvements in VAS and ODI scores compared with non-users.

### Design:

This was a retrospective cohort study comparing postoperative outcomes between marijuana users and non-users undergoing spinal deformity fusion surgery.

### Introduction:

Marijuana use is becoming increasingly prevalent and may influence pain perception, functional recovery, and patient-reported outcomes following spinal surgery. With growing interest in the role of cannabis in perioperative care, this study evaluates the impact of marijuana use on Visual Analog Scale (VAS) pain scores and Oswestry Disability Index (ODI) scores in patients undergoing spinal deformity correction.

### Methods:

We reviewed 159 patients with spinal deformity who underwent fusion procedures. Patients were grouped as marijuana users ( $n=34$ ) and non-users ( $n=125$ ). Variables analyzed included demographics (age, gender), pre- and postoperative VAS pain scores, pre- and postoperative ODI scores, and magnitude of ODI change. Statistical comparisons were performed using t-tests for continuous variables, with significance set at  $p < 0.05$ .

### Results:

Groups were comparable in age (62.0 vs. 65.4 years,  $p=0.999$ ) and gender distribution (21 vs. 75 males). Marijuana users had significantly lower preoperative VAS scores (12.4 vs. 14.4,  $p=0.006$ ) and baseline ODI scores (52.9 vs. 56.9,  $p=0.045$ ). However, they reported significantly worse postoperative outcomes, with higher VAS (3.2 vs. 2.5,  $p=0.005$ ), higher ODI (16.2 vs. 12.4,  $p=0.005$ ), and less ODI improvement ( $-37.1$  vs.  $-43.7$ ,  $p=0.003$ ).

### Conclusion:

Marijuana use is associated with worse postoperative pain and functional outcomes in spinal deformity surgery, despite comparable demographics and lower baseline disability. These findings underscore the importance of preoperative screening for marijuana use and support counseling, optimizing perioperative pain management, and considering cannabis cessation strategies to improve recovery outcomes.

### Paper #23. Four Milligrams Per Level: Defining the BMP Threshold to Prevent Rod Fracture and Proximal Junctional Kyphosis in Adult Spinal Deformity Surgery

*Nuri Demirci, MD; Yasemin Yavuz, PhD; Munish C. Gupta, MD, MBA*

### Hypothesis:

A per-level bone morphogenetic protein (BMP) dose  $\geq 4$  mg reduces rod fracture (RF) and proximal junctional kyphosis (PJK) and improves complication-free survival in adult spinal deformity (ASD) surgery.

### Design:

Prospective cohort analysis

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### Introduction:

BMP is widely used to enhance fusion in ASD surgery, but optimal dosing remains unclear. Establishing a threshold dose per level may guide strategies to reduce mechanical complications.

### Methods:

We analyzed 207 ASD patients undergoing thoracic-to-pelvis fusion with  $\geq 7$  levels and  $\geq 2$  years follow-up. BMP dose per level was categorized as  $< 3$ ,  $3-3.99$ , and  $\geq 4$  mg. Outcomes were RF and PJK, assessed by Kaplan–Meier analysis and multivariable Cox regression stratified by osteoporosis. Propensity-weighted adjustment balanced age, sex, BMI, bone health, fused levels, osteotomy use, rod characteristics, and approach.

### Results:

Mean age was  $62.1 \pm 11.1$  years, BMI  $29.7 \pm 5.7$ , and 77.8% were female; 20.8% underwent PSO and 6.3% VCR. Over a mean 46-month follow-up, 20 patients (9.7%) developed RF and 32 (15.5%) developed PJK. The mean BMP dose per fused level was  $3.2 \pm 1.0$  mg, with a median of 3.0 (IQR 2.7–3.6, range 0.8–6.0). For RF, crude event rates declined stepwise with higher BMP dose per level: 15.6% with  $< 3$  mg/level, 8.1% with  $3-3.99$  mg/level, and 3.1% with  $\geq 4$  mg/level. For PJK, corresponding crude rates were 25.0%, 10.8%, and 12.5%. Kaplan–Meier estimates showed 36-month RF risks of 13.4%, 6.0%, and 0.0% across these dose groups. After IPTW adjustment, 36-month PJK risk decreased from 13.8% with  $< 4$  mg/level to 2.5% with  $\geq 4$  mg/level (HR 0.29, 95% CI 0.07–1.14,  $p=0.076$ ). In Cox regression, higher BMP dose per level was significantly associated with a lower hazard of PJK (HR 0.39 per mg/level, 95% CI 0.23–0.66,  $p<0.001$ ) and showed a nonsignificant protective trend for RF (HR 0.75, 95% CI 0.40–1.43,  $p=0.15$ ).

### Conclusion:

At 36 months, rod fracture risk decreased from 13.8% with  $< 3$  mg/level to 0% with  $\geq 4$  mg/level, while proximal junctional kyphosis risk decreased from ~14% with  $< 4$  mg/level to ~2–3% with  $\geq 4$  mg/level. These findings suggest that the ideal BMP dose should be at least 4 mg per level fused meaningfully improves construct durability and lowers late mechanical complications.

### Paper #24. Dynamic Adaptations of the Thoracolumbar Spine: A Cross-Sectional Analysis of Vertebral Pelvic Angle Changes from Standing to Sitting

Atahan Durbas, MD; Han Jo Kim, MD; Robert N. Uzzo, MBA; Gabrielle Dykhouse, BS; Tejas Subramanian, MD; Andrea Pezzi, MD; Michael P. Kelly, MD; Francis Lovecchio, MD

### Hypothesis:

Vertebropelvic angles (VPA) significantly vary with sitting position and are strongly affected by patient-specific factors, including pelvic incidence (PI), age, BMI, and gender.

### Design:

Retrospective cross-sectional imaging study.

### Introduction:

Spinal alignment changes significantly when moving from standing to sitting. VPAs are increasingly used to describe sagittal alignment, yet their sitting-related changes and the effects of patient-specific modifiers on this positional change have not been fully examined.

### Methods:

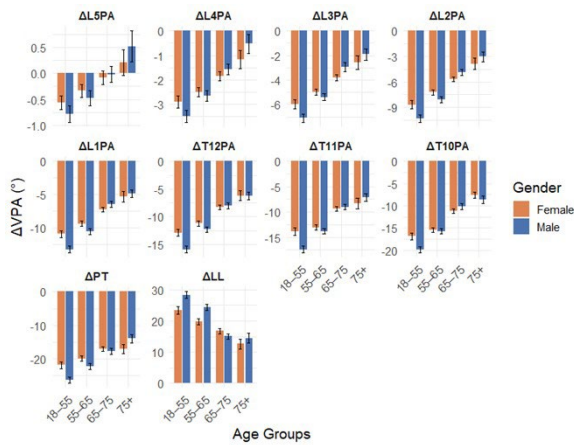
Adults ( $\geq 18$  years) being evaluated for hip replacement surgery were included. Exclusions: prior spinal surgery, spondylolisthesis, coronal Cobb angle  $> 20^\circ$ , or severe hip osteoarthritis (OA; Tönnis Grade 3). Standing and sitting radiographs through T10 were measured.  $\Delta$ VPAs (standing–sitting; more negative ~ higher increase) were calculated. Analyses included group comparisons across age quartiles (Q1–Q4) and gender, with multivariable regression assessing associations of  $\Delta$ VPAs with PI, age, BMI, and gender.

### Results:

A total of 1,197 patients (632 F [52.8%]; mean age  $62.2 \pm 11.1$  years; BMI  $28.8 \pm 5.6$  kg/m<sup>2</sup>; PI  $52.5^\circ \pm 11.8$ ) were included. All VPAs differed significantly between positions ( $p<0.001$ ). Greater changes occurred in the thoracic spine than the lumbar:  $\Delta$ L5PA ( $-0.2^\circ$ ) to  $\Delta$ T10PA ( $-13.7^\circ$ ). Patients with mild HOA had smaller  $\Delta$ Pt and  $\Delta$ VPA magnitudes than those without ( $p<0.001$ ). All  $\Delta$ VPAs varied across age quartiles ( $p<0.001$ ), decreasing progressively from Q1 to Q4 at all thoracolumbar levels (Figure).  $\Delta$ Pt wasn't correlated with PI ( $r=-0.05$ ,  $p=0.1$ ) but decreased from Q1 to Q4 ( $p<0.001$ ). Regression models showed that higher PI correlated with a smaller magnitude of  $\Delta$ VPAs at L4 and L5 (both  $p<0.001$ ). Older age was associated with smaller  $\Delta$ Pt and  $\Delta$ VPAs at all levels (all  $p<0.001$ ). BMI was positively associated with  $\Delta$ Pt ( $p=0.01$ ), but negatively with  $\Delta$ VPAs at T11 ( $p=0.05$ ), T12 ( $p=0.001$ ), and L1–L4 (all  $p<0.001$ ). Males were associated with greater  $\Delta$ Pt,  $\Delta$ T12PA, and  $\Delta$ L1PA ( $p=0.03$ , 0.01, 0.03).

### Conclusion:

Spinal posture changes markedly with sitting, most prominently near the thoracolumbar junction. Pelvic adaptation was independent of PI. Reduced flexibility with aging and higher BMI affected both magnitude and regional distribution of  $\Delta$ VPAs, reflecting differences in compensatory strategies across patient groups.



$\Delta VPA$ ,  $\Delta PT$ , and  $\Delta LL$  by Age Group and Gender Groups.

**Paper #25. Posterior Lumbosacral Tether: A Novel Surgical Approach Preserves Motion at The Lumbosacral Junction in Adult Spinal Deformity Surgery; Early experience**

Ahmed Sulieman, MD; Ahmad Alnasser, BS; Brian Tableman, MS; Andrew H. Kim, MD; Goutham Yalla, MD; Yesha Parekh, MD; Tej Azad, MD; Khaled M. Kebaish, MD

**Hypothesis:**

In select patients with adult spinal deformities (ASD), lumbosacral (LS) fusion can be avoided by temporarily extending the instrumentation to the Ilium

**Design:**

Prospective Case Series

**Introduction:**

Fusion to the pelvis is usually required in most patients with ASD given the unique biomechanical forces. Ending the fusion proximal to the sacrum often leads to inadequate correction and high risk of failure and revision. Loss of motion at the LS junction has been shown to negatively affect functional outcomes in younger adults

**Methods:**

Prospective case series of ASD patients who underwent long posterior thoracolumbar fusion at a single institution, while preserving one or more motion segment(s) at the LS junction. This was achieved by extending the instrumentation to the Ilium on the correction side. Then removing that portion of instrumentation at 3-4 months. Patients' demographics, HRQOLs, radiographic data, surgical data and complications were recorded

**Results:**

11 patients with a mean follow-up of 26.1 months (range: 10.1–41.6) were included. Mean time to PLT removal was 4.5 months (range: 2.8–6.5). Preoperatively, mean major Cobb angle was 40.6° (range:

4.6–78.4), T4–T12 kyphosis was 44.8° (range: 13.8–95.0), SVA was 28.1 mm (range: –20.9–104.0), CVA was 23.3 mm (range: 4.3–43.5), and PI–LL mismatch was 11.1° (range: 0.33–30.2). At 2-year follow-up, the major Cobb angle was 16.2° (range: 2.9–42.0), T4–T12 kyphosis was 36.3° (range: 10.7–51.8), SVA 3.3 mm (range: –35.6–45.6), CVA 14.6 mm (range: 4.3–24.0), and PI–LL mismatch 8.4° (range: 0.73–16.85). Patients demonstrated significant improvement in PROMIS Pain (50.4 vs. 61.0,  $p < 0.01$ ), PROMIS Physical Function (46.4 vs. 40.5,  $p = 0.02$ ), ODI (12.5 vs. 33.3,  $p < 0.01$ ), SRS Pain (4.0 vs. 2.7,  $p < 0.01$ ), and SRS Function (4.0 vs. 3.3,  $p < 0.01$ ) scores 2 years postoperatively. Complications included S2AI screw fracture in two patients (1 requiring revision for distal rod dislodgement) and adjacent segment degeneration distally in 1 patient at 2 years postoperatively.

**Conclusion:**

We report the early results of a novel surgical approach for select ASD patients, that preserves LS junction motion. This is achieved by applying temporary instrumentation to the Ilium using a unilateral S2AI screw, allowing and maintaining deformity correction. This approach may be beneficial in active ASD patients by preserving functional mobility.

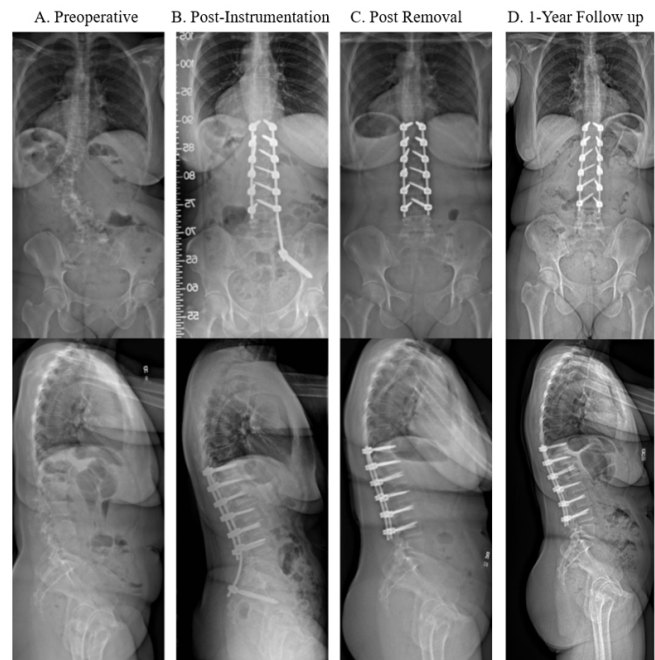


Figure 1: Case Example: A. A 51-year-old female presented with lumbar scoliosis. B. She underwent instrumented arthrodesis from T11–L4, with addition of a right-sided posterior lumbosacral tether. C. The tether was removed 3 months post-operatively. D. Shows correction maintained at one year follow-up.

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## Paper #26. Which ASD Patients Are at Risk of PJK Despite Posterior Ligament Tether Reconstruction?

*Kingsley Ogelle, BS; Fares Ani, MD; Akil Paturi, MD; Themistocles S. Protopsaltis, MD; Jeffrey P. Mullin, MD; Renaud Lafage, MS; Alex Soroceanu, MD, FRCS(C); Jeffrey Gum, MD; Bassel G. Diebo, MD; Justin S. Smith, MD, PhD; Robert K. Eastlack, MD; Gregory M. Mundis Jr., MD; Munish C. Gupta, MD, MBA; Han Jo Kim, MD; Eric O. Klineberg, MD; Lawrence G. Lenke, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Frank Schwab, MD; Shay Bess, MD; International Spine Study Group*

### Hypothesis:

ASD corrections with posterior ligament reconstruction (Tether) may still develop PJK if the corrections are large and if patients are overcorrected.

### Design:

Multi-center retrospective cohort study.

### Introduction:

While Tether is meant to prevent post-operative PJK, the complication may still arise. This study aims to identify factors associated with PJK despite Tether prophylaxis and the effect on HRQL.

### Methods:

ASD patients with Tether prophylaxis, fusions to the pelvis, UIV >T12, and 2Y follow-up were included. Tether patients who developed PJK (change >10) and PJF patients (change >20) were compared to those who did not (noPJK, noPJF) by radiographic and HRQL outcomes. Propensity score matching by age was performed. Analysis included independent t-tests and  $\chi^2$  tests. A sub-analysis compared PJK vs noPJK for patients with UIV at T1-T7 (UT) and T8-T12 (LT).

### Results:

306 patients were included (PJK=165, noPJK=141). Modes of PJK failure were characterized as disc collapse with ligamentous stretch (74%), UIV (or above UIV) fracture (21%), UIV+1 spondylolisthesis (6%), or UIV screw or hook pull-out (2%). Mean number of levels tethered above UIV were similar (1.6 vs 1.5, p=0.33). At baseline, PJK had more patients with osteoporosis (p=.020), greater pelvic tilt (p=.015), and greater T1PA (p=.051). Re-operation rates and 2Y HRQLs were not significantly different between groups. At baseline, PJF (PJF= 37, noPJF=269) had more osteoporosis (p=.014), lower ODI score (p=.041), and lower DEXA Hip T scores (p=.042). PJF had greater PI-LL correction (p=.029). In the sub-analysis, there were 124 UT (PJK=75, noPJK=50) and 182 LT (PJK=91, noPJK=91). At baseline in UT, PJK had more osteoporosis (p=.009), lower DEXA Total Spine T scores (p=.049), and more thoracic kypho-

sis (TK) (p=.052). At baseline in LT, PJK had higher PI-LL (p=.049) and less TK (p=.008). At 2Y in LT, PJK had lower PCS (p=.028). Between baseline and 2Y in LT, PJK had more PI-LL correction (p=.027) and more TK (p<.001).

### Conclusion:

Tether prophylaxis patients who developed PJK had significantly greater disability and functional limitations with larger deformities by TPA at baseline. PJK reoperation rates were similar to noPJK. PJF had significantly lower bone health at baseline. LT had more severe spinopelvic malalignment at baseline and larger corrections. Further investigations are needed to understand which patients remain at risk of PJK despite prophylactic tethering.

Table 1: Comparison of Radiographic Measurements Between Patients with and without Postoperative PJK

|                  | Baseline       |              |      | 2Y             |              |      | Delta          |              |       |
|------------------|----------------|--------------|------|----------------|--------------|------|----------------|--------------|-------|
|                  | noPJK<br>n=141 | PJK<br>n=165 | p    | noPJK<br>n=141 | PJK<br>n=165 | p    | noPJK<br>n=141 | PJK<br>n=165 | p     |
| Osteoporosis     | 20<br>(14.2%)  | 41 (25%)     | .020 |                |              |      |                |              |       |
| Tether Above UIV | 1.6 ± .5       | 1.5 ± .6     | .326 |                |              |      |                |              |       |
| PT               | 24.6 ± 9.2     | 27.2 ± 9     | .015 | 24.8 ± 8.8     | 22 ± 9.3     | .094 | -.27 ± 7.0     | -3.5 ± 8     | .041  |
| PI-LL            | 19.4 ± 19.1    | 22.8 ± 19    | .122 | 5.4 ± 10.6     | 2.7 ± 12     | .217 | -11.0 ± 18     | -17 ± 17     | .102  |
| L1PA             | 11.5 ± 9.6     | 11.8 ± 9.7   | .834 | 10.7 ± 8.2     | 8.9 ± 6.9    | .241 | -.51 ± 7.1     | -2.2 ± 6.8   | .232  |
| T4PA             | 21 ± 12        | 23.4 ± 11    | .082 | 16.3 ± 8.7     | 14 ± 8.1     | .168 | -4.4 ± 12      | -7.1 ± 9.1   | .187  |
| T1PA             | 25 ± 11.9      | 27.3 ± 11    | .051 | 21.2 ± 9.0     | 19 ± 8.5     | .134 | -3.9 ± 12      | -6.5 ± 9.3   | .216  |
| PJK Angle        | -8.65 ± 18     | -11 ± 20     | .469 | -14.1 ± 7      | -18 ± 10     | .017 | -5.1 ± 4.0     | -16.2 ± 7    | <.001 |
| LT               |                |              |      |                |              |      |                |              |       |
|                  | noPJK<br>n=91  | PJK<br>n=91  | p    | noPJK<br>n=91  | PJK<br>n=91  | p    | noPJK<br>n=91  | PJK<br>n=91  | p     |
| PI-LL            | 20 ± 18        | 25 ± 17      | .049 | 6.0 ± 11       | 4.6 ± 12     | .632 | -12 ± 20       | -22 ± 15     | .027  |
| T4-T12 TK        | -35 ± 16       | -29 ± 15     | .008 | -50 ± 11       | -50 ± 12     | .845 | -9.3 ± 6.5     | -25 ± 10     | <.001 |
| L1-S1 Lordosis   | 35 ± 20        | 28 ± 18      | .008 | 52 ± 11        | 49 ± 13      | .328 | 13 ± 19        | 23 ± 15      | .014  |
| UT               |                |              |      |                |              |      |                |              |       |
|                  | noPJK<br>n=50  | PJK<br>n=75  | p    | noPJK<br>n=50  | PJK<br>n=75  | p    | noPJK<br>n=50  | PJK<br>n=75  | p     |
| Osteoporosis     | 7 (14%)        | 26 (35%)     | .009 |                |              |      |                |              |       |
| T4-T12 TK        | -31 ± 19       | -39 ± 21     | .052 | -54 ± 11       | -51 ± 16     | .560 | -19 ± 16       | -6.3 ± 19    | .033  |
| PJF              |                |              |      |                |              |      |                |              |       |
|                  | noPJF<br>n=269 | PJF<br>n=37  | p    | noPJF<br>n=269 | PJF<br>n=37  | p    | noPJF<br>n=269 | PJF<br>n=37  | p     |
| Osteoporosis     | 48 (18%)       | 13 (35%)     | .014 |                |              |      |                |              |       |
| PI-LL            | 21 ± 19        | 24 ± 20      | .341 | 4.2 ± 11       | 1.6 ± 12     | .384 | -13 ± 17       | -23 ± 17     | .029  |
| L1-S1 Lordosis   | 33 ± 21        | 30 ± 21      | .382 | 51 ± 12        | 51 ± 11      | .384 | 13 ± 17        | 24 ± 17      | .019  |

## Paper #27. Multiple Fixation, Fewer Failures: A Multicenter Adult Spinal Deformity Analysis

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### Hypothesis:

We hypothesized that multiple pelvic fixation (MPF) constructs in long-segment adult spinal deformity (ASD) surgery would lower implant failure and rod breakage requiring reoperation compared with single-fixation benchmarks.

### Design:

This was a multicenter retrospective cohort study at four spine centers (2010–2024). All eligible adults with ASD who underwent long-segment

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posterior fusion to the pelvis and had  $\geq 1$  year follow-up were included.

### Introduction:

Failure at the lumbosacral junction remains a major challenge in ASD surgery. While single pelvic fixation has been studied, evidence for MPF is limited. This study compared mechanical complications of MPF with published single-fixation benchmarks.

### Methods:

MPF was defined as  $>2$  pelvic fixation points with  $\geq 1$  sacral-alar-iliac (SAI) implant per hemipelvis. Demographics, spinopelvic parameters, implant characteristics, and complications were recorded. Five endpoints were analyzed: implant failure requiring reoperation (RR), all-modality RR, all-modality non-reoperation (NRR), screw loosening, and rod breakage. Rates were compared with Eastlack et al. (2022) using one-sample z-tests.

### Results:

The cohort included 229 patients (52.4% female; mean age  $67.2 \pm 10$  years; mean BMI  $29.8 \pm 6.3$ ). Average fusion length was 11.3 levels; 59.8% had prior ASD surgery. MPF constructs averaged 3.6 screws/patient, mostly S2AI (77.7%). At one year, implant failure requiring reoperation occurred in 2.2% (95% CI 0.3–4.1%) and all-modality RR in 3.1% (0.8–5.3%), both lower than Eastlack benchmarks (8.5% and 22.8%,  $p < 0.001$ ). Rod breakage was 2.2% vs. 11.9% ( $p < 0.001$ ). Screw loosening (5.2%) and all-modality NRR (6.6%) were not different. Failures trended toward greater preoperative deformity (PT  $29.6^\circ$  vs.  $26.2^\circ$ , TPA  $30.4^\circ$  vs.  $27.4^\circ$ ) and shorter screws, though not significant.

### Conclusion:

MPF reduces implant failure and rod breakage requiring reoperation compared with single-fixation, supporting its protective role in lumbosacral fusion biomechanics. Although radiographic non-revision failures persisted, the marked reduction in reoperation underscores MPF as a valuable option for high-risk ASD patients. Future studies should refine indications and optimize construct design to further reduce risk.dual risk.

| Endpoint                         | N  | % (95% CI)    | Comparator (Eastlack 202) | P-Value vs. Estimate | P-Value vs. Lower Bound |
|----------------------------------|----|---------------|---------------------------|----------------------|-------------------------|
| Implant failure (RR)             | 5  | 2.2 (0.3-4.1) | 8.5 (5.9-11.3)            | <0.001               | 0.017                   |
| all-modality failure (RR compo)  | 7  | 3.1 (0.8-5.3) | 22.8 (18.7-26.7)          | <0.001               | <0.001                  |
| all-modality failure (NRR compo) | 15 | 6.6 (3.3-9.8) | 7.8 (5.3-10.5)            | 0.481                | 0.398                   |
| Screw loosening (NRR)            | 12 | 5.2 (2.4-8.1) | 7.3 (4.9-9.9)             | 0.231                | 0.812                   |
| Rod breakage                     | 5  | 2.2 (0.3-4.1) | 11.9 (8.9-15.1)           | <0.001               | <0.001                  |

*Mechanical Failure endpoints and comparisons to Eastlack et al. (2022)*

## Paper #28. Primary Study for Treatment of Severe Rigid AIS Via the Intraoperative Pre-Distracton Technique on Concave Side

*Xuhong Xue, MD, PhD; Kai Li, MD; Sheng Zhao, MD*

### Hypothesis:

Intraoperative pre-distracton technique on concave side can achieve satisfactory outcome for severe rigid scoliosis.

### Design:

Retrospective analysis of a prospective database.

### Introduction:

Severe rigid scoliosis is characterized by greater than  $90^\circ$ , low mobility, and often accompanied by cardiopulmonary dysfunction. The treatment is very challenging. The traditional methods had high complication rates. We applied the concave pre-distracton technique in patients with severe idiopathic scoliosis. The purpose is to investigate the efficacy and safety of concave pre-distracton technique in the treatment of severe rigid idiopathic scoliosis

### Methods:

The patients with severe rigid idiopathic scoliosis (Cobb angle  $>90^\circ$ ) were included and analyzed from January 2020 to December 2022 retrospectively. During operation, one short rod was implanted into the concave side and pre-distracton, and then long rods were implanted in bilateral sides. Main curve, compensatory curve, thoracic kyphosis (TK), lumbar lordosis (LL), apex vertebra translation (AVT) and trunk shift (TS) were measured in posterior-anterior (PA) X-ray pre-operatively, post-operatively and at the final follow-up.

### Results:

In all, 25 patients were included in present study. The mean followed up time was  $29.0 \pm 6.3$  months (24-42months). The main curve, compensatory curve, thoracic kyphosis, lumbar lordosis, AVT and TS were  $97.4^\circ \pm 10.0^\circ$ ,  $55.6^\circ \pm 8.4^\circ$ ,  $50.4^\circ \pm 20.3^\circ$ ,  $62.7^\circ \pm 6.3^\circ$ ,  $(7.64 \pm 1.55)$  cm and  $(2.00 \pm 1.93)$  cm preoperatively, which were improved to  $25.8^\circ \pm 8.1^\circ$ ,  $21.0^\circ \pm 12.0^\circ$ ,  $24.9^\circ \pm 9.6^\circ$ ,  $31.6^\circ \pm 11.9^\circ$ ,  $(2.34 \pm 1.45)$  cm and  $(1.26 \pm 0.63)$  cm postoperatively, and  $21.2^\circ \pm 9.1^\circ$ ,  $22.4^\circ \pm 16.1^\circ$ ,  $32.8^\circ \pm 12.0^\circ$ ,  $37.6^\circ \pm 14.0^\circ$ ,  $(2.41 \pm 0.81)$  cm and  $(1.6 \pm 1.4)$  cm at the last follow-up. Except TS, the values of the other indicators mentioned above at the immediate and last follow-up after operation were significantly different from those before operation ( $P < 0.05$ ), but there was no statistically significant difference in the values between the immediate and last follow-up after operation ( $P > 0.05$ ). One patient developed delayed infection 7 months after surgery, and then healed again after surgical debridement and internal fixation removal.

## PODIUM PRESENTATION ABSTRACTS

### Conclusion:

Intraoperative pre-distraction technique on concave side can achieve satisfactory outcome for severe rigid scoliosis, with less bleeding and neurological complications.

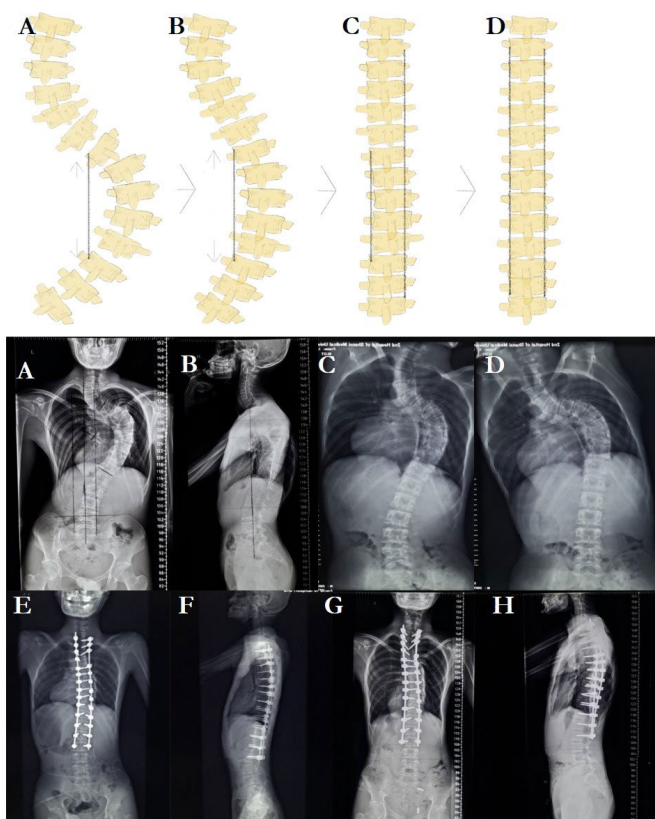


Figure in concave pre-distraction

### Paper #29. The Tethering Method in Transpedicular Dynamic Stabilization of Lumbar Secondary Curves in L1C Deformities in Combination with 3D Instrumented Correction and Posterolateral Fusion of the Main Thoracic Curve

*Martin Repko, MD, PhD; Milan Filipovic, MD, PhD*

#### Hypothesis:

The use of tethering system in transpedicular fixation eliminates the need for anterior surgical approach, prevents progression of the lumbar curve during growth, and allows correction of the secondary lumbar curve without the need for posterolateral fusion.

#### Design:

Prospective consecutive study.

#### Introduction:

The tethering method is a modern method used to correct scoliosis deformities, predominantly applied from the anterior surgical approach. This approach also has a number of disadvantages and risks. The

innovative use of tethering as a transpedicular system simplifies the introduction of this system from the posterior minimally invasive approach.

#### Methods:

A total of 20 patients with L1C scoliosis deformities underwent posterolateral instrumented bone fusion of the main thoracic curve using transpedicular fixation and 3D correction maneuvers. This correction was supplemented by transpedicular correction and stabilization of the secondary lumbar curve on the convex side from less invasive approach. All patients were examined using the EOS radiological system preoperatively, immediately postoperatively, at 4 months, 12 months, and then at annual intervals. The average age at the time of surgery was 12 years and 4 months, and the minimum follow-up period was 12 months after surgery. Informed consent was obtained from all parents for the use of transpedicular fixation with tethering.

#### Results:

The average size of the main thoracic curve was 52 degrees preoperatively, immediately after surgery the corrected curve was 8 degrees (85% correction), and 4 and 12 months after surgery there was no significant loss of correction (9 degrees on average). The average size of the lumbar curve was 44 degrees preoperatively, with postoperative correction to an average value of 10 degrees (78% correction), 4 and 12 months after surgery without significant loss of correction (12 degrees on average). No significant complications were reported. In one case, due to decompensation and progression of the lumbar curve, we converted lumbar tethering to a fusion system.

#### Conclusion:

Transpedicular insertion of tethering instrumentation allows preserved limited mobility in the lumbar region and allows further guided growth of this area of the spine with the suppression of risks associated with the anterior surgical approach.

### Paper #30. The Closing Argument: A Randomized Controlled Trial of Three Spinal Wound Closure Methods for Adolescent Idiopathic Scoliosis (AIS)

*Alastair W. Sterns, BS; Pasha Shakoori, MD, DDS, MEd; John Wyatt, BS; Tishya Wren, PhD; Jasmine Gasca, PA-C; Lori Howell, MD; Kenneth D. Illingworth, MD; Tyler Tetreault, MD; Michael J. Heffernan, MD; Vernon T. Tolo, MD; David L. Skaggs, MD, MMM; Lindsay M. Andras, MD*

#### Hypothesis:

We hypothesize that there will be improved cosmesis in spinal wound closures performed with a noninvasive zipper system.

## PODIUM PRESENTATION ABSTRACTS

### Design:

Single-center Randomized Controlled Trial

### Introduction:

To our knowledge, there are no prior randomized controlled trials (RCT) comparing closure methods following PSF for AIS. Our 4 spine attendings agreed to randomize for this study to determine which spinal wound closure method offered the best cosmesis and patient satisfaction following PSF.

### Methods:

Patients with AIS undergoing PSF were prospectively enrolled and randomized into one of three closure groups: zipper group: a noninvasive zipper system (Zipline), adhesive group: surgical adhesive with mesh (Dermabond Prineo), or steri group: steri-strips alone. Results at 3 months and  $\geq 1$  year post-operatively were evaluated by the Stony-Brook Scar Evaluation Scale (SBSES, 0 to 5 higher score=better cosmesis) and Patient (Pt) Assessment. Clinical photographs were scored by a plastic surgeon blinded to closure type.

### Results:

61 patients (48 females, 13 males; mean age  $15.1 \pm 2.7$  years) were randomized as follows: 18 zipper, 24 adhesive, and 19 steri. Groups were similar in age ( $p=0.72$ ), BMI ( $p=0.29$ ), curve magnitude ( $p=0.51$ ) and mean follow up ( $p=0.50$ ). There was a difference in sex distribution with more males in the zipper group ( $p=0.03$ ). 54 patients completed the 3-month evaluation, at which time, SBSES median scores were zipper=3, adhesive=3, steri=2 and were not statistically different ( $p=0.21$ ). The following percentages of patients reported they either “like” or “love” their scar at that time: zipper=67%, adhesive=83%, steri=64%. 41 patients completed the  $\geq 1$ yr evaluation. The SBSES median scores at that time were zipper=3, adhesive=4, steri=3 and were not statistically different ( $p=0.24$ ). The following percentages of patients reported they either “like” or “love” their scar at that time: zipper=93%, adhesive=79%, steri=50%. Although the difference was not significant, the median SBSES score in the adhesive group was 1 point higher than the zipper or steri groups (Table).

### Conclusion:

Despite a higher percentage of favored scars in the adhesive and zipper groups, there were no significant differences in scar appearance in this RCT with over 50 patients.

|                 | Zipper  | Adhesive | Steri   | P    |
|-----------------|---------|----------|---------|------|
| <b>3 Months</b> |         |          |         |      |
| Pt Assessment   | N=15    | N=18     | N=14    | 0.34 |
| Dislike         | 1 (7%)  | 0        | 1 (7%)  |      |
| Neutral         | 4 (27%) | 3 (17%)  | 4 (29%) |      |
| Like            | 4 (27%) | 9 (50%)  | 7 (50%) |      |
| Love            | 6 (40%) | 6 (33%)  | 2 (14%) |      |
| SBSES           | N=15    | N=18     | N=13    | 0.21 |
| Median (IQR)    | 3 (2)   | 3 (1)    | 2 (2)   |      |
| <b>1+ Years</b> |         |          |         |      |
| Pt Assessment   | N=13    | N=14     | N=14    | 0.31 |
| Dislike         | 0       | 0        | 2 (14%) |      |
| Neutral         | 1 (7%)  | 3 (21%)  | 5 (36%) |      |
| Like            | 8 (62%) | 4 (29%)  | 2 (14%) |      |
| Love            | 4 (31%) | 7 (50%)  | 5 (36%) |      |
| SBSES           | N=12    | N=15     | N=15    | 0.24 |
| Median (IQR)    | 3 (2.5) | 4 (2)    | 3 (3)   |      |

Table: SBSES + Pt Assessment Results

### Paper #31. Thoracic Anterior Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Long-Term Outcomes with Minimum 5-Year Follow-Up

Taemin Oh, MD; Manan Patel, MD; Emily Nice, BS; Sanjana Davuluri; Joshua M. Pahys, MD; Steven W. Hwang, MD; Amer F. Samdani, MD

### Hypothesis:

Although most patients with vertebral body tethering do well at  $> 5$  years' follow-up, there is still a large reoperation rate, with many patients requiring posterior spinal fusion.

### Design:

Retrospective review

### Introduction:

While posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS) provides robust deformity correction, it may sacrifice motion and potentially lead to adjacent segment disease. Anterior vertebral body tethering (VBT) has shown significant promise, but long-term outcomes data are currently lacking.

### Methods:

We performed a retrospective review of all thoracic VBTs performed at a single institution with minimum 5-year follow-up. Clinical and radiographic data were collected at preoperative, 2-year, and final follow-up. Independent t-tests were used to compare clinical and radiographic measurements.

### Results:

113 patients met inclusion criteria. Mean age at index surgery was  $12.3 \pm 1.2$  years (range 9.0–16.7); mean follow-up was  $76.8 \pm 14.2$  months. The majority of patients were skeletally immature (Risser 0.4  $\pm 0.9$ , Sanders 3.0  $\pm 0$ , 41% open triradiates). At final

## PODIUM PRESENTATION ABSTRACTS

follow-up, 112 patients (99%) had achieved skeletal maturity (Risser 5 and/or Sanders 7). Average number of levels tethered was  $7.8 \pm 0.7$  (range 6 - 9). At pre-op, 2-year, and final follow-up, average thoracic Cobb angles were  $50.6^\circ \pm 10.8^\circ$ ,  $18.0^\circ \pm 11.4^\circ$  and  $26.3^\circ \pm 12.9^\circ$ , respectively; this represented a significant improvement ( $p < 0.0001$ ). At final follow-up, 79 patients (70%) had successful coronal correction (Cobb angle  $< 35^\circ$ ). At pre-op, 2-year, and final follow-up, thoracic kyphosis was  $19.6^\circ \pm 11.2^\circ$ ,  $21.0^\circ \pm 11.4^\circ$ , and  $23.1^\circ \pm 13.6^\circ$ , respectively ( $p < 0.0001$ ). Overall reoperation rates were 27%, and 10 patients (9%) required conversion to fusion. Further breakdown of the etiologies for revision showed that 9 patients (8%) had overcorrection, 6 (5%) had adding-on, and 1 (1%) had significant curve progression after tether breakage.

### Conclusion:

70% of patients who underwent thoracic VBT had a Cobb angle  $< 35^\circ$  at  $> 6$  years follow-up. However, the reoperation rate was 27%, with 9% of patients requiring PSF. These results highlight the importance of shared decision making when discussing fusion versus tether for patients with thoracic scoliosis.

TABLE 1. Comparison of radiographic outcomes

| Visit                               | Sanders (Median) | Risser | Open Tri-Radiates | Proximal Cobb     | Main Thoracic Cobb | Lumbar Cobb      | Kyphosis          | Lordosis          |
|-------------------------------------|------------------|--------|-------------------|-------------------|--------------------|------------------|-------------------|-------------------|
| Preop                               | 3B               | 0      | 46 (40.71%)       | 25.84 $\pm$ 9.56  | 50.62 $\pm$ 10.75  | 28.18 $\pm$ 8.61 | 19.58 $\pm$ 11.15 | 55.35 $\pm$ 10.78 |
| 2-Year                              | 5                | 3      | 6 (6.00%)         | 16.57 $\pm$ 10.15 | 18.02 $\pm$ 11.39  | 14.48 $\pm$ 9.75 | 21.01 $\pm$ 11.38 | 55.34 $\pm$ 10.40 |
| Latest FU                           | 8                | 5      | 0 (0.00%)         | 18.96 $\pm$ 11.94 | 26.31 $\pm$ 12.93  | 19.41 $\pm$ 9.43 | 23.13 $\pm$ 13.62 | 57.24 $\pm$ 13.31 |
| Comparison of Outcomes              |                  |        |                   | P Value           | P Value            | P Value          | P Value           | P Value           |
| Preop vs 2-Year                     |                  |        |                   | <0.0001           | <0.0001            | <0.0001          | 0.0766            | 0.7094            |
| Preop vs Latest FU                  |                  |        |                   | <0.0001           | <0.0001            | <0.0001          | <0.0001           | <0.0001           |
| Variable                            | No. (%)          |        |                   |                   |                    |                  |                   |                   |
| Thoracic Tethered Cobb $< 35^\circ$ | 79 (69.91%)      |        |                   |                   |                    |                  |                   |                   |
| Thoracic Tethered Cobb $< 30^\circ$ | 65 (57.52%)      |        |                   |                   |                    |                  |                   |                   |

Preop: Preoperative

### Paper #32. Will the Real Curve Correction Please Stand Up!

*John T. Braun, MD; Sofia Federico, BS*

### Hypothesis:

Of multiple radiographs used to assess curve correction after vertebral body tethering (VBT), the 6 week timepoint will provide the most accurate and consistent baseline measurement.

### Design:

Retrospective 2019-23.

### Introduction:

Accurate and consistent evaluation of curve correction after VBT is often difficult due to multiple confounding factors that conspire to obscure true curve magnitude. Though overestimation of curve correction is expected on recumbent intra-op films, few have commented on the residual overcorrection evident on first erect films--potentially related to pain posturing after lateral chest or flank incisions or even early but incomplete realignment after spine deformity correction.

### Methods:

Eighty-one AIS patients consecutively treated with VBT had appropriate pre-op, intra-op, and post-op radiographs with  $\geq 2$ -year follow-up. Cobb measurements were compared at 4 timepoints (intra-op, first erect, 6 weeks, and 12 weeks) to establish the most accurate and consistent baseline measure of curve correction.

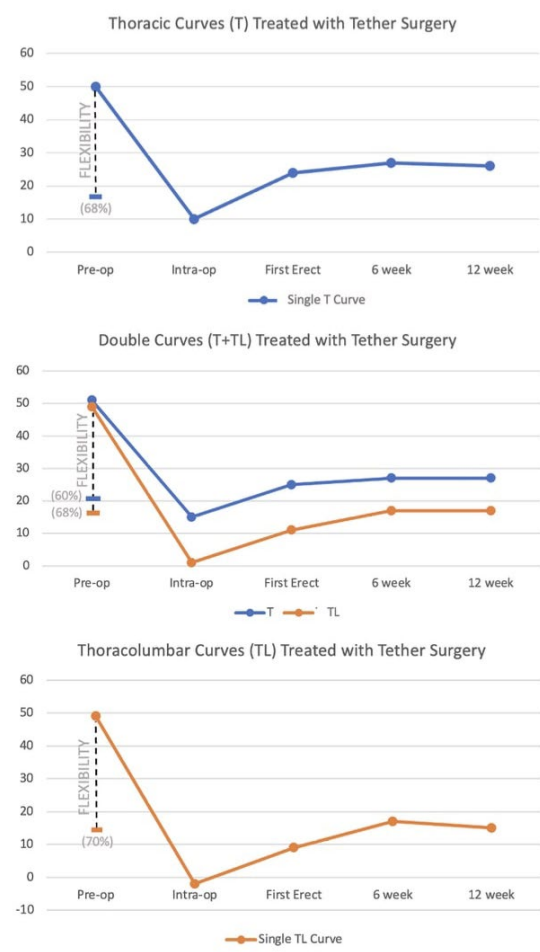
### Results:

Eighty-one AIS patients with 112 curves (39T, 31T+TL, 11TL) measuring  $40-72^\circ$  were treated with VBT. Thoracic curves (T) corrected from  $50^\circ$  (68% flexibility) pre-op at age 15.0 years/Sanders 5.4 to  $10^\circ$  intra-op,  $24^\circ$  first erect,  $27^\circ$  at 6 weeks, and  $26^\circ$  at 12 weeks. Double curves (T+TL) corrected from  $51^\circ$  (60% flexibility) pre-op at age 13.4 years/Sanders 4.9 to  $15^\circ$ ,  $25^\circ$ ,  $27^\circ$ , and  $27^\circ$  for T curves and from  $49^\circ$  (68% flexibility) to  $1^\circ$ ,  $11^\circ$ ,  $17^\circ$ , and  $17^\circ$  for TL curves, respectively. TL curves corrected from  $49^\circ$  (70% flexibility) pre-op at age 15.4 years/Sanders 5.6 to  $-2^\circ$ ,  $9^\circ$ ,  $17^\circ$ , and  $15^\circ$ . All curves changed  $11^\circ$  ( $10-14^\circ$ ) intra-op to first erect ( $p < 0.001$ ). TL curves changed  $7^\circ$  ( $6-8^\circ$ ) and T curves  $2.5^\circ$  ( $2-3^\circ$ ) first erect to 6 weeks ( $p < 0.001$ ). No significant changes were seen 6 to 12 weeks.

### Conclusion:

This study demonstrated significant variability in the assessment of curve correction at multiple timepoints after VBT. Overestimation of curve correction was noted on intra-op films and first erect films ( $p < 0.001$ ) but seemed to stabilize at 6 weeks with no further change between 6 and 12 weeks. The 6 week time point may offer the best estimate of true initial curve correction as it is not only an erect film but allows for the resolution of pain posturing and early realignment issues that alter curve magnitude.

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### Paper #33. Vertebral Body Tethering for Adolescent Idiopathic Scoliosis: Durability of Outcomes with 5-8 Year Follow-up

*Baron S. Lonner, MD; Yazan Alasadi, BA; Olgerta Mucollari, BS; Mark Kurapatti, BS; Charu Jain, BA; Prabhjot Singh, BA; Tariq Issa, MD*

#### Hypothesis:

Acceptable clinical outcomes are expected for most patients at 5–8 Year follow-up (FU) despite loss of correction after Vertebral Body Tethering (VBT) for adolescent idiopathic scoliosis (AIS).

#### Design:

Retrospective review of a single-surgeon consecutive series.

#### Introduction:

VBT is a non-fusion approach for skeletally immature AIS that preserves motion has faster recovery but less correction and more reoperations than the standard of care spinal fusion. Durability of outcomes may be limited by tether breakage (TB) and overcorrection. Long-term data, especially for thoracolum-

bar/lumbar (TL/L) curves, are scarce. We assessed  $\geq 5$ -year outcomes in a single-surgeon cohort.

#### Methods:

Forty-three consecutive AIS patients underwent VBT. Inclusion: Risser  $\leq 3$ , Sanders  $\leq 6$ , Proximal Humerus Ossification System  $\leq 4$ ; thoracic curves  $\leq 65^\circ$ , TL/L  $\leq 70^\circ$ . All had  $\geq 2$  postoperative visits and  $\geq 5$  years radiographic data. Outcomes were recorded at first-erect, 2–3 years, and latest FU. TB was defined radiographically with frequency and location recorded. Paired t-tests compared curves at different time points.

#### Results:

Mean age  $13.5 \pm 1.9$  years; FU  $69 \pm 10.6$  months (5–8.5 years); 76.8% female. Thoracic major (TM) curves 53.5%. Constructs: 69.8% unilateral, 30.2% bilateral; dual-row tethers 23.3% (all TL/L). Mean preoperative major curve (PreMC)  $51.1^\circ \pm 8.1^\circ$  improved to  $25.9^\circ \pm 8.1^\circ$  at final FU (FFU), 49.3% correction ( $p < 0.0001$ ). Kyphosis improved; lumbar lordosis maintained. TM ( $n=24$ ): PreMC  $51.3^\circ \pm 8.4^\circ$  to  $26.8^\circ \pm 9.2^\circ$  (47.8%). TL/L ( $n=19$ ):  $50.8^\circ \pm 7.9^\circ$  to  $24.8^\circ \pm 6.7^\circ$  (51.2%). At FFU, 63.4% had curves  $< 30^\circ$ , and 85.4%  $< 35^\circ$  (excluding reoperations). At 2-year FU, 23.2% had  $\geq 1$  TB (mean 1.5 breaks/patient). At FFU, 81.4% had TB, mean 2.05 breaks/patient. Major complications occurred in 3 patients (7.0%). Revision surgery was performed in 2 patients (4.7%): thoracic fusion plus lumbar tether revision in both. Overcorrection occurred in 2 (4.7%) without clinical impact.

#### Conclusion:

In this  $\geq 5$ -year series, despite TB in 81.4%, 85.4% of patients had curves  $< 35^\circ$ . Revision was required in 4.7%, with no lumbar fusions. VBT provided durable, satisfactory outcomes for most skeletally immature AIS patients with relatively low complication rates compared with early series that represented the learning curve for this procedure.

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| Cohort Demographics (N=5)               |   |             |             |              |           |            |         |
|---|---|-------------|-------------|--------------|-----------|------------|---------|
| Gender (F)                              | 33 (76.8%)  |             |             |              |           |            |         |
| Age                                     | 13.5 ± 1.9  |             |             |              |           |            |         |
| Major Cobb                              | 51.1 ± 8.1  |             |             |              |           |            |         |
| Risser 0   1   2   3                    | 13 (30.2%)   5 (7.0%)   8 (18.6%)   19 (44.2%)            |             |             |              |           |            |         |
| PHOS* 2   3A   3B                       | 5 (13.2%)   11 (28.9%)   22 (57.9%)                       |             |             |              |           |            |         |
| Lenke 1   2   5   6                     | 22 (51.2%)   1 (2.3%)   13 (30.2%)   7 (16.3%)            |             |             |              |           |            |         |
| Mean FU                                 | 69 ± 10.6   |             |             |              |           |            |         |
| Major complications                     | 2 (4.7%)  |             |             |              |           |            |         |
| <b>Pre-operative Major Curve</b>        |   |             |             |              |           |            |         |
| Thoracic                                | 24 (55.8%)  |             |             |              |           |            |         |
| Thoracolumbar                           | 19 (44.2%)  |             |             |              |           |            |         |
| <b>Construct</b>                        |   |             |             |              |           |            |         |
| Unilateral   Bilateral                  | 30 (69.8%)   13 (30.2%)                                   |             |             |              |           |            |         |
| Single Row   Dual Row                   | 33 (76.7%)   10 (23.2%)                                   |             |             |              |           |            |         |
| Tether Breakage   No Tether Breakage    | 35 (81.4%)   8 (18.6%)                                    |             |             |              |           |            |         |
| Number of Breakages   1   2   3   4   5 | 12 (34.3%)   8 (22.9%)   6 (17.1%)   6 (17.1%)   1 (2.9%) |             |             |              |           |            |         |
|   | 1 (2.9%)   1 (2.9%)                                       |             |             |              |           |            |         |
|   | Pre   | First Erect | Latest FU   | % Correction | p-Value * | p-Value ** |         |
| <b>T Major Curve (N = 38)</b>           |   |             |             |              |           |            |         |
| T Curve (°)                             | 51.3 ± 8.3  | 22.7 ± 6.4  | 20.9 ± 9.9  | 26.8 ± 9.2   | 47.8      | 0.0797     | <0.0001 |
| TL Curve (°)                            | 30.4 ± 10.9   | 16.7 ± 8.9  | 16.5 ± 9.8  | 19.95 ± 8.5  | 34.4      | 0.2022     | 0.0006  |
| Thoracic Kyphosis (T5-T12) (°)          | 15.8 ± 9.1  | 16.9 ± 7.7  | 20.3 ± 8.7  | 17.7 ± 7.0   | -         | 0.7082     | 0.4217  |
| Lumbar Lordosis (T12-S1) (°)            | 49.4 ± 10.4   | 47.8 ± 11.3 | 51.6 ± 9.1  | 53.5 ± 11.0  | -         | 0.083      | 0.1907  |
| <b>TL Major Curve (N = 19)</b>          |   |             |             |              |           |            |         |
| T Curve (°)                             | 37.6 ± 11.6   | 17.5 ± 7.2  | 19.4 ± 9.7  | 24.8 ± 6.6   | 34        | 0.0025     | 0.0002  |
| TL Curve (°)                            | 50.8 ± 7.9  | 11.7 ± 6.0  | 14.3 ± 5.9  | 24.8 ± 6.8   | 51.2      | <0.0001    | <0.0001 |
| Thoracic Kyphosis (T5-T12) (°)          | 16.5 ± 12.0   | 19.7 ± 6.9  | 23.1 ± 10.7 | 21.4 ± 9.2   | -         | 0.5234     | 0.1664  |
| Lumbar Lordosis (T12-S1) (°)            | 49.1 ± 10.1   | 46.2 ± 11.2 | 53.1 ± 9.2  | 47.8 ± 10.6  | -         | 0.6538     | 0.701   |

PHOS\*=proximal humerus ossification stage \* = change from 1st erect → latest follow-up; \*\* = change from baseline → latest follow-up.

## Paper #34. Flex on 'em: A Novel Flexibility Index Classification System for AIS

Mackenzie Morris, BS; Margaret L. Sullivan, BS; Chiara Morley-McLaughlin, BA; Shanika De Silva, PhD, MS; David D. Liu, MD; Grant D. Hogue, MD

### Hypothesis:

In operative adolescent idiopathic scoliosis (AIS) patients, specific cut-offs in the flexibility index (FI) metric will differentiate levels of surgical complexity and perioperative outcomes, with lower flexibility predicting greater surgical burden and lower postoperative curve correction.

### Design:

Retrospective cohort

### Introduction:

Quantifying curve flexibility is integral to AIS evaluation and preoperative planning. While prior research identifies curve flexibility determinants, no standardized FI grading scale exists. Previous literature differentiates between stiff and flexible curves using arbitrary threshold values, limiting clinical consistency.

### Methods:

Patients aged 11-19 treated with instrumented PSF between 2011-2019 with 2-years of postoperative follow-up were identified from a single-center AIS database. Non-idiopathic curves and revision procedures were excluded. FI was defined as the percentage of the major Cobb angle corrected in bending radiographs. Gaussian mixture modeling (GMM) with bootstrapping was used to estimate FI cut-offs. Surgical and perioperative characteristics were assessed for their association with the resulting cut-offs.

### Results:

Among 525 patients (84% female, median age 14

years, median FI 38%), GMMs identified three FI classifications: stiff (≤25%), normal (>25% to ≤70%), and hyperflexible (>70%), representing 21%, 75% and 4% of the cohort respectively. Overall surgical complexity was highest in the stiff group for most intraoperative measures, followed by the normal and hyperflexible groups. The total number of implants and levels fused significantly decreased as flexibility increased, along with EBL and operative time (all p<0.005). The number of osteotomies and rates of intraoperative or postoperative complications did not statistically differ across FI grades. Hyperflexible patients had shorter hospital stays and greater curve correction than normal flexibility and stiff patients (both p<0.05).

### Conclusion:

This study proposes an FI classification system for AIS patients correlating with surgical complexity and postsurgical outcomes. Stiff curves are associated with increased surgical burden, which may warrant enhanced preoperative planning and intraoperative considerations. These findings raise the potential for individualized clinical guidance, allowing better anticipation of recovery trajectories tailored to each curve flexibility classification.

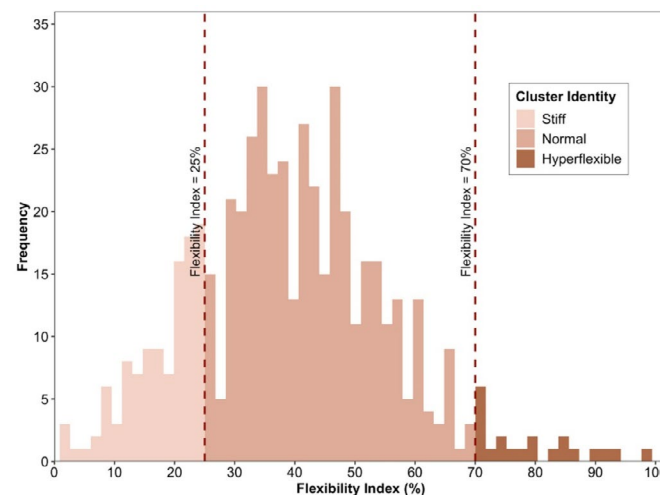


Figure 1: FI Histogram with GMM-estimated cut-offs

## Paper #35. Cervical Vertebral Maturation System and Its Correlation with Established Skeletal Maturity Staging in Idiopathic Scoliosis

Talissa O. Generoso, MD; Lorena Floccari, MD; Amishi Jobanputra, MS; Arianne T. Salunga, DO; Hiba Naz, BS; Nicole S. Pham, MPH; Jason Pui Yin Cheung, MD, MBBS, MS, FRCS; Scott Yang, MD; Susan Nelson, MD; Jessica McQuerry, MD; Ron El Hawary, MD, MSc; James T. Bennett, MD; Craig R. Louer Jr, MD; Kali R. Tileston, MD; John S. Vorhies, MD

# PODIUM PRESENTATION ABSTRACTS

## Hypothesis:

The cervical vertebral maturation (CVM) system will demonstrate inter- and intra-rater reliability comparable to established skeletal maturity staging systems used in scoliosis.

## Design:

Retrospective multicenter study

## Introduction:

Accurate assessment of skeletal maturity is critical to optimize idiopathic scoliosis (IS) treatment timing, particularly for growth-dependent interventions. The Cervical Vertebral Maturation (CVM) system, based on upper cervical morphology on lateral spine radiographs, is widely used in orthodontics but less studied in IS. Its reliability and correlation with established markers such as the Sanders Skeletal Maturity System (SSMS), Risser, and Triradiate Cartilage (TRC) classifications are not well defined. This study evaluates the inter- and intra-rater reliability of CVM staging and its correlation with SSMS, Risser, and TRC in IS patients.

## Methods:

Seven independent raters evaluated PA, lateral spine, and hand radiographs from a multi-center scoliosis database. After a standardized training session, raters assigned skeletal maturity stages using CVM, SSMS, Risser, and TRC. Fifty images were randomly repeated to assess intra-rater reliability. Inter-rater reliability was measured with Kendall's W, and Spearman's correlation among staging methods. Image quality limitations were documented.

## Results:

125 patients were included (82% female, mean age 12.7 years, range 6–18). Poor image quality exclusion left 24% of lateral radiographs for CVM, compared to 8% for SSMS and 18% for Risser/TRC. After exclusion, CVM intra-rater reliability (Kendall's W = 0.86) was higher than Risser (0.76) and TRC (0.59), but lower than SSMS (0.92). Inter-rater reliability for CVM (0.60) was similar to Risser (0.63) and TRC (0.59) but inferior to SSMS (0.91). CVM demonstrated moderate correlation with SSMS ( $\rho = 0.60$ ), Risser ( $\rho = 0.53$ ), and TRC (0.59) ( $p < 0.001$ ).

## Conclusion:

The CVM system shows reliability comparable to Risser and TRC staging but is less reliable than SSMS. Discrepancies between CVM and SSMS suggest differences in axial versus appendicular skeletal maturation. High-resolution images may enhance reliability with CVM. Further study is warranted to clarify these differences and determine the clinical utility of CVM in IS management.

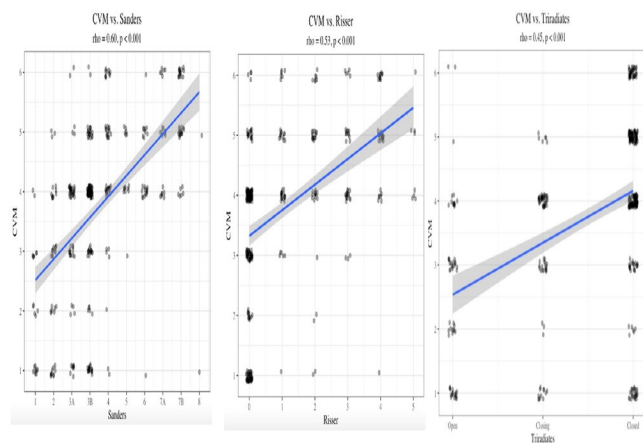


Figure 1. CVM demonstrated a moderate correlation with Sanders, Risser, and TRC.

## Paper #36. Beyond Full-Time Bracing: Defining the Minimum Effective Dose of Brace Wear and Synergy of Scoliosis Specific Exercises in Adolescent Idiopathic Scoliosis Treatment

*Nikos Karavidas, MSc, PT*

## Hypothesis:

Part-time bracing (14–16 h/day) plus physiotherapeutic scoliosis-specific exercises (PSSE) achieves stability in most AIS patients with 25–40° curves.

## Design:

Retrospective cohort study.

## Introduction:

The traditional paradigm of “full-time” bracing (>20–23 h/day) in adolescent idiopathic scoliosis (AIS) is increasingly questioned. Establishing the minimum effective dose of brace wearing time (BWT), and the potential synergistic role of PSSE, could support individualized, adherence-friendly treatment strategies.

## Methods:

We retrospectively analyzed 168 AIS patients (baseline 25–40°) treated with brace plus PSSE. Outcomes were defined per SRS/SOSORT criteria as Improved, Stable, or Progressed ( $\geq 6^\circ$  change). BWT was examined continuously, by quartiles, and stratified by baseline Cobb (25–30°, 30–35°, 35–40°). Logistic regression with cubic splines estimated predicted probabilities (95% bootstrap CI). ROC analyses (Youden's J) identified thresholds. Models adjusted for Risser stage and in-brace correction, with PSSE days/week included as an interaction.

## Results:

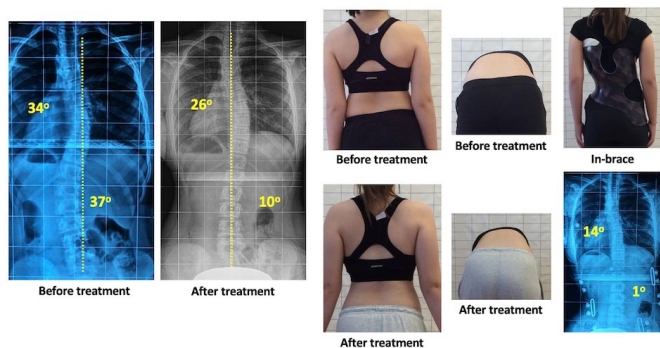
In thoracic curves ( $n=120$ ), 20.8% improved, 65.0% remained stable, and 14.2% progressed. In lumbar curves ( $n=119$ ), 32.8% improved, 61.3% remained stable, and 5.9% progressed. Success increased from ~75% in the lowest quartile (~11 h/day) to >95% in

## PODIUM PRESENTATION ABSTRACTS

the highest (~18 h/day); improvement rose from ~15% to ~35%. Progression was concentrated in patients wearing <14 h/day. Predicted probabilities showed success at 70%, 85%, and 95% at 10, 14, and 18 h/day, respectively, while progression fell from 30% to 5% across the same range. ROC thresholds identified  $\geq 14$  h/day as the minimum dose overall. Stratified analysis showed 25–30° curves stabilized with ~14 h/day, 30–35° required ~16 h/day, and 35–40° needed  $\geq 18$  h/day. At all BWT levels,  $\geq 3$  days/week of PSSE further increased success and improvement probabilities.

### Conclusion:

Radiographic outcomes in AIS demonstrate a clear dose-response to brace wearing time. For 25–30° curves, ~14 h/day part-time bracing was sufficient for stability; 30–35° required ~16 h/day, and 35–40°  $\geq 18$  h/day to maximize improvement and minimize progression. BWT <14 h/day accounted for nearly all progression. Regular PSSE further enhanced outcomes, supporting integrated brace+exercise treatment and redefining the minimum effective dose beyond the rigid concept of full-time bracing.



### Paper #37. Preoperative Paraspinal Muscle Size and Fat Infiltration as Predictors of Postoperative Recovery in Adolescent Idiopathic Scoliosis Patients: A Pilot Study

*Paolo Brigato, MD; Sergio De Salvatore, MD; Davide Palombi, MD; Pier Francesco Costici, MD; Leonardo Oggiano, MD*

#### Hypothesis:

Preoperative CSA and muscle quality of the iliopsoas, erector spinae, and multifidus are associated with key perioperative parameters in AIS patients, including blood loss, operative time, time to first ambulation, and length of hospital stay (LOS).

#### Design:

Retrospective single-center observational study

#### Introduction:

The iliopsoas and paraspinal muscles are crucial for spinal stability and postoperative mobility. In adults

undergoing lumbar surgery, preoperative CSA influences recovery. To date, no studies have evaluated these parameters in pediatric populations, including AIS patients.

#### Methods:

Eighty-one consecutively treated AIS patients undergoing posterior spinal fusion between January 2021 and August 2023 were included. Preoperative MRI at L3 measured paraspinal muscle CSA and Goutallier grade. Two trained radiologists performed blinded independent measurements, and mean values were used; inter-observer reliability was assessed. Postoperative outcomes included intraoperative blood loss, surgical duration, time to first ambulation, and LOS. Correlation analyses and Kruskal-Wallis tests assessed associations ( $p < 0.05$ ).

#### Results:

Patients (mean age  $14.8 \pm 1.7$  years) were stratified by Lenke type: 1–2 (Group 1, N=26), 5 (Group 2, N=18), and 3–4–6 (Group 3, N=37). Fatty infiltration was higher in Groups 2 and 3 than in Group 1 (all  $p < 0.05$ ). In Group 2, greater fat infiltration of erector spinae, multifidus, and total paraspinal muscles was linked to longer LOS. In Group 3, higher multifidus CSA correlated with both surgical duration and LOS, while higher paraspinal muscles CSA was also associated with longer LOS ( $p < 0.05$ ). No significant associations were found in Group 1.

#### Conclusion:

Preoperative paraspinal muscle size had little impact on intraoperative parameters in AIS surgery. However, greater fat infiltration and higher CSA, especially in the erector spinae, were linked to longer LOS in lumbar-dominant curves (Lenke 3–6). Lumbar curves also showed more muscle degeneration than thoracic ones. These results suggest that preoperative muscle assessment may help predict recovery, warranting further prospective studies on targeted prehabilitation.

### Paper #38. Cancer Risk Among Women with Scoliosis: A Nationwide Danish Register-Based Study

*Frederik Hjsager, MD; Luise Borch, MD, PhD; René M. Castelein, MD, PhD; Steen B. Christensen, MD, PhD; Ane Simony, MD, PhD*

#### Hypothesis:

Women with scoliosis are more likely to develop cancer, predominantly breast cancer, than women without scoliosis

#### Design:

Register based cohort study

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### Introduction:

Adolescent Idiopathic Scoliosis (AIS) affects over 1% of adolescents, and is often diagnosed during a sensitive developmental period, with repeated radiographs, potentially increasing cancer risk. Previous studies have suggested an association between scoliosis and breast cancer, but have been limited by small cohorts, lack of matched controls, and incomplete registry data. The aim of this study therefore was to assess the hazard ratio (HR) of cancer among women with scoliosis compared to age-matched controls using nationwide registry data.

### Methods:

This observational cohort study included all Danish women born 1967–1977 with a scoliosis diagnosis (ICD-8 735.0/735.2 or ICD-10 DM411), and four age-matched controls per case, identified through national health registers. Cancer outcomes were obtained from the Danish National Cancer Register, and Cox regression was used to estimate HRs, with time at risk, beginning at age 12.

### Results:

Among 6,217 women (1,238 (20% with scoliosis), mean follow-up time was approximately 38 years. The HR (95% CI) for any cancer was 1.06 [0.85-1.31]. For breast cancer HR was 1.25 [0.86-1.80], while HR for carcinoma in situ (CIS) of the breast was 13.62 [3.75-49.50]. Among 12 cases of ovarian cancer, the HR was 2.91 [0.92-9.18]. This study could not, however, discriminate between idiopathic and nonidiopathic scoliosis.

### Conclusion:

Women with scoliosis showed a significantly increased HR for CIS of the breast, and a non-significant trend toward increased risk of invasive breast and gynecologic cancers. Findings support further investigation into genetic or developmental links between scoliosis and cancer risk.

### Paper #39. Is Your Surgical Field as Sterile as You Think When Operating Patients with Adolescent Idiopathic Scoliosis?

*Niklas Tondevold, MD, PhD; Thomas B. Andersen, MD, PhD; Martin Gehrchen, MD, PhD; Benny T. Dahl, MD, PhD*

### Hypothesis:

The presence of skin bacteria, especially *Cutibacterium acnes*, is more prevalent in the surgical field of patients treated for adolescent idiopathic scoliosis (AIS) than that of patients treated for adult spinal deformity (ASD).

### Design:

Prospective, consecutive one-center study.

### Introduction:

Late surgical site infection (>90 days) is seen in 1.7 to 6.9% of patients undergoing surgery for AIS. *Cutibacterium acnes* (*C. acnes*) is reported to be the most common finding in these patients. However, the same pattern is not seen ASD patients. *P. acnes* is known to act as an opportunistic pathogen through biofilm. Particularly shoulder arthroplasties but also breast implants and cardiovascular device-related infections are known to have high infection rates with that pathogen. However, whether inoculation is hematogenic or the result of bacterial contamination at the initial surgery is not known.

### Methods:

We included patients at least two years after their last spine surgery (ASD group) or no prior spine surgery (AIS group) undergoing surgery at our institution from January 1 2021 through December 31, 2024. The patients were surgically prepared according to the consensus guidelines. Three muscle tissue samples were obtained before wound closure, and two positive cultures were considered a positive test result. Furthermore, the unused rod tip was sent for sonication. All cultures were observed for 14 days. All positive tests for skin bacteria were whole genome sequenced (WGS) in order to rule out a single contaminate source among the surgical staff.

### Results:

We included 208 AIS patients and 37 ASD patients. There were no statistically significant differences within the 2 groups regarding surgical time or blood loss. Cultures were positive in 148 AIS patients (71%) and in 4 ASD patients (11%). Of the 142 positive AIS cultures 121 (85%) had *C. Acnes* as the only pathogen. The remaining were other skin bacteria. Bacteria were found on 115 of the rod tip (81%) all were *C. acnes*. WGS showed no sign of a single contaminate source.

### Conclusion:

*C. acnes* is present in the muscle tissue of most patients surgically treated for AIS. In the majority of cases the same bacteria were found on the unused sterile implant only handled by the surgeons, possibly by contamination from the surgical gloves. Surgeons treating these patients should therefore make sure of targeting this pathogen in their prophylactic strategy.

### Paper #40. Virtual Reality Training Improves Freehand Pedicle Screw Placement: A High-Fidelity Validation Study in Neurosurgical Trainees

*Steve S. Cho, MD; Juan Pedro Giraldo, MD; S. Harrison Farber, MD; Jakub Godzik, MD; Juan S. Uribe, MD*

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### Hypothesis:

A short session of virtual reality education will improve freehand pedicle screw performance.

### Design:

Randomized trial of VR and standard educational tools

### Introduction:

Pedicle screw placement is technically demanding, with a steep learning curve and important safety implications. Virtual reality (VR) offers an immersive, risk-free environment for trainees to develop psychomotor and procedural skills. Few prior studies have evaluated performance outcomes. This study assesses the impact of VR-based training on pedicle screw accuracy using a high-fidelity 3D-printed spine model and actual instrumentation.

### Methods:

Thirteen neurosurgical trainees were randomized 3:1 to VR training or control (9 VR, 4 control). All participants completed baseline surveys and performed freehand pedicle screw placement from L1–S1 on a 3D-printed spine model simulating surgical exposure and using commercial hardware. They then underwent a 30-minute study session: VR participants used an in-house VR lumbar pedicle screw application, while controls used conventional resources (textbooks, videos, and internet). Participants repeated contralateral L1–S1 screw placement, followed by post-session surveys.

### Results:

All participants had placed <10 freehand and <10 navigated lumbar pedicle screws prior to the study. Baseline pedicle breach rate was 3.8±1.5 out of 6 (63.3%) without inter-group differences ( $p=0.832$ ). After training, the control group showed no improvement (3.5±2.1 vs 3.8±2.2,  $p=0.824$ ), while the VR group improved significantly (4.0±1.2 vs 1.4±1.7,  $p=0.0004$ ). For L1–L5 screws, mean deviation from the ideal entry point was similar at baseline for the two groups ( $p=0.0691$ ); this decreased significantly in the VR group (7.1±5.8mm to 2.1±2.6mm,  $p<0.0001$ ) but not in controls (3.9±5.9mm to 4.5±3.0mm,  $p=0.732$ ). Screw placement time also decreased in the VR group (96.1±33.5s to 80.4±27.6s,  $p=0.0006$ ) but not in controls (107.7±50.9s to 92.7±28.7s,  $p=0.170$ ). For S1 screws, which were not included in the VR module, neither group showed improvements in accuracy or time (all  $p>0.05$ ). Subjective confidence in pedicle anatomy and freehand technique did not change in controls ( $p=0.0577$ ) but increased significantly in the VR group ( $p=0.0061$ ).

### Conclusion:

VR training improved pedicle screw accuracy,

efficiency, and trainee confidence in a realistic operative simulation, without transfer to non-included levels (S1).

### Paper #41. Development and Initial Validation of a Free and Open-source Virtual Reality TLIF Surgical Simulator for Resident Training: A Prospective Randomized Study

*Léonard Chatelain, MD; Renaud Lafage, MS; Emil Haikal, MD; Blerta Budani, BS; Jonathan Elyse, BS; Max Kohn, BS; Marc Khalif, MD, MS; Emmanuelle Ferrero, MD, PhD; Virginie Lafage, PhD*

### Hypothesis:

We hypothesized that a new virtual reality (VR) TLIF simulator would improve procedural performance, global technical skills, and user satisfaction compared to an already validated screen-based simulator.

### Design:

Intermediary analysis of a prospective, randomized, controlled, multicenter study comparing VR and computer-based simulation for TLIF training.

### Introduction:

In a previous study, a computer-based TLIF simulator improved procedural knowledge acquisition over a traditional PDF surgical technique guide. This study aimed to translate the simulator into a VR environment and compare its pedagogical impact to the screen-based version.

### Methods:

The TLIF simulator was developed for VR, based on anonymized lumbar spine CT. The environment reproduced a full operating room setup, including draped patient and instrument tables. Users performed pedicle screw placement, laminectomy, facetectomy, discectomy, and interbody cage trial using virtual tools. Guidance was provided via step-by-step instructions. The application was deployed on a standalone VR headset, requiring no external computer or hardware. Procedural flow and accuracy were validated by two senior spine surgeons. Orthopedic surgery residents were randomized into two groups: VR or screen-based simulator. After an initial questionnaire, all participants underwent a 45-minute simulation session, then performed a TLIF on a synthetic bone model and filled out a satisfaction questionnaire. The primary endpoint was a TLIF-specific checklist score; secondary endpoints included OSATS score and procedure time.

### Results:

Twenty-one residents were included so far (48% VR, 52% screen-based). Baseline characteristics were comparable. The VR group showed trend toward

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higher checklist scores ( $27.4 \pm 4.2$  vs  $22.6 \pm 5.6$ ;  $p=0.070$ ). No difference in OSATS scores ( $25.7 \pm 7.5$  vs  $23.2 \pm 6.0$ ;  $p=0.5$ ) or procedure time ( $23.1 \pm 7.2$  vs  $19.5 \pm 6.3$  min;  $p=0.3$ ) was found. Satisfaction was high in both groups; VR showed slightly greater immersion ( $8.0$  vs  $6.8$ ;  $p=0.2$ ).

### Conclusion:

This study confirms the feasibility of a free VR TLIF simulator developed with open-source tools. Preliminary results suggest a trend toward improved procedural performance in VR, with comparable user satisfaction. Further recruitment is ongoing to confirm statistical significance.

### Paper #42. Spine Reviews: Crowdsourcing Global Spine Experts Knowledge via Digital Ledger Technology

*Bassel G. Diebo, MD; Vincent Challier, MD; Virginie Lafage, PhD*

### Hypothesis:

A decentralized platform leveraging digital ledger technology (DLT) can cost-effectively aggregate high-quality surgical decision-making data from global spine specialists, enabling AI model training to streamline treatment pathways and reveal clinical patterns.

### Design:

Retrospective observational study using a DLT-based crowdsourcing platform to collect 2,115 expert opinions on 500 standardized low back pain vignettes over three weeks.

### Introduction:

AI models predicting low back pain treatment pathways are limited by small, homogenous datasets. Traditional data collection is expensive, slow, and geographically constrained. We developed "Spine Reviews," a blockchain platform to rapidly gather surgical judgments from diverse international experts at unprecedented cost efficiency.

### Methods:

Five hundred synthetic vignettes for low back pain (degenerative/deformity with/without radiculopathy) were generated using curated corner cases ( $n=162$ ) and constrained-random sampling ( $n=338$ ). Variables included demographics, frailty, pain, ODI, neurologic red flags, and treatment history with automated validation. Fifty-two vetted spine specialists from 8 countries reviewed vignettes via web dashboard secured by soulbound tokens—blockchain credentials verifying identity and tracking expertise. Each vignette received  $\geq 4$  independent reviews with surgery likelihood scores (0–10), confidence scores (1–5), and

treatment recommendations. Blockchain-automated compensation was provided.

### Results:

Vignettes represented diverse presentations (mean age 52.4 years, ODI 48.9, 10% prior surgery). From 2,115 reviews, 2,066 completed (97.7%). Mean surgery likelihood was 3.46/10 ( $SD=2.70$ ). Agreement was high for red flag/emergency cases (97.2% consensus) but moderate for surgical/interventional recommendations (72.5–74.5%), reflecting clinical variability. Cost was \$0.97 per review.

### Conclusion:

Spine Reviews represents the first platform bridging data, human intelligence, and AI for spine care. Digital ledger technology enabled rapid, global, cost-effective aggregation of expert judgment. Soulbound tokens provided access control and immutable credentialing, establishing transparent credibility tracking. This approach produced a robust dataset for training AI models constrained by diverse clinical expertise, applicable to other surgical domains.

### Paper #43. A Non-Irradiated Portable 3D Electronic Spine Measurement System for Large-Scale Adolescent Scoliosis Screening: A Diagnostic Accuracy and Implementation Study

*Wenjie Wu, MD*

### Hypothesis:

This Measurement System has the advantages of being fast and cost-effective. Compared with the traditional X-ray gold standard, it has the same diagnostic efficacy.

### Design:

A prospective diagnostic accuracy study

### Introduction:

Early screening for adolescent idiopathic scoliosis (AIS) is essential to prevent curve progression and improve long-term outcomes. Current reliance on standing full-spine radiography exposes youths to ionizing radiation, while physical examinations like the Adams forward bend test suffer from subjectivity and variable accuracy.

### Methods:

A prospective diagnostic accuracy study embedded with an implementation science component was conducted across 20 schools and 5 community health centers in China. A total of 5000 adolescents aged 10–18 years were enrolled. The index test was a multi-sensor portable device measuring Cobb angle and vertebral rotation. The reference standard was standing full-spine radiography, interpreted by two blinded radiologists. All screen-positive participants and a random 10% of screen-negative participants

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underwent radiography. Implementation outcomes were evaluated using the RE-AIM framework. Health economic analysis included cost-effectiveness and budget impact analyses.

### Results:

Preliminary data from a pilot study (n=3000) showed excellent agreement between the device and radiography: intraclass correlation coefficient (ICC) for Cobb angle was 0.93 (95% CI: 0.90–0.95), with a mean difference of 1.5° (95% LoA: -4.2° to +7.2°). The device-derived vertebral rotation correlated strongly with Perdriolle rotation (r=0.78, p<0.001). Operational feasibility was high: 100% of non-professional operators (n=20) passed proficiency testing after 1 hour of training, with an error rate <1.5%. Participant satisfaction reached 96%. The new screening model demonstrated a potential cost reduction of >30% per 1000 participants compared to traditional methods.

### Conclusion:

The portable 3D spine measurement system is an accurate, feasible, and cost-effective tool for large-scale AIS screening. Its non-irradiated nature and ease of use make it suitable for community and school-based settings.



Instruments and measurement results

### Paper #44. 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 Miyajji, MD, FRCS(C); Stefan Parent, MD, PhD; Thierry A. Odent, MD, PhD; Neil Saran, FRCS(C); Anne Tabard-Fougere, PhD; Natahly Gavira, MD; Romain Dayer, MD; Jean A. Ouellet, MD, FRCS(C)

### Hypothesis:

A smartphone-based 3D imaging system can provide reliable Cobb angle measurements comparable to radiography.

### Design:

Prospective multicenter cohort study across five sites in three countries (Nov 2022–Mar 2025).

### Introduction:

Idiopathic scoliosis (IS) accounts for ~80% of pediatric spinal deformities, with Adolescent Idiopathic Scolio-

sis (AIS) affecting 1–4% of adolescents. Radiographic monitoring exposes patients to repeated radiation, though only ~10% need treatment. Surface topography (ST) offers a radiation-free alternative by estimating deformity through torso asymmetry. Smartphone-based 3D imaging may allow broader access, but validation is required.

### Methods:

Patients aged 5–21 years with confirmed or suspected IS were consecutively enrolled. Exclusions: in-brace radiographs, pregnancy, or additional deformities. Each visit included standard biplanar radiographs and a smartphone-based 3D scan. Demographic and clinical variables (age, sex, BMI, skin type, bracing status, curve location, Risser stage) and radiographic parameters (Cobb angle, thoracic kyphosis, lumbar lordosis) were collected. Scan quality was graded 0–2. Agreement was assessed with Spearman's correlation and Bland–Altman analysis; accuracy with Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE). Determinants of discrepancies were explored with Kruskal–Wallis and correlation tests. Diagnostic performance for detecting scoliosis  $\geq 20^\circ$  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  $13.6 \pm 2.4$  years). Surface scan–derived Cobb angles correlated strongly with radiographic angles (r = 0.775, p < 0.001), with a mean bias of -3.6° and limits of agreement -16.9° to 24.0°. Prediction errors were significantly influenced by brace status, site, Cobb class, skin type, and scan quality. For detecting scoliosis  $\geq 20^\circ$ , the model achieved an accuracy of 84%, precision of 90%, and recall of 89%.

### Conclusion:

Smartphone-based 3D imaging showed good agreement with radiographic Cobb angles, with minor underestimation. Accuracy depended on image quality and clinical factors, with best performance in high-quality scans. This technology may serve as a complementary, radiation-free tool for scoliosis monitoring, though further refinement and validation are needed before widespread use.

### Paper #45. Objective Measurement of Post-Operative Recovery Using Smartphone Activity Data in Lumbar and Cervical Spine Surgery

Ryan Turlip, BA; Daksh Chauhan, MD; Mert Marcel Dagli, MD; Richard J. Chung, BA; Hasan S. Ahmad, MD; Julia Kincaid; Richelle Kim; Akash Verma; Johannes Ghenbot, MD; Ben Gu, MD; Niall Buckley, MD; Jang Yoon, MD, MS

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### Hypothesis:

We hypothesize that smartphone accelerometer data can quantify variability in post-operative recovery following spine surgery.

### Design:

Retrospective cohort.

### Introduction:

Contemporary outcomes assessment in spine surgery utilizes patient-reported outcome measures, which are subjective and can be biased. In contrast, smartphone-based activity tracking can objectively measure patients' post-operative improvement. This study uses a data-driven approach leveraging high-fidelity activity data from patient smartphones to quantify variability in functional recovery after spinal decompression and fusion.

### Methods:

Four years of peri-operative activity data (steps-per-day) from 43 patients (lumbar decompression: 18; lumbar fusion: 21; cervical fusion: 4) were retrospectively extracted from patient smartphones. A data-driven algorithm was constructed to first characterize peri-operative functional activity into temporal epochs to determine pre-operative baseline (Figure 1). Baselines were categorized by whether patients had a stable baseline (E1) or an acute decline (E2). Post-operative recovery was then classified into 4 gradations: (1) No Recovery, defined by post-operative activity < pre-operative baseline, (2) Minimal Recovery, defined by post-operative activity between 0 and 0.6 SD above pre-operative baseline, (3) Moderate Recovery, defined by post-operative activity between 0.6 and 1.0 SD above pre-operative baseline, and (4) Significant Recovery, defined by post-operative activity >1.0 SD above pre-operative baseline.

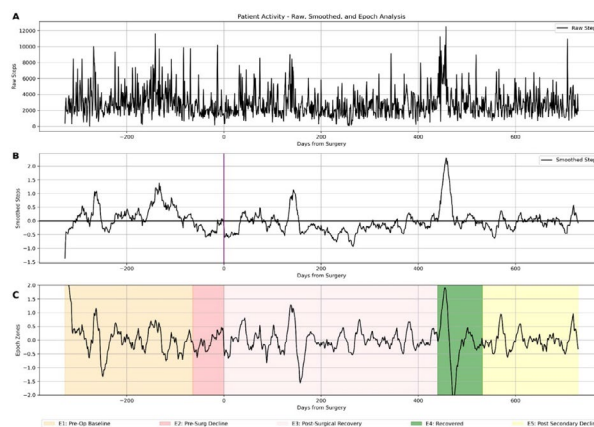
### Results:

Thirty patients had improved post-operative activity, while 13 patients demonstrated decreased post-surgery physical activity. There was no clear distribution of patients amongst the No Recovery (30.2%, mean normalized activity =  $-0.129 \pm 1.198$ ), Minimal Recovery (32.6%, mean =  $0.275 \pm 0.1.55$ ), Moderate Recovery (9.3%, mean =  $0.883 \pm 0.079$ ), and Significant Recovery (27.9%, mean =  $2.834 \pm 1.740$ ) groups. There was a statistically significant relationship between the presence of an acute decline (E2) and recovery level ( $P = 0.045$ ).

### Conclusion:

Analysis of patient activity datasets allows clinicians to identify inter-patient differences in degree of recovery and allow for more accurate post-operative follow up. Future studies with larger datasets should build on this work to understand the under-

lying contributions to variability in degree of functional recovery.



**Figure 1.** Patient example of functional data pre-processing and algorithm development. (A) Raw steps plotted across peri-operative period. (B) Normalized and smoothed steps using 14-day sliding average. (C) Temporal epoch designation according to functional activity patterns.

## Paper #46. AP-DADNet: An Anatomical Prior-Driven Framework for 3D Spinal Cord Segmentation and Shape Quantification in CT with Metal Artifacts

*Junyu Li, MD; Hanlin Xia, MD; Hanwen Zhang, MD; Zhuoran Sun, MD; Yongqiang Wang, MD; Weishi Li, MD; Duanduan Chen, MD; Miao Yu, MD*

### Hypothesis:

In pre- and postoperative CT scans of patients with spinal deformity containing metal artifacts, the proposed AP-DADNet achieves significantly higher three-dimensional spinal cord segmentation accuracy than a baseline U-Net.

### Design:

A retrospective methodological development and validation study.

### Introduction:

Spinal deformities such as scoliosis and kyphosis can markedly reduce quality of life. Surgery is a mainstay of treatment, but reliable assessment of outcomes requires accurate quantification of spinal cord morphology. We present an anatomical prior-driven framework for spinal cord segmentation and shape analysis that overcomes postoperative metal artifacts, providing a robust 3D basis for surgical parameter calculation.

### Methods:

We introduce AP-DADNet, an anatomical prior-driven network that couples deformable attention with anatomy-conditioned dynamic convolution. Prior vertebral segmentations generate direction-aware spinal cord candidates. In the U-Net encoder, convolutional kernels are modulated by vertebral position to enhance discrimination within metal-artifact

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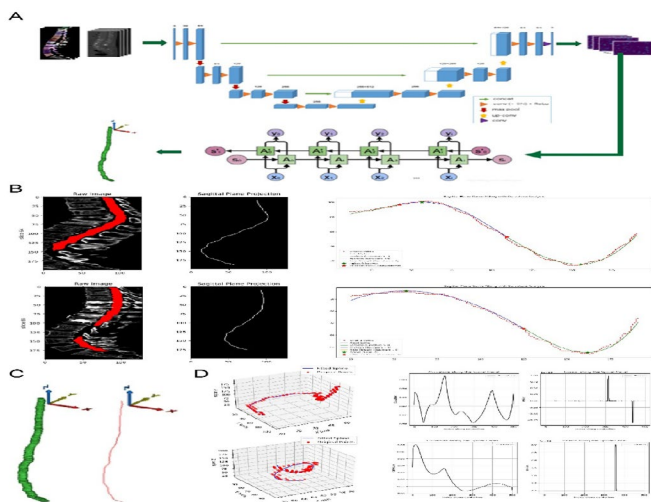
regions. Skip connections use deformable attention to align multi-scale features guided by vertebral coordinates. A BiConvLSTM enforces long-range axial continuity and reduces fragmentation. After segmentation, a B-spline is fitted to the cord centerline, and curvature/torsion are computed to quantify surgical correction.

### Results:

Validated on 120 patients (240 pre/post-op CTs), AP-DADNet achieved a test-set Dice of 0.88—12.7% higher than baseline U-Net—markedly reducing segmentation discontinuities and false positives. Curvature and torsion from B-spline centerlines captured pre-/postoperative morphological differences, supporting the effectiveness of surgical correction.

### Conclusion:

This study achieves high-precision three-dimensional reconstruction of the spinal cord from metal-artifact-affected CT in patients with spinal deformity. The anatomically driven dynamic fusion mechanism represents a new segmentation paradigm. Surgery-induced morphological changes are quantified using differential-geometry metrics, enabling interpretable, patient-specific planning. Future work will integrate biomechanical simulation to support outcome prediction.



Analysis of Spinal Cord Segmentation and Centerline Extraction with the AP-DADNet Framework

### Paper #47. Automated Computer Vision Model Reveals Hidden Disability Predictors From Standing Radiographs in Adult Spinal Deformity

*Tej Azad, MD; Anmol Warman; Swapnil Bhat; Devansh Lalwani; Ahmed Sulieman, MD; Liam Hughes, MD; Amit Jain, MD, MBA; Munish C. Gupta, MD, MBA; Khaled M. Kebaish, MD; Christopher P. Ames, MD*

### Hypothesis:

Computer vision (CV) applied to standing radiographs outperforms spinopelvic metrics in classifying preoperative disability in ASD.

### Design:

Retrospective multi-center cohort.

### Introduction:

New radiographic parameters (e.g., T4-L1-Hip, PI-LL) are proposed to align with PROs in ASD, but limitations remain. We hypothesize that CV can identify radiographic features correlating with PROs more effectively than legacy spinopelvic metrics.

### Methods:

We retrospectively analyzed 316 ASD patients from three centers. Disability was measured by ODI, dichotomized 0–40 vs 41–100. A deep learning approach using a ResNet-based convolutional neural network was applied to non-annotated preoperative radiographs (Fig 1A) to classify ODI. A reader study using 2 independent reviewers was conducted to determine if CV-based heatmaps could predict one-year clinical improvement in ODI following surgery.

### Results:

In the primary prediction task (ODI  $\leq 40$  vs  $>40$ ), the CV model achieved accuracy 0.81 [0.78-0.82], precision 0.80 [0.79-0.84], recall 0.75 [0.73-0.77], F1 0.77 [0.74-0.79], and AUROC 0.88. In contrast, a logistic regression model with standard spinopelvic parameters (SRS-Schwab) had an AUROC 0.62. Even when augmented with Gradient boosted trees machine learning models, legacy spinopelvic measures had a lower performance (accuracy = 0.65, precision = 0.67, recall = 0.78, F1 = 0.71). In a blinded reader study of class-activation maps, cases with “positive” heatmaps (i.e., localized to the spinopelvic region) had greater improvement in functional outcomes ( $\Delta$ ODI  $-18$  vs  $-13$ ,  $P = 0.005$ , Fig 1B-C); effects were larger in the baseline ODI  $>40$  subgroup ( $28$  vs  $42$ ;  $\Delta$ ODI  $-26$  vs  $-14$ ;  $P < 0.001$ ).

### Conclusion:

An automated CV approach outperformed legacy spinopelvic parameters in predicting preoperative ODI. Further, the CV approach identified patients whose disability responded more aptly to surgical realignment. CV may unlock hidden radiographic features to inform surgical planning and patient counseling.

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### Paper #48. Machine Learning (ML) in Intraoperative Neuromonitoring (IONM): Updated Model Integrating Hemodynamic Data Detects Changes 35 Minutes Earlier Than Clinical Teams

*Varun Arvind, MD, PhD; Mehdi Elfilali, BA; Madeline C. Monness, BSA; Erik Williams, BS; Miles Bomback, BA, MPH; Alexander Park, BS; Michael W. Brown, BS; Omar Taha, BS; Matthew Weintraub, BS; Teeda Pinyavat, MD; Anil Mendiratta, MD; Michael G. Vitale, MD, MPH*

#### Hypothesis:

We hypothesize that an updated machine learning (ML) model integrating hemodynamic and intraoperative neuromonitoring (IONM) data will detect neurologic changes preceding clinical teams.

#### Design:

IONM and hemodynamic data from pediatric spine surgeries at a single high-volume center were retrospectively analyzed.

#### Introduction:

IONM improves safety during pediatric 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 such as heart rate (HR) and mean arterial pressure (MAP). Previously, our ML model trained strictly on motor-evoked potentials (MEPs) detected changes 23 minutes earlier than clinical teams. This study evaluates an updated ML model that integrates HR and MAP data to predict neurological injury.

#### Methods:

A patient-specific ML model was trained on baseline MEPs, MAP, and HR data to identify changes during surgery. The model continuously analyzed intraoperative 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.

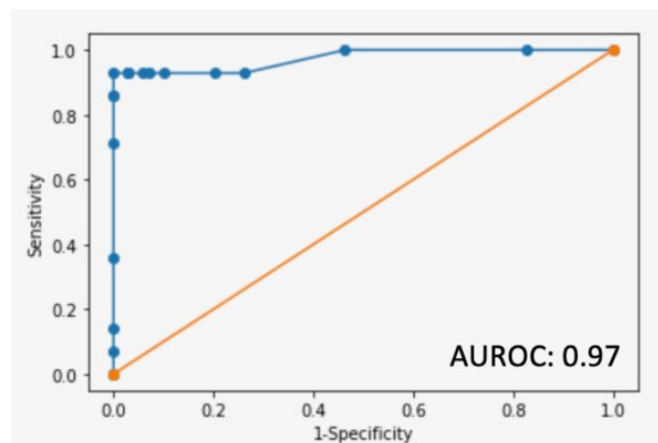
#### Results:

Data from 84 patients (51 female, 33 male; mean age at surgery 14.2 years) were included. Surgical interventions included 79 fusions, 2 magnetically controlled growing rod, 2 Shilla, and 1 traditional growing lengthening. Fourteen patients experienced MEP signal changes, 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, offering standardized IONM interpretation and integration of hemodynamic factors, demonstrated significant early detection of IONM changes, overwhelmingly preceding clinical alerts. Its high AUC, sensitivity, and negative predictive value suggest potential for real-time support during pediatric spine surgery.



### Paper #49. Predicting Non-Idiopathic Scoliosis from Plain Radiographs: A Deep Learning Approach

*Kellen Mulford, PhD; Hans Nugraha, MD; Julia Todderud, BS; Andrew Pumford, BA; Todd A. Milbrandt, MD, MS; A. Noelle Larson, MD*

#### Hypothesis:

A newly-developed deep-learning (DL)-based image-classifier will demonstrate superior performance in radiographic classification of scoliosis etiology compared to experienced spine surgeons based on spine radiographs.

#### Design:

Training, validation, and testing from a retrospective cohort

#### Introduction:

The etiology of scoliosis ranges from idiopathic, congenital, to those with spinal cord abnormalities. Each needs specific and timely management to optimize treatment.

#### Methods:

1,036 pediatric patients at a single institution with a scoliosis diagnosis and paired AP-lateral images from the same visit were included. Patients were manually classified based on their scoliosis etiology from chart review, including previous spine imaging studies when available. Categories included idiopathic, con-

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genital, and scoliosis related to spinal cord pathology. Images were then randomized & assigned for training, validation, and testing. A DL classifier using the EfficientNetB4 architecture was trained on the paired radiographs. Accuracy and positive predictive value as defined by precision, recall, and F1score were calculated to assess final performance metrics.

## Results:

The trained classifier performed very well in identifying the correct scoliosis etiology. It achieved an F1-Score of 0.97, which combines both precision (how often model's positive predictions were correct) and recall (how well model identified all actual cases). An F1 Score of 0.97 means the model was highly accurate. The model's F1-score was 0.99 for AIS, 0.89 for congenital cases, and 0.78 for spinal-cord-pathology-related cases. When compared to 2 experienced spine surgeons, the model performed better. It achieved precision, recall, and F1 Scores of 0.96, showing consistent accuracy across all categories. In comparison, Surgeon 1 had a precision of 0.80, recall of 0.79, and F1 Score of 0.79. Surgeon 2 had lower values, with a precision of 0.76, recall of 0.67, and F1 Score of 0.71. Inter-rater variability among surgeons (Cohen's Kappa = 0.40) further highlights the potential for AI to improve diagnostic accuracy.

## Conclusion:

A DL classifier has been trained to a high degree of accuracy to distinguish 3 classes of etiologies for scoliosis on spine radiographs of pediatric patients. The model had superior diagnostic performance compared to experienced spine surgeons. This tool when validated in clinical settings will be valuable as a teaching tool for patients and families.

## Paper #50. Development and Validation of an AI Model for Anatomical Structure Detection in Endoscopic Spine Surgery

Jung Sub Lee, MD, PhD; Yoonjae Cho, MD; Joonyoung Park, MD; Ki Hun Kim, MD; Hansol Kim, MD; Tae Sik Goh, MD, PhD; Ha Young Jo, MD

## Hypothesis:

We hypothesized that an AI-based object detection model trained on multicenter endoscopic video data would achieve clinically acceptable accuracy in localizing and classifying anatomical structures, thereby supporting surgical navigation and reducing intra-operative errors.

## Design:

This was a retrospective, multicenter development and validation study. Videos from 112 patients undergoing endoscopic spine surgery were analyzed. One frame per 300 was extracted to construct a representative dataset, which was divided into training and validation cohorts in a 4:1 ratio. Key anatomical structures were manually annotated by spine surgeons.

## Introduction:

Endoscopic spine surgery relies on precise identification and differentiation of anatomical structures. To support this, we developed an AI-based object detection model capable of accurately distinguishing structures in spine scope videos.

## Methods:

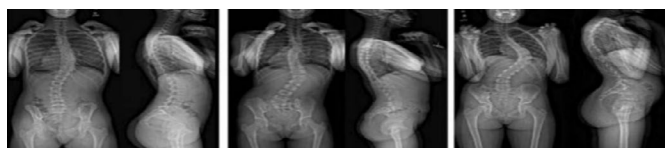
Annotated frames were used to train the AI detection model. Performance was evaluated on the validation dataset using Intersection over Union (IoU) for localization accuracy and Mean Average Precision (mAP) for classification performance.

## Results:

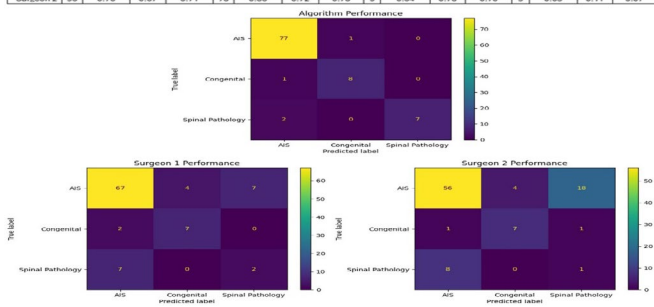
The model achieved an average IoU of 0.753 and mAP of 0.857, confirming its ability to reliably localize and classify anatomical structures. The inclusion of multicenter data improved generalizability across diverse imaging conditions.

## Conclusion:

The proposed AI model accurately detects anatomical structures in endoscopic spine videos. By combining precise localization with robust classification, it demonstrates strong potential for enhancing intraoperative navigation and reducing surgical errors. Future research will focus on real-time clinical integration.



|           | Overall |           |        |          | AIS |           |        |          | Congenital |           |        |          | Spinal Pathology |           |        |          |
|-----------|---------|-----------|--------|----------|-----|-----------|--------|----------|------------|-----------|--------|----------|------------------|-----------|--------|----------|
|           | N       | Precision | Recall | Accuracy | N   | Precision | Recall | F1-Score | N          | Precision | Recall | F1-Score | N                | Precision | Recall | F1-Score |
| Algorithm | 90      | 0.96      | 0.98   | 0.96     | 78  | 0.98      | 0.99   | 0.97     | 9          | 0.89      | 0.88   | 0.89     | 9                | 0.78      | 0.78   | 0.78     |
| Surgeon 1 | 90      | 0.80      | 0.79   | 0.79     | 78  | 0.88      | 0.96   | 0.92     | 9          | 0.64      | 0.78   | 0.70     | 9                | 0.22      | 0.22   | 0.22     |
| Surgeon 2 | 90      | 0.76      | 0.67   | 0.71     | 78  | 0.88      | 0.72   | 0.78     | 9          | 0.64      | 0.78   | 0.70     | 9                | 0.68      | 0.11   | 0.67     |



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### Paper #51. Data-Driven Identification of Spinal Cord Injury Endotypes with Superior Outcomes: Implications for Personalized Care

Michael G. Fehlings, MD, PhD, FRCS(C); Karlo M. Pedro, MD; Mohammed Ali Alvi, MD, PhD, MS

#### Hypothesis:

Integrating fragmented recommendations into a unique phenotype, consensus clustering may offer a novel framework to guide personalized management and future clinical trials in SCI.

#### Design:

Retrospective

#### Introduction:

The management of acute spinal cord injury (SCI) has been shaped by fragmented evidence from independent studies advocating early surgery (<24 hrs), maintenance of mean arterial pressure (MAP) between 75–95 mmHg, and selective corticosteroid use. Whether these practices converge to define a distinct subgroup with superior outcomes has not been established.

#### Methods:

We retrospectively analyzed a pooled cohort of acute SCI patients from four large prospective studies. Acute clinical and management variables including neurological level of injury, baseline ASIA grade, hemodynamics, and timing of surgery and steroids were subjected to cluster ensemble analysis to derive stable patient clusters. Neurological (ASIA motor score) and functional (SCIM) outcomes were assessed at 6 and 12 months. Inter-group comparisons were performed using ANOVA.

#### Results:

A total of 1,048 patients (mean age  $41.80 \pm 17.40$  years, 80% male) were included. Consensus clustering identified four distinct SCI endotypes. Mechanism of injury differed, with motor vehicle crashes predominating in Cluster II (45.2%), falls in Cluster IV (32.7%), and sports-related injuries in Cluster III (6.8%). Cluster II ( $n=217$ ) and Cluster IV ( $n=342$ ) were defined by higher rates of early surgery (65.0% and 71.3%), optimal MAP (44.2% and 52.3%), and greater steroid use within 8 hours (75.1% and 62.9%). These clusters demonstrated significantly greater neurological and functional recovery at both 6 and 12 months compared with Clusters I and III, characterized by delayed surgery, lower MAP, and inconsistent steroid use. At one year, patients in Cluster II and IV achieved higher mean total motor scores (60.8 and 37.5 vs. 65.0 in Cluster I and 34.5 in Cluster III;  $p<0.001$ ) and SCIM scores (71.3 and 40.0 vs. 92.3 and 48.7;  $p<0.001$ ). This subgroup effect was robust across sensitivity analyses.

#### Conclusion:

This study provides the first evidence that the combination of early surgery, MAP optimization, and timely steroid administration defines a distinct SCI subgroup with superior outcomes.

### Paper #52. Alignment Factors Associated with the Need for Revision Extension Surgery to the Sacrum After Previous Lumbar Spinal Fusion

Catherine B. Hurley, MS; Mingxing Fan, BS; Nicolas Carayannopoulos, BS; Jinseong Kim, MD; Zvipo Chisango, BS; Gabriel Gonzalez, BS; Michael Farias, BS; John Czerwein, MD; Bryce A. Basques, MD, MHS; Eren Kuris, MD; Bassel G. Diebo, MD; Alan H. Daniels, MD

#### Hypothesis:

Adult patients undergoing revision lumbar fusion with higher frailty, longer index constructs, and reduced caudal lordosis are more likely to require sacral extension, while closer alignment of L1 pelvic angle (L1PA) to ideal is protective against sacral extension.

#### Design:

Retrospective cohort study.

#### Introduction:

Lumbar fusion is common, with revision rates up to 25.9% within two years. When planning a revision of lumbar fusion, surgeons may extend constructs from L5 to the sacrum to improve stability, decompression, or alignment, but sacral extension alters biomechanics and increases risks such as pseudoarthrosis, adjacent segment disease, and proximal junctional kyphosis. Predictors for sacral extension during revision remain poorly defined.

#### Methods:

Adult patients undergoing anterior or transforaminal lumbar interbody fusion (ALIF or TLIF) between 2017–2022 at a single academic institution, and those referred for revision with sacral extension, were reviewed. Eligible patients had an index fusion spanning L1–L4 to L5 or above. Sacral extension was defined as instrumentation to S1 or the pelvis within two years. Demographics, frailty indices, radiographic parameters, and complications were collected. Operative notes were reviewed to identify indications. Analyses included t-tests, chi-square, and multivariable logistic regression.

#### Results:

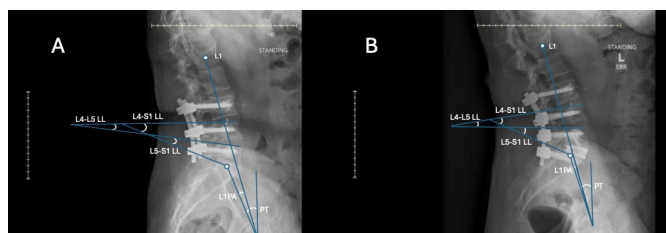
Of 181 patients, 50 (27.6%) underwent SE and 131 (72.4%) remained fused between L1–L5. SE patients had higher frailty scores (MFI-5,  $p=0.018$ ) and lower L4–L5 lordosis ( $p=0.020$ ). Independent predictors for extension included increased frailty (OR 7.015,  $p=0.032$ ), greater fusion length (OR 1.796,  $p=0.012$ ),

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and reduced L4–S1 lordosis (OR 1.137,  $p=0.007$ ). Closer alignment of L1PA to ideal was protective (OR 0.81 per degree,  $p=0.009$ ). Common indications for extension were distal junctional degeneration (58%), foraminal stenosis (40%), and pseudoarthrosis (38%).

### Conclusion:

Frailty, longer constructs, and inadequate caudal lordosis independently predicted sacral extension during revision, while optimal L1PA alignment was protective. The most common indications were distal junctional degeneration, pseudoarthrosis, foraminal stenosis, and spondylolisthesis. These findings may aid preoperative risk stratification and surgical planning.



| Parameter   | Pre-operative Measures | Post-operative Measures | Change |
|-------------|------------------------|-------------------------|--------|
| Pelvic Tilt | 18.4°                  | 14.7°                   | -3.7°  |
| L4-S1 LL    | -29.7°                 | -45.2°                  | -15.5° |
| L4-L5 LL    | -10.0°                 | -8.2°                   | +1.8°  |
| L5-S1 LL    | -19.7°                 | -37.0°                  | -17.3° |
| L1PA        | 4.6°                   | 2.3°                    | -2.3°  |

Case example of sacral extension during revision lumbar fusion with net improvement in caudal lordosis and L1PA.

### Paper #53. The Relative Weight of the Most Common Biological Factors in Predicting Adverse Events after Adult Spinal Deformity Surgery

Javier Pizones, MD, PhD; Alejandro Gomez-Rice, MD, PhD; Lucia Moreno-Manzanaro, BS; Susana Nunez Pereira, MD, PhD; Sleiman Haddad, MD, PhD, FRCS; Anika Pupak, PhD, BS; Yann Phillippe Charles, MD, PhD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD; Ahmet Alanay, MD; Ferran Pellise, MD, PhD

### Hypothesis:

Frailty is the strongest predictor of complications following Adult Spinal Deformity (ASD) surgery, compared to other biological factors.

### Design:

Retrospective multicenter observational study

### Introduction:

Biological factors have become vital in predicting complications after ASD surgery. However, the relative contribution of each biological variable to adverse event prediction remains unclear.

### Methods:

We included ASD operated patients, with a minimum 2-year follow-up, and complete biological data. The independent biological variables analyzed

were chronological age, BMI, Charlson Comorbidity Index (CCI), and the ASD-Frailty Index (ASD-FI). We assessed correlations and collinearity (VIF) between these variables. Four postoperative adverse events—major complications, mechanical complications, reinterventions, and readmissions—were selected as dependent variables. Univariate analyses were performed to identify biological risk factors for each event, which were then included in multivariable binary logistic regression models, normalized using min-max scaling.

### Results:

A total of 1,133 patients were included [median age 63 years (49;72), BMI 25 kg/m<sup>2</sup> (22.1;28.5), ASD-FI 0.39 (0.3-0.48), CCI 3 (2-5)]. Frailty distribution was as follows: 20.8% robust, 55.4% prefrail, and 23.7% frail. VIF values (<3) and Spearman R<sup>2</sup> (<0.18) indicated minimal collinearity among age, BMI, ASD-FI, and CCI, with some collinearity between age and CCI (R<sup>2</sup>=0.61, VIF=2.8). All four biological factors were significantly associated with all four adverse events ( $p<0.001$ ) in univariate analyses. In multivariate regression, age, BMI, and ASD-FI were independent predictors for major and mechanical complications ( $p<0.001$ ), while CCI only emerged as an added significant predictor for reinterventions and readmissions. The strongest predictor across all models was chronological age, followed by ASD-FI. However, the overall predictive power of the models was modest, with Pseudo R<sup>2</sup> values <0.1 and AUC values <0.64.

### Conclusion:

Age, BMI, ASD-FI, and CCI measure distinct biological domains with minimal collinearity. All influence the occurrence of adverse events, particularly chronological age, which is a stronger predictor than frailty. This study confirms the importance of biological factors in risk stratification but highlights the need to identify new markers with greater discriminative power.

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Table 1. Multivariate binary logistic regression models for each adverse event

|  | B      | OR    | Wald   | Valor P | CI 95%        |
|--|--------|-------|--------|---------|---------------|
| <b>Major complications</b> (Omnibus 0.000; R2 Nagelkerke 0.082)      |        |       |        |         |               |
| Age norm   | 1.626  | 5.081 | 12.395 | 0.000   | 2.056-12.559  |
| BMI norm   | 1.344  | 3.833 | 8.265  | 0.004   | 1.534-9.581   |
| ASD-FI norm  | 1.532  | 4.626 | 16.001 | 0.000   | 2.184-9.798   |
| <b>Mechanical complications</b> (Omnibus 0.000; R2 Nagelkerke 0.093) |        |       |        |         |               |
| Age norm   | 1.974  | 7.196 | 19.210 | 0.000   | 22.977-17.394 |
| BMI norm   | 1.214  | 3.366 | 7.028  | 0.008   | 1.372-8.258   |
| ASD-FI norm  | 1.343  | 3.829 | 13.073 | 0.000   | 1.849-7.929   |
| <b>Reinterventions</b> (Omnibus 0.000; R2 Nagelkerke 0.075)          |        |       |        |         |               |
| Age norm   | 1.967  | 7.146 | 16.221 | 0.000   | 2.744-18.607  |
| BMI norm   | 1.257  | 3.516 | 6.790  | 0.009   | 1.366-9.051   |
| ASD-FI norm  | 1.407  | 4.083 | 12.530 | 0.000   | 1.874-8.898   |
| CCI norm   | -1.640 | 0.194 | 5.108  | 0.024   | 0.047-0.804   |
| <b>Readmissions</b> (Omnibus 0.000; R2 Nagelkerke 0.093)             |        |       |        |         |               |
| Age norm   | 1.967  | 7.146 | 16.221 | 0.000   | 2.744-18.607  |
| BMI norm   | 1.257  | 3.516 | 6.790  | 0.009   | 1.366-9.051   |
| ASD-FI norm  | 1.407  | 4.083 | 12.530 | 0.000   | 1.874-8.898   |
| CCI norm   | -1.640 | 0.194 | 5.108  | 0.024   | 0.047-0.804   |

OR: odds ratio; CI: confidence interval; norm: min-max standardized values; Age: chronological age; BMI: Body mass index; ASD-FI: Adult Spinal Deformity Frailty Index (Miller); CCI: Charlson comorbidities index.

## Paper #54. Influence of Active Social Life on Patient-Reported Outcome Measures (PROMs) in Patients undergoing Surgery for Complex Adult Spinal Deformity: A Multicenter Propensity Score-Matched Analysis

*Peter G. Passias, MD; Francesca Totis, MD; Kyriakos Chatzis, BS; Oluwatobi Onafowokan, MBBS, MS; Peter Tretyakov, BS; Max Fisher*

### Hypothesis:

To evaluate the impact of active social life on recovery following ASD surgery

### Design:

Retrospective cohort

### Introduction:

The effects of active social life on postop health-related quality of life (HRQL) metrics are understudied and may enhance operative planning and prognostication

### Methods:

Patients were included if T1-pelvic angle  $\geq 30^\circ$ , PI-LL  $\geq 25^\circ$ , or SVA  $> 15$  cm. Active social life (SOC+) was defined as PROMIS Social DSA and Role scores  $> 40$ ; inactive (SOC-) as  $\leq 40$ , with 40 representing 1 SD below the mean. Propensity score matching was applied. PASS thresholds were: subtotal SRS  $> 3.5$ , function  $> 3.3$ , pain  $> 3.5$ , image  $> 3.3$ , mental health  $> 3.8$ ; NRS pain  $\leq 3$ ; PCS  $> 44.6$ ; MCS  $> 43.8$ ; and ODI  $\leq 18$ , per prior research (PMID: 32189123)

### Results:

272 patients included after PSM (n=136 each). Both cohorts homogenous in demographics (age, gender & BMI, all  $p > 0.05$ ), deformity (PI-LL, SVA, PT, all  $p > 0.05$ ) and surgical invasiveness (mean fused levels, osteotomy frequency, blood loss, all  $p > 0.05$ ).

Adverse events up to 2 years postop did not differ significantly. SOC- generally had worse scores in all HRQLs at baseline (Table 1). SOC- also maintained inferior HRQL scores at 2 years postoperatively (Table 1). There were no differences between groups in achievement of the minimum clinically important difference in ODI or SRS-22 improvement. Logistic regression analyses revealed SOC+ demonstrated higher odds of achieving PASS in all SRS-22 domains: SRS total (OR 2.71, 1.02-7.18,  $p=0.046$ ), Pain (7.50, 2.61-21.57,  $p < 0.001$ ), Function (4.61, 1.69-12.56,  $p=0.003$ ), Image (3.56, 1.33-9.55,  $p=0.012$ ) and Mental Health (4.77, 1.75-12.95,  $p=0.002$ ). SOC+ also had higher odds of achieving substantial clinical benefit in ODI at 2 years (OR 3.68, 1.32-10.25,  $p=0.013$ )

### Conclusion:

Despite no differences deformity and adverse event rates, patients with active social lives demonstrate superior HRQL metrics postop. Social support is a potentially modifiable factor for optimizing outcomes in complex adult spinal deformity (ASD) patients

## Paper #55. Surgeon Cognitive Load While Inserting Pedicle Screws: Results from a Prospective Study

*Patrick Cannon; Bruce Robie; Annalisa Michielli; Timothy Minogue; Daniel O'Connor*

### Hypothesis:

Using active robotic-assisted guidance for percutaneous pedicle screw placement may reduce cognitive load for spinal surgeons, leading to an improved functional work experience.

### Design:

Six fellowship-trained spine surgeons took part in the study, each implanting 24 pedicle screws percutaneously in a porcine thoracolumbar specimen. Each surgeon performed 3 workflows (fluoroscopic guidance alone, Freehand Navigation, & Active Robotic-Assisted Guidance), implanting 8 screws in 4 vertebral bodies for each workflow.

### Introduction:

This study was to quantitatively measure surgeon cognitive load during pedicle screw placement. Previous research has shown that cognitive load is associated with increased blood flow & increased oxyhaemoglobin (HbO) in the blood of the prefrontal cortex. Measurement of these factors is possible using skin sensors, enabling in vivo estimation of cognitive load while subjects conduct a variety of activities.

### Methods:

Cognitive load was measured using functional near-infrared spectroscopy (fNIRS) to analyse HbO & HbR (deoxyhaemoglobin) in the prefrontal cortex of

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surgeons as they placed pedicle screws. The following outcomes were collected for each screw: Peak Oxygenation (sum of 5 max OXY peaks (OXY = HbO - HbR)), Duration-dependent Oxygenation (integrated oxygenation over time), Average Oxygenation (duration-dependent oxygenation ÷ duration), & Peak Total Haemoglobin (sum of 5 max HbT peaks (HbT = HbO + HbR)). Statistical analyses was performed for the outcomes using ANOVA with a generalized linear model, including workflow & surgeon. Post-hoc analyses were conducted using Tukey's Honest Significant Difference (HSD) tests, comparing fluoroscopic (baseline) to the other workflows.

### Results:

Workflow was a significant predictor for all four outcomes measured. The Active Robotic-Assisted Guidance workflow resulted in the lowest mean values, & all metric outcomes were significantly less than those for the fluoroscopic guided workflow, indicating significantly less cognitive load, shown in Figure 1. The Freehand Navigation workflow resulted in significantly lower mean values than the fluoroscopic guided workflow for 3 of the 4 outcomes.

### Conclusion:

Under simulated operative conditions, this study shows that active robotic-assisted guidance reduces cognitive load required for percutaneous pedicle screw placement compared to fluoroscopic guidance.

### Hypothesis:

CT-F requires a longer registration time than S&P, and is also longer when curve magnitude  $\geq 80^\circ$ .

### Design:

Prospective cohort

### Introduction:

Robotics coupled with navigation (RCN) is an emerging technology for pedicle screw placement in pediatric spine surgery. Registration for RCN, achieved by merging pre-op CT to intraoperative fluoroscopy (CT-F) or by intraoperative pulsed fluoroscopy with screw planning (Scan & Plan, S&P), is defined as the time from when the robotic arm begins surveying to when the imaging device is removed. Larger Cobb angles increase the complexity of RCN surgeries, yet little is known about the efficiency of these two registration techniques across varying Cobb angles. We compared registration times for CT-F and S&P and the effect of curve magnitude in patients with Cobb angles above and below  $80^\circ$ .

### Methods:

All pediatric RCN posterior spinal fusions from a prospective multi-center database performed from 2021–2025 were reviewed. Data included demographics, pre-operative curve magnitude, registration method, and registration time. Patients were grouped by curve magnitude ( $<80^\circ$  vs.  $\geq 80^\circ$ ), and registration methods were compared across and within these groups. Statistical significance was defined as  $p < 0.05$ .

### Results:

There were 306 RCN posterior spinal fusions. The cohort averaged 16.1 years ( $\pm 3.2$ ) and was 64% female. Pre-operative curves were  $<80^\circ$  in 251 patients and  $\geq 80^\circ$  in 55. Registration methods included 198 S&P and 108 CT-F cases. Overall registration time trended shorter with CT-F than S&P ( $15.2 \pm 11.5$  vs.  $17.8 \pm 12.4$  minutes,  $p = 0.065$ ). Registration for S&P trended longer in curves  $\geq 80^\circ$  versus  $<80^\circ$  ( $p = 0.055$ ), but CT-F showed no difference ( $p = 0.136$ ). When analyzing average time per individual registration, CT-F was significantly shorter than S&P ( $10.4 \pm 7.2$  vs.  $15.4 \pm 7.1$  min,  $p < 0.001$ ). Within CT-F, curves  $\geq 80^\circ$  trended longer than  $<80^\circ$  ( $11.7 \pm 5.8$  vs.  $10.1 \pm 7.5$  min,  $p = 0.366$ ), and within S&P, curves  $\geq 80^\circ$  also trended longer ( $17.4 \pm 10.4$  vs.  $14.9 \pm 6.1$  min,  $p = 0.178$ ).

### Conclusion:

In this multi-institutional study of 306 robotic-assisted scoliosis surgeries, both registration method and curve magnitude influenced registration time. CT-F trended faster than S&P overall and was significantly shorter per registration. Curves  $\geq 80^\circ$  trended

### Concentration of Hemoglobin in the Prefrontal Cortex

- observed reductions from fluoroscopic baseline -

| Measurement                    | Active                    |                     |
|--------------------------------|---------------------------|---------------------|
|                                | Robotic-Assisted Guidance | Freehand Navigation |
| Peak Oxygenation (OXY)*        | 28%, $p < 0.001$          | 21%, $p < 0.05$     |
| Duration-dependent Oxygenation | 36%, $p < 0.002$          | 31%, $p < 0.005$    |
| Average Oxygenation per Second | 20%, $p < 0.01$           | 14%, NS             |
| Peak Total Hemoglobin (HbT)*   | 39%, $p < 0.001$          | 37%, $p < 0.001$    |

\*Sum of five maximum OXY peaks (OXY = HbO - HbR). Sum of five maximum HbT peaks (HbT = HbO + HbR). NS: Not Statistically Significant.

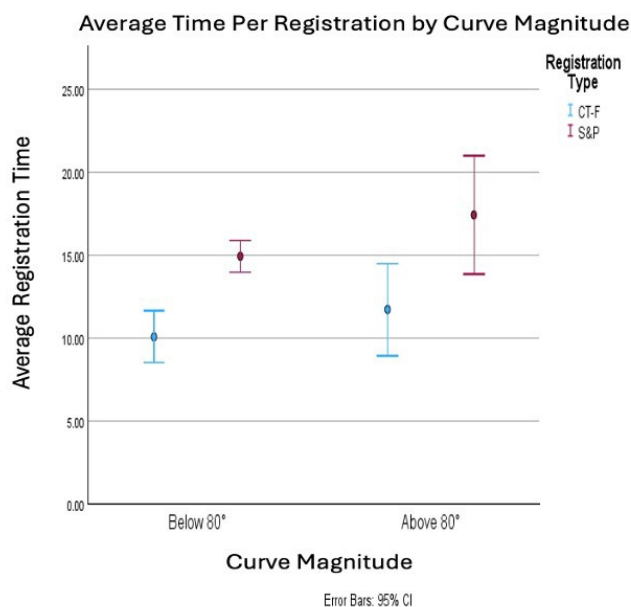
Figure 1

### Paper #56. Registration Times Differ Significantly Comparing Two Registration Techniques in Robotic Pediatric Spine Surgery

Robert F. Murphy, MD; Margaret L. Sullivan, BS; Mackenzie Morris, BS; Craig Birch, MD; Roger F. Widmann, MD; Jessica Heyer, MD; Kirsten E. Ross, MD; Dennis P. Devito, MD; Shanika De Silva, PhD, MS; M T. Hresko, MD; Grant D. Hogue, MD; Daniel J. Hedequist, MD

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to prolong registration with both methods, without significance.



Average time per registration for each technique across curve magnitudes

### Paper #57. Robotic Pediatric Spinal Fusion with Large Coronal Curves

Margaret L. Sullivan, BS; Mackenzie Morris, BS; Grant D. Hogue, MD; Craig Birch, MD; M T. Hresko, MD; Mark A. Erickson, MD; Roger F. Widmann, MD; Jessica Heyer, MD; Dennis P. Devito, MD; Robert F. Murphy, MD; Kirsten E. Ross, MD; Shanika De Silva, PhD, MS; Daniel J. Hedequist, MD

#### Hypothesis:

For severe coronal deformities, registration and screw placement with robotics-coupled with navigation (RCN) will be more extensive and complex but will remain a safe tool for pediatric posterior spinal fusion (PSF).

#### Design:

Prospective Multicenter Registry

#### Introduction:

RCN is increasing in prevalence for pedicle screw placement in PSF. Previous studies demonstrate that larger baseline major Cobb angles increase the likelihood of an intraoperative RCN technical difficulty. This multi-institutional, prospective study is the first to examine the impact of preoperative coronal Cobb angle on the use of RCN in pediatric spinal deformity.

#### Methods:

Data from a prospective national registry from 2021-2024 was reviewed. Patients with coronal spinal deformity with RCN-assisted PSF were included. RCN

registration metrics were compared across patients with major Cobb  $<90^\circ$  and  $\geq 90^\circ$  using Wilcoxon rank sum tests and chi-squared tests, as appropriate. Intraoperative metrics, RCN technical difficulties and postoperative complications were compared using generalized estimating equation (GEE) models to account for potential confounders in age, sex, BMI, comorbidities and diagnosis.

#### Results:

Of 500 patients, 53 (11%) had Cobb angles  $\geq 90^\circ$ . This group was significantly younger with a median age of 14 vs. 15 years in the  $<90^\circ$  group ( $p=0.007$ ), and had increased neuromuscular etiology, comorbidities, and impaired neurologic status (all  $p<0.001$ ). BMI was comparable across groups. Patients in the  $\geq 90^\circ$  group were more likely to require multiple RCN registrations ( $p=0.003$ ). The median registration time was significantly longer in the  $\geq 90^\circ$  group (22 minutes), vs. the  $<90^\circ$  group (15 minutes,  $p<0.001$ ). While the number of RCN screws was similar, median time for RCN screw placement was longer in the  $\geq 90^\circ$  group (47 minutes vs. 29 minutes,  $p=0.002$ ). After controlling for confounders, the prevalence of RCN-related technical difficulties did not significantly differ between groups. However, blocked or inaccessible trajectories were more common in the  $\geq 90^\circ$  group (25%) compared to  $<90^\circ$  group (9%,  $p<0.001$ ). Perioperative complications were comparable across groups after adjusting for confounders ( $p>0.05$ ). No instances of RCN-related deficit or long-term complications were observed in either group.

#### Conclusion:

RCN use in PSF for patients with major Cobb angles  $\geq 90^\circ$  is associated with longer registration time and more frequent trajectory challenges but maintained an excellent safety profile.

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**Table 1:** Technical difficulties, stratified by Cobb angle group

| Technical difficulty                  | Unadjusted Frequency (%) |                         | Estimated Proportions (95% CI) <sup>3</sup> |                        | p <sup>1</sup> | Adjusted p <sup>2</sup> |
|---------------------------------------|--------------------------|-------------------------|---|------------------------|----------------|-------------------------|
|                                       | Cobb angle <90° (N=447)  | Cobb angle ≥ 90° (N=53) | Cobb angle <90° (N=447)                     | Cobb angle ≥90° (N=53) |                |                         |
| <b>Technical difficulty</b>           | 137 (31%)                | 23 (43%)                | 29% (16%, 46%)                              | 36% (18%, 59%)         | 0.278          | 0.878                   |
| <b>Type of technical difficulty</b>   |                          |                         |   |                        |                |                         |
| Loss of calibration                   | 40 (9%)                  | 5 (9%)                  | 8% (5%, 23%)                                | 8% (2%, 26%)           | 0.913          |                         |
| Loss of registration                  | 33 (7%)                  | 5 (9%)                  | 7% (4%, 13%)                                | 9% (6%, 14%)           | 0.057          |                         |
| Inability to perform trajectory       | 43 (10%)                 | 14 (26%)                | 9% (5%, 15%)                                | 25% (15%, 37%)         | <0.001         |                         |
| Screw malposition                     | 24 (5%)                  | 2 (4%)                  | 6% (4%, 8%)                                 | 4% (0.3%, 29%)         | 0.721          |                         |
| Dural Leak                            | 1 (0%)                   | 1 (2%)                  | 0.3% (0.1%, 1%)                             | 2% (0.4%, 10%)         | 0.188          |                         |
| System malfunction/registration delay | 24 (5%)                  | 6 (11%)                 | 5% (3%, 9%)                                 | 11% (2%, 38%)          | 0.333          |                         |
| Robot aborted                         | 12 (3%)                  | 2 (4%)                  | 3% (2%, 4%)                                 | 4% (2%, 8%)            | 0.422          |                         |

<sup>1</sup>p-value for the association between Cobb angle and technical difficulties are estimated from a univariate GEE (accounting for site).

<sup>2</sup>Multivariable model for technical difficulty adjusting for age, sex, BMI, diagnosis, comorbidities, and implant density.

<sup>3</sup>Presented as adjusted estimated proportions for occurrence of technical difficulty and unadjusted proportions for type of technical difficulties.

## Paper #58. Be Careful What You Ask For: Few Patients Meet Mean Arterial Pressure (MAP) Goals After Intraoperative Neuromonitoring (IONM) Changes During Pediatric Scoliosis Surgery

*Michaela O'Connor, MD; Michael W. Brown, BS; Mehdi Elfilali, BA; Alexander Park, BS; Joshua Choi, MHA; Josephine R. Coury, MD; Benjamin D. Roye, MD; Michael G. Vitale, MD, MPH*

### Hypothesis:

Patients will spend <20% of the time below target mean arterial pressure (MAP).

### Design:

Single-center, retrospective review of patients who underwent spine surgery with intraoperative neuro-monitoring (IONM) changes between 2023 and 2025.

### Introduction:

Patients with IONM changes during spine surgery are vulnerable to hypotension as their spinal cord has demonstrated sensitivity to correction, and hypotension may exacerbate areas of inadequate perfusion. Because of this, these patients are admitted postoperatively to the ICU for close neurologic monitoring and blood pressure management. This study evaluated adherence to patient-specific MAP goals in the first 24 hours postoperatively.

### Methods:

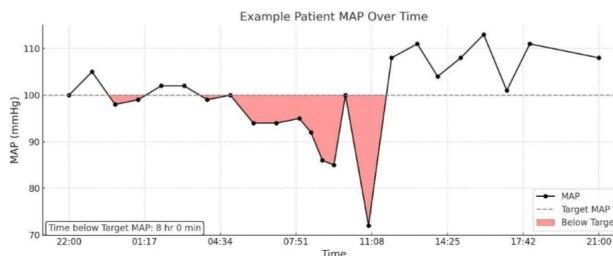
Demographic and radiographic data were documented. Per protocol, individual 'Target MAP' goals were established for 24 hours following surgery. Arterial line MAP values during this period were collected. Hypotension was defined as <5th percentile MAP according to normative age-based charts.

### Results:

Twenty-one patients (57% female; mean age 14.3 ± 2.6 years) were included. Etiologies were 8 idiopathic, 6 neuromuscular, 5 congenital, and 2 syndromic patients. Mean pre- and post-operative major Cobbs were 79 ± 22° and 38 ± 16°, respectively, with an average correction of 56 ± 11% in completed cases (n=17). Surgery was aborted in four patients. Mean EBL was 530 ± 360 mL and 17 patients (81%) underwent transfusion. Four patients (19%) did not return to neurologic baseline intraoperatively. However, the entire cohort returned to baseline neurologic function in the ICU. The median MAP goal was >80 mmHg (range >60 to >100). Twenty patients (95%) did not meet their goal, defined as ≥1 instance of MAP beneath target. Seven patients' (33%) 24-hour average MAPs were below target. On average, patients spent 27% of the time (6.4 hours) beneath target. Four patients (19%) had a period of hypotension.

### Conclusion:

Despite ICU-level care in critical patients with IONM deficits, 95% of patients failed to meet MAP targets in the first 24 hours after spine surgery. Additionally, 19% had hypotension well below their physiologic MAP for end organ perfusion. This is the first study to highlight this crucial gap between management goals and postoperative hemodynamic adherence. Standardized protocols across interdisciplinary ICU teams may improve adherence and mitigate risk.



## Paper #59. Efficacy of Multimodal Intraoperative Neuromonitoring in Pediatric Spinal Deformity Surgery: A 39-Year Comparative Analysis

*Gabrielle Rogie, MD, MEng; Hilton C. Braithwaite IV, BS; Leah Rakers, MBS, CNIM; Scott J. Luhmann, MD*

### Hypothesis:

Advances in intraoperative neuromonitoring (IONM), anesthesia, and surgical technique since 2008 have improved the efficacy of multimodal IONM in reducing neurologic complications during pediatric spinal deformity surgery.

### Design:

Retrospective comparative cohort study

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## Introduction:

Multimodal intraoperative neuromonitoring (IONM) is standard in pediatric spinal deformity surgery to mitigate neurologic risk. A 2010 single-institution study demonstrated efficacy in 3436 patients (1985–2008). Since then, advances in technology, anesthesia, and surgical technique could impact outcomes. This study compared IONM and neurologic outcomes from 2008–2024 with 1985–2008.

## Methods:

A review was conducted of 3,316 consecutive pediatric spinal deformity surgeries (2008–2024) at a single institution. Neuromonitoring modalities included somatosensory evoked potentials (SSEP), transcranial electrical motor evoked potentials (TCeMEP), and descending neurogenic evoked potentials (DNEP).

## Results:

The 2008–2024 cohort (66% female) was demographically comparable to 1985–2008 (64% female). Alerts were more frequent in 2008–2024—135 cases (4.1%, 1 in 24) versus 74 (2.2%, 1 in 46). Highest alert rates were in kyphosis/kyphoscoliosis (14.8% vs. 9.3%; NS) and revision procedures (9.5% vs. 3.0%;  $p=0.0027$ ). Most alerts occurred during correction/instrumentation (62.2% vs. 47%) and osteotomy/decompression (25.9% vs. 14%). Alert modalities shifted: TCeMEP alone accounted for 43.7% versus 1.5%, while SSEP-only declined (10.4% vs. 35%) and DNEP-only decreased (17.8% vs. 33.5%). Permanent neurologic deficits were more common recently: 16 patients (0.48%, 1 in 207) versus 6 (0.17%, 1 in 573). False negatives occurred at similar frequencies (0.15% vs. 0.2%) but were more consequential, with 80% resulting in permanent deficits versus 14% previously. Despite shifts, IONM maintained protective value, lowering permanent deficit risk from 4.1% to 0.48%, nearly a ten-fold reduction (1985–2008: 2.2% down to 0.17%; 13x decrease).

## Conclusion:

Multimodal IONM provides substantial neurologic protection in pediatric spinal deformity surgery, reducing permanent deficits from 4.1% to 0.48%. However, the recent era showed more alerts and higher deficit rates. False negatives, particularly nerve root-related, remain a key limitation.

| Category   | 1985–2008 (n=3436)  | 2008–2024 (n=3316)  |
|--|---|---|
| <b>Demographics</b>                                |   |   |
| Male / Female / Other                              | 1220 / 2216 / —   | 1139 / 2174 / 3   |
| Age Range  | 13 mo – 18 y  | 25 mo – 18 y  |
| <b>Overall Alerts</b>                              |   |   |
| Total Alerts                                       | 74 (2.2%, 1 in 46)  | 135 (4.1%, 1 in 24)   |
| Leading Surgical Causes                            | Correction 47%,<br>Osteotomy/Decompression 14%, Hypotension 15% | Correction 62.2%,<br>Osteotomy/Decompression 25.9%,<br>Hypotension 2.2% |
| <b>By Diagnostic Subgroup (top three)</b>          |   |   |
| Idiopathic Scoliosis                               | 1618 pts → 12 alerts (0.7%)                                     | 1835 pts → 43 alerts (2.3%) + 4 FN (0.22%)                              |
| Kyphosis/Kyphoscoliosis                            | 226 pts → 21 alerts (9.3%) + 1 FN (0.4%)                        | 270 pts → 40 alerts (14.8%)   |
| Revision   | 329 pts → 10 alerts (3.0%) + 1 FN (0.3%)                        | 211 pts → 20 alerts (9.5%) + 1 FN (0.47%)                               |
| <b>Alert Modalities (top three)</b>                |   |   |
| SSEP only  | 35%   | 10.4%   |
| DNEP only  | 33.5%   | 17.8%   |
| SSEP + DNEP  | 27%   | 18.8%   |
| <b>Neurologic Outcomes &amp; Protective Effect</b> |   |   |
| Transient Deficits                                 | Not consistently tracked  | 3 (0.09%)   |
| Permanent Deficits                                 | 6 (0.17%, 1 in 573)   | 16 (0.48%, 1 in 207)  |
| False Negatives                                    | 7 (0.2%, 1 permanent = 14%)                                     | 5 (0.15%, 4 permanent = 80%)  |
| Relative Risk Reduction                            | 2.2% → 0.17% (~13x reduction)                                   | 4.1% → 0.48% (~10x reduction)   |

DNEP indicates descending neurogenic-evoked potentials; SSEP, somatosensory-evoked potential; Pts, patients; FN, false negative

Table: Direct Comparisons of the Two Eras

## Paper #60. Intraoperative Neuromonitoring (IONM) Alerts in Severe Spinal Deformity Corrections with Baseline Neurodeficit – Are They Different from Those Without – Results from International Multicenter Prospective Spinal Deformity Intraoperative Monitoring (SDIM) Study

Saumyajit Basu, MS (Ortho), DNB (Ortho), FRCS (Ed); Stephen J. Lewis, MD, FRCS(C); Yong Qiu, PhD; Ferran Pellise, MD, PhD; Ahmet Alanay, MD; Justin S. Smith, MD, PhD; Go Yoshida, MD, PhD

## Hypothesis:

The characteristics of IONM alerts in spinal deformity surgery are different in patients with or without a baseline neurodeficit

## Design:

Post-hoc analysis of data from prospective, international multicentric cohort study

## Introduction:

Preexisting neurological deficit can be a risk factor in deformity surgery, however detailed analysis of this patient population has not been reported earlier. edit

## Methods:

20 international centers prospectively documented the demographics, radiographic findings, and surgical events of patients undergoing spinal deformity correction (major Cobb >80°) with EMG, SSEP and MEP monitoring. Detailed neurological examination was performed at baseline, immediately post-op and prior to discharge from hospital. IONM alert was defined as a loss of amplitude of >50% in SSEP or MEP from baseline or sustained EMG activity that lasts > 10 seconds. Post-hoc analysis of patients with baseline neurologic deficit vs patients with normal neurological status was performed.

## Results:

546 patients were analysed - 477 had no deficit (ND) or an isolated sensory deficit and 69 had motor

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deficits (D) of which 45 were isolated motor and 24 combined motor and sensory. There was significant difference ( $p < 0.001$ ) in baseline MEPs and SSEPs, which was decreased or absent in 3.1% and 2.1% in ND and 18.8% and 14.1% in D patients. 66 (13.9%) of patients in ND had a total of 90 alerts during surgery, and 12 (17.4%) in D had 15 alerts. LEMS score from baseline to postop worsened in 8.4% in ND versus 21.7% in D ( $p < 0.01$ ). Decline in neurological status from baseline to discharge was recorded in 5.9% in ND versus 23.2% in D ( $p < 0.001$ ). Surgical events were identified as potential causes in 68 alerts out of 90 in ND and 10 out of 15 in D ( $p = 0.4$ ) with osteotomy and rod insertion being the most frequent cause in both groups. In D patients, 11 out of 15 alerts fully recovered to baseline, 3 did not and 1 recovered only partially. edit

### Conclusion:

Patients with preoperative motor deficits had a higher rate of decreased or absent baseline MEP and SSEP signal and a higher rate of neurological deterioration after surgery. The difference in the rate of alerts was most significant with osteotomy and rod insertion being the most frequent surgical cause of alerts in both groups.

### Paper #61. Impact of GLP-1 Receptor Agonists on Pseudarthrosis Following Spinal Fusion Surgery

*Siraj Shaikh, MD; Daniel Coban, MD; George Abdelmalek, MD; Mohammed T. Younis, BS; Adam Elkholy, BS; Nikhil Sahai, MD; Kumar Sinha, MD; Ki S. Hwang, MD; Arash Emami, MD*

### Hypothesis:

Patients receiving GLP-1 receptor agonists will have lower rates of pseudarthrosis following spinal fusion surgery compared with non-users.

### Design:

Systematic review and meta-analysis.

### Introduction:

Spinal fusion is a common treatment for degenerative spinal disease, but outcomes may be limited by complications such as pseudarthrosis. With the increasing use of glucagon-like peptide-1 receptor agonists (GLP-1s), particularly semaglutide, there is growing interest in their influence on fusion outcomes. While individual studies suggest possible benefits, findings remain heterogeneous and no synthesis of the literature currently exists.

### Methods:

A comprehensive search of PubMed, Embase, Scopus, and Cochrane identified 14 studies reporting on GLP-1 use in spinal fusion. Data were extracted on study design, cohort size, spinal procedure, GLP-

1 agent, and reported outcomes. Risk of bias was assessed using ROBINS-I, and certainty of evidence graded with GRADE. A random-effects meta-analysis was conducted to assess pseudarthrosis risk.

### Results:

Twelve retrospective cohorts (~15,000 patients) were included. Many cervical and lumbar studies reported reduced pseudarthrosis and higher fusion success with GLP-1 use. Some perioperative analyses described shorter hospital stay and lower complication rates. In contrast, procedure-specific TLIF and posterior cervical cohorts reported increased reoperation and medical complications (e.g., anemia, AKI, pneumonia). No study was rated low risk of bias; most were moderate, and two were serious. Certainty of evidence was low for pseudarthrosis and length of stay, and very low for complications, readmissions, and reoperations. Meta-analysis of six studies found no overall association between GLP-1 use and pseudarthrosis (pooled OR 0.90, 95% CI 0.54–1.51;  $I^2 = 87\%$ ). Heterogeneity was driven by one cervical cohort reporting increased risk. Excluding this outlier, GLP-1 use was significantly associated with reduced pseudarthrosis (pooled OR 0.68, 95% CI 0.59–0.78;  $I^2 = 21\%$ ), with consistent benefit across lumbar cohorts at 6 months, 1 year, 2 years, and 3 years.

### Conclusion:

GLP-1 therapy may reduce pseudarthrosis and length of stay after spinal fusion, though findings for reoperation and medical complications remain inconsistent. Current evidence suggests a potentially favorable but variable impact. Larger, prospective studies are needed to clarify whether GLP-1s consistently improve fusion outcomes.

### Paper #62. Testosterone Replacement Therapy in Transforaminal Lumbar Interbody Fusion Reoperation Rates: A Propensity-Matched Analysis of 1278 Surgical Patients

*Puru Sadh, BS; Haley Warzecha, BS; Maxwell Dassow, BS; Alexander Lewis, BS; Simbarashe Peresuh, MD; Nicolas Carayannopoulos, BS; Alan H. Daniels, MD; Bryce A. Basques, MD, MHS; Catherine B. Hurley, MS*

### Hypothesis:

We hypothesize that TRT will reduce pseudoarthrosis and reoperation rates.

### Design:

Retrospective cohort study

### Introduction:

Testosterone replacement therapy (TRT) has become increasingly common for testosterone-deficient men, supported by evidence of its effects on bone turnover, muscle mass, erythropoiesis, and quality of life.

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Its potential influence on lumbar fusion healing and long-term outcomes, specifically, remains unclear.

### Methods:

We conducted a study of male patients ( $\geq 18$  years) undergoing transforaminal lumbar interbody fusion (TLIF) from 2010–2020 using a large healthcare database. Patients were stratified into testosterone replacement therapy (TRT) and non-TRT groups, with TRT defined as  $\geq 3$  months of preoperative use. Propensity matching was performed on demographic and clinical variables. Baseline comorbidities and surgical indications were compared between groups. Multivariable logistic regression, adjusted for age, comorbidities, and Charlson Comorbidity Index, evaluated associations between TRT and 90-day complications as well as 2- and 5-year reoperation rates, with results reported as odds ratios (95% CI,  $p < 0.05$ ).

### Results:

A total of 1278 patients (840 TRT, 438 Non-TRT) were included. TRT was significantly associated with lower odds of 2-year surgical reoperations (OR: 0.343; CI, 0.233–0.501;  $p < 0.001$ ), 5-year surgical reoperations (OR: 0.646; CI, 0.477–0.874;  $p = 0.005$ ), and urinary complications (OR: 0.395; CI, 0.198–0.769;  $p = 0.007$ ). There were no significant differences between TRT and non-TRT patients for these complications: Acute Kidney Injury, Deep Vein Thrombosis, hemorrhage, Pulmonary embolism, surgical site, readmission, neurostimulation, persistent pain, instrumentation, pseudoarthrosis, and sepsis.

### Conclusion:

In this large, matched cohort, preoperative TRT was independently associated with reduced reoperation risk after TLIF, suggesting a potential protective or fusion-supportive effect. Prospective studies are needed to confirm these findings and clarify biologic mechanisms.

| Outcome                      | Odds Ratio | 95% Lower Confidence Interval | 95% Upper Confidence Interval | p-value          |
|------------------------------|------------|-------------------------------|-------------------------------|------------------|
| 2-Year Surgical Reoperations | 0.343      | 0.232                         | 0.501                         | <b>&lt;0.001</b> |
| 5-Year Surgical Reoperations | 0.646      | 0.477                         | 0.874                         | <b>0.005</b>     |
| <b>90 Day Complications</b>  |            |                               |                               |                  |
| Urinary                      | 0.395      | 0.198                         | 0.769                         | <b>0.007</b>     |
| Acute Kidney Injury          | 0.394      | 0.139                         | 1.033                         | 0.066            |
| Deep Vein Thrombosis         | 1.028      | 0.397                         | 2.752                         | 0.956            |
| Hemorrhages                  | 0.577      | 0.120                         | 2.804                         | 0.482            |
| Pulmonary Embolism           | 0.574      | 0.104                         | 2.768                         | 0.497            |
| Surgical Site                | 1.155      | 0.463                         | 2.920                         | 0.758            |
| Readmission                  | 0.711      | 0.471                         | 1.073                         | 0.104            |
| Neurostimulator              | 0.216      | 0.010                         | 1.917                         | 0.207            |
| Persistent Pain              | 0.585      | 0.320                         | 1.055                         | 0.077            |
| Instrumentation              | 1.803      | 0.175                         | 14.409                        | 0.598            |
| Pseudoarthrosis              | 0.116      | 0.006                         | 0.732                         | 0.052            |
| Sepsis                       | 1.078      | 0.347                         | 3.393                         | 0.896            |

Table 1. TRT and non-TRT TLIF patient post-operative complications

### Paper #63. Comparison of Domiciliary Deep Vein Thrombosis (DVT) Pharmacological Prophylaxis in Paraplegic Patients Due to Spinal Cord Injury (SCI): An Exploratory RCT

*Pankaj Kandwal, MD, MS; Utsav Anand, MD; Bhaskar Sarkar, MD; Kaustubh Ahuja, MD*

### Hypothesis:

Dabigatran and Rivaroxaban is superior to Aspirin in DVT prophylaxis in SCI

### Design:

Randomised Control Trial (RCT)

### Introduction:

Venous thromboembolism (VTE), particularly deep vein thrombosis (DVT), is a major complication in paraplegic patients following spinal cord injury (SCI). The use of pharmacological and mechanical prophylaxis early after injury is essential in minimizing this risk.

### Methods:

Randomized, assessor-blind, controlled trial CTRI/2025/04/086038, conducted at tertiary care university hospital. Paraplegic patients (ASIA I & II) were included. Exclusion criteria: cancer, ISS  $> 13$ , pregnant & lactating female, females on HRT, established DVT on presentation, deranged Liver Function/Kidney Function, already on antiplatelets. All received enoxaparin along with mechanical prophylaxis. On discharge patients were randomly allocated to receive aspirin, dabigatran or rivaroxaban. DVT screening with ultrasound Doppler and Biomarkers was performed on day 0, 14, 45, 90 and at 6 months. Primary efficacy endpoints included ultrasound-based detection of DVT and biomarker normalization. Non-parametric tests were used for statistical analysis due to non-normal data distribution.

### Results:

81 out of 93 patients met inclusion criteria; M(56)/F(25), (ASIA I 50, ASIA II 31). 2 out of 25 patients under Aspirin group developed DVT, no evidence of DVT in 27 patients receiving Dabigatran and 29 patients receiving Rivaroxaban. No significant difference in DVT prevention efficacy was noted among the three agents with significant intragroup difference in ESR, CRPH and D-dimer values  $p < 0.05$ . Using Dwass-Steel-Critchlow-Fligner pairwise comparison test in ESR, CRPH and D-dimer values between 3 groups comes non significant ( $p$  value  $> 0.05$ ).

### Conclusion:

Aspirin, Dabigatran and Rivaroxaban are equally effective in preventing DVT in paraplegic patients. Larger randomized trials are required to further validate these findings.

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### Paper #64. Additional Vertebrae are Imaged in 44% of Pediatric Patients when Limited CTs are Ordered

Robert G. Watkins IV; Vivien Chan, MD, MS; Christopher Watterson, MD; Elaine Butterworth, RN; Kenneth D. Illingworth, MD; David L. Skaggs, MD, MMM

#### Hypothesis:

We hypothesize that a substantial amount of pediatric limited spine CT scans will include vertebrae beyond those ordered, resulting in significantly higher radiation doses compared to the intended order.

#### Design:

This was a single-center retrospective review of pediatric patients undergoing limited spine CT scans between 2021 and 2025.

#### Introduction:

Computed Tomography (CT) imaging accounts for over 60% of medical imaging radiation. This is especially concerning in pediatric patients, who are at higher lifetime risk of developing cancer from radiation. This study aimed to determine how often physician-ordered limited CTs in pediatric spine patients are not followed, and if this leads to additional radiation exposure.

#### Methods:

Inclusion: CT scans ordered for specific vertebrae (e.g., L4-5) Exclusion: generalized regions (cervical, thoracic, lumbar). Demographics, CT orders and scans, and radiation data were obtained from electronic records. A vertebra was considered imaged only if the entire vertebral body was imaged. Analyses used descriptive statistics and chi-square tests.

#### Results:

93 patients (mean age  $16.1 \pm 3.4$ ) with 121 CT scans met criteria. In 43.8% (53/121) of CTs, more vertebrae were imaged than ordered, yielding a mean of 2.1 times more radiation. Scans occurred at 30 sites. A tertiary medical center with a new limited CT protocol performed 61 (50.4%) scans, with 30 (49.2%) scanning additional vertebrae. A private network of 3 outpatient imaging centers with established protocols performed 26 scans, with 3.8% scanning additional vertebrae. The remaining 34 scans were performed at 23 external sites, with 64.7% scanning additional. The imaging center was significantly associated with additional vertebrae imaging frequency ( $X^2=23.6$ ,  $P=0.0002$ ).

#### Conclusion:

44% of patients with limited CT scans of the spine had additional vertebrae scanned compared to what was ordered. This led to more than twice the radiation of the intended CT. Limited CTs at centers with established protocols do not image additional

vertebrae in >96% of patients. Pediatric spine centers should develop specific limited CT protocols to help decrease radiation exposure.

Table 1. Scan accuracy by location

| Location  | n (%)<br>n=129 | Frequency of<br>additional vertebrae<br>imaged (n, %) | % Intended<br>radiation<br>received | Mean CTDI<br>(mGy) |
|---|----------------|---|-------------------------------------|--------------------|
| Tertiary<br>Medical Center                                    | 61 (50.4%)     | 30/61 (49.2%)   | 188.8%                              | 14.1               |
| External  | 34 (28.1%)     | 22/34 (64.7%)   | 245.2%                              | 12.3               |
| A private<br>network of 3<br>outpatient<br>imaging<br>centers | 26 (21.5%)     | 1/26 (3.8%)   | 133.3%                              | 18.2               |
| Total   | 129            | 53/121 (43.8%)  | 211.2%                              | 14.5               |

Scan accuracy by location

### Paper #65. Impact of Preoperative Disc Signal Index-2 Score and Disc Herniation on Cervical Sagittal Alignment Following Deformity Correction in Idiopathic Scoliosis

Hong Jin Kim, MD, PhD; Jae Hyuk Yang, MD, PhD; Seung Woo Suh, MD, PhD

#### Hypothesis:

Both disc degeneration and disc herniation influence cervical sagittal alignment, either directly or indirectly, in adolescent idiopathic scoliosis (AIS)

#### Design:

A retrospective cohort study

#### Introduction:

AIS is characterized by thoracic hypokyphosis and compensatory cervical kyphosis, which results in disc degeneration (DD) and herniation. Although cervical kyphosis is commonly observed in AIS, the clinical significance of asymptomatic DD and its potential impact on cervical malalignment before and after deformity correction remains unclear.

#### Methods:

A total of 195 patients with idiopathic scoliosis who underwent deformity correction were retrospectively reviewed and classified into two groups according to preoperative cervical alignment: the CA group (normal cervical alignment,  $n = 103$ ) and the CMA group (cervical malalignment,  $n = 92$ ). The DSI2 score and sagittal grade of herniation on preoperative magnetic resonance imaging were measured to evaluate disc degeneration and herniation. Cervical alignment was analyzed at the 2-year follow-up. A structural equation model with mediation analysis was performed to assess the relationship between DD/herniation and cervical malalignment.

#### Results:

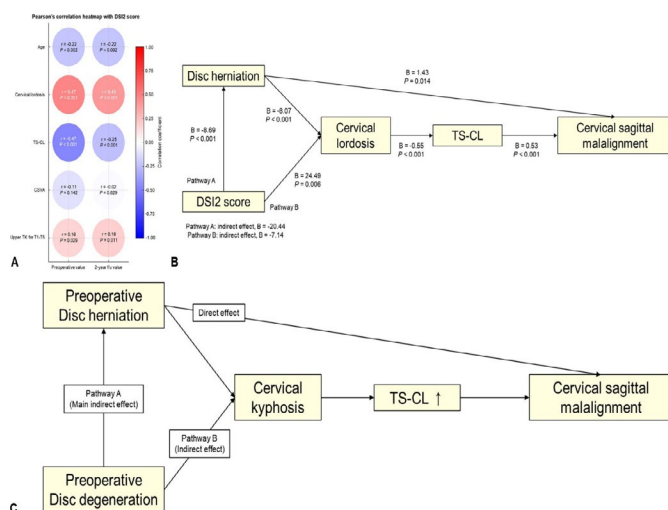
The mean DSI2 score was significantly lower in the CMA group (0.19) than in the CA group (0.31) ( $P <$

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0.001). The prevalence of disc herniation was higher in the CMA group (63.0%) than in the CA group (21.4%) ( $P < 0.001$ ). The DSI2 score was significantly correlated with both preoperative ( $r = 0.47$ ,  $P < 0.001$ ) and 2-year follow-up ( $r = 0.40$ ,  $P < 0.001$ ) cervical lordosis. Structural equation modeling demonstrated that preoperative DD had an indirect effect on cervical malalignment through disc herniation and progression of cervical kyphosis. In contrast, preoperative disc herniation had a direct effect on both cervical kyphosis and cervical malalignment.

### Conclusion:

Preoperative disc herniation appears to directly influence cervical sagittal malalignment in idiopathic scoliosis. Although preoperative DD itself does not have a direct effect, it indirectly affects cervical sagittal alignment through two pathways: disc herniation as the primary indirect effect of degeneration, and progression of cervical kyphosis as the secondary indirect effect of degeneration.



Structural equation model between preoperative disc status and cervical sagittal malalignment

### Paper #66. Measuring Spinopelvic Parameters in Patients with 6 Lumbar Vertebrae: A Matched Comparison of Asymptomatic Volunteers

Chloe Cadieux, MD, FRCS(C); Ruheksh Raj, MD; Farbod Moghaddam, BS; May Choi, MD; Fred H. Nicholls, MD

### Hypothesis:

Using L6 as a reference compared to S1 will lead to significantly different spinopelvic measurements, indicating the importance of using the correct reference in patients with anatomic variants.

### Design:

Retrospective

### Introduction:

Spinopelvic parameters are crucial for evaluating

sagittal alignment and guiding surgical planning. While traditionally measured using the superior endplate of S1 as a reference, anatomic variants such as the presence of a sixth lumbar vertebra (L6) complicate this convention. In such cases, it remains unclear whether parameters should be referenced to the L6 or S1 endplate. This study aims to assess the difference in measurements when using L6 and S1 as a reference in comparison to matched controls.

### Methods:

Volunteers with no pre-existing spine pathology were recruited ( $n = 497$ ). Whole-body 2D EOS scans were obtained. Cases with a well-formed L6 vertebrae were identified ( $n = 29$ ). Two independent surgeons reviewed radiographs included in the L6 cohort and spinopelvic angles were calculated. Measurements included lumbar lordosis, pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), L1-pelvic angle (L1PA), T4-pelvic angle (T4PA), and sagittal vertical angle (SVA) using both L6 and S1 as a reference. Cases were matched 1:1 to normative controls based on PI and SS.

### Results:

Nine cases measured off of S1 and eight cases measured off of L6 were matched to controls within one degree. Comparison was made between cases measured off S1, cases measured off L6, and cases that could not be matched 1:1. In the S1 reference cohort, PI and SS were found to be significantly higher in comparison to cases using L6 (PI  $49.6^\circ$  vs.  $42.7^\circ$ ,  $p = .038$ ; SS  $43.0^\circ$  vs.  $32.5^\circ$ ,  $p < .001$ ). L5-6 and L6-S1 lordosis were higher in the S1 reference group, with significant differences seen in L6-S1 lordosis between the S1 cohort and all other groups. Lastly, the total lordosis from L4-S1 in the S1 reference group most closely approximated  $40^\circ$  in comparison to other groups.

### Conclusion:

After matching to normative controls, the S1 reference cohort had significantly higher values in PI, SS, L5-L6 and L6-S1 lordosis compared to the L6 reference cohort. Additionally, the S1 reference group had a more typical L4-S1 lumbar lordosis, nearing  $40^\circ$ . This suggests that if the L6-S1 disc is lordotic, using S1 as a reference likely provides more accurate spinopelvic measurements in patients with a L6 vertebrae.

## PODIUM PRESENTATION ABSTRACTS

### Paper #67. Impact of Different Osteoporosis Treatments on Endplate Changes and Their Correlation with Trabecular Vertebral Bone, as Measured by Hounsfield Units

Abdelrahman Hamouda, MBBS; Zach Pennington, MD; Derrick ObiriYeboah, MD; Anthony L. Mikula, MD; Jeremy L. Fogelson, MD; Benjamin D. Elder, MD, PhD

#### Hypothesis:

Osteoporosis agent selection may differentially effect Hounsfield unit (HU) improvements in cancellous and cortical bone compartments.

#### Design:

Retrospective cohort.

#### Introduction:

Poor bone quality has been repeatedly associated with increased mechanical complications following spine surgery. Recent work purports endplate bone quality may better predict such complications than trabecular bone quality. Here we investigate the differential response of endplate and trabecular bone to medical bone health optimization.

#### Methods:

Patients treated with osteoporosis medications at a single, multi-site institution were identified and records were queried for pre- and post-treatment CT scans. Scans were used to measure the HUs of trabecular and endplate bone. Patient demographics and treatment details were also extracted. The primary outcome was endplate HU change from baseline. Changes in endplate and trabecular bone density were subjected to Spearman's correlation.

#### Results:

250 patients were included (median age: 74 years; IQR 66.0-81.0) of whom 62.0% were female. Treatment agents included denosumab (39.6%), alendronate (37.6%), romosozumab (12%), and teriparatide (10.8%), and median treatment duration was 18.5 months (12.4, 32.0). Comparison of pre- and post-treatment HU values showed significant increases in both trabecular (109 vs 103; <0.001) and endplate HU (309 vs 288; p<0.001). Changes in trabecular and endplate HU were moderately correlated (R=0.611; p<0.001). Subdivision by treatment agent showed the strongest correlation in the denosumab group (R=0.665; p<0.001).

#### Conclusion:

In patients undergoing osteoporosis treatment, both trabecular and endplate bone density appear to improve significantly following therapy, with the most pronounced gains being after treatment with anabolic versus anti-resorptive therapies. There was a strong correlation between changes in trabecular and endplate HU, suggesting that endplate response

mirrors that of trabecular bone. These findings support the utility of endplate HU as a complementary marker for monitoring treatment response in osteoporosis.

### Paper #68. Osteoporosis Screening Gaps Among Patients Undergoing Lumbar Fusion Surgery

Eric Mao, BA; Krystell E Ceballos Alvarez, BS; Sydney Thai, BS; Jonathan Wang, BS; Amit Jain, MD, MBA

#### Hypothesis:

We hypothesize that osteoporosis screening is inadequately performed in lumbar fusion patients in the two years prior to surgery.

#### Design:

Retrospective Cohort

#### Introduction:

Osteoporosis screening is recommended using a DEXA scan in lumbar fusion patients over age 50 to reduce risk of postoperative complications. Further, current guidelines from the American Association of Clinical Endocrinologists and the Endocrine Society recommend routine osteoporosis screening for all at-risk patients, including: 70+ males, 65+ females, and 50+ patients with endocrine conditions affecting sex hormones (e.g. hypogonadism), chronic obstructive pulmonary disease, history of fragility fractures, history of smoking, or alcohol use disorder. The aim of this study is to assess osteoporosis screening in patients undergoing lumbar fusion surgery.

#### Methods:

Patients over the age of 50 undergoing lumbar fusion were identified using a national clinical claims database using procedural codes. Patients receiving surgery for indications of malignancy or infection, as well as those with prior diagnosis of osteoporosis were excluded. The prevalence of DEXA scans in the two years prior to surgery was calculated for the overall and for at-risk cohorts.

#### Results:

Of 95,280 patients who underwent lumbar fusion surgery between 2005 and 2025, only 2.3% of men and 9.5% of women received a preoperative DEXA scan in the two years prior to their fusion (Table 1). Women were more likely to receive DEXA scans (OR = 4.41; 95%CI = 4.13-4.72; p < 0.001). Overall, 59.5% of patients were identified as at-risk for osteoporosis following the endocrinology society criteria. However, only 2.9% of at-risk men and 11.6% of at-risk women received preoperative DEXA scans. Further, patients with endocrine conditions were most likely to receive DXA scans (15.0%), and males >70 were least likely (3.4%).

## PODIUM PRESENTATION ABSTRACTS

### Conclusion:

Despite a majority of patients undergoing lumbar fusion being at risk for osteoporosis (and eligible for screening), a small minority were screened using DEXA in the two years prior to their lumbar surgery. Efforts are warranted to increase the prevalence of DEXA screening so that osteoporosis is appropriately diagnosed prior to lumbar fusion surgery.

| Category                 | Lumbar Spine Surgery   |  |
|--------------------------|------------------------|--|
|                          | Total Number in Cohort | Patients in Cohort Receiving DEXA; n (%) |
| Total                    | 95,280                 | 5,648 (5.9%)                             |
| Male                     | 47,331                 | 1,098 (2.3%)                             |
| Female                   | 47,949                 | 4,550 (9.5%)                             |
| Risk Factor              |                        |  |
| Male 70+                 | 15,681                 | 527 (3.4%)                               |
| Female 65+               | 25,940                 | 3,112 (12.0%)                            |
| Endocrine Conditions     | 2,452                  | 368 (15.0%)                              |
| Smoker                   | 16,788                 | 957 (5.7%)                               |
| COPD                     | 9,174                  | 720 (7.8%)                               |
| Prior Fragility Fracture | 1,194                  | 137 (11.5%)                              |
| Alcohol Use Disorder     | 3,923                  | 252 (6.4%)                               |
| Male, Any Risk Factor    | 25,559                 | 741 (2.9%)                               |
| Female, Any Risk Factor  | 31,134                 | 3,600 (11.6%)                            |

Prevalence of DEXA scans by subgroup.

### Paper #69. Ultra-Early Intervention with Percutaneous Kyphoplasty for Acute Osteoporotic Vertebral Compression Fractures: Efficacy and Safety Outcomes from a High-Volume County Hospital Center

Wenjie Wu, MD

#### Hypothesis:

Ultra-early surgery (<72 hours) may offer superior pain relief and functional recovery. This study presents a large-scale prospective analysis from a high-volume county hospital, evaluating the feasibility, safety, and efficacy of ultra-early PKP.

#### Design:

A prospective controlled study

#### Introduction:

The optimal timing for performing percutaneous kyphoplasty (PKP) in acute osteoporotic vertebral compression fractures (OVCFs) remains controver-

sial, particularly regarding the risk of cement leakage in hyperacute cases. While delayed intervention is conventional, ultra-early surgery (<72 hours) may offer superior pain relief and functional recovery.

#### Methods:

From January 2023 to January 2025, 526 patients with single-level acute OVCFs were prospectively enrolled. Group A (ultra-early, ≤72 hours; n=302) and Group B (conventional, >72 hours to 2 weeks; n=224). All procedures were performed by the same surgical team using a uniform technique with high-viscosity cement. Primary outcomes included visual analog scale (VAS) score, Oswestry Disability Index (ODI), vertebral height restoration, and cement leakage rate. Secondary outcomes included operative time, hospital stay, and patient satisfaction.

#### Results:

The ultra-early group (A) demonstrated significantly better outcomes in pain reduction at 24 hours post-operatively (mean VAS: 2.3 ± 0.8 vs. 3.6 ± 1.1, p<0.01) and shorter average hospital stay (4.5 ± 1.2 days vs. 7.8 ± 2.4 days, p<0.01). Notably, the cement leakage rate was lower in Group A (6.1% vs. 11.4%, p<0.01). Vertebral height restoration was significantly greater in the ultra-early group (88.5% ± 6.7% vs. 76.3% ± 8.9%, p<0.01). There were no significant differences in operative time or overall complication rates. Patient satisfaction scores were higher in Group A (9.2/10 ± 0.7 vs. 8.1/10 ± 1.4, p<0.01).

#### Conclusion:

Ultra-early PKP performed within 72 hours of symptom onset is not only feasible but also associated with superior clinical outcomes, reduced cement leakage, and greater cost-effectiveness due to shortened hospitalization. This study provides compelling evidence that challenges traditional timing paradigms and highlights the advantages of high-volume regional centers in implementing early intervention protocols. These findings support the adoption of ultra-early PKP as a standard of care for eligible patients.

### Paper #70. How Does Sacral Slanting Change After Lumbar Hemivertebra Resection in Children?

Ziming Yao, PhD; Dong Guo, MD; Xue Jun Zhang, MD

#### Hypothesis:

Sacral slanting occurs in children with congenital scoliosis (CS) caused by lumbar hemivertebra (HV) and doesn't change after HV resection.

#### Design:

Retrospective study

#### Introduction:

Lumbar HV can directly impact coronal sacral align-

## PODIUM PRESENTATION ABSTRACTS

ment, leading to significant coronal sacral slanting (CSS) and coronal imbalance. The aim of this study is to investigate the characteristics of CSS in children with lumbar HV and to evaluate the changes in CSS following HV resection.

### Methods:

We analyzed the clinical data of 90 pediatric patients with CS who underwent posterior lumbar HV resection at our institution between June 2015 and June 2022. Radiographic parameters, mainly including CSS and Cobb angle, were collected preoperatively, postoperatively, and at the final follow-up. The correlation between preoperative HV location and Cobb angle with CSS was analyzed. Changes in CSS after HV resection were assessed. And analyze the influence of changes in CSS and Cobb angle over time in patients after HV resection.

### Results:

A total of 90 patients (50 male, 40 female; mean age  $4.3 \pm 2.4$  years) were included. Hemivertebrae were distributed across the lumbar spine: L1 (n=27, 30.0%), L2 (n=27, 30.0%), L3 (n=20, 22.2%), and L4 (n=16, 17.8%). Preoperatively, CSS was present in 55 patients (61.1%). A more caudal HV location (closer to S1) was associated with a larger CSS angle ( $R=0.475$ ,  $P<0.001$ ), and the preoperative Cobb angle was positively correlated with the CSS angle ( $R=0.399$ ,  $P<0.001$ ). When grouped by HV location, the CSS angle was significantly smaller in the L1 group ( $P<0.05$ ). The Cobb angle was significantly larger in the L1 and L2 groups ( $P<0.05$ ). At the final follow-up, the mean CSS angle decreased from  $6.8 \pm 4.4^\circ$  preoperatively to  $2.7 \pm 3.3^\circ$  ( $P<0.001$ ), and the mean Cobb angle was corrected from  $36.3 \pm 10.6^\circ$  preoperatively to  $1.8 \pm 0.4^\circ$  ( $P<0.001$ ). The significant decrease in CSS at 3 months postoperatively ( $P<0.001$ ), with a further significant reduction until the final follow-up ( $P=0.041$ ). In contrast, the Cobb angle decreased significantly by 3 months postoperatively, with no significant change thereafter until the final follow-up ( $P=1.000$ ).

### Conclusion:

CSS occurs in 61.1% of children with LHV. The severity of CSS increases as the LHV approaches the sacrum and is correlated with a larger preoperative Cobb angle. Following hemivertebra resection, CSS undergoes spontaneous correction concurrent with the surgical correction of the lumbar scoliosis.

### Paper #71. A Comparison of Radiographic Sagittal Parameters at 2 Years Follow Up in Paediatric Patients Undergoing Fusion for High Grade Spondylolisthesis Managed Via Fusion In-Situ Vs Reduction and Circumferential Fusion

*Karim Aboelmagd, MD; Emma Nadler, MSc; Mark Camp, MD; Reinhard D. Zeller, MD, FRCS(C); David E. Lebel, MD, PhD*

### Hypothesis:

Sagittal parameters improve progressively following fusion for HGS

### Design:

Single Centre, retrospective, cohort

### Introduction:

High-grade spondylolisthesis (HGS) in pediatric patients is a rare but challenging spinal deformity associated with unique pelvic anatomy and compensatory spinopelvic mechanisms. Surgical management remains controversial, with fusion in situ (FIS) historically favoured due to reduced neurologic risk, whilst reduction with circumferential fusion (RF) aims to restore lumbosacral alignment. Despite improved instrumentation and safety, the long-term functional benefit of reduction remains unclear.

### Methods:

We retrospectively reviewed 39 consecutive patients (20 RF, 19 FIS) treated at a single institution (2006–2022) with  $\geq 2$  years radiographic follow-up. Demographics were comparable between groups. Standardized radiographic parameters (slip %, sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), lumbosacral angle (LSA), L4/L5 incidence, lumbar lordosis) were measured preoperatively, 6 months, and 2 years postoperatively. Mixed-model ANOVAs assessed temporal and inter-group differences, with subgroup analysis for vertical sacrum morphology.

### Results:

RF achieved greater acute slip reduction (81.7% to 25.4% vs. 76.2% to 60.0%;  $p<0.001$ ) and lumbosacral kyphosis correction (LSA:  $64.2^\circ$  to  $94.6^\circ$  vs.  $63.9^\circ$  to  $78.1^\circ$ ;  $p<0.001$ ). RF also showed greater improvement in L4/L5 incidence and reduced lordosis at 2 years. Both groups demonstrated progressive remodelling of SS and PT, with no difference at final follow-up (SS:  $48.2^\circ$  vs.  $49.1^\circ$ ,  $p=0.727$ ; PT:  $25.4^\circ$  vs.  $21.5^\circ$ ,  $p=0.092$ ). Vertical sacrum patients exhibited the greatest compensatory changes regardless of technique: in those with  $SS<35$ , SS improved from  $27.7$  to  $45.1$  (RF) and  $29.1$  to  $43.4$  (FIS), while PT improved from  $34.9$  to  $19.7$  (RF) and  $38.5$  to  $24.8$  (FIS). Patients with  $SS>35$  showed minimal changes (SS:  $45.7$  to  $50.3$  and  $51.8$  to  $52.5$ ; PT:  $25.8$  to  $23.9$  and  $25.9$  to  $25.9$  for RF and FIS, respectively)

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### Conclusion:

Both IFIS and RF achieved improved sagittal alignment at 2 years. RF achieved greater acute correction of slip angle and translation. Comparable progressive improvement in SS and PT was achieved in both groups, particularly in those with vertical sacra. These findings suggest the potential for improved sagittal alignment over time.

### Paper #72. 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:

McMaster and Ohtsuka's natural history is applicable for patients with congenital scoliosis.

### Design:

This was a retrospective multicenter cohort study.

### Introduction:

The natural history by McMaster and Ohtsuka remains the framework for scoliosis treatment, and we sought to confirm and expand upon it.

### Methods:

464 patients with congenital scoliosis with baseline and follow-up X-rays were included. Patients with neurological conditions were excluded. Deformities were classified using McMaster's system. The primary outcome was a Cobb angle  $\geq 50^\circ$  assessed at final follow-up. 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 based on baseline Cobb angle and deformity type. A Cox regression model was used to assess independent associations between progression and baseline age, deformity type, and gender.

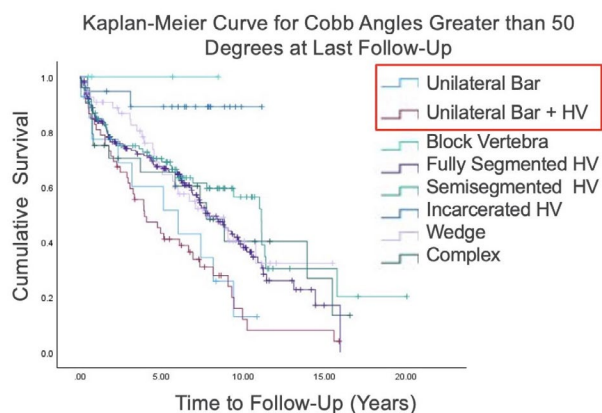
### Results:

The mean baseline and follow-up ages were  $3.5 \pm 3.5$  years and  $8.8 \pm 4.7$  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  $46.5^\circ \pm 18.9^\circ$  and  $51.3^\circ \pm 22.9^\circ$ , respectively. Kaplan-Meier analysis demonstrated that patients with unilateral unsegmented bars, with or without hemivertebra (HV), were at the highest risk of curve progression. Thoracic and thoracolumbar curves showed higher progression risk, and female patients were more likely to progress. Cox regression confirmed these findings, identifying 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  $\leq 38^\circ$ : 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  $> 54^\circ$ : High risk of maintenance at  $> 50^\circ$  (92.2%) regardless of deformity type.

### Conclusion:

Baseline Cobb angle and deformity type can both be used to predict outcome.



The unsegmented bar with/without contralateral HV had the greatest risk of progression.

### Paper #73. A Novel Surgical Procedure: Selected Muscle Transfer to Correct the Malrotation and Elevation of the Scapula of Sprengel's shoulder deformity in Children and Adult

Xuhong Xue, MD, PhD; Kai Li, MD; Sheng Zhao, MD

### Hypothesis:

Selected muscle transfer to correct the malrotation and elevation of the Scapula of Sprengel's deformity, which can achieve good cosmetic and functional results

### Design:

Retrospective analysis of a prospective database

### Introduction:

Sprengel's shoulder is a rare congenital deformity resulting from failure of the scapula to descend properly. Affected children have two major problems: cosmetic and functional. The function is closely related to the rotation of the scapula. Some doctors have already developed some procedure to correct the malrotation to improve the function. But the cosmetic effect is not satisfying. How to surgically

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improve the rotation of the scapula to improve the function and low the scapula at the same time still need more explore. We here introduce our result of a procedure based on malrotation correction to improve the function and cosmetic result in children and adult.

### Methods:

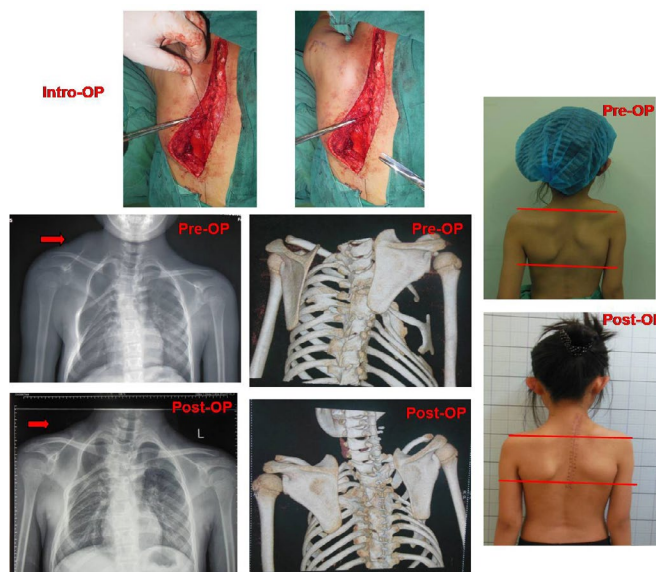
A novel surgical rotate procedure was performed in 23 patients (23 shoulders) with Sprengel deformity between Jan, 2009 and Dec, 2021. The degree of the deformity was graded clinically and radiologically according to the classifications of Cavendish and Rigault, respectively. All patients underwent a novel procedure, with selected muscle transfer to correct the malrotation and elevation of the Scapula of Sprengel's shoulder deformity of the elder children and adult.

### Results:

There were 21 girls and 2 boys with a mean age at surgery of  $9.96 \pm 7.52$  years (2 to 34 years). The deformity involved the right shoulder in 10 cases and the left in 13. After a mean follow-up of  $43.7 \pm 37.0$  months (12 to 108 months), there was cosmetic improvement by at least 1 Cavendish grade in all 23 shoulders. The mean abduction of the shoulder improved from  $83.8 \pm 19.9^\circ$  ( $62^\circ$  to  $120^\circ$ ) to  $159.1 \pm 8.0^\circ$  ( $140^\circ$  to  $170^\circ$ ). The mean height difference of the shoulder improved from  $2.73 \pm 1.14$ cm to  $0.80 \pm 0.52$ cm. The tilt angle of the scapula improved from  $20.8 \pm 12.4^\circ$  ( $5.7^\circ$  to  $41.4^\circ$ ) to  $5.5 \pm 7.3^\circ$  ( $-14.8^\circ$  to  $18^\circ$ ). Complication rate (recurrent) was 8.69% (2/23). No brachial plexus palsy occurred post-operatively.

### Conclusion:

We suggest that selected muscle transfer to correct the malrotation and elevation of the Scapula of Sprengel's shoulder deformity of the children and adult, which provides good cosmetic and functional results in patients with Sprengel's shoulder.



Demo case with Sprengel' deformity

### Paper #74. Cryoablation Reduces Intraoperative Times, Pain, and Opioid Consumption in AIS Patients Undergoing PSF with Thoracoplasty

Vishal Sarwahi, MD; Anabelle Cohen, BS; Alexander Morledge, BA; Sarah Trent, MD; Brian Li, BS; Yungtai Lo, PhD; Terry D. Amaral, MD

#### Hypothesis:

Cryoablation effectively targets intra- and postop pain levels associated with concomitant rib resection during posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS) patients. On average, this results in significant improvements for OR time, patient pain experience, and functional outcomes

#### Design:

Retrospective chart review

#### Introduction:

Cryoablation is an intraop procedure where fluid-cooled probes rapidly extract heat from the surgical site, freezing adjacent structures and inducing a Grade II peripheral injury (reversible axonotmesis) that temporarily disrupts local pain signals. Rib resection for rib-hump deformity during PSF has been associated with significantly increased perioperative pain and opioid consumption. Our study investigates whether cryoablation used during rib resection for AIS patients will reduce the pain experienced throughout postop recovery and thus result in more positive outcomes such as lower overall opioid consumption and better pain management.

#### Methods:

245 AIS patients who underwent PSF with concurrent thoracoplasty at a single institution were included. 86 patients underwent cryoablation (Cryo group)

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and 175 patients did not (Standard). Data collected on VAS pain scores, narcotic refill, intraop, postop, and total morphine consumption, out of bed (OOB), length of hospital stay (LOS), and 90-day complications including respiratory complications. Surgical variables were collected.

### Results:

No differences observed in demographics, pre- and post-op Cobb angles. Operative and anesthesia time were significantly lower in the Cryo group (242 vs 217min,  $p < 0.001$ ; 381.5 vs 323min,  $p < 0.001$ ). No differences in VAS pain scores ( $p > 0.05$ ) or 90-day complications ( $p = 1.0$ ). Both groups experienced similar respiratory complication rates ( $p = 1.0$ ). Morphine consumption was significantly lower in the Cryo group during the intraop, 0-24hr, 24-48hr, 48-72hr and total morphine consumption ( $p = 0.015$ ,  $p < 0.001$ ,  $p < 0.001$ ,  $p = 0.012$ , and  $p < 0.001$ ). Cryo group experienced a median reduction of 20 MME in total morphine consumption. POD1 OOB times (98.1% vs 96.3%,  $p = 1.0$ ) and LOS ( $p = 40$ ) were comparable.

### Conclusion:

Cryoablation can be used to control local pain signaling for AIS patients during PSF with thoracoplasty. This procedure could have significant positive pay offs such as lower analgesic consumption and OR times while reducing postop opioid consumption.

### Paper #75. Intraoperative Erector Spinae Plane Block with Ropivacaine-Epinephrine-Clonidine-Ketorolac Reduces In-Hospital Opiate Consumption in Idiopathic Scoliosis Patients

*Miran Stubican, MD; Bryan Menapace, MD, MBA; Michelle C. Welborn, MD; Daniel Bouton, MD; Ashley Pikero, BS; Robert Bernstein, MD; Rebecca Hall, MD; Chinmay Paranjape, MD, MHSc*

### Hypothesis:

Intra-operative ropivacaine-epinephrine-clonidine-ketorolac (RECK) delivered via ESPB reduces post-operative opiate use in patients undergoing posterior spinal instrumented fusion for adolescent idiopathic scoliosis.

### Design:

Retrospective controlled cohort

### Introduction:

Posterior spinal instrumentation and fusion (PSIF) for management of AIS is associated with significant postoperative pain, often managed with opioids which carry the risk of side effects and long-term dependency. Erector spinae plane (ESP) blocks have shown promise, but previous research relied on cost-ly liposomal bupivacaine.

### Methods:

We retrospectively reviewed 77 consecutive surgical cases of juvenile and adolescent idiopathic scoliosis patients who underwent PSIF between January 2024 and May 2025. There were two groups of patients: those who received a RECK-ESPB ( $n = 38$ ) and those who did not ( $n = 39$ ). All procedures followed a standardized ERAS protocol. Two surgeons always used a RECK-ESPB while the other two did not until March 2025. Demographics, Cobb angles, patient reported outcomes, MME opiate consumption and milligram benzodiazepine usage were compared between groups and according to post-operative day. The data was analyzed using paired t-tests and ANOVA, with significance defined as  $p < 0.05$ .

### Results:

The baseline characteristics between the two groups were comparable except for age, higher EBL, more levels fused, and longer operative time in the RECK-ESPB group. The mean total postoperative day 0 milligram morphine equivalent use was 4.1 in RECK and 9.2 in control ( $p = 0.047$ ). Opiate use was similar on the remaining post-operative days. Benzodiazepine usage did not vary between the groups. There were no adverse events related to the intervention.

### Conclusion:

Erector spinae plane block with RECK significantly reduced postoperative opioid consumption in the first 12-18 hours. Despite a trend toward longer surgeries, more levels fused and higher blood loss with the ESP cohort, patients receiving the block used less post operative opiates than the non-RECK cohort. The cost of RECK is substantially less than liposomal bupivacaine, \$57.06 compared with \$1447.5 respectively.

### Paper #76. Does Obesity Enhance the Analgesic Effect of Liposomal Bupivacaine in Pediatric Spinal Fusions?

*Emmanuel Ogu, BS; David C. Thornberg, BS; Christopher B. McLeod, MD; Chan-Hee Jo, PhD; Amy L. McIntosh, MD; Brandon A. Ramo, MD; Judy-Mae Lima, BS; Jays-son T. Brooks, MD*

### Hypothesis:

We hypothesize that liposomal bupivacaine (LB) will be less effective in obese AIS patients, and thus they will require more opioids than their non-obese counterparts despite equal use of LB.

### Design:

Retrospective cohort study.

### Introduction:

Liposomal bupivacaine is increasingly used in post-operative pain protocols after posterior spinal fu-

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sions (PSFs) for adolescent idiopathic scoliosis (AIS), yet its efficacy in obese children remains unclear. Obesity is associated with larger spine deformities at presentation and increased pain burden, potentially diminishing LB's effects. The purpose of this study is to evaluate the effect of BMI on postoperative opioid consumption in AIS patients treated with LB.

## Methods:

We conducted a retrospective cohort study of AIS patients aged 10–19 who underwent PSF with intraoperative LB between 2020 and 2022 at a single institution. Patients were stratified by BMI percentile. Postoperative opioid consumption was quantified in morphine equivalents per kilogram (MME/kg). Pain scores, SRS-30, and pain catastrophizing scales were also assessed. Multivariate linear regression was used to evaluate predictors of opioid consumption in first 24 hours following PSF and the total inpatient stay. Regressions were repeated with backward selection to identify the most relevant predictors.

## Results:

A total of 190 patients were included. There were no significant differences in preoperative curve magnitudes or number of levels fused between BMI categories. In the first 24 hours following PSF, obese patients consumed significantly fewer MME/kg ( $\beta=-0.08$ ,  $p=0.0290$ ), but this association was not significant with backward selection. Over the total inpatient stay, obese patients consumed significantly fewer total inpatient MME/kg than healthy-weight patients ( $\beta=-0.50$ ,  $p=0.0001$ ), and this association was sustained with backward selection. Higher pain scores and male sex were predictors of early increased opioid consumption. Increasing BMI percentile correlated negatively with total inpatient opioid use ( $\rho=-0.182$ ,  $p=0.012$ ). There were no differences in pain, SRS-30, or pain catastrophizing scale scores across BMI groups.

## Conclusion:

Obesity in pediatric AIS patients was associated with significantly lower postoperative opioid use following PSF with LB, without differences in pain scores. These findings suggest an opioid-sparing effect of LB in obese children, potentially due to altered drug pharmacokinetics.

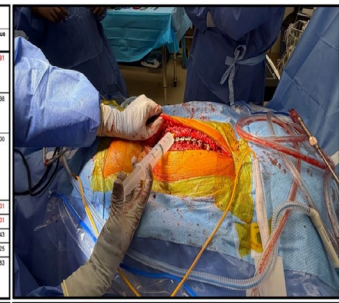
| Demographics                               | Overall<br>n=192 | Stratified by BMI Percentile |                        |                    |              | p-value |
|--|------------------|------------------------------|------------------------|--------------------|--------------|---------|
|  |                  | Underweight<br>N=111         | Healthy Weight<br>N=52 | Overweight<br>N=20 | Obese<br>N=9 |         |
| Sex  |                  |                              |                        |                    |              | 0.001   |
| Female                                     | 141 (73.4%)      | 4,056 (4%)                   | 154 (30.0%)            | 13 (65.0%)         | 20 (100%)    |         |
| Male                                       | 50 (26.6%)       | 7,823 (8%)                   | 26 (50.0%)             | 7 (35.0%)          | 0 (0%)       |         |
| Ethnicity                                  |                  |                              |                        |                    |              | 0.488   |
| Non-Hispanic/Latino                        | 180 (94.2%)      | 6,72 (7%)                    | 108 (20.3%)            | 18 (90.0%)         | 20 (100%)    |         |
| Hispanic/Latino                            | 12 (6.2%)        | 3,27 (3%)                    | 22 (42.3%)             | 2 (10.0%)          | 0 (0%)       |         |
| Race                                       |                  |                              |                        |                    |              | 0.903   |
| White                                      | 122 (63.5%)      | 7,823 (8%)                   | 88 (16.7%)             | 14 (70.0%)         | 16 (80.0%)   |         |
| African American or Black                  | 16 (8.3%)        | 2,184 (2%)                   | 21 (40.0%)             | 4 (20.0%)          | 3 (15.0%)    |         |
| Asian or Asian American                    | 4 (2.1%)         | 6 (0.1%)                     | 4 (7.7%)               | 0 (0%)             | 0 (0%)       |         |
| Hispanic/Latino                            | 36 (18.8%)       | 2,184 (2%)                   | 20 (37.0%)             | 2 (10.0%)          | 0 (0%)       |         |
| Age (years) (Avg ± SD)                     | 14.79 ± 2.22     | 16.78 ± 1.27                 | 14.71 ± 2.26           | 16.81 ± 2.17       | 13.11 ± 1.38 | <0.001  |
| BMI (kg/m <sup>2</sup> ) (Avg ± SD)        | 21.80 ± 5.07     | 16.21 ± 1.59                 | 19.80 ± 2.10           | 25.84 ± 1.73       | 31.28 ± 4.14 | <0.001  |
| Major Curve Magnitude (degrees) (Avg ± SD) | 30.35 ± 10.17    | 64.05 ± 12.48                | 50.61 ± 9.13           | 57.35 ± 6.68       | 62.22 ± 4.45 | 0.746   |
| Levels Fused                               | 17.08 ± 1.92     | 17.91 ± 2.24                 | 17.24 ± 1.76           | 16.92 ± 2.68       | 16.09 ± 1.92 | 0.302   |
| Pain Category                              |                  |                              |                        |                    |              | 0.002   |
| Pain Catastrophizing                       | 20 (10.4%)       | 0 (0%)                       | 16 (31.2%)             | 2 (10.0%)          | 1 (5.0%)     |         |
| Non-Pain Catastrophizing                   | 167 (87.6%)      | 11,002 (9%)                  | 114 (21.7%)            | 18 (90.0%)         | 24 (120%)    |         |

| Variables                | 0-24 hr Morphine Eq. (mg/kg) |            |         | Variables                | Backward Selection |            |         |
|--------------------------|------------------------------|------------|---------|--------------------------|--------------------|------------|---------|
|                          | Est. Beta                    | Std. Error | p-value |                          | Est. Beta          | Std. Error | p-value |
| Sex                      |                              |            |         | Sex                      |                    |            |         |
| Female                   | 0.01                         | 0.01       | 0.3979  | Female                   | 0.01               | 0.01       | 0.3979  |
| Male                     | -0.07                        | 0.03       | 0.0290  | Male                     | -0.09              | 0.03       | 0.0161  |
| Age                      | 0.00                         | 0.01       | 0.7979  | Pain Catastrophizing     | 0.01               | 0.01       | 0.0001  |
| Major Curve              | 0.00                         | 0.00       | 0.1000  | Average 24-hr Pain Score | 0.01               | 0.01       | 0.0161  |
| Average 24-hr Pain Score | 0.01                         | 0.01       | 0.0447  |                          |                    |            |         |
| BMI Categories           |                              |            |         |                          |                    |            |         |
| Underweight              | 0.01                         | 0.06       | 0.8122  |                          |                    |            |         |
| Healthy Weight           | 0.00                         | 0.05       | 0.9401  |                          |                    |            |         |
| Overweight               | 0.00                         | 0.04       | 0.6161  |                          |                    |            |         |
| Obese                    | -0.08                        | 0.04       | 0.0290  |                          |                    |            |         |

| Variables                | Total Inpatient Morphine Eq. (mg/kg) |            |         |                          | Variables              | Backward Selection |            |         |
|--------------------------|--------------------------------------|------------|---------|--------------------------|------------------------|--------------------|------------|---------|
|                          | Est. Beta                            | Std. Error | p-value | position                 |                        | Est. Beta          | Std. Error | p-value |
| Sex                      |                                      |            |         |                          | Length of Stay (Hours) | 0.06               | 0.03       | <0.001  |
| Female                   | 0.01                                 | 0.01       | 0.3979  | Female                   | 0.01                   | 0.01               | 0.3979     |         |
| Male                     | -0.08                                | 0.03       | 0.0290  | Male                     | -0.09                  | 0.03               | 0.0161     |         |
| Age                      | 0.00                                 | 0.01       | 0.7979  | Average 24-hr Pain Score | 0.01                   | 0.01               | 0.0161     |         |
| Length of Stay (Hours)   | 0.01                                 | 0.01       | <0.001  | Healthy Weight           | 0.01                   | 0.01               | 0.0001     |         |
| Major Curve              | 0.00                                 | 0.00       | 0.4881  | Overweight               | 0.02                   | 0.14               | 0.8724     |         |
| Average 24-hr Pain Score | 0.01                                 | 0.01       | 0.0447  | Obese                    | -0.02                  | 0.12               | <0.001     |         |
| BMI Categories           |                                      |            |         |                          |                        |                    |            |         |
| Underweight              | -0.02                                | 0.10       | 0.9154  |                          |                        |                    |            |         |
| Healthy Weight           | 0.00                                 | 0.01       | 0.6771  |                          |                        |                    |            |         |
| Overweight               | 0.02                                 | 0.14       | 0.8724  |                          |                        |                    |            |         |
| Obese                    | -0.02                                | 0.12       | 0.0001  |                          |                        |                    |            |         |



## Paper #77. Comparative Study of Spinal Casting Strategies in Early Onset Scoliosis: Five-year Progression-Free Survival Analysis

Jennifer A. Dermott, PT, PhD candidate; Dorothy Kim, MSc; Lily Switzer; Emma Nadler, MSc; Mark Camp, MD; David E. Lebel, MD, PhD

## Hypothesis:

Continuous casting (CC) is more effective than intermittent casting (IC) at preventing curve progression and delaying surgery in early onset scoliosis (EOS) patients.

## Design:

Retrospective review

## Introduction:

Spinal casting is widely accepted as a surgical delay strategy in the management of EOS. There is no consensus on the most appropriate protocol to optimize outcomes. This study compares the 5-year outcomes of IC versus CC casting strategies, focusing on deformity control.

## Methods:

All EOS patients who had spinal casting between 2002-25 at a single tertiary care center were reviewed. IC was defined as 2-3 casts applied over 6 months, followed by bracing and/or single repeat casts if progression was noted. CC was defined as the repeat application of casts every 12-16 weeks, over a period >1 year. Patients with <12-month follow-up or with a congenital etiology were excluded. The primary outcome was curve progression >5° or transition to surgery. In-cast correction and complications related to casting were recorded. Kaplan-Meier analysis with log-rank test compared the efficacy of each strategy to halt curve progression or delay surgery. Cox proportional hazards model was used to estimate the adjusted hazard ratio between strategies.

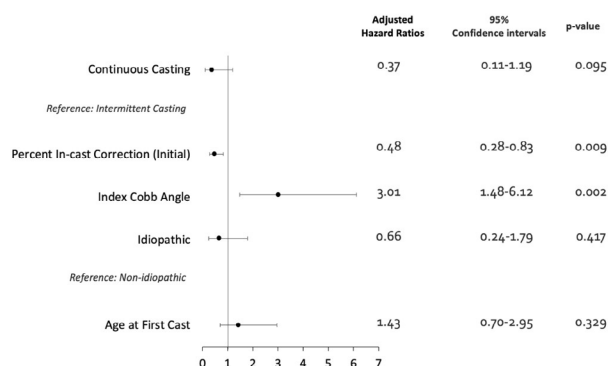
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### Results:

Of the study cohort, 59% (n=30) underwent IC and 41% (n=21) underwent CC. Both groups were similar at baseline in sex, age, etiology, and index curve magnitude (mean: 64° ±15°). The 5-year progression-free survival rate was 47% (95% CI 33.7-66.0), which did not differ by casting strategy (p=0.10). In-cast correction was stable with CC, whereas less correction was achieved over time with IC (p=0.004). The adjusted risk of progression decreased with greater correction in first cast (aHR=0.48, 95% CI 0.28-0.83, p=0.009) and increased with larger index curve magnitudes (aHR=3.01, 95% CI 1.48-6.12, p=0.002). Each group had one complication.

### Conclusion:

Both casting strategies minimize risk of curve progression, effectively delaying surgery in EOS, regardless of etiology. Patients with severe deformity prior to treatment are at the highest risk of progressing. The long-term implications of ongoing in-cast correction are yet to be determined.



Greater in-cast correction lowers risk of progression or early surgery while larger curve magnitudes increase risk.

### Paper #78. Can Rib Splints Reduce Risk of Proximal Anchor Failure in Distraction-Based Growing Constructs? A Biomechanical Pilot Study

Arianne T. Salunga, DO; Talissa O. Generoso, MD; Calvin Chan, MS; Vivian Ho, BSN; Nicole S. Pham, MPH; John S. Vorhies, MD

### Hypothesis:

Rib splints can enhance rib strength and reduce risk of proximal anchor failure in distraction based growing constructs.

### Design:

Biomechanics

### Introduction:

Anchor failure is a common complication in growing rod treatment in early onset scoliosis (EOS). Rib-based proximal anchors are sometimes used

because they preserve spinal anatomy and reduce neurologic risk; however, ploughing and cut-through remain common modes of failure. Intramedullary (IM) splinting, previously used to stabilize rib fractures, may offer a strategy to decrease the risk of anchor migration. This study investigated whether IM splinting can enhance rib strength and whether hook position relative to splint entry and anchor holes influences fracture risk.

### Methods:

Forty-four fresh-frozen paired ribs from 2 immature porcine specimens were stratified by laterality and randomized to experimental or control groups. Experimental ribs were instrumented with a 1.0 mm IM Kirschner wire secured at the medial aspect of the rib with a unicortical 2.0 mm screw (Figure 1A, 1B). All ribs underwent a three-point bending failure test at a rate of 2.5 millimeters per second with a twelve millimeter wide load applicator to simulate in vivo rib hook forces. Load application was tested in two areas 1) between splint entry and anchor holes and 2) one centimeter lateral to splint entry point (Figure 1C).

### Results:

Instrumented ribs failed at a higher maximum compressive stress than uninstrumented ribs (109 MPa vs 95.6 MPa p=0.030) (Figure 1D). When the load was applied lateral to the splint entry point, splinted ribs demonstrated superior strength (101 MPa vs. 88 MPa, p = 0.019). No significant difference in failure strength was observed between splinted and unsplinted ribs when the load was applied between entry and anchor holes.

### Conclusion:

IM rib splinting enhances acute rib strength in a cadaveric model. Optimal resistance to hook migration was observed when load was applied lateral to the splint entry site, but placement between the entry and anchor holes did not significantly compromise strength.

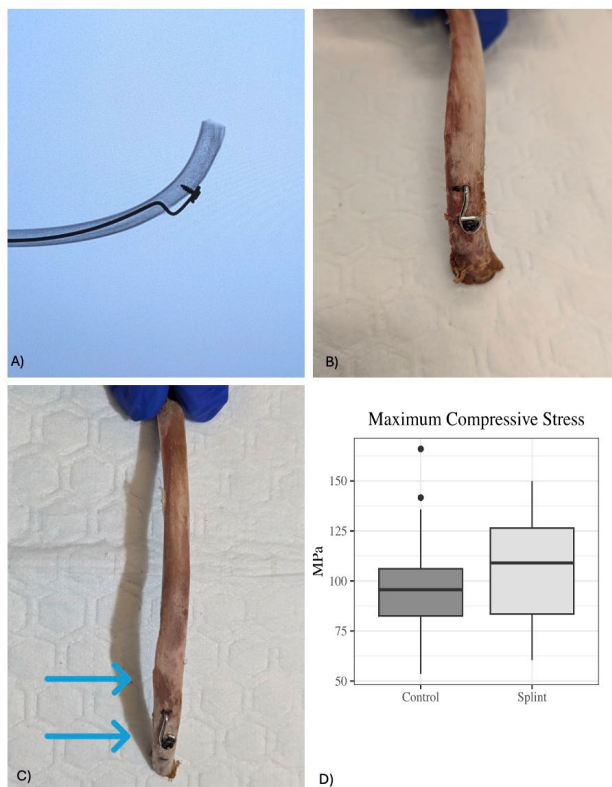


Fig. 1 A) Fluoroscopy image of rib with 1 mm Kirschner wire with Z-bend and 2 mm uni cortical screw B) Anchor and entry point 1 cm apart C) Arrows indicating where load pressure of simulated hook was applied: Top arrow: lateral to entry point, Bottom arrow: between drill holes D) Maximum compressive stress between control and splinted rib

**Paper #79. TEG Identifies Altered Intrinsic Pathway Kinetics in CP PSF**

Jessica Siragusa, MBA; Sydney Thai, BS; William ElNemer, BS; Paul D. Sponseller, MD

**Hypothesis:**

Children with neuromuscular scoliosis exhibit impaired clot propagation on thromboelastography compared to adolescents with idiopathic scoliosis, contributing to increased intraoperative blood loss.

**Design:**

Prospective, translational laboratory study using ex vivo whole blood and viscoelastic testing.

**Introduction:**

Excessive intraoperative blood loss is a major concern during pediatric spinal fusion, especially in children with neuromuscular scoliosis (NMS), who bleed up to 56% more than those with adolescent idiopathic scoliosis (AIS). While platelets are central to hemostasis, platelet dysfunction has not been well characterized in this population. Identifying coagulation abnormalities may improve perioperative risk stratification and blood loss mitigation.

**Methods:**

Children <18 years undergoing posterior spinal

fusion for AIS (n=34) or NMS (n=16) were prospectively enrolled. Arterial blood was collected at baseline (post-induction) and 30 minutes post-incision. Thromboelastography (TEG) was performed using rapid and standard assays to evaluate extrinsic and intrinsic pathways. Parameters included initiation time (R), clot propagation (K,  $\alpha$ -angle), maximum clot strength (MA), and fibrinolysis (LY30). Delta values (post-incision – baseline) were compared across groups, with subgroup analysis for cerebral palsy (CP, n=9).

**Results:**

Global coagulation parameters did not differ significantly between AIS and NMS overall. However, CP patients showed altered intrinsic pathway kinetics, with  $\Delta K$  significantly different from AIS (CP:  $-0.3 \pm 0.3$  min vs AIS:  $0 \pm 0.5$  min;  $p=0.036$ ), suggesting impaired clot propagation (Fig. 1). No other significant differences in R,  $\alpha$ , MA, or LY30 were observed between groups.

**Conclusion:**

Although global coagulation profiles did not differ between children with NMS and AIS, patients with CP demonstrated intrinsic pathway abnormalities consistent with impaired clot formation. These findings suggest that platelet-leukocyte dysfunction may underlie the excessive intraoperative blood loss seen in this population. Recognition of these subtle abnormalities highlights the need for further investigation into platelet-leukocyte interactions and supports the potential use of early biomarkers to improve perioperative risk stratification and blood loss mitigation strategies.

**Paper #80. Operative Treatment of Severe Scoliosis and Pelvic Obliquity in Patients with Spinal Muscular Atrophy**

Heng Sun, MD; Jianxiong Shen, MD

**Hypothesis:**

Few reports exist that focus on patients with spinal muscular atrophy (SMA) and severe spinal deformity. In this study, we aimed to report surgical outcomes and complications for SMA patients with severe scoliosis and pelvic obliquity.

**Design:**

retrospective cohort study

**Introduction:**

Few reports exist that focus on patients with spinal muscular atrophy (SMA) and severe spinal deformity. In this study, we aimed to report surgical outcomes and complications for SMA patients with severe scoliosis and pelvic obliquity.

**Methods:**

A retrospective review of data on operatively treat-

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ed SMA patients with severe scoliosis and pelvic obliquity (minimum major coronal curve Cobb angle > 100° and pelvic obliquity > 20°) was performed. Radiography findings, pulmonary function, motor status, the sitting function score, and perioperative and postoperative complications were the main clinical outcomes examined. Muscular dystrophy spine questionnaire (MDSQ) responses and caregiver responses to four anchor questions (quality of life/comfort/ease of care/overall health) using Likert scales were recorded.

### Results:

Of 28 consecutive patients, 22 (79%) completed the minimum 2-year follow-up (mean age at surgery = 16.1, 68% female). The mean follow-up duration was 40.3-mo. All patients underwent one-stage posterior spinal fusion (PSF) with pelvic fixation. Radiographic measurements (main coronal curve, kyphosis, pelvic obliquity) were significantly corrected (all  $p < 0.001$ ) and were maintained at the last follow-up. The mean forced vital capacity (FVC) remained stable during follow-up, with 50% of patients showing improvement. The percentage of patients who could sit independently increased significantly from 22.7% preoperatively to 77.3% postoperatively ( $p < 0.001$ ). The total sitting-related MDSQ score significantly increased from 8.5 to 12.5 at 6 months postoperatively, and to 15.0 at the last follow-up ( $p < 0.001$ ). Six instances of complications (two instances each of pneumonia, epiglottic edema, and delayed wound healing) occurred perioperatively in six patients (27.3%), but no surgical intervention was required.

### Conclusion:

Operative treatment significantly improved radiographic parameters and sitting function and maintained pulmonary function without serious complications in SMA patients with severe scoliosis and pelvic obliquity.

### Paper #81. Increased Cumulative Incidence of 10-Year Reoperation and Surgical Complications Following Anterior Cervical Discectomy and Fusion Compared to Cervical Disc Arthroplasty

*Theodore Quan, MD; Philip Parel, BS; Jeremy Clements, BS; Adrianna Kowblansky, BS; Sabrina Gill, MD; Tushar Chandrakant Patel, MD; Addisu Mesfin, MD*

### Hypothesis:

We hypothesized that patients who underwent CDA will experience lower 10-year complications compared to those who underwent ACDF.

### Design:

Retrospective cohort study.

### Introduction:

Although short-term and mid-term data suggest comparable outcomes between anterior cervical discectomy and fusion (ACDF) and cervical disc arthroplasty (CDA), there are few studies examining the 10-year outcomes between these two procedures. Therefore, the purpose of this study was to (1) compare the 10-year survivorship and cumulative incidence of secondary cervical procedures of CDA and ACDF and (2) identify differences in surgical complications.

### Methods:

Patients who underwent primary single-level CDA and ACDF were identified using a national database. CDA patients were propensity-score matched to the ACDF cohort in a 1:1 ratio. The 10-year cumulative incidence rate of secondary cervical procedures, which included ACDF, CDA, cervical decompression, and posterior cervical fusion, was determined using Kaplan-Meier survival analysis. Additionally, separate surgical complications including 10-year cumulative incidence rate of all-cause revision or hardware removal, spinal complications, nerve root compression, dural tear, dysphonia/dysphagia, drainage/evacuation, and mechanical failure were determined. Hazard ratios (HR) were conducted using Cox Proportional Hazard modeling.

### Results:

In total, 18,192 CDA patients were matched to 18,192 ACDF patients. The 10-year cumulative incidence of secondary cervical procedures for CDA was 8.7% and ACDF was 11.4%. ACDF patients were significantly more likely to undergo secondary cervical procedures over a 10-year period compared to their CDA counterparts (HR: 1.12,  $P=0.005$ ). Additionally, ACDF patients were significantly more likely to experience spinal complications (HR: 4.73), nerve root compression (HR: 2.61), drainage/evacuation (HR: 2.01), and mechanical failure (HR: 1.36) when compared to patients who underwent CDA over a 10-year period ( $P<0.05$  for all).

### Conclusion:

While short and mid-term studies have demonstrated comparable outcomes between the two procedures, this study highlights the potential long-term benefits favoring CDA over the historical gold standard of ACDF for single-level cervical degeneration. Spine surgeons should consider these 10-year data when counseling patients on the most appropriate surgical option.

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### Paper #82. Conservative vs Anterior Cervical Discectomy Fusion (ACDF), and Anterior Cervical Disc Replacement (ACDR) Approaches—Do Management Outcomes Differ in Patients Presenting with Cervical Radiculopathy without Neurological Deficits?

*Vikas Hanasoge, MBBS, MS; Saumyajit Basu, MS (Ortho), DNB (Ortho), FRCS (Ed); Ayon Ghosh, MS; Dhruvil Kumar Patel, MBBS, MS; Dhruv Patel, MS; Harsh Patel, MS; Ajay VM, MS*

#### Hypothesis:

Management outcomes were comparable between all approaches at the end of follow-up

#### Design:

Retrospective single-center matched cohort study

#### Introduction:

Degenerative cervical radiculopathy results from nerve root compression in the cervical neural foramina, often due to a herniated disc, osteophyte, or facet/ligamentum flavum hypertrophy. Typically, 80% of patients show improvement within the initial 12 weeks through nonoperative measures, with surgical intervention considered for non-responders

#### Methods:

Our study involved 780 patients with cervical radiculopathy from January 2012 to December 2021. About 80.12% found relief with conservative management within 12 weeks. The remaining 155 patients were offered surgery, with 73 opting for continued conservative care, and 82 undergoing surgeries (55 with ACDF and 27 with ACDR). Evaluation was done using the visual analogue scale (VAS), Neck Disability Index (NDI), and radiographic parameters

#### Results:

The mean follow-up was  $11.58 \pm 6.7$  months. ACDR group: Mean age  $43.38 \pm 8.56$ , VAS  $7.81 \pm 1.04$  preoperatively, improved significantly to  $2.07 \pm 1.34$  ( $P < 0.05$ ) at 1-year follow-up. ACDF group: Mean age  $44.85 \pm 10.65$ , VAS  $8.22 \pm 1.21$  preoperatively, improved significantly to  $2.09 \pm 1.01$  ( $P < 0.05$ ) at 1-year follow-up. Conservative group: Mean age  $45.04 \pm 11.19$ , VAS  $7.77 \pm 1.86$  preoperatively, improved significantly to  $2.08 \pm 1.40$  ( $P < 0.05$ ) at 1-year follow-up. Radiographic parameters significantly improved in all groups at 1-year follow-up ( $P < 0.05$ ). The range of motion (ROM) changes varied across groups. Miyazaki's grading and Kim's score showed comparable results.

#### Conclusion:

Comparable clinical and radiological outcomes were observed among conservative, ACDF, and ACDR approaches. ACDR approach demonstrated a better NDI score outcome. Neck ROM was better main-

tained or improved in the ACDR approach, decreased in ACDF, and remained almost similar in the conservative group.

### Paper #83. Deep Learning Fusion of Operative Notes with Structured Preoperative Data Improves 2-Year Outcome Prediction for Cervical Spinal Myelopathy Surgery

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#### Hypothesis:

Integrating operative notes with structured registry data via multimodal deep learning enhances prediction of meaningful outcomes after cervical spinal myelopathy (CSM) surgery.

#### Design:

Retrospective analysis of prospectively-collected, multicenter registry.

#### Introduction:

Predicting which patients achieve the minimum clinically important difference (MCID) after CSM surgery remains challenging, given the limits of structured data. This study aims to 1) evaluate encoding and dimensionality-reduction strategies for unstructured operative notes, and 2) assess performance of multimodal models in predicting 24-month MCID achievement across patient-reported outcomes (PROs).

#### Methods:

We included 1,141 patients who underwent CSM surgery. MCID thresholds were applied to 2-year PROs, including the modified Japanese Orthopaedic Association (mJOA), Neck Disability Index (NDI), EuroQol Visual Analogue Scale (EQ-VAS), EuroQol-5D (EQ-5D), and the Numeric Rating Scales for neck pain (NRS-NP) and arm pain (NRS-AP). Operative notes were encoded using TF-IDF and BlueBERT. For each PRO, feed-forward neural networks were trained using structured data alone (baseline) versus fused datasets with full, reduced (95% variance), or minimal (75% variance) dimensions.

#### Results:

Fusion models could outperform baseline structured models, though the magnitude of improvement varied across PROs. For EQ-5D, the strongest base-

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line model achieved an AUC of  $0.82 \pm 0.04$ . Adding operative note embeddings produced a modest gain, with the TF-IDF fusion technique yielding an AUC of  $0.85 \pm 0.03$ . The most pronounced improvement was observed for EQ-VAS, where the baseline AUC of  $0.73 \pm 0.05$  increased to  $0.82 \pm 0.04$  following use of BERT encoding. For functional outcomes, BERT fusion substantially improved mJOA from an AUC of  $0.69 \pm 0.05$  to  $0.76 \pm 0.04$ . However, NDI increased minimally with TF-IDF from  $0.74 \pm 0.04$  to  $0.76 \pm 0.04$ . Use of BERT fusion also yielded modest gains for NRS-AP from  $0.82 \pm 0.04$  to  $0.84 \pm 0.03$  and minimal change in performance for NRS-NP from a baseline of  $0.82 \pm 0.03$ .

### Conclusion:

We present a novel AI application fusing operative notes with registry data to improve long-term outcome prediction after CSM surgery. Our findings highlight the value of integrating unstructured documentation into multimodal deep learning models. Future work should interpret which operative note features most contribute to these gains.

### Paper #84. Biomechanical Performance of Uniform and Hybrid Screw Constructs in Long-Segment Cervical Spine Fusion: A Finite Element Study

*Authors: Ataollah Shahbandi, MD; Mohamad Bakhaidar, MD, FRCS(C); Balaji Harinathan, PhD, MS; Abdul Mounnem Yassin Kassab, MD; Pegah Ghamasae, MD; Narayan Yoganandan, PhD; Saman Shabani, MD; Kevin Wojcik, DO*

### Hypothesis:

This study aimed to evaluate the biomechanical performance of pars, pedicle, and trans laminar, and hybrid screw constructs at C2 in a C2-T1 finite element (FE) spine model.

### Design:

In-silico study.

### Introduction:

Screw placement at the C2 plays a pivotal role in providing a robust anchor point for long cervicothoracic constructs. However, the optimal screw configuration remains unclear due to limited biomechanical evidence.

### Methods:

A validated FE model of the C2-T1 spine was employed to simulate long-segment posterior fusion. Tested C2 Screw configurations included pedicle, pars, and trans laminar screws, in addition to seven hybrid constructs. Lateral mass screws were placed from C3 to C6, and a pedicle screw was used at T1. A 2 Nm force was applied to simulate physiological

loading conditions across all scenarios. Biomechanical outcomes included the range of motion (ROM) at C2-C3 in flexion, extension, lateral bending, and axial rotation, as well as the von Mises stress on the instruments.

### Results:

At C2-C3, pars screws permitted greater motion in flexion ( $3.51^\circ$ ) and extension ( $2.38^\circ$ ) compared with pedicle ( $2.75^\circ$  flexion,  $2.18^\circ$  extension) and trans laminar screws ( $1.11^\circ$  flexion,  $0.99^\circ$  extension). In lateral bending, trans laminar screws showed higher ROM at C2-C3 ( $0.94^\circ$ ) than pedicle ( $0.49^\circ$ ) and pars screws ( $0.5^\circ$ ), but they provided the greatest ROM restriction at C2-C3 in axial rotation ( $0.72^\circ$  versus  $1.58^\circ$  pedicle screws,  $0.83^\circ$  pars screws). Among hybrid constructs, the bilateral pedicle-bilateral trans laminar (BiPed-BiTranslam) construct was the stiffest, demonstrating the least C2-C3 ROM ( $0.82^\circ$  flexion,  $0.87^\circ$  extension), with minimal difference compared to bilateral pars-bilateral trans laminar (BiPars-BiTranslam) ( $0.92^\circ$  flexion,  $0.91^\circ$  extension). BiPed-BiTranslam also demonstrated the lowest von Mises stress on both C2 screws (24.06 MPa flexion, 21.59 MPa extension) and rods (135.93 MPa flexion, 96.77 MPa extension).

### Conclusion:

Under physiological loading, trans laminar screws provided robust fixation in a C2-T1 construct in flexion, extension, and axial rotation but were inferior in lateral bending compared with pars and pedicle screws. The BiPed-BiTranslam construct offered the greatest rigidity and lowest implant stress among hybrid constructs. Future studies should examine the biomechanical performance of constructs under abnormal spinal alignments, such as kyphosis.

### Paper #85. Extent of Medial Facetectomy Required Varies by Level for Posterior Cervical Foraminotomy: A Radiographic Study

*Joshua H. Lee, MD; Tarun Mattikalli, BS; Brian Cho, MD; Daniel Berman, MD; Wesley Bronson, MD; Saad Chaudhary, MD; Andrew C. Hecht, MD; Jeremy Steinberger, MD; James D. Lin, MD, MS*

### Hypothesis:

The extent of medial facetectomy required for adequate foraminal decompression increases from cranial to caudal cervical spine levels, with greater resection distances and percentages at lower cervical and upper thoracic segments.

### Design:

Retrospective radiographic analysis.

### Introduction:

Posterior cervical foraminotomy treats cervical

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radiculopathy from foraminal stenosis. Adequate decompression typically involves a medial facetectomy to the lateral border of the caudal pedicle to decompress the anatomic borders of the neuroforamen. While it is known that resecting >50% of the facet can be associated with instability, the precise amount of medial facetectomy required at each spinal level has not been previously studied. This study aims to quantify the medial facet resection needed for foraminal decompression on a level by level basis from C3 to T2.

### Methods:

This retrospective study included 50 patients undergoing cervical surgery from 2024 to 2025. Patients were excluded for prior posterior surgery, trauma, infection, tumor, or lack of cervical CT. Bilateral medial facetectomy distances (mm) and percentages (relative to total facet) were measured from C3/C4 to T1/T2 on preoperative CT.

### Results:

Mean facet resection increased from the C3/C4 level to T1/T2 level (Table 1), for both percentage of total facet and absolute facet resection distances. At C3/4, the mean facet resection was  $3.05 \pm 0.84$  mm (23.3  $\pm$  5.3%). At T1/2, the mean facet resection was  $7.53 \pm 1.13$  mm (59.0  $\pm$  7.2%). One-way ANOVA demonstrated a significant difference in facet resection across spinal levels for the left, right, and when both sides were averaged for each patient ( $p < 0.01$ ). Small but significant differences were observed at the C3/C4 level for both percentage of facet (mean difference 2.3%,  $p = 0.01$ ) and distance (mean difference 0.45 mm,  $p = 0.01$ ), favoring slightly greater resection on the left. No other levels demonstrated significant side-to-side differences. Males had significantly greater resection distances at C7/T1 (8.01 mm vs. 6.85 mm,  $p = 0.03$ ) and T1/T2 (7.73 mm vs. 6.96 mm,  $p = 0.03$ ). No other levels showed statistically significant sex-based differences.

### Conclusion:

Medial facetectomy extent needed for adequate decompression increases in a cranial to caudal direction, from  $3.05 \pm 0.84$  mm (23.3  $\pm$  5.3%) at C3/C4 to  $7.53 \pm 1.13$  mm (59.0  $\pm$  7.2%) at T1/T2.

| Level | Left  |      | Right |      | p    | Average |      |
|-------|-------|------|-------|------|------|---------|------|
|       | Mean  | SD   | Mean  | SD   |      | Mean    | SD   |
| C3/4  | 24.5% | 6.5% | 22.2% | 5.8% | 0.01 | 23.3%   | 5.3% |
| C4/5  | 30.3% | 9.3% | 28.8% | 8.7% | 0.18 | 29.6%   | 8.2% |
| C5/6  | 33.7% | 6.7% | 33.9% | 9.5% | 0.90 | 33.8%   | 6.8% |
| C6/7  | 44.3% | 8.0% | 42.2% | 7.8% | 0.06 | 43.2%   | 6.8% |
| C7-T1 | 54.0% | 8.1% | 51.4% | 9.2% | 0.06 | 52.7%   | 7.4% |
| T1-T2 | 59.4% | 8.0% | 58.6% | 8.9% | 0.56 | 59.0%   | 7.2% |

Table 1: Medial facetectomy (% of total facet)

### Paper #86. Surgical and Clinical Outcomes of French Door vs. Open Door Laminoplasty: A Long-Term Analysis of Neurological Recovery

Alexandra N. Yiachos, BS; Lefko Charalambous, MD; Akil Paturi, MD; Kingsley Ogelle, BS; Constance Maglaras, PhD; Themistocles S. Protopsaltis, MD; Tina Raman, MD

### Hypothesis:

French-door Laminoplasty (FDL) provides durable long-term neurologic recovery compared to open-door laminoplasty (ODL), despite similar outcomes and complication profiles.

### Design:

Retrospective cohort review.

### Introduction:

ODL and FDL are techniques used to treat multi-segmental cervical spondylotic myelopathy. Previous studies report similar operative times, mJOA scores, radiographic outcomes, and range of motion, but data on long-term neurological outcomes, Nurick scores, and readmissions remain limited.

### Methods:

Patients  $\geq 18$  years old who underwent laminoplasty were included. Demographics, surgical characteristics, complications, and 30-/90-day readmissions or reoperations were assessed. Neurologic function was evaluated preoperatively and at 6 weeks, 3 months, 6 months, 1 year and 2 years postoperatively. Patients undergoing subsequent lumbar or hip surgery (LHS) were analyzed as potential confounders of Nurick scores. Outcomes were compared using t-tests and  $\chi^2$ , with Fisher's exact test for small samples ( $p < 0.05$ ).

### Results:

182 patients met inclusion criteria (69.2% FDL vs 30.8% ODL). Demographics were similar, though ODL patients had higher CCI ( $p < 0.001$ ). ODL showed longer operative time ( $p = 0.023$ ) and greater laminar plate use (48.2% vs 19.2%,  $p < 0.001$ ). Complications, readmissions and reoperations were comparable. Nurick scores were better in the FDL at 2 years (FDL  $1.4 \pm 1.5$ ,  $p = 0.01$  vs. ODL  $2.9 \pm 1.6$ ). Early improvements were similar between groups, but at 2 years, more FDL patients improved (68.4% vs 12.5%,  $p = 0.006$ ) while more ODL patients showed no improvement (75% vs 28.9%,  $p = 0.03$ ). 31 patients (17%) underwent LHS  $\sim 460$  days post-laminoplasty, with worse preop ( $3 \pm 1.1$  vs  $2.3 \pm 1.3$   $p = 0.005$ ), 6-week ( $2.5 \pm 1.5$  vs  $1.9 \pm 1.5$ ,  $p = 0.014$ ), and 3-month ( $2.4 \pm 1.4$  vs  $1.5 \pm 1.4$ ,  $p = 0.01$ ) Nurick scores. By 2 years, scores were comparable with and without LHS. After excluding these patients, FDL and ODL Nurick scores remained similar at all timepoints except at 2 years, where ODL outcomes were worse (ODL:  $2.7 \pm 1.8$  vs. FDL:  $1.2 \pm 1.4$ ,  $p = 0.03$ ).

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### Conclusion:

FDL and ODL had similar complication and readmission rates. ODL showed longer operative times (likely from plating use) and worse 2-year Nurick outcomes, even after controlling for LHS. FDL may provide more durable long-term neurologic recovery.

### Paper #87. Evaluating the Impact of Single or Two-Level Anterior Cervical Surgery on Extensor Neck Muscle Volume in Patients with Degenerative Pathology

Sydney Pattison, BS; Aiyush Bansal, MD, MASC; Madison Alessi, BS; Kento Yamanouchi, MD; Kenneth Nguyen, BS; Rakesh Kumar, MD; Jean-Christophe A. Leveque, MD; Venu M. Nemani, MD, PhD; Philip K. Louie, MD

### Hypothesis:

Patients undergoing anterior cervical discectomy and fusion (ACDF) will have a greater reduction in cervical extensor muscle (CEM) volume postoperatively compared to those undergoing cervical disc replacement (CDR), as measured by MRI cross-sectional area (CSA).

### Design:

Retrospective Cohort

### Introduction:

Degenerative changes in the cervical spine can cause radicular symptoms requiring surgery. Studies have shown that cervical extensor muscles (CEM) contribute to degeneration; atrophy is with worse outcomes. Yet, research exploring changes in CEM following anterior cervical discectomy and fusion (ACDF) or cervical disc replacement (CDR) is limited. This study 1) assessed MRI-measured CEM volume changes in patients undergoing 1-2 level ACDF or CDR for degenerative pathology, 2) compared changes in ACDF vs CDR, and 3) established a preliminary effect size.

### Methods:

Retrospective analysis of patients undergoing single- or two-level ACDF or CDR for degenerative pathology, without prior instrumentation or cervical spine surgery. Cross-sectional areas (CSA) of bilateral CEMs were measured on pre- and postoperative axial T2 MRIs at the C4-C5 intervertebral disc using Philips IntelliSpace PACS. Wilcoxon signed-rank tests assessed pre- to post-op changes; Wilcoxon rank-sum tests compared ACDF vs CDR.

### Results:

Thirty-four patients (nACDF=22; nCDR=12) were included. ACDF patients were older (62.1 vs. 46.4 years,  $p < 0.001$ ); other demographics were similar. Across the full cohort, postoperative CSA decreased significantly. Right-sided CSA decreased from a median

of 10.14 cm<sup>2</sup> to 9.44 cm<sup>2</sup> ( $p < 0.001$ ) and left-sided CSA from 9.84 cm<sup>2</sup> to 9.68 cm<sup>2</sup> ( $p = 0.003$ ). After age-matching, (nACDF = 10; nCDR = 10) no significant differences in muscle CSA change were observed between surgeries. Median right-sided change was -1.21 cm<sup>2</sup> for ACDF versus -0.44 cm<sup>2</sup> for CDR ( $p = 0.35$ ); median left-sided change was -0.885 cm<sup>2</sup> for ACDF versus -0.300 cm<sup>2</sup> for CDR ( $p = 0.48$ ).

### Conclusion:

At ~1 year after ACDF or CDR, CEM CSA decreases. While muscle atrophy did not differ between surgeries, ACDF showed greater variability in muscle change. This suggests ACDF is non-inferior to CDR for postoperative muscle preservation, but larger studies are needed to clarify potential differences in CEM morphology.

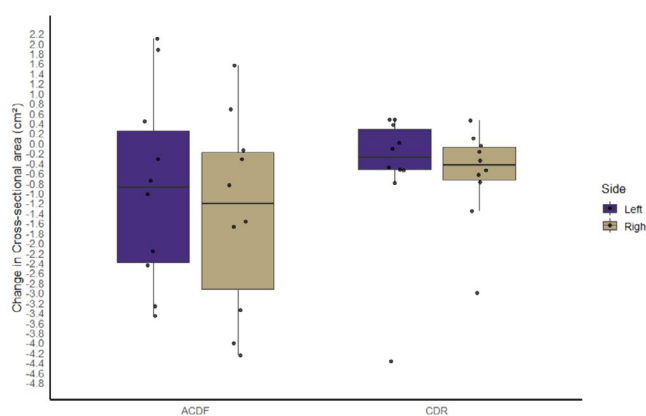


Figure 1. Changes in left and right CEM cross-sectional area following ACDF or CDR in an age-matched cohort.

### Paper #88. Transient Skeletal Muscle Loss After Cervical Decompression for Myelopathy

Isaiah Gritters, BA; Reagan Grieser-Yoder, BS; Natalie Glass, PhD; Bradley Hindman, MD; Andrea Strayer, PhD; Matthew Howard, MD; Catherine Olinger, MD, MS

### Hypothesis:

Cervical decompression for degenerative cervical myelopathy (DCM) increases appendicular skeletal muscle index (ASMI) postoperatively.

### Design:

This was a prospective study of adults aged 47-83 undergoing non-emergent cervical decompression for DCM. Exclusion criteria were the presence of cardiac electronic devices or the inability to stand unsupported. Patients were followed through 26 weeks postoperatively.

### Introduction:

DCM is a prevalent spinal cord disorder in older adults, causing gait instability and disruption of fine motor control. Surgical decompression aims to halt

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or reverse symptoms measured by the modified Japanese Orthopaedic Association (mJOA) scale, and factors affecting recovery remain unclear. Sarcopenia, defined as low skeletal muscle mass and/or strength, is common in older adults, is associated with functional decline and mortality, and may affect cervical spine procedure outcomes. Bioelectrical impedance analysis (BIA) quantifies skeletal muscle mass and can calculate ASMI (kg/m<sup>2</sup>) to detect sarcopenia. This study evaluated preoperative sarcopenia prevalence and postoperative ASMI changes in patients undergoing decompression for DCM.

### Methods:

ASMI was measured by BIA at baseline and 3, 6, 13, and 26 weeks postoperatively. Functional status was assessed with mJOA scores at the same time points. Longitudinal ASMI change was modeled using repeated measures generalized linear models with postoperative week as the independent variable. Estimated marginal means were compared with baseline, with simulation adjustment for multiple comparisons. Analyses were repeated with sex, mJOA, and surgical invasiveness (levels fused: 1, 2-3, ≥4) as covariates.

### Results:

Thirty-one patients were analyzed. Preoperatively, 6.5% (n=2) of patients met the criteria for sarcopenia. ASMI was significantly reduced compared with baseline at weeks 3, 6, and 13 (P=0.002, 0.001, 0.008), but not week 26 (P=0.71). ASMI was greater in males (9.0±1.3) than in females (7.2±1.2), P=0.001, but sex did not modify postoperative ASMI change (P=0.78). mJOA was not associated with ASMI (P=0.66).

### Conclusion:

ASMI decreased significantly during the first 13 weeks after decompression but recovered to baseline by week 26. This transient decline is consistent with postoperative activity and lifting restrictions, suggesting temporary muscle loss. Continued follow-up will determine whether decompression is associated with long-term ASMI or sarcopenia prevalence.

### Paper #89. Personalizing the Approach to Degenerative Cervical Myelopathy (DCM): Multivariable Trajectory Models to Define Precise Clinical Recovery Patterns

*Michael G. Fehlings, MD, PhD, FRCS(C); Karlo M. Pedro, MD; Mohammed Ali Alvi, MD, PhD, MS*

### Hypothesis:

Joint modelling of neurological, functional, and quality of life outcomes may improve prognostication and inform surgical decision-making beyond single metric analysis.

### Design:

Retrospective

### Introduction:

Clinical heterogeneity among DCM patients limits utility of univariate longitudinal models in capturing postoperative recovery patterns. We applied joint longitudinal modeling of core outcomes to identify multidimensional prognostic DCM phenotypes.

### Methods:

We retrospectively analyzed individual patient data pooled from three major multicenter DCM studies (CSM-NA, CSM-I, and CSM-PROTECT). One-year longitudinal changes in the modified Japanese Orthopaedic Association (mJOA) score, Neck Disability Index (NDI), and SF-36 Physical Component Score (PCS) were simultaneously modelled using Bayesian Consensus Clustering (BCC). Optimal trajectory number was determined via maximum mean adjusted adherence (MAA). Cluster membership and minimal clinically important differences (MCID) achievement in mJOA and SF-36 PCS were evaluated using logistic regression, with model validation performed using 100 bootstrap replicates.

### Results:

Among 1,047 DCM patients, BCC identified three distinct trajectories. Trajectory 1 (n=177, 17%) included patients with minimal recovery and persistently low mJOA and SF-36 PCS scores. Trajectory 2 (n=525, 50%) showed most significant reductions in NDI, while Trajectory 3 (n=346, 33%) achieved global improvements across all measures. Patients in Trajectory 3 had the highest odds of achieving MCID in both mJOA (OR 10.90, 95% CI 6.15-19.32) and SF-36 PCS (OR 2.90, 95% CI 1.90-4.42). BCC outperformed other multivariable finite mixture models in reducing cluster uncertainty, and bcc-derived class inclusion improved model discrimination. Anterior surgical approach (OR 3.55, 95% CI 1.21-10.37) and frailty (OR:1.42, 95% CI 1.14-1.76) emerged as independent predictors of global response trajectory.

### Conclusion:

Recovery after surgery follows three distinct multidimensional trajectories. Joint modelling of neurological, functional, and quality of life outcomes improves prognostication and informs surgical decision-making beyond single metric analysis. Integrating trajectory-derived phenotypes into treatment algorithms and clinical trials could refine patient selection and optimize outcomes in DCM.

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### Paper #90. Does Surgery Reduce Neck Pain and Restore Independence 5 years After Surgery for Cervical Spondylotic Myelopathy (CSM)? A SpineCORE QOD Study.

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#### Hypothesis:

We aim to study what degree of self-care independence and neck pain resolution patients regain after CSM surgery.

#### Design:

Prospective

#### Introduction:

Many patients with CSM are functionally limited by severe neck pain, compromising their ability to care for themselves.

#### Methods:

The SpineCORE QOD study group prospectively collects baseline and patient-reported outcomes (PROs) across 14 high-enrolling sites. We conducted a retrospective analysis 2-5 years after surgery. The Neck Disability Index (NDI) includes a subscore for self-care, where scores of 0-1 indicate “normal” self-care. Scores of 2-5 indicate worsening degrees of neck pain-related functional impairment. Accordingly, we classified patients with self-care scores  $\geq 2$  as impaired. We analyzed factors associated with regaining self-care ability postoperatively.

#### Results:

Of QOD CSM cohort's 1141 patients, 1029 patients were alive 5 years postoperatively. Of these 1029, 412 patients (40.0%) were impaired for personal care at baseline due to neck pain (NDI personal care score  $\geq 2$ ). Of these 412 patients, 298 (72.3%) had 5-year postoperative follow-up data. At 2 years postoperatively, 177/298 patients (59.4%) reported recovery from impaired personal care and reduced neck pain (NDI personal care score  $\leq 1$ ). By 5 years, an additional 44 patients improved for a total of 221/298, 74.2%. On univariate and multivariate analysis, approach (anterior vs posterior) was not associated with differing rates of 5-year personal care and neck pain recovery.

#### Conclusion:

A significant proportion of patients with CSM suffer from neck pain-related functional and self-care disability (40.0%). Following surgery for CSM, most patients recover from self-care impairment due to neck pain after CSM surgery—59.4% by 2 years and 74.2% by 5 years. There were no significant differences based on anterior versus posterior approach. These findings have important implications for patient counseling and quality of life, particularly for those presenting with preoperative functional and self-care deficits.

### Paper #91. Does Timing Matter? Impact of Early Surgery for Cervical Spondylotic Myelopathy on 5-Year Patient-Reported Outcomes

Eunice Yang, BS; Harrison Howell, BS; Praveen V. Mummaneni, MD; Dean Chou, MD; Mohamad Bydon, MD; Erica F. Bisson, MD; Christopher I. Shaffrey, MD; Oren N. Gottfried, MD; Anthony L. Asher, MD; Domagoj Coric, MD; Eric A. Potts, MD; Kevin T. Foley, MD; Michael Y. Wang, MD; KaiMing G. Fu, MD, PhD; Michael S. Virk, MD, PhD; John J. Knightly, MD; Scott Meyer, MD; Paul Park, MD; Cheerag D. Upadhyaya, MD; Chun Po Yen, MD; Juan S. Uribe, MD; Luis M. Tumialan, MD; Jay D. Turner, MD, PhD; Regis W. Haid, MD; Andrew K. Chan, MD

#### Hypothesis:

Earlier surgical intervention for cervical spondylotic myelopathy (CSM) promotes superior recovery and improved postoperative outcomes relative to delayed surgery.

#### Design:

Retrospective analysis of prospectively-collected, multicenter registry.

#### Introduction:

Surgical decompression provides definitive treatment for CSM, halting disease progression and often improving pain, function, and quality of life. However, the optimal timing of surgery remains controversial, with no consensus on the impact of preoperative symptom duration.

#### Methods:

CSM patients were stratified into “early” (<12 months) and “late” surgery cohorts ( $\geq 12$  months). Baseline demographic, clinical, and surgical characteristics were compared via univariate analysis. Patient-reported outcomes (PROs) and achievement of the minimum clinically important difference (MCID) were assessed at 2 and 5 years. Multivariable models were adjusted for significant univariate features ( $p < 0.05$ ).

#### Results:

A total of 1,085 patients were included, with 489 early and 507 late surgery patients. At baseline, the early

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cohort had lower BMI (29.7±6.1 vs 30.6±6.8), higher SES index (53.1±5.1 vs 52.5±4.8), and higher rates of prior major surgery (35.2% vs 27.2%). They were less likely to report diabetes (18.0% vs 24.1%) and anxiety (15.1% vs 20.7%). The early cohort started with lower NDI (36.3±20.2 vs 40.7±20.6), lower NRS-NP (4.9±3.2 vs 5.6±3.2), higher mJOA (12.3±2.8 vs 11.9±2.8), and higher EQ-5D (0.59±0.21 vs 0.54±0.23) (p<0.05). At 24 months, early surgery was independently associated with greater mJOA ( $\beta=0.29$ , 95% CI 0.02–0.56), lower NRS-NP ( $\beta=-0.34$ , 95% CI -0.56 to -0.12), lower NRS-AP ( $\beta=-0.24$ , 95% CI -0.46 to -0.011), and superior NASS satisfaction ( $\beta=-0.29$ , 95% CI -0.53 to -0.056). By 60 months, early surgery patients continued to report lower NRS-NP ( $\beta = -0.23$ , 95% CI -0.45 to -0.01). Early intervention was also associated with higher odds of achieving MCID for EQ-5D (OR = 1.40, 95% CI 1.03–1.90) (p<0.05).

### Conclusion:

Both early and late cohorts experienced durable improvement after surgery for CSM. Early surgery was associated with superior 24-month outcomes, with benefits persisting at 60 months, including lower pain and superior quality-of-life. Our findings suggest that earlier intervention may confer faster and more sustained recovery, supporting timely referral for operative management in appropriately selected patients.

### Paper #92. Clinical Validation of a Novel Psoas Classification for Optimal L4–L5 Access: OLIF vs LLIF

Harjot Uppal, MD; George Abdelmalek, MD; Daniel Coban, MD; Siraj Shaikh, MD; Nikhil Sahai, MD; Kumar Sinha, MD; Ki S. Hwang, MD; Arash Emami, MD

### Hypothesis:

Psoas morphology independently predicts approach-specific neurovascular complications in OLIF vs LLIF at L4–5

### Design:

Retrospective cohort study.

### Introduction:

Oblique lumbar interbody fusion (OLIF) and lateral lumbar interbody fusion (LLIF) are commonly performed for L4–L5 degenerative spondylolisthesis. The Emami classification categorizes psoas morphology relative to the L4 vertebral body and may guide approach selection to mitigate neurologic and vascular risk. However, no prior study has correlated this classification system with complication profiles.

### Methods:

We retrospectively reviewed 350 patients who underwent single-level OLIF (n=178) or LLIF (n=172) at

L4–L5 between 2012–2022 for low-grade degenerative spondylolisthesis. Preoperative axial T2-weighted MRI at the inferior endplate of L4 was used to classify psoas morphology: Class A (>2 mm anterior), Class B ( $\leq 2$  mm anterior/posterior), and Class C (>2 mm posterior). Neurologic and vascular complications were analyzed using multivariable logistic regression.

### Results:

Neurologic complications were significantly more frequent in LLIF versus OLIF (13.4% vs. 2.8%, p<0.001), particularly in Class A (16.4% LLIF vs. 2.3% OLIF, p<0.001). Conversely, Class C had fewer neurologic injuries with LLIF (2.1%) than OLIF (8.9%) (p=0.019). Vascular complications were more common in OLIF (5.1% vs. 1.2%, p=0.026), especially in Class C (13.3% OLIF vs. 1.8% LLIF, p=0.011). Logistic regression confirmed that Class A predicted neurologic injury with LLIF (OR 4.52, p<0.001), while Class C predicted vascular injury with OLIF (OR 5.29, p=0.003).

### Conclusion:

Psoas morphology independently predicts neurovascular complication risk with OLIF versus LLIF at L4–L5. Class A favors OLIF due to lower neurologic risk, while Class C favors LLIF due to lower vascular risk. Class B represents intermediate risk. Preoperative MRI-based psoas classification may optimize approach selection and improve patient safety.

### Paper #93. Revision Anterior Lumbar Spine Access Surgery: Is It Safe?

Karim A. Shafi, MD; Sree Vemu, MD; Rajeev Rao, MD; Todd H. Lanman, MD; Hyun W. Bae, MD; Willis Wagner, MD

### Hypothesis:

Revision anterior lumbar spine surgery is a feasible and safe approach when performed with proper planning and a multidisciplinary team.

### Design:

Retrospective cohort study conducted at two tertiary care centers from 2009 to 2021.

### Introduction:

Anterior lumbar approaches, including anterior lumbar interbody fusion (ALIF) and lumbar total disc replacement (L-TDR), have been widely adopted due to their biomechanical advantages and clinical success. However, limited data exist on the feasibility, safety, and outcomes of revision anterior lumbar surgery. The purpose of the study is to evaluate the techniques, success rates, and complications associated with revision anterior lumbar spine surgery, utilizing data from a large, single-institution registry.

### Methods:

A retrospective review of a single-institution registry

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identified 137 revision anterior lumbar procedures in 135 patients out of 6,130 anterior lumbar surgeries performed between 2009 and 2021. Revision procedures were defined as those performed >4 weeks after the index surgery. A standard midline retroperitoneal approach was used. Data collected included demographics, surgical indication, approach (contralateral, ipsilateral, bilateral, or transperitoneal), EBL, operative time, and complications.

### Results:

The mean age was 55.7 years (range 19–83), and mean BMI was 25.7 kg/m<sup>2</sup> (range 17–43). The most common indication for revision was ASD (n=83, 61%), followed by failed L-TDR (n=25, 18%). Approaches included contralateral (n=74, 54%), ipsilateral (n=61, 45%), bilateral (n=1), and transperitoneal (n=1). Mean EBL was 150 mL (range 10–2,050). Seven procedures (5%) were aborted six due to iliac vessel adherence and one due to morbid obesity. Vascular injuries occurred in 20 cases (15%), with one requiring iliac vein stenting. Two ureteral injuries (1.4%) were noted without long-term sequelae. No mortalities were reported

### Conclusion:

Revision anterior lumbar spine surgery is feasible and safe when performed with appropriate planning. Although the risk of iliac vein injury is higher than in primary exposures, long-term sequelae were not observed. A multidisciplinary approach, including both vascular and spine surgeons, optimizes safety and surgical success.

### Paper #94. Impact of Screw Diameter on the Mechanical Performance of Cement-Augmented Lumbar Spinal Fusion Constructs

*Akar J. Jani, BS; Nicole DeVries Watson, PhD; Douglas C. Fredericks, BS; Catherine Olinger, MD, MS*

### Hypothesis:

We hypothesize that (1) larger-diameter cement-augmented fenestrated pedicle screws will show higher pullout strength than non-fenestrated screws after cyclic loading, and (2) larger diameter screws will increase cement distribution, enhancing resistance to pullout.

### Design:

Fifty-millimeter length titanium polyaxial pedicle screws were tested in three groups: fenestrated screws of 5.5 and 6.5 mm diameter (n=8 each), and non-fenestrated 6.5 mm screws (n=8). Screws were implanted into anatomical osteoporotic-grade synthetic L3 lumbar vertebrae (Sawbones®) and fenestrated screws were augmented with 3 cc of PMMA. Outcomes included pullout strength and CT analysis

of cement distribution, screw-hole volume changes, and implant-related damage after cyclic loading.

### Introduction:

In osteoporotic bone, the advantage of using larger fenestrated screw diameters with polymethylmethacrylate (PMMA) cement augmentation may be limited. Augmentation concentrates stress at the screw-bone interface, potentially reducing the effectiveness of larger screws. Thus, the benefit of larger screws in cement-augmented fixation remains unclear.

### Methods:

3D-printed drill guides ensured consistent screw trajectories parallel to the vertebral endplates. All constructs were mounted to a Material Testing System (MTS) following modified ASTM F1717-21 and subjected to 90,000 cycles of compressive loading (100–200 N, 3 Hz) with axial rotation ( $\pm 1.5^\circ$ , 1.8 Hz). Pullout strength was measured according to modified ASTM F543-23.

### Results:

Initial CT confirmed intact cortical shells after screw implantation. Cement injection caused superior endplate extravasation in one of four vertebrae with 5.5 mm screws and three of four vertebrae with 6.5 mm screws. Comparison between left and right fenestrated screws showed no significant differences in pullout strength for 5.5 mm (left:  $1726.23 \pm 333.12$  N, right:  $1672.72 \pm 285.36$  N,  $p = 0.64$ ) or 6.5 mm screws (left:  $1806.20 \pm 314.90$  N, right:  $2033.68 \pm 106.70$  N,  $p = 0.12$ ). 6.5 mm fenestrated screws demonstrated higher mean pullout strength than 5.5 mm screws ( $1919.94 \pm 249.37$  N vs  $1699.47 \pm 288.73$  N), but this difference was not significant ( $p = 0.12$ ).

### Conclusion:

Preliminary findings suggest increasing screw diameter does not significantly improve biomechanical performance. Larger fenestrated screws experienced more frequent extravasation, indicating elevated structural risk without increased fixation strength.

### Paper #95. Development and Validation of a Novel Survey Measuring Lumbar Activity Levels: Core Health Evaluation - Lumbar Activity Rating Scale (CHEV-LARS)

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### Design:

Phased prospective validation study

### Introduction:

While there are surveys measuring activity levels

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in other areas of orthopedics there are no validated surveys in spine surgery. Stratifying patients by preoperative activity level may help guide treatment decisions such as conservative versus surgical management and decompression alone versus fusion

### Methods:

Our goal was to develop and validate an activity rating scale for lumbar spine patients. This study had 4 stages: Item Generation/Item Reduction/Pilot-Testing Phases: clinic patients > 18 years with lumbar pathology and no prior lumbar surgery. Validation phase: volunteer respondents > 18 and < 89 years currently in the United States. We collected demographics, BMI, level of activity, ODI, and PROMIS PF CAT. Item generation: 40 patients were interviewed on activities that involve their low back. Item reduction: 40 separate patients rated activities from 1-10 for "importance" and "difficulty". Correlation matrices and clinical judgement were used to generate a pilot survey. Pilot-testing: 40 separate patients provided feedback on clarity, structure, and relevance to generate a final survey: HSS CHEV-LARS. Validation: 205 respondents from CloudResearchTM completed the HSS CHEV-LARS, ODI, and PROMIS PF CAT. The same respondents completed the HSS CHEV-LARS again 1 week later to assess test-retest validity (ICC). Construct validity was assessed by correlating the HSS CHEV-LARS with ODI, PROMIS PF CAT, age, and BMI. Internal consistency was assessed with Cronbach's alpha.

### Results:

The 12 activities from phase 1 involved activities such as walking, sitting, carrying, lifting, bending, and twisting. The HSS CHEV-LARS demonstrated significant correlation with age ( $p < 0.001$ , all). There was no significant correlation between HSS CHEV-LARS and BMI. No floor or ceiling effects were noted on the HSS CHEV-LARS. Cronbach alpha showed good internal consistency (0.80). HSS CHEV-LARS scores approached a normal distribution. ICC showed good/almost excellent reliability (0.867).

### Conclusion:

We developed and validated a novel lumbar activity rating scale. Future studies should investigate associations between the HSS CHEV-LARS and other metrics to assess prognostic potential.

### Paper #96. Tranexamic Acid Does Not Significantly Change Thromboembolic Risk in Spinal Metastasis Tumor Patients

*Braxton Morrison, MS; Jay Kumar, MD; Vardhaan Ambati, MS; Hunter S. Yamada, BS; Abraham Dada, BA; Rithvik Ramesh, BS; Parisa Jahangirizadeh, BA; Paul McMillan Villalobos, BE; Christopher P. Ames, MD; Vedat Deviren, MD; Sigurd H. Berven, MD; Alekos A. Theologis, MD; Dean Chou, MD; Aaron J. Clark, MD, PhD; Praveen V. Mummaneni, MD; Nima Alan, MD*

### Hypothesis:

We hypothesized that peri-op TXA ( $\leq 24$  h pre-op, intra-op, or  $\leq 24$  h post-op) is not associated with VTE after spinal metastasis surgery.

### Design:

Single Center Retrospective Review

### Introduction:

Tranexamic acid (TXA) is used to reduce blood loss in spine surgery, but its influence on venous thromboembolism (VTE) risk remains a concern.

### Methods:

We retrospectively reviewed consecutive adult patients who underwent spinal metastasis surgery at a single institution (2005-2024). Outcomes included post-op deep vein thrombosis (DVT), pulmonary embolism (PE), or other VTE. Multivariable regression adjusted for age, race, language, sex, BMI, corpectomy, number of operated levels, pre-op embolization, pre-op hemoglobin, pre-op immunotherapy, VCR, vertebroplasty, and whether metastases arose from hypervascular primaries (renal cell, thyroid, or hepatocellular carcinoma). Covariates were determined via univariate analysis. For dose subgroups, when bolus and drip categories differed, patients were placed in the high dose category.

### Results:

488 patients (39.3% female; mean age 62.4) were identified; 138 (28.3%) received peri-op TXA. Post-op DVT occurred in 4.1% and VTE/PE in 3.3%. The TXA cohort differed in average number of operated levels ( $6.5 \pm 2.9$  vs  $5.1 \pm 2.5$ ,  $p < 0.001$ ) and rates of pre-op embolization (36.8% vs 15.0%,  $p < 0.001$ ), VCR (22.4% vs 10.4%,  $p < 0.001$ ), corpectomies (60.3% vs 45.2%,  $p = 0.001$ ), vertebroplasty (21.3% vs 10.9%,  $p = 0.002$ ), whether metastases arose from hypervascular primaries (35.9% vs 23.5%,  $p = 0.003$ ), and pre-op immunotherapy (10.3% vs 18.6%,  $p = 0.018$ ). On univariate analysis, TXA was not associated with DVT (4.3% [ $n=6$ ] vs. 4.0% [ $n=14$ ]) or VTE/PE (1.4% [ $n=2$ ] vs. 4.0% [ $n=14$ ]) ( $p > 0.05$ ). On multivariate regression analysis, TXA was not associated with DVT (OR 1.54) or VTE/PE (OR 0.62) ( $p > 0.05$ ). Subgroup analysis stratified patients by TXA dose: low ( $\leq 10$  mg/kg and/or 1 mg/

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kg/hr, n=55), medium (10-20 mg/kg and/or 2 mg/kg/hr, n=41) and high ( $\geq 20$  mg/kg and/or 3 mg/kg/hr n=42). Among groups, there was no significant difference in DVT (no TXA 3.9% [n=14]; low 0.0%; medium 11.4% [n=5]; high 2.4% [n=1]  $p > 0.05$ ) or VTE/PE (no TXA 0.60% [n=1]; low 0.0%, medium 0.0%; high 4.8% [n=2]  $p > 0.05$ ).

### Conclusion:

TXA administration was not associated with increased VTE risk, supporting its safety profile in spinal metastasis surgery.

### Paper #97. Does Preoperative Embolization Lower Surgical Blood Loss in Nonvascular Metastatic Spine Tumor Surgery?

*Hunter S. Yamada, BS; Vardhaan Ambati, MS; Danielle Nieto, BA; Paul McMillan Villalobos, BE; Parisa Jahangirizadeh, BA; Braxton Morrison, MS; Abraham Dada, BA; Rithvik Ramesh, BS; Christopher P. Ames, MD; Sigurd H. Berven, MD; Alekos A. Theologis, MD; Dean Chou, MD; Aaron J. Clark, MD, PhD; Lee A. Tan, MD; Praveen V. Mummaneni, MD; Nima Alan, MD*

### Hypothesis:

We hypothesize that preoperative embolization will lower mean surgical blood loss in nonvascular spine tumor surgeries.

### Design:

A retrospective consecutive cohort study conducted at a single institution.

### Introduction:

It remains unclear if preoperative embolization improves blood loss during resection of spinal column metastases originating from non-vascular primary tumors.

### Methods:

Patients who underwent resection of vertebral column metastases (excluding renal, hepatocellular, and thyroid) were identified. Uni- and multivariate analyses compared effect of embolization on blood loss and transfusion rates. Next, embolized and non-embolized cohorts were propensity-score matched (PSM) (1:3 on age, sex, BMI, corpectomy, levels operated) and compared.

### Results:

In total, 414 patients (44.4% female) with non-vascular spinal column metastases were identified with mean age 62.7 years and preop hemoglobin level (Hgb=11.7). 47 patients (11.4%) patients underwent embolization. The cohorts did not differ significantly in age, BMI, or preop Hgb. However, the embolized cohort had a higher proportion of female patients (68.1% vs 41.4%,  $p < 0.001$ ). The embolized cohort had more corpectomies (74.5% vs 45.2%,  $p < 0.001$ )

and levels operated ( $6.7 \pm 2.2$  vs  $5.4 \pm 2.8$ ,  $p < 0.001$ ). The embolized and non-embolized cohorts had no significant differences in EBL ( $1221.5 \pm 1159.1$  vs  $938.2 \pm 1257.0$ ), change (post—preop) in Hgb, pRBC transfusions rates (53.3% vs 49.7%), or units transfused ( $4.0 \pm 3.3$  vs  $3.1 \pm 3.1$ ,  $p = 0.249$ ). On multivariate analysis, increased levels operated (EBL  $\beta$ -Coef: 116.96,  $p < 0.001$ ), and corpectomy (EBL  $\beta$ -Coef: 447.96,  $p = 0.001$ ) were associated with higher EBL and increased transfusion rates. Higher preop Hgb was associated with lower rates of transfusion (OR:0.81, CI:0.71-0.91). Corpectomy ( $\beta$ -Coef:-0.37,  $p = 0.006$ ) was associated with lower postop Hgb levels, while higher preop Hgb ( $\beta$ -Coef:0.28,  $p < 0.001$ ) and embolization ( $\beta$ -Coef:0.41,  $p = 0.030$ ) were associated with higher postop Hgb levels. After PSM, 188 patients (47 [25%] embolized) were included. The embolized and non-embolized cohorts had no significant differences in age, sex, BMI, pre- and postop Hgb, EBL, and transfusion rates.

### Conclusion:

Embolization prior to resection of non-vascular spinal column metastases did not reduce EBL or pRBC transfusion rates.

### Paper #98 has been WITHDRAWN

### Paper #99 has been WITHDRAWN

### Paper #100. Expandable Cage versus Mesh Cage in the Treatment of Vertebral Osteomyelitis

*Mitsuhiro Nishizawa, MD; Mladen Djurasovic, MD; Steven D. Glassman, MD; John R. Dimar, II, MD; Charles H. Crawford III, MD; Benjamin Kostic, BS; Leah Y. Carreon, MD*

### Hypothesis:

Clinical outcomes and costs between mesh cages and expandable cages are similar in patients with vertebral osteomyelitis.

### Design:

Retrospective observational cohort

### Introduction:

Surgical treatment of vertebral osteomyelitis often includes anterior column reconstruction due to large bone defects following debridement. However, consensus regarding the optimal method for anterior column reconstruction in vertebral osteomyelitis has not been established.

### Methods:

We retrospectively reviewed the clinical records of consecutive patients who underwent surgical intervention for vertebral osteomyelitis at a single institution between 2012 and April 2024. Patients who underwent anterior column debridement with either

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a mesh cage or an expandable cage and posterior fusion involving four or more levels were included. Clinical outcomes, including fusion, nonunion, revision surgery, and recurrence, as well as costs, were compared between the expandable cage and mesh cage groups.

### Results:

A total of 92 patients were included: 20 (22%) in the expandable cage group and 72 (78%) in the mesh cage group. The expandable cage group had a significantly higher nonunion rate (35% vs 9.7%,  $p = 0.014$ ) and revision rate (30% vs 9.7%,  $p = 0.032$ ). Costs were also higher in the expandable cage group, with a significant difference in in-hospital costs (Expandable:  $77,737 \pm 34,586$ ; Mesh:  $63,250 \pm 27,899$ ;  $p = 0.028$ ). The number of fused levels (OR = 1.32, 95% CI: 1.05–1.71;  $p = 0.024$ ) and the use of an expandable cage (OR = 3.27, 95% CI: 1.04–11.02;  $p = 0.046$ ) were independent risk factors for treatment failure, defined as revision surgery, recurrence, or mortality.

### Conclusion:

The use of an expandable cage for reconstruction after anterior column debridement was associated with higher costs and with increased risks of nonunion, revision surgery, and treatment failure compared to the use of mesh cages.

### Paper #101. Tuberculosis of the Spine in Children- Is Conservative Treatment Effective?

*Bhushan Sagade, MS; Alaric Aroojis, MD; Ira Shah, MD; Rujuta Mehta, MD; Tausif Ahmed A. Shikalgar, MD, MBBS, D.Ortho, DNB Ortho; Arjun Dhawale, MD; Abhay Nene, MS*

### Hypothesis:

To study outcomes of non-operative treatment of paediatric spinal tuberculosis and its transition to surgical intervention.

### Design:

Retrospective cohort study

### Introduction:

Spinal TB especially drug-resistant TB has emerged as challenge. The study aimed to evaluate culture and sensitivity patterns and outcomes of non-operative treatment with first-line and second-line anti-tubercular therapy in paediatric patients with spinal TB and identify reasons for failures of treatment and conversion to operative treatment.

### Methods:

Clinico-radiological data of children treated conservatively for spinal TB at a single center with at least 2-years of follow-up were analyzed. Data collected included age, gender, level of affection, number of vertebrae involved, neurological status, microbiologi-

cal reports, duration, type of anti-tubercular therapy, details of orthopaedic management, and any complications during treatment.

### Results:

105 children with an average age  $9.07 \pm 3.83$  years, (50 boys, 55 girls) were managed conservatively with a mean follow-up of  $5.15 \pm 1.69$  years. The average number of vertebral bodies involved was  $2.41 \pm 0.91$ ; the pre-treatment kyphosis angle was  $12.8 \pm 10.75$ ; and the post-treatment kyphosis angle was  $23.88 \pm 18.93$ . Sixty-one children were treated with first-line ATT (58.10%) while 44 required second-line ATT (41.90%). Steroids were prescribed to 43 patients. Fifteen children required conversion to surgery due to progressive neurodeficit, worsening of deformity, or persistent instability pain. Comparing patients needing first and second-line treatment showed significant differences in pre- and post-treatment kyphosis angle, pattern of healing, history of contact, need for steroids and conversion to surgery in patients who required 2nd line ATT ( $p < 0.001$ ). Drug resistance analysis revealed Rifampicin and Isoniazid resistance in all resistant cases. There was a significant difference in the number of vertebral bodies involved, pre-treatment kyphosis angle, need for steroids and history of contact in patients requiring surgery compared to those treated conservatively ( $p < 0.001$ ).

### Conclusion:

Conservative treatment is effective in most cases of drug-sensitive or drug-resistant spinal TB in children with appropriate ATT. Close monitoring is required for neurological worsening, progression of kyphosis, and drug-related complications. Post-treatment deformity, healing pattern, and need for surgery are higher in drug-resistant cases.

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Paper #200 has been WITHDRAWN

## Paper #201. Radiation-Free 3D Assessment of Back Height Differences via Three-Dimensional Depth Sensing in Adolescent Idiopathic Scoliosis: Prospective, Single-Center, Observational Study

Shao Chen, MD; Chen Liu, MD; Jia-hao Mou, MD; Yin-ling Sun, MD; Xiao-min Chen, MD; Honggen Du, MD

### Hypothesis:

We hypothesize that back height difference (BHD) measured via a three-dimensional (3D) depth-sensing imaging system can serve as a reliable, radiation-free parameter for assessing adolescent idiopathic scoliosis (AIS).

### Design:

Prospective, Single-Center, Observational Study

### Introduction:

AIS is a three-dimensional (3D) spinal deformity that can lead to serious physical and psychological effects, making early and accurate detection essential. Back height difference (BHD) represents a promising parameter for non-invasive scoliosis assessment using 3D depth-sensing systems. This study aimed to evaluate the reliability and clinical utility of BHD using a 3D depth-sensing imaging system to assess AIS and its correlation with clinical indicators.

### Methods:

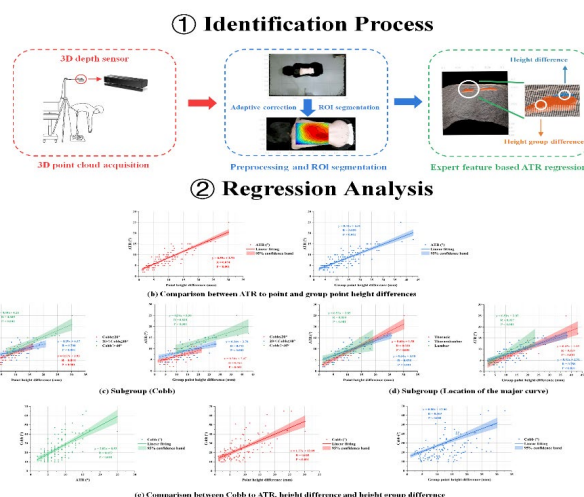
This study is a prospective, single-center, observational study. Thirty-six patients with AIS were enrolled to compare the reliability between the scoliosis measuring scale and a 3D depth-sensing imaging system. Additionally, 128 patients were included to evaluate the correlation of BHD with the angle of trunk rotation (ATR) and the Cobb angle.

### Results:

BHD showed excellent reliability (intraclass correlation coefficient  $>0.90$ ), strong correlation with ATR ( $R \leq 0.874$ ;  $p < 0.001$ ), and moderate correlation with Cobb angle ( $R \leq 0.653$ ;  $p < 0.001$ ). Subgroup analyses showed the highest correlation in thoracic curves. BHD was sensitive in detecting advanced deformities and maintained strong correlations in mild curves.

### Conclusion:

Although not a substitute for radiographs, BHD provides a radiation-free tool for early AIS screening and management, with good reproducibility and alignment with radiographic and trunk rotation measures. Notably, its radiation-free nature aids in reducing exposure among pediatric cohorts.



Identification Process and Regression Analysis

## Paper #202. Utility of Confirmatory Intraoperative CT scan in Patients Undergoing One- to Two-Level Instrumented Lumbar Fusions

Colson Tomberlin, MD; Paul C. Celestre, MD; Steven D. Glassman, MD; Charles H. Crawford III, MD; Jeffrey Gum, MD; Kirk Owens, MD; John R. Dimar, II, MD; Mladen Djurasovic, MD; Kathryn McCarthy Mullooly, MD; Benjamin Kostic, BS; Sonia Djurasovic; Morgan Brown, MS; Christy L. Daniels, MS; Leah Y. Carreon, MD

### Hypothesis:

Confirmatory intra-operative CT scans reduces incidence of screw malposition and prevents returns to the operating room for screw repositioning.

### Design:

Retrospective chart review.

### Introduction:

Pedicle screw fixation is the current standard of care in lumbar fusion, however screw malposition can result in neurologic or vascular injury, or compromise construct stability. Intraoperative CT navigation (Nav/CT) allows for three-dimensional planning and real-time evaluation of screw placement. Confirmatory CT spin after screw placement offers the opportunity to identify and revise nonoptimal screws prior to wound closure, but the effectiveness of this strategy remains unclear.

### Methods:

We conducted a retrospective review of adult patients undergoing one- to two-level posterior lumbar instrumented fusions at a single tertiary spine center. Patients were stratified into three cohorts: (1) no navigation use, (2) initial Nav/CT only, and (3) Nav/CT with confirmatory spins. The primary outcome was the rate of return to the operating room for screw repositioning. Secondary outcomes included operative time, blood loss, length of stay, and post-operative imaging.

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### Results:

A total of 339 patients were included (117 No Nav, 162 initial Nav/CT Only and 60 Nav/CT + Conf). Confirmatory Nav/CT use resulted in no significant change in intraoperative screw repositioning (1 vs 2 vs 0,  $p=0.683$ ) or in return to the operating room for screw repositioning (1 vs 1 vs 0,  $p = 0.780$ ). The overall incidence of return to OR for screw repositioning without confirmatory CT spin is 2 of 279 or 0.72%. OR time was increased in the Nav/CT + conf cohort (199min vs 176min vs 205min,  $p = 0.010$ ) while EBL was higher in the No Nav cohort (368mL vs 241mL vs 220mL,  $p<0.001$ ). No significant differences were found for complication rates or length of stay.

### Conclusion:

Based on this study, routine confirmatory Nav/CT spins prior to wound closure offer no clear benefit in reducing screw malposition or preventing return to the operating room for screw repositioning. In addition to increased radiation exposure from a second intraoperative CT scan, the confirmation group also had slightly longer operative time. While intraoperative Nav/CT provides demonstrated value for initial screw placement, this study underscores the potential risk for overuse of the technology.

**Paper #203 has been WITHDRAWN**

### Paper #204. Evaluating the Role of C2PA in Predicting Proximal Junctional Failure

Lane H. McCoy, BS; Christopher Diaz, BS; Neset Tang, MD; Brian J. Neuman, MD

### Hypothesis:

We hypothesize that immediate postoperative C2 pelvic angle (C2PA), either alone or in combination with other sagittal alignment parameters or increased proximal junctional angle (PJA), predicts the development of proximal junctional failure (PJF) in patients undergoing adult spinal deformity (ASD) surgery.

### Design:

This is a retrospective cohort study evaluating the relationship between immediate postoperative radiographic alignment parameters and the development of PJF in ASD patients.

### Introduction:

C2PA has been proposed as a predictor of symptomatic proximal junctional kyphosis, with prior work suggesting a C2PA  $>20^\circ$  may be linked to worse outcomes. This study assesses whether immediate postoperative C2PA – alone or alongside other alignment measures such as L1PA, T4PA, and PJA – is associated with PJF development following ASD surgery.

### Methods:

We included 730 ASD patients who underwent fusion

of  $\geq 7$  levels with pelvic instrumentation. Patients were divided into two groups based on the presence or absence of PJF. Immediate postoperative radiographic parameters—C2PA, PJA, L1PA, and T4PA—were recorded. The L1PA formula ( $L1PA = 0.5PI - 19 \pm 2$ ) was used to assess alignment. Various C2PA thresholds ( $\geq 10^\circ$ ,  $\geq 15^\circ$ ,  $\geq 20^\circ$ ,  $\geq 25^\circ$ ,  $\geq 30^\circ$ ,  $\geq 35^\circ$ ,  $\geq 40^\circ$ ) were tested for association with PJF.

### Results:

The mean age was 49.1 years, with a follow-up of 20.5 months. PJF developed in 5.75% of patients. Immediate postoperative C2PA, including values  $>20^\circ$  and in combination with L1PA alignment, was not significantly associated with PJF ( $p=0.71$ ,  $p=0.95$ ). Likewise, no C2PA threshold was linked to increased PJF risk (all  $p > 0.1$ ). However, immediate postoperative PJA was significantly higher in patients who developed PJF (mean  $11.17^\circ$ ) compared to those who did not (mean  $6.13^\circ$ ,  $p<0.001$ ).

### Conclusion:

Immediate postoperative C2PA did not correlate with PJF in this cohort, even when evaluated across multiple cutoff points or combined with alignment metrics like L1PA or T4PA. In contrast, elevated immediate postoperative PJA was significantly associated with PJF development. These findings suggest PJA may provide more relevant predictive insights than C2PA in evaluating PJF risk.

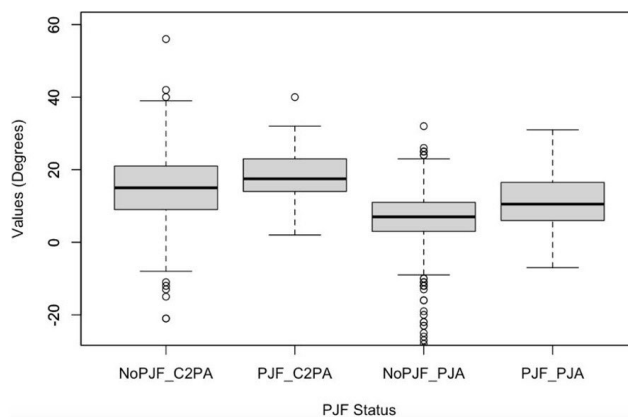


Figure 1. Box Plot of C2PA and Proximal Junctional Angle (PJA) in Patients With and Without PJF

### Paper #205. Evaluating Frailty and Epigenetic Tests for Predicting Complications Following Adult Spinal Deformity Surgery

Steven Zhang, MD; Christopher Diaz, BS; Lane H. McCoy, BS; Neset Tang, MD; Garrison Bentz, BS; Kayode Matthew, MD, MPH; Munish C. Gupta, MD, MBA; Camilo A. Molina, MD; Nicholas A. Pallotta, MD, MS; Brian J. Neuman, MD

### Hypothesis:

We hypothesize that epigenetic age (EA) metrics better predict 30-day postoperative complications in

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adult spinal deformity (ASD) surgery than chronological age (CA) or frailty scores.

### Design:

Prospective cohort study comparing frailty scores, CA, and epigenetic-clinical age gaps to identify the strongest complication predictors in ASD patients.

### Introduction:

CA is a traditional risk factor for ASD surgery, but emerging data suggest frailty and EA may better reflect biological vulnerability. This study evaluates various aging metrics as predictors of perioperative complications.

### Methods:

ASD patients undergoing  $\geq 7$ -level fusion or 3-column osteotomy were enrolled and monitored for 30-day complications. Blood was collected on surgery day to assess DNA methylation in PBMCs. Epigenetic age was calculated using Horvath's DNAmAge, Levine's DNAmAge (LevD), and Levine's PhenotypicAge (LevP). Frailty was measured using the Edmonton Frailty Index (EFI). The predictive value of each metric—including the differences between chronological and epigenetic age—was assessed using univariate and multivariate models.

### Results:

40 surgical ASD patients were enrolled. 23 (57.5%) were revisions. 29 patients (72.5%) received all-posterior and 11 (27.5%) underwent anterior-posterior surgery. 10 (25%) received a three-column osteotomy and average levels fused was 11.5. Complications were pulmonary emboli (N=2), death (N=1), reoperation for dehiscence (N=1), altered mental status (N=6), and acute kidney injury (N=5). There were no 30-day readmissions. Univariate analysis revealed that CA, EFI, DNAmAge, LevP, LevD did not predict complication rates (all p-values $>0.1$ ). However, CA-DNAmAge (p=0.015), CA-LevP (p=0.033), and CA-LevD (p=0.045) all demonstrated a predictive value. The multivariate model revealed that CA-DNAmAge was the only significant predictor of complication rate (p = 0.029). Odds ratio (OR) of CA- DNAmAge was 1.03, meaning a 3% increase in complication rate for every year that DNAmAge was greater than CA.

### Conclusion:

Frailty indices and age metrics, including chronological and epigenetic age, do not predict postoperative complications in ASD patients. However, the gap between chronological and epigenetic age (DNAmAge) may aid risk assessment. Future studies should use larger datasets and advanced models to refine these findings and improve patient risk stratification.

| UNIVARIATE                    | Mean Age Difference<br>Complication vs No<br>Complication | 2.5% CI | 97.5% CI | p-value      |
|-------------------------------|---|---------|----------|--------------|
| Chronological Age (CA)        | -2.25   | -2.57   | 4.57     | 0.240        |
| Edmonton Frailty Index        | -0.36   | -1.09   | 1.82     | 0.614        |
| Epigenetic Age (EA)           | 2.09  | -2.59   | 6.76     | 0.372        |
| Levine PhenoAge (LevP)        | 3.83  | -3.83   | 11.48    | 0.312        |
| Levine DNA Methylation (LevD) | 3.49  | -8.62   | 1.33     | 0.190        |
| CA-DNAmAge                    | 3.05  | 0.88    | 7.79     | <b>0.015</b> |
| CA-LevD                       | -5.89   | -9.36   | 0.02     | <b>0.045</b> |
| CA-LevP                       | -6.09   | -10.07  | -0.17    | <b>0.034</b> |
| MULTIVARIATE                  | OR  | 2.5% CI | 97.5% CI | p-value      |
| CA-DNAmAge                    | 1.03  | 1.004   | 1.057    | <b>0.029</b> |
| CA-LevD                       | 1.09  | 0.872   | 1.37     | 0.445        |
| CA-LevP                       | 0.94  | 0.761   | 1.15     | 0.533        |

Table 1. Univariate and multivariate correlation of frailty indices and epigenetic age calculators with complication rate.

## Paper #206. Beyond Cement: Identifying Drivers of Junctional Failure in Cement-Augmented Thoracolumbar Posterior Spine Fusion Constructs

*Alekos A. Theologis, MD; Aaron J. Clark, MD, PhD; Abdulah Alshammari, MD; Asra Toobaie, MD*

### Hypothesis:

In patients undergoing long thoracolumbar posterior fusion with cement augmentation at the UIV and/or UIV+1, spinal alignment parameters significantly influence the risk of proximal junctional failure, indicating that cementation alone is insufficient for prevention.

### Design:

Retrospective review

### Introduction:

Proximal junctional failure (PJF) is a complication following adult spinal deformity surgery. Cement augmentation at the upper instrumented vertebra (UIV), UIV+1, or both is often utilized to reduce PJF risk. However, it remains unclear whether cementing alone is protective. This study aimed to evaluate the frequency of PJF in long thoracolumbar posterior fusion constructs, already cemented at the UIV, UIV+1, or both, and to identify additional contributors to junctional failure in this population.

### Methods:

A retrospective review was performed on adult patients treated at our centre between 2020 and 2025 who underwent thoracolumbar-to-pelvis posterior fusion with cement augmentation at the UIV, UIV+1, or both. Eighty-nine patients were included. Patients were grouped based on whether they developed PJF (n=12) or not (n=77). Preoperative and postoperative radiographic, surgical, and demographic variables were compared.

### Results:

Age, gender, BMI, and osteoporosis status were similar between groups. Cement location did not differ significantly between the PJF and no-PJF groups (p = 0.74), indicating no clear association with junctional

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failure. Global alignment parameters were also not significantly different. In contrast, thoracic kyphosis, especially T4–12 angle, was significantly greater in the PJF group ( $p < 0.05$ ). Focal kyphosis at or above the UIV was also associated with PJF. The distance from accessory rods to the UIV was significantly smaller in the PJF group (mean 18.2 mm vs. 25.4 mm;  $p < 0.01$ ), suggesting that closer proximity may act as a mechanical stress riser.

### Conclusion:

The level of cementing did not significantly influence PJF incidence. Instead, thoracic and focal kyphosis and accessory rod proximity to the UIV were more strongly associated with PJF. Global spinal alignment did not appear to influence PJF risk; rather, focal thoracic alignment was more predictive. These results suggest that, even in cemented constructs, biomechanical alignment and construct design are critical in addition to cementation alone in preventing PJF.

### Paper #207. Too Much of a Curve? Rethinking Spinal Alignment Strategies for High Pelvic Incidence Patients

*Matthew Geck, MD; Devender Singh, PhD; Vik Kohli, MD; John Stokes, MD; Eric Truumees, MD; Rory R. Mayer, MD*

### Hypothesis:

Higher PI patients will experience greater difficulty in achieving optimal sagittal alignment due to increased pelvic morphology demands. Among the three alignment strategies (PI-LL = 10, PI-LL = 0, PI-LL = -10), certain strategies will fail more frequently, particularly in aligning C2PL and T1 slope.

### Design:

Biomechanical modeling

### Introduction:

This study assesses the effectiveness of three alignment strategies in high pelvic incidence (PI > 60°) patients, evaluating compliance with key sagittal alignment parameters.

### Methods:

A cohort of 20 patients with PI > 60° underwent computational modeling of three sagittal balance strategies: PI-LL = 10° (less\_curve), PI-LL = 0° (ideal\_curve), and PI-LL = -10° (more\_curve). Each strategy was tested using three alignment goals: C2PL = 0 mm, T1PA = 10°, and T1PA = 15°. Plans were analyzed based on three criteria: T1 slope between 15°–35°, T1 pelvic angle (T1PA < 20°), and C2PL between +9 mm and -33 mm.

### Results:

The results revealed significant variability in compliance rates across strategies. The highest compliance was observed in the C2PL = 0 mm strategy, reaching 35%, whereas the lowest compliance occurred in the

T1PA = 10° strategy, with only 0%. The most frequently failed parameter was T1 Slope 15°–35, which showed failure rates exceeding 100% in some cases. Patients with high PI exhibited significant difficulty in maintaining T1 slope within the ideal range, suggesting that standard alignment strategies may not fully compensate for the increased lumbar lordosis demands of these individuals. Failure to align sagittal parameters correctly could lead to increased thoracolumbar stress, heightening the risk of postoperative instability and adjacent segment disease.

### Conclusion:

These findings suggest that conventional spinal alignment strategies may not fully accommodate the postural needs of high PI patients. The inability to achieve consistent sagittal alignment underscores the need for refined planning techniques that incorporate global spinal balance adjustments, particularly in the thoracolumbar region. Future studies should explore dynamic models that integrate thoracic and pelvic compensatory mechanisms for improved surgical outcomes.

### Paper #208. Biomechanical Impact of Splint Rods in Posterior Cervicothoracic Fixation: A Finite Element Analysis

*Jaskaran Singh, MD; Ian Polyzois, PhD; Sara Gustafson, PEng; Trevor Gascoyne, PEng; Michael J. Goytan, MD*

### Hypothesis:

We hypothesized that splint rods improve load-sharing and fatigue resistance in cervicothoracic fixation, while excessive construct stiffness from larger rods or stiffer alloys may compromise performance at the bone-screw interface.

### Design:

Finite element analysis (FEA) of C7 vertebrectomy posterior fixation constructs modelled C5–T2 pedicle screw fixation with and without splint rods.

### Introduction:

Posterior cervicothoracic fixation requires balancing stability and load-sharing to prevent rod fracture and screw loosening. While splint rods and stiffer materials are often used, their biomechanical effects are incompletely understood. This study quantifies worst- and best-case construct behaviours under physiologic loads.

### Methods:

FEA was used to simulate 8 construct variations in a C7 vertebrectomy model with pedicle screw fixation C5–T2 (Figure 1), including: Primary rods: Titanium (Ti) or cobalt-chrome (CoCr), diameters 3.5–4.5 mm. Splint rods: Presence/absence, diameters 3.5–4.5 mm. Screws: Lateral mass (3.5–4.0 mm) and pedicle screws (4.5 mm). Boundary conditions replicated ASTM F1717/ISO 12189 standards. Yield

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load, displacement, stiffness, and stress distributions were analyzed under worst-case loading (2 cm displacement).

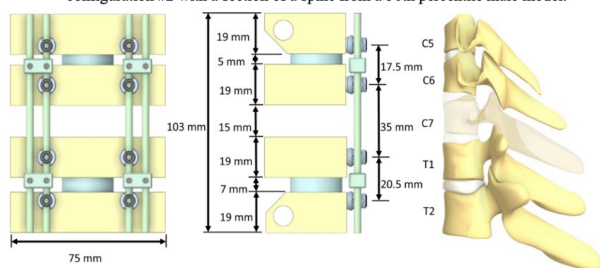
### Results:

Best-case: 3.5 mm Ti primary rods + splint rods (configuration #2) achieved highest load capacity (107 N) and stiffness (29.8 N/mm). Worst-case: single 3.5 mm Ti rods (configuration #1) had lowest capacity (66 N). Key findings: (1) Splint rods increased load-bearing capacity. (2) Increasing stiffness by larger rods/screws or switching to CoCr did not consistently improve load capacity and risked earlier screw-bone interface failure. (3) Optimal design requires balancing stiffness and load-sharing. Failure modes included screw-bone interface failure and secondary rod notching at T1 tulips.

### Conclusion:

Splint rods improve load-sharing in cervicothoracic fixation, but larger diameter rods or screws may paradoxically compromise performance. Construct stiffness alone does not predict load capacity, highlighting the need for balanced designs. These findings caution against over-reliance on stiffening strategies and support clinical use of supplemental rods with standard diameters.

**Figure 1:** Design of the C5-C6 to T1-T2 cervicothoracic vertebrectomy construct showing configuration #2 with a section of a spine from a 50th percentile male model.



**Figure 1:** Design of the C5-C6 to T1-T2 cervicothoracic vertebrectomy construct showing configuration #2 with a section of a spine from a 50th percentile male model.

### Paper #209. Biomechanical Comparison of Seven Occipital-Cervical Fixation Constructs Using Finite Element Analysis

*Jaskaran Singh, MD; Ian Polyzois, PhD; Sara Gustafson, PEng; Trevor Gascoyne, PEng; Michael J. Goytan, MD*

### Hypothesis:

We hypothesized that keel plate constructs would provide superior biomechanical performance compared to medial clamp-based constructs or increased screw diameter by optimizing stiffness while limiting pullout forces.

### Design:

Finite element analysis (FEA) of seven occipital-cervical fixation constructs per ASTM F2706/ISO 12189 guidelines.

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### Introduction:

Occipitocervical (OC) surgery is indicated for instability or neural compression, but optimal construct design remains debated. Prior biomechanical studies used outdated fixation or variable cadaver bone quality. This FEA compared seven modern OC constructs under standardized conditions.

### Methods:

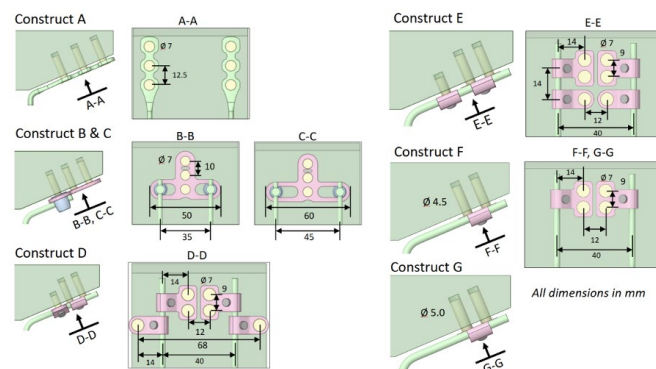
Seven bilateral OC constructs spanning C1 with fixation in C2-C3 were modeled (Figure 2). Variations included clamp configurations, keel plates, screw diameters (4.5–5.0 mm), and screw number. A flexion torque of 6.12 Nm simulated physiologic loading. Stiffness and screw pullout forces were recorded. The Multi-Attribute Utility Theory (MAUT) score balanced stiffness against pullout resistance. Stress distribution was analyzed to identify potential failure.

### Results:

Construct E (1-hole + 2-hole medial clamps) had the highest MAUT utility score (0.79), with superior stiffness (820 N·mm/deg) and moderate pullout (78 N). Keel plate constructs showed higher pullout (up to 117 N) but lower stiffness (Table 2). Screw diameter increase from 4.5 to 5.0 mm had minimal impact. Stress analysis showed rod notching at implant interfaces, predicting potential fatigue failure.

### Conclusion:

Medial clamp constructs optimize stiffness and pullout balance, outperforming keel plates or larger screw diameters. This is the first study to holistically rank OC constructs using a utility score, supporting clamp-based fixation as the preferred strategy, especially in patients with compromised bone quality.



**Figure 2:** The seven designs of occipital fixation as modeled.

### Paper #210. An Obstetrical and Gynaecological Insight to Measure the Gender Specific Issues Including Menstrual Disorders in Patients with Scoliosis – A Genuine Step Towards Empowering Women's Inclusive Health

*Tejaswin Jha, MS; Bhavuk Garg, MS; Nishank Mehta, MS; Buddhaddev Chowdhury, MS; JB Sharma, MD, MS; Smita Manchanda, MD*

## E-POINT PRESENTATION ABSTRACTS

### Hypothesis:

Females with scoliosis, particularly of congenital and syndromic origin, experience a higher prevalence menstrual and gynaecological abnormalities compared to age-matched controls, and have an increased risk of adverse obstetric outcomes.

### Design:

Ambispective observational comparative study

### Introduction:

Scoliosis has systemic implications beyond musculoskeletal changes. Its potential impact on hormonal, menstrual, reproductive, and obstetrical health in females remains underexplored. The objective of this study is to evaluate and compare the menstrual, reproductive, and obstetrical health of females with different subtypes of scoliosis and to identify associated gynaecological abnormalities.

### Methods:

The study was conducted between January 2021 and November 2022. A total of 292 female scoliosis patients (192 retrospective, 100 prospective) and 50 age-matched controls were enrolled. Participants were assessed through clinical evaluation, questionnaires, and ultrasonographic examination. Parameters studied included age at menarche, cycle regularity, bleeding characteristics, physical/psychological symptoms, and ultrasonographic findings (endometrial thickness, ovarian morphology). Obstetric outcomes were recorded where applicable. Statistical tests included Fisher's exact test and Bartlett's test for variance.

### Results:

Mean age at menarche was delayed in scoliosis patients, especially in congenital scoliosis ( $12.5 \pm 0.77$  years) compared to controls ( $12.04 \pm 0.75$  years,  $p < 0.01$ ). Menstrual irregularities, menorrhagia, and dysmenorrhea were significantly higher in congenital and syndromic scoliosis groups. Physical complaints were significantly more common in scoliosis groups than controls ( $p = 0.003$ ), but psychological symptoms showed no statistical difference. Endometrial thickness and incidence of follicular cysts/bulky ovaries were significantly elevated in congenital and syndromic scoliosis groups. Of 15 patients who conceived, 13 had unplanned caesarean sections; no cases of spontaneous abortion or infertility were recorded.

### Conclusion:

Scoliosis, particularly of congenital and syndromic origin, is associated with delayed menarche, menstrual irregularities, and gynaecological abnormalities. Although obstetrical data were limited, trends suggest potential complications that merit further investigation.

### Paper #211. High-Precision Optical Gait Analysis for Non-Invasive Detection of Adolescent Idiopathic Scoliosis: A Prospective Study in District Hospitals

*Wenjie Wu, MD*

### Hypothesis:

This study aims to explore the correlation between biomechanical parameters derived from high-precision optical gait analysis and the Cobb angle in AIS patients, and to validate the clinical application value of this system for scoliosis screening in district and county hospital settings.

### Design:

prospective cross-sectional study

### Introduction:

Adolescent idiopathic scoliosis (AIS) diagnosis remains dependent on radiography, especially in resource-limited district hospitals where repeated radiation exposure and delayed diagnosis pose significant challenges. Artificial intelligence (AI)-enhanced gait analysis utilizing optical array-based plantar pressure mapping offers a radiation-free alternative for dynamic biomechanical profiling.

### Methods:

A prospective cross-sectional study was conducted among 5,000 participants from district schools between January 2024 and June 2025, including 325 AIS patients (Cobb angle  $\geq 10^\circ$ ) and 100 healthy controls. All participants underwent: 1. Full-spine X-ray (Cobb angle as gold standard); 2. High-resolution optical gait analysis capturing: Static/dynamic plantar pressure (12 parameters) Spatiotemporal gait characteristics (18 parameters) Pelvic kinematics (tilt, rotation, displacement) 3. Clinical documentation (age, sex, Risser sign) Proprietary deep learning algorithms integrated multi-dimensional biomechanical features. Statistical analyses included group comparisons, Pearson correlation, and multivariate regression.

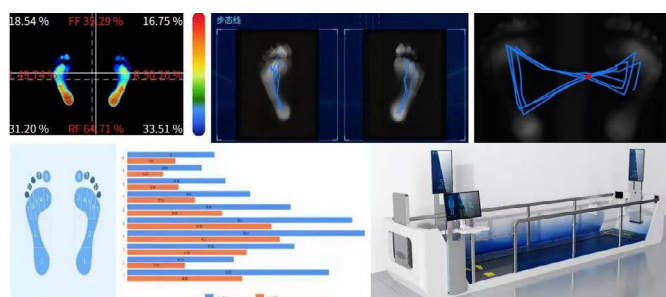
### Results:

Key parameters significantly differed between AIS and controls (all  $p < 0.001$ ). Plantar asymmetry strongly correlated with Cobb angle ( $r = 0.83$ ,  $p < 0.001$ ), while pelvic tilt correlated with vertebral rotation ( $r = 0.81$ ,  $p < 0.001$ ). The AI model achieved AUC=0.95 (sensitivity 93.6%, specificity 90.2%), maintaining 88.9% sensitivity for mild cases (Cobb  $10-25^\circ$ ).

### Conclusion:

AI-driven optical gait analysis accurately identifies AIS biomechanical patterns without radiation exposure. This rapid ( $< 1$  minute), high-precision (0.01mm resolution) solution is ideal for large-scale screening in district hospitals, enabling early intervention while overcoming resource constraints.

## E-POINT PRESENTATION ABSTRACTS



Instrument appearance and detection images

### Paper #212. Evaluation of Multimodal Analgesia with Specialist Nurses as the Main Body in Adult Patients with Degenerative Scoliosis During Perioperative Period

Wenjie Wu, MD

#### Hypothesis:

To explore the role and significance of specialist nurses in pain management system.

#### Design:

A prospective, non-randomized controlled study

#### Introduction:

To explore the analgesic effect of multi-modal analgesia program with specialist nurses as the main body on adult degenerative scoliosis patients during perioperative period, and to observe the applicability of multi-modal analgesia program, so as to provide scientific guidance for clinical nursing and provide high-quality nursing services for patients.

#### Methods:

A prospective, non-randomized controlled study was conducted in 69 patients with adult degenerative scoliosis diagnosed preoperatively in three hospitals. Fifty-four patients underwent posterior long-segment fixed orthopedics were selected, including 30 patients in the experimental group. In the control group, 24 patients were treated with conventional on-demand analgesia. The VAS score, Ramsay sedation score (4, 8, 12, 24, 48 hours after operation), S-AI state anxiety scale score (36 hours before and after operation), patient satisfaction rate and recovery.

#### Results:

VAS and sedation score of multimodal analgesia group were significantly lower than routine nursing group at each time point after operation ( $P < 0.05$ ). The satisfaction rate of postoperative analgesia was significantly better than that in control group. There was no significant difference in S-AI state anxiety scale score before operation, and there was a score of 36 hours after operation. Significant difference ( $P < 0.05$ ). The anxiety score of 36 hours after operation was significantly lower than that before operation ( $P < 0.05$ ); The time of first functional exercise was significantly earlier than that in the control group

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( $P < 0.05$ ), and the length of hospitalization was shorter than that in the control group ( $P < 0.05$ ). The incidence of adverse reactions in the experimental group was 1.7%, and that in the control group was 8.4%. There was a significant difference between the two groups ( $P < 0.05$ ).

#### Conclusion:

Nurse-based multi-modal analgesia can significantly relieve acute pain, improve patient satisfaction, reduce the incidence of adverse reactions, and optimize the quality of medical and nursing services in adult patients with degenerative scoliosis during perioperative period. It can also alleviate anxiety and psychological pressure of patients and shorten hospitalization.

### Paper #213. Multimodal Intervention Targeting Sarcopenia-Osteoporosis Complex Improves Functional Outcomes and Reduces Complications in Elderly Patients Undergoing Spinal Surgery: A Prospective Propensity-Matched Cohort Study

Wenjie Wu, MD

#### Hypothesis:

To evaluate the efficacy of a multimodal intervention (nutrition, exercise, and pharmacotherapy) targeting the muscle-bone axis in improving functional recovery and reducing complications in sarcopenic-osteoporotic patients undergoing spinal surgery.

#### Design:

A prospective propensity-matched cohort study

#### Introduction:

The coexistence of sarcopenia and osteoporosis in elderly patients undergoing spinal surgery is associated with increased postoperative disability and complications. However, evidence-based, resource-efficient perioperative management strategies remain scarce, particularly in resource-limited settings.

#### Methods:

A total of 160 patients aged  $\geq 50$  years with sarcopenia (EWGSOP2 criteria) and osteoporosis (T-score  $\leq -2.5$ ) undergoing lumbar/thoracic surgery (TLIF/PLIF/vertebroplasty) were enrolled. After propensity score matching (1:1 for age, sex, diabetes, fracture type), 80 patients were allocated to the intervention group and 80 to the control group. Intervention group: Received whey protein (30 g/day), vitamin D<sub>3</sub> (2000 IU/day), calcium (1200 mg/day), structured elastic band resistance training (pre- and postoperatively), and denosumab or zoledronic acid. Control group: Received routine care with calcium supplementation as needed. Primary outcomes included ODI success ( $\geq 30\%$  improvement at 12 months) and fusion success (Bridwell grade I-II on CT). Secondary outcomes included VAS pain scores, instrumentation failure, and serum biomarkers (IL-6, IGF-1, CTX, PINP).

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### Results:

All 160 patients completed the 12-month follow-up. The intervention group showed significantly better outcomes: ODI success: 58% (46/80) vs. 28% (22/80) in controls (aOR = 2.8, 95% CI: 1.5–5.3,  $p = 0.002$ ). Fusion success: 83% (66/80) vs. 65% (52/80) in controls (absolute increase 18%, NNT = 5.6,  $p = 0.01$ ). Complications: 7.5% (6/80) vs. 15.6% (12/80) in controls (HR = 0.48, 95% CI: 0.25–0.91,  $p = 0.02$ ). Biomarkers: Reduction in IL-6 correlated with ODI improvement ( $r = -0.41$ ,  $p < 0.001$ ).

### Conclusion:

A low-cost, multimodal intervention targeting sarcopenia and osteoporosis significantly improves functional recovery, fusion rates, and reduces complications in elderly spinal surgery patients. This protocol offers a scalable and practical model for resource-limited healthcare settings.

### Paper #214. Selection of Proximal Fusion Level in Osteoporotic Vertebral Compression Fracture (OVCF) with Kyphosis: The Guidance of Hounsfield Unit

*Junyu Li, MD; Yiqiao Zhang, MD; Xueshi Tian, MD; Jiahao Zhang, MD; Hanwen Zhang, MD; Zhuoran Sun, MD; Yongqiang Wang, MD; Miao Yu, MD; Weishi Li, MD; Yan Zeng, MD*

### Hypothesis:

Placing the upper instrumented vertebra (UIV) at or above the HU-guided UMV or USRV, rather than below these landmarks, reduces the incidence of proximal junctional kyphosis (PJK) and adjacent segment degeneration (ASD).

### Design:

A single-center retrospective cohort study.

### Introduction:

The selection of the upper instrumented vertebra (UIV) in chronic Osteoporotic Vertebral Compression Fracture (OVCF) has been proven to be related to postoperative complications. For the first time, we defined the upper maximal vertebra (UMV) as the vertebra above the compressed section that had a higher Hounsfield Unit (HU) value than two vertebrae proximal to the fracture level. The upper sagittal reverse vertebra (USRV) was defined as the first vertebra that presented opposite HU value distribution from the anterior to posterior part of the vertebra compared to proximal vertebrae, counting from the compressed vertebra. In accordance with previous studies, we believe that the UMV and USRV might play an important role in the biomechanical stability of the spine. We therefore conducted a retrospective analysis to determine whether locating the UIV at these levels lowers the incidence of ASD and PJK.

### Methods:

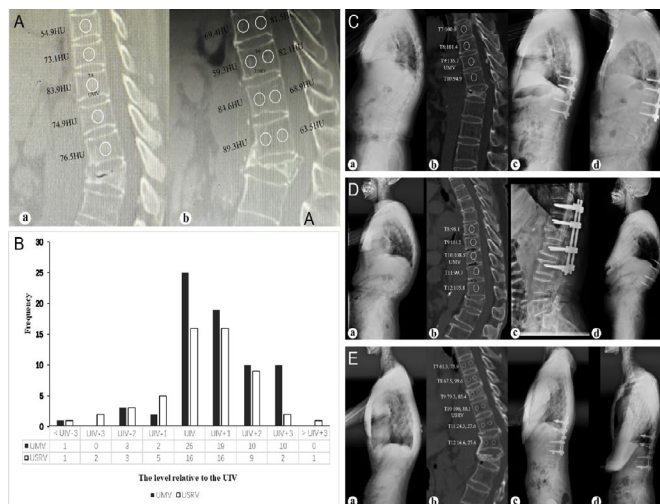
This clinical research included 82 chronic OVCF patients (18 males and 64 females) with a mean age of  $62.99 \pm 8.29$  years and mean follow-up of  $48.13 \pm 20.22$  months. Whole spine CT were performed for each patient. The patients were divided into groups according to whether their UIV was below the UMV or USRV. The incidence of ASD and PJK was evaluated in each subgroup.

### Results:

The average HU was  $94.98 \pm 22.76$ , and all sagittal parameters improved postoperatively and at follow-up. For UMV, 41 patients had the UIV on/above the UMV and 41 below; PJK was significantly lower in the on/above group (12.20% vs 46.34%,  $P < 0.001$ ), whereas ASD was not (4.88% vs 14.63%,  $P = 0.137$ ). USRV was identifiable in 68 patients (82.93%); among them, 38 had the UIV on/above the USRV and 30 below, with significantly lower rates of both PJK (7.89% vs 63.33%,  $P < 0.001$ ) and ASD (2.63% vs 23.33%,  $P = 0.007$ ) in the on/above group.

### Conclusion:

HU values should be considered in the selection of UIV. Locating UIV on UMV might decrease the incidence of PJK and ASD, and taking USRV into the fusion level might reduce the occurrence of ASD.



Definitions and Clinical Outcomes of UMV and USRV in OVCF Patients

### Paper #215. Modified Pedicle Subtraction Osteotomy for Osteoporotic Vertebral Compression Fractures (OVCF): A Retrospective Study of 104 Patients

*Junyu Li, MD; Jiahao Zhang, MD; Siming Xian, MD; Yihao Liu, MD; Hanwen Zhang, MD; Zhuoran Sun, MD; Yongqiang Wang, MD; Miao Yu, MD; Yan Zeng, MD*

### Hypothesis:

Compared with SPO, conventional PSO, and VCR, modified pedicle subtraction osteotomy (mPSO) achieves equal or superior correction of kyphosis/

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sagittal alignment with lower operative burden and without increasing postoperative complications in OVCF.

### Design:

A single-center, retrospective comparative cohort study

### Introduction:

Osteoporotic vertebral compression fractures (OVCF) caused by osteoporosis is a common clinical fracture type. There are many surgical treatment options for OVCF, but there is a lack of comparison among different options. Therefore, we counted a total of 104 cases of OVCF operations with different surgical plans, followed up the patients, and compared the surgical outcome indications before, after and during the follow-up.

### Methods:

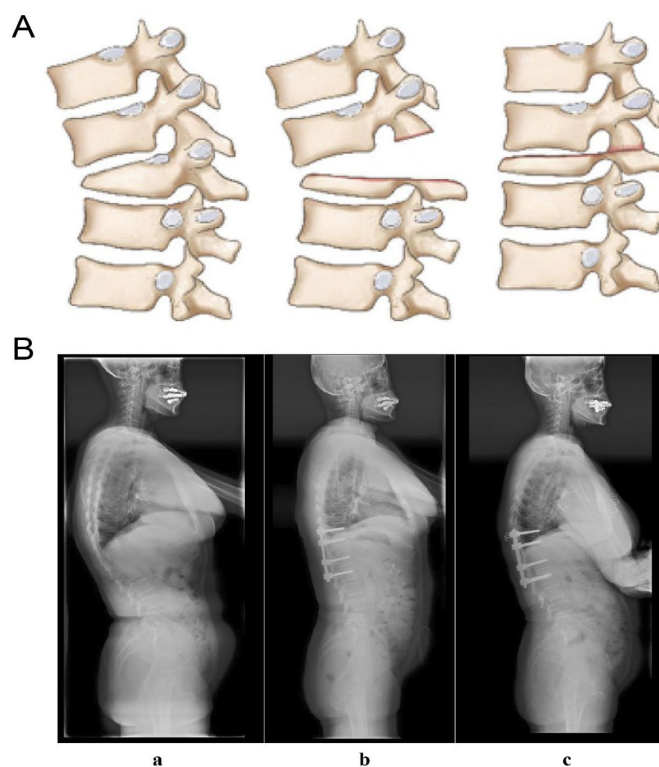
104 patients who underwent posterior osteotomy (Modified PSO, SPO, PSO, VCR) and kyphosis correction surgery at our hospital between April 2006 and August 2021 with a minimum follow-up period of 24 months were included. All cases were injuries induced by a fall incurred while standing or lifting heavy objects without high-energy trauma. The mean CT value was 71 HU, which was below 110 HU, indicating severe osteoporosis. The indications for surgery included gait disturbance due to severe pain with pseudarthrosis, increased kyphotic angle, and progressive neurological symptoms. Pre- and post-operative CL, TLK, TK, PrTK, TKmax, GK, LL, PI, SS, PT, SVA, TPA, were investigated radiologically. Additionally, We evaluated estimated blood loss, surgical time and perioperative symptom.

### Results:

The results show, after operation, TLK ( $P < 0.001$ ), TK ( $P < 0.001$ ), TKmax ( $P < 0.001$ ), SVA ( $P = 0.013$ ), CL ( $P = 0.024$ ) and TPA ( $P = 0.009$ ) were improved significantly in modified Pedicle subtraction osteotomy (mPSO) after operation. During follow-up, TLK ( $P < 0.001$ ) and TKmax ( $P < 0.001$ ) were improved significantly in Modified PSO group. In addition, estimated blood loss ( $P = 0.038$ ), time of operation ( $P = 0.025$ ) were favorable in Modified PSO group compared to control group.

### Conclusion:

In conclusion, mPSO achieves substantial kyphosis correction with fewer subsequent complications, while offering reduced surgical trauma and shorter operative time compared with other techniques. Accordingly, mPSO represents an effective therapeutic option for OVCF.



*Schematic and Outcomes of Modified PSO for OVCF: Preoperative, Postoperative, and Follow-up Parameters*

### Paper #216 has been WITHDRAWN

### Paper #217. Are Multi-Level Three Column Osteotomies Required in Deformity Surgery? ±

*Alexander J. Schupper, MD; Amer F. Samdani, MD; William Purtill Zachary Weingrad, BS; Joshua M. Pahys, MD; Terrence G. Ishmael, MBBS; Steven W. Hwang, MD*

### Hypothesis:

Multi-level three column osteotomies can be safely performed, but confer a significant risk of neuro-monitoring changes and reoperations.

### Design:

Retrospective, single institution

### Introduction:

Three column osteotomies (3CO) carry some of the greatest risk in deformity surgery, but occasionally they are required and even less commonly multiple 3COs at adjacent levels may be necessary. We sought to investigate outcomes and safety of multilevel 3COs.

### Methods:

We reviewed a series of patients having undergone more than 1 3CO in our center collecting demographic, radiographic, surgical details and complications. All patients with 3 COs from 2008 to 2022 at a single institution with 2-year follow-up and preop imaging were included.

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### Results:

17 patients underwent multilevel 3COs of which 3 had pre-existing VEPTR constructs. The primary deformity was predominantly sagittal plane (3 with focal kyphosis/dislocations; 5 with kyphosis and 6 with kyphoscoliosis). The means age at surgery was 10.3±5.6 years with a mean follow-up of 43±26 months. The median number of 3COs was 2 with a mean pre-op maximal curve of 100±40° [40-160°] and a mean DAR of 24±9. The mean preop coronal Cobb was 70±40° which corrected to 34±20° and was 38±24 at last follow-up (p<0.05). 6 (35%) patients were treated with halo gravity traction prior to the spine fusion. The mean OR time was 487±119min and an EBL of 686±679mL for the fusion. 7 patients were staged with a mean OR time of 435±113min and EBL of 1170±1512mL during the second stage. 5/17 (29%) patients had IONM changes during surgery; one upper extremity and 4 MEP changes with 2 associated new neurological changes postop. Both patients improved over time; one returned to their baseline function and one was still improving at latest follow-up. 8 (47%) patients required further surgery (4 wound/infection related and 3 instrumentation/curvature and 1 delayed neurological decline).

### Conclusion:

Multi-level 3CO can be performed but are associated with a significant risk of neuromonitoring changes as well as a significant risk of reoperation (50%). Surgeons should anticipate these associated risks when considering multi-level 3COs.

### Paper #218. Does Inclusion of Pelvic Fixation with Posterior Spinal Fusion Change Reoperation Outcomes for Neuromuscular Scoliosis? A 10-Year Matched Cohort Analysis

*Suhas Etigunta, BS; Vivien Chan, MD, MS; Adeesya Gausper, BS; Andy M. Liu, BS; Christopher Mikhail; Alexander Tuchman; Kenneth D. Illingworth, MD; David L. Skaggs, MD, MMM*

### Hypothesis:

Pelvic fixation in neuromuscular scoliosis surgery increases spinal wound debridement rates but does not impact subsequent posterior instrumentation rates.

### Design:

Retrospective Cohort Study

### Introduction:

Neuromuscular scoliosis (NMS) often necessitates surgical intervention with posterior spinal fusion (PSF), but the benefits of including pelvic fixation remain unclear. Current studies are limited to small cohorts, underscoring the need for larger analyses to better inform surgical decision-making. This study aims to compare subsequent posterior spinal instru-

mentation and spinal wound debridement (SWD) rates in NMS patients undergoing PSF with or without pelvic fixation.

### Methods:

Using the PearlDiver insurance repository, we identified patients who underwent PSF for NMS using CPT and ICD codes. Cohorts were matched for age, gender, number of levels fused, and wheelchair use. Subsequent posterior instrumentation rates and spinal wound debridement rates were evaluated over 10-years. Additional analysis further matched SWD status to assess its impact on subsequent instrumentation rates.

### Results:

In a cohort of 946 patients (473 with pelvic fixation, 473 without), no significant difference in subsequent posterior instrumentation rates was observed over 10 years (6.3% vs. 7.2% at 10 years). However, patients undergoing pelvic fixation had significantly higher SWD rates compared to those without pelvic fixation (8.2% vs. 5.5% at 10 years). When matching for SWD status, subsequent posterior instrumentation rates remained statistically comparable between groups (6.3% vs. 6.8% at 10 years).

### Conclusion:

Over ten years, subsequent posterior spinal instrumentation rates did not differ significantly between NMS patients receiving PSF with or without pelvic fixation. Pelvic fixation was associated with higher SWD rates. Even after accounting for SWD, there was no difference in subsequent posterior instrumentation rates. These findings confirm that pelvic fixation is a risk factor for infection and suggest that current practices effectively identify patients who require pelvic fixation, as evidenced by similar reoperation rates between the two cohorts.

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Subsequent posterior instrumentation rates

| Time     | Matched with pelvic fixation (n=473) | %    | Matched without pelvic fixation (n=473) | %    | P value |
|----------|--------------------------------------|------|---|------|---------|
| 1 year   | 23                                   | 4.9% | 17                                      | 3.6% | >0.05   |
| 2 years  | 28                                   | 5.9% | 24                                      | 5.1% | >0.05   |
| 3 years  | 28                                   | 5.9% | 29                                      | 6.1% | >0.05   |
| 4 years  | 28                                   | 5.9% | 30                                      | 6.3% | >0.05   |
| 5 years  | 29                                   | 6.1% | 30                                      | 6.3% | >0.05   |
| 10 years | 30                                   | 6.3% | 34                                      | 7.2% | >0.05   |

Subsequent spinal wound debridement rates

| Time     | Matched with pelvic fixation (n=473) | %    | Matched without pelvic fixation (n=473) | %    | P value |
|----------|--------------------------------------|------|---|------|---------|
| 1 year   | 28                                   | 5.9% | 20                                      | 4.2% | >0.05   |
| 2 years  | 31                                   | 6.6% | 20                                      | 4.2% | 0.05    |
| 3 years  | 33                                   | 7.0% | 22                                      | 4.7% | <0.05   |
| 4 years  | 37                                   | 7.8% | 22                                      | 4.7% | <0.05   |
| 5 years  | 39                                   | 8.2% | 24                                      | 5.1% | <0.05   |
| 10 years | 39                                   | 8.2% | 26                                      | 5.5% | <0.05   |

Matched subsequent posterior instrumentation rates and spinal wound debridement rates following posterior fusion with vs without pelvic fixation neuromuscular scoliosis patients.

### Paper #219. New Pedicle Screw Stimulation Technique Can Identify Medial Pedicle Breeches

*Vivien Chan, MD, MS; Kenneth D. Illingworth, MD; Andy Nguyen Jeffrey Chung, MD; David L. Skaggs, MD, MMM*

#### Hypothesis:

Pulse-train pedicle screw stimulation can identify medial breeches in the pedicle

#### Design:

Single-center retrospective cohort study.

#### Introduction:

Thoracic pedicle screw insertion in pediatric scoliosis surgery carries a risk of neurological injury due to proximity to the spinal cord in the setting of a medial pedicle breach. Non-medial breeches rarely lead to problems. Triggered electromyography (t-EMG) pedicle screw stimulation is one method of assessing if pedicle screws are entirely within bone or have a breach in the pedicle wall.

#### Methods:

This was a single-center prospective study. Patients under 18 years of age who received thoracic posterior spinal instrumented fusion for all spinal deformities were included in this study. Pulse-train stimulation was employed to verify screw placement when standard single-pulse stimulation stimulated <6mA. The settings for pulse-train stimulation were pulse count of 4, filter 30Hz to 5kHz, pulse width 200msec, repetition rate 3.11, timer intervals 50 mV/div at 10 msec, and threshold 30 mA. Responses were recorded from rectus femoris, tibialis anterior/gastrocnemius, and abductor hallucis brevis/extensor digito-

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rum brevis. If no response was seen in the recording muscles, the screw was considered not to have a medial breach. If a response was seen in any of the recording muscles, the pedicle screw was removed, and the tract was palpated by the attending surgeon to assess for a pedicle breach. Fluoroscopy was used to confirm pedicle screw placement.

#### Results:

There was a total of 615 screws placed in 26 patients. Of the 615 screws, 31 stimulated <6mA on single-pulse stimulation. Of those 31 screws, pulse-train stimulation did not elicit a response in the recording muscles in 11 screws, suggesting a non-medial breach. Fluoroscopy confirmed proper placement in all 11 screws (100%, 11/11). Pulse-train stimulation elicited a response in recording muscles in 20 screws, suggesting a medial breach. Of those 20 screws, 16 (80.0%) had a medial breach confirmed by palpation and 4 (20.0%) did not have a palpable breach. There were no postoperative neurological injuries or other complications.

#### Conclusion:

Pulse-train stimulation can be a useful tool in differentiating between medial and non-medial breeches with thoracic pedicle screw insertion.

### Paper #220 has been WITHDRAWN

### Paper #221. Is it Worth the Risk of a “Blown Save?” Calling in an Incision “Closer” May Increase Infection Rates in Pediatric Scoliosis Surgery

*Ally Yang, MD; Matthew Kanzler, BS; Amy Noyes, CPNP; Dominick A. Tuason, MD*

#### Hypothesis:

A separate closing team may lead to longer closure and surgical time, potentially leading to higher rate of surgical site infection.

#### Design:

A retrospective cohort study

#### Introduction:

Surgical site infection (SSI) is one of the most dreaded complications after pediatric posterior spinal fusion. Previous studies have demonstrated the benefits of a multilayered closure in non-idiopathic scoliosis surgery, performed by a separate closing team, and it has become more common to operate with a co-surgeon specializing in plastic surgery. The purpose of this study is to evaluate the risk factors of SSIs following pediatric spinal fusion surgery, with a specific focus on the effect of having closures done by a plastic surgeon.

#### Methods:

Pediatric patients who presented between 2020 and 2024 who underwent posterior spinal fusion were identified. Pre-operative, intra- and post oper-

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ative risk factors were recorded. All neuromuscular, syndromic, and congenital scoliosis were classified as non-idiopathic. SSI was diagnosed when infection was found to involve tissue below the fascia within 60 days of the initial surgery. Significance was determined using a cut-off of  $p < 0.05$ .

### Results:

241 patients were included in the study, of which 159 were in the idiopathic group, and 82 were in the non-idiopathic group. A separate surgical team performed wound closures in 34 patients. SSI occurred in 9 (3.7%) patients, of which 6 were patients in the non-idiopathic group and 3 were patients in the idiopathic group. SSI was more common in patients with drain placement ( $p=0.001$ ), revision status ( $p=0.016$ ), longer closing time ( $p=0.044$ ), and a separate team for closure ( $p=0.025$ ) (Table 1). A separate team for closure was associated with longer surgical time and closing time ( $p<0.001$ ). SSI was more common when there was a separate team for closure in the idiopathic group ( $p=0.010$ ), but there was no significant difference in the non-idiopathic group. The relative risk for SSI in patients with drains removed after 3 weeks compared to patients with drains removed before 3 weeks was 5 (95% CI: 1.26–19.86).

### Conclusion:

A separate closing team led to longer closing time, and these factors along with drain placement and duration were associated with higher SSI rates in patients with idiopathic scoliosis. Closure by an orthopaedic surgeon in the non-idiopathic population appears to be noninferior.

### Paper #222. Clinical Utility of Non-Invasive Hemodynamic Monitoring in Patients Undergoing Multi-Level Posterior Instrumented Fusion ±

*Colson Tomberlin, MD; Steven D. Glassman, MD; Desiree Chappell, CRNA; Mladen Djurasovic, MD; Justin Mathew, MD; Jeffrey Gum, MD; Shawn Adams, MD; Leah Y. Carreon, MD*

### Hypothesis:

A novel non-invasive hemodynamic monitor using a finger cuff yields similar data to an arterial line.

### Design:

Prospective observational cohort.

### Introduction:

Emerging research has shown associations between hypotensive events and adverse outcomes for patients undergoing spine surgery. Invasive hemodynamic monitoring begins only after arterial line placement, missing critical events during induction and prone positioning. A novel finger-cuff device enables continuous, non-invasive monitoring of radial artery pressures, capturing critical hemodynamic data preoperatively, during prone positioning, and

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post-operatively. This non-invasive device paired with a predictive hemodynamic monitor (PHM) may allow interventions to prevent hypotension in the post-operative period.

### Methods:

Patients undergoing elective multi-level ( $\geq 2$  levels) posterior instrumented fusions with continuous (every 20s) mean arterial pressure (MAP) measurements from both the finger-cuff (Cuff) and arterial line (A-line) were identified. Data was recorded on the PHM and on the Electronic Medical Record (EMR). Standard demographic and surgical data as well as hemodynamic data were collected. Correlation coefficients among the MAP data sources was determined.

### Results:

Thirty-one patients were included in the study, 19 (61%) and 12 males (39%), mean age 64.3 years, BMI of 31.04 kg/m<sup>2</sup>, ASA grade of 2.77, number of fusion levels of 4.63, operative time of 256.1 minutes and estimated blood loss of 562.3mL. A total of 20,718 MAP readings were analyzed (730/case). MAP values from the PHM Cuff, PHM A-Line, EMR Cuff, and EMR A-line were highly correlated ( $r = 0.80-0.88$ ) with absolute MAP differences between 3.73-5.36mmHg. The correlation between the PHM Cuff and PHM A-line in predicting impending hypotension was 0.782.

### Conclusion:

The results of the study support the clinical use of a novel non-invasive finger cuff device to monitor hemodynamics and predict impending hypotension in patients undergoing multi-level posterior instrumented fusion. The utility of this technology in preventing hypotensive events post-operatively and potentially decreasing adverse events is the subject of future studies.

### Paper #223. Pre-Bent Posterior Fusion Rods Reduce Surgeon Musculoskeletal Load

*Serena S. Hu, MD; John F. Burke, MD, PhD; Philip K. Louie, MD; Laurel C. Blakemore, MD; Amy A. Claeson, PhD*

### Hypothesis:

Compared to straight spine rods, pre-bent rods reduce surgeon muscle expenditure and require fewer bending efforts to contour to patient-derived rod templates.

### Design:

Muscular function assessment using surface EMGs in a simulated surgical environment.

### Introduction:

Work-related musculoskeletal disorders are common among surgeons. While improvements in OR ergonomics, surgical tools, and training have reduced injury and fatigue, it remains unclear whether

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choice of surgical implant can lessen cumulative force demands. Pre-bent rods could be a cost-effective means to decrease both time contouring and surgeon musculoskeletal burden. We assessed surgeon muscle activity via surface EMG as surgeons bent straight and pre-bent rods to patient-derived rod templates.

## Methods:

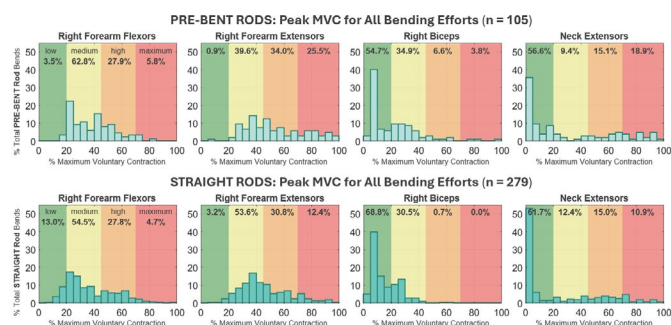
Four right-hand dominant spinal deformity surgeons with 3 to 34 years in practice and glove size [7.5-8.0] contoured four CoCr straight rods and four CoCr pre-bent rods using their preferred technique (plate and/or French benders) to four patient-derived rod templates over two sessions. Templates were created by segmenting the left rod from four deidentified post-operative CTs. Pre-bent rods had three options for sagittal contour corresponding to low, medium and high lordosis, surgeons selected the best-fit to the templates. Eight surface EMG sensors measured muscle output of surgeons' forearms, right upper arm, trapezius and neck extensors. Before each session, the maximum voluntary contraction (MVC) of each muscle was measured. Associations between number of rod bends vs. rod type and bends vs. surgeon technique were assessed with chi-squared tests ( $\alpha = 0.05$ ). T-tests assessed EMG amplitude for each muscle vs. rod type ( $\alpha = 0.05$ ). Bends were categorized by risk of overuse injury via MVC from literature: low- (0-20%), medium- (20-45%), high- (45-70%) and maximum-risk (70-100%).

## Results:

Across all templates and with each surgeon's preferred technique, pre-bent rods took significantly fewer bends ( $n=105$ ) than straight rods ( $n=279$ ,  $p < 0.05$ ), though the magnitude of peaks were consistent across all muscle groups for both rod types ( $p > 0.05$ ). Right forearm flexors and extensors were at risk of overuse injury for  $>87\%$  of bends.

## Conclusion:

Pre-bent rods required only 38% of bending effort to achieve the target contours, but with similar magnitude of muscular contractions. Use of pre-bent rods may reduce surgeon musculoskeletal burden.



Rod bends categorized by risk of overuse injury

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## Paper #224. Caregiver Comprehension Following Initial Pediatric Scoliosis Consultation: A Single-Center Concordance Study

Rachel Woods; Benjamin D. Martin, MD; Khayla Easley, BS; Rati Deshpande, MBBS; Laurel C. Blakemore, MD

### Hypothesis:

Accuracy of caregiver recall will vary by information type and demographic factors, with most caregivers reporting a desire for supplemental educational materials.

### Design:

Prospective, survey-based study.

### Introduction:

Effective communication is critical in pediatric orthopedics, particularly for scoliosis diagnoses that require long-term management. However, little is known about how accurately caregivers recall diagnostic and treatment information after the initial consultation. Assessing caregiver-physician concordance may identify communication gaps and guide development of targeted educational resources.

### Methods:

We conducted a prospective study at a single pediatric orthopedic clinic. Caregivers of children ( $<18$  years) newly diagnosed with scoliosis (Cobb angle  $\geq 10^\circ$ ) completed a post-visit survey assessing recall of diagnosis type, curve magnitude, expected curve progression, treatment plan, and recommended brace wear time. Demographics and resource preferences were also collected. Treating physicians completed parallel surveys. Concordance was defined as caregiver-physician agreement; percent agreement and Cohen's kappa (95% CI) were calculated.

### Results:

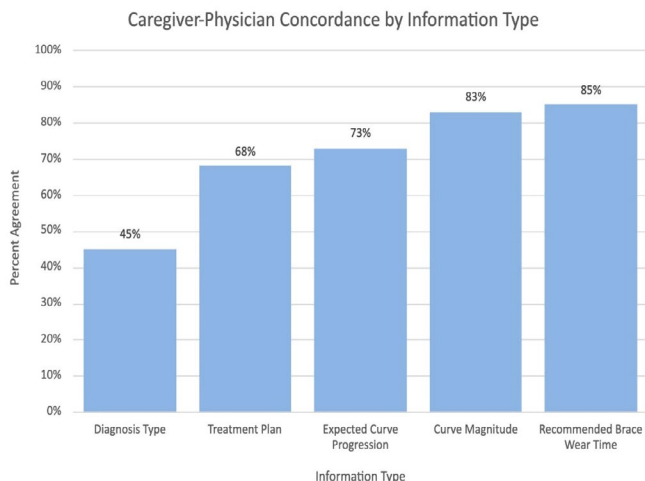
Sixty caregiver-physician dyads were analyzed. Only 22% were fully concordant across all five items; the mean concordance score was 3.5/5 (SD 1.1). Agreement was highest for numerical details: curve magnitude (83%,  $\kappa = 0.85$ , 95% CI 0.69-0.95) and brace wear time (85%,  $\kappa = 0.47$ , 95% CI 0.02-0.81). Moderate concordance was observed for expected curve progression (73%,  $\kappa = 0.55$ , 95% CI 0.39-0.70) and treatment plan (68%,  $\kappa = 0.54$ , 95% CI 0.38-0.70). Diagnosis type had the lowest agreement (45%,  $\kappa = 0.09$ , 95% CI -0.01-0.22), reflecting difficulty with terminology that may hinder comprehension. Caregivers with lower education and non-English primary language had reduced concordance. Nearly three-quarters (72%) requested supplemental resources, most commonly printed handouts (30%) or web-based materials (27%).

### Conclusion:

Caregivers more accurately recalled numerical details than diagnostic or prognostic concepts, with re-

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duced concordance among those with lower education or non-English language backgrounds. Although limited to a single site and two providers, these findings likely reflect common challenges in caregiver comprehension. Supplemental written and digital resources could reinforce verbal explanations and strengthen adherence to scoliosis treatment plans.



### Paper #225. Intervertebral Disc Stiffness as a Prognostic Biomarker for Adolescent Idiopathic Scoliosis: A Prospective Pilot Study

*Dorothy Kim, MSc; Jennifer A. Dermott, PT, PhD candidate; Mark Camp, MD; Alison Howell, MD; Emma Nadler, MSc; Brian Ciruna, PhD; David E. Lebel, MD, PhD*

#### Hypothesis:

Adolescent idiopathic scoliosis (AIS) patients with mild curves will have elevated intervertebral disc (IVD) stiffness compared to healthy controls, which may be prognostic for progressive deformity.

#### Design:

Prospective observational study

#### Introduction:

The pathogenic mechanisms underlying AIS remain poorly understood. Ultrafast shear wave elastography (SWE) is a non-invasive imaging technique, which allows tissue stiffness to be quantified. Zebrafish scoliosis models have demonstrated significantly stiffer IVDs prior to spinal curve onset, suggesting a causal link with disease. The relevance of zebrafish studies to human AIS is unknown. Our study objectives are to estimate the differences in IVD stiffness between patients with and without AIS.

#### Methods:

AIS patients, 10-16 years old, with coronal curve magnitude  $<25^\circ$  were recruited at a tertiary care spine clinic. Patients with previous treatment were excluded. Age and sex matched healthy controls were recruited for comparison. Two trained researchers performed ultrafast SWE scans of the IVD between the

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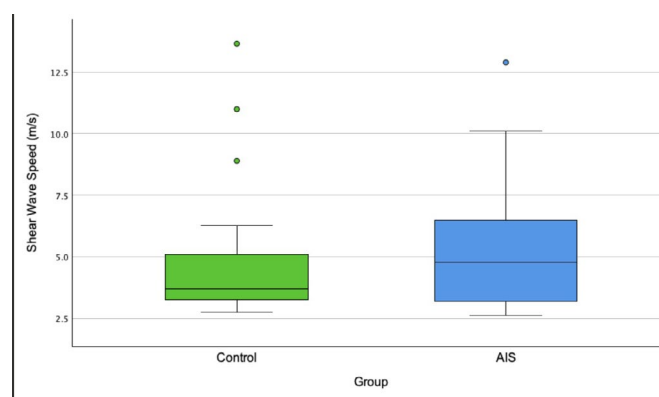
4th and 5th lumbar vertebrae on study participants. The IVD stiffness was independently quantified from the resultant shear wave by a blinded rater. Independent t-test was used to compare IVD stiffness between the two groups. Interrater reliability was computed for the shear waves produced by the two researchers to determine methodological feasibility.

#### Results:

Fifty participants have been recruited since November 2024. The AIS study cohort ( $n=26$ ) was mostly female (73%) and 12.9 (SD=1.73) years old, on average. Mean coronal curve magnitude was  $19.2^\circ$  (SD=3.6°, range 11-25°). Healthy controls ( $n=24$ ) were similar in sex ( $p=0.29$ ) and age ( $p=0.61$ ). Four outliers (AIS  $n=1$ , control  $n=3$ ) were removed from final analysis. AIS patients had higher shear wave measures, indicative of increased disc stiffness, when compared to healthy controls ( $p=0.03$ ). There was good agreement between scans produced by the two researchers (ICC= 0.89, 95% CI 0.78-0.94).

#### Conclusion:

Our preliminary data demonstrates that IVD stiffness may be elevated in a cohort of AIS patients. Continued longitudinal work is necessary to determine if IVD stiffness detected by SWE is a viable prognostic tool for progressive AIS deformity and prediction of severe curvature.



With outliers removed, AIS patients had higher shear wave measurements compared to healthy controls ( $p=0.03$ ).

### Paper #226 has been WITHDRAWN

### Paper #227. Rod Fracture After ASD Fusion: Curvature Dynamics and Rod Material/Diameter as Independent Risk Factors

*Alice Baroncini, MD, PhD; Daniel Larrieu, PhD; Anouar Bourghli, MD; Javier Pizones, MD, PhD; Ferran Pellise, MD, PhD; Ahmet Alanay, MD; Frank S. Kleinstueck, MD; Yann Phillippe Charles, MD, PhD; Cecile Roscop, MD; Louis Boissiere, MD; Ibrahim Obeid, MD*

#### Hypothesis:

Greater distal rod curvature early after surgery, limited curvature change over time, and cobalt-

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chrome (CoCr) 6.0-mm rods increase the risk of rod fracture (RF).

### Design:

Retrospective analysis of a prospective database.

### Introduction:

RF is a major mechanical complication in adult spinal deformity (ASD) surgery. We evaluated whether (1) distal (L4–S1) and global (L1–S1) rod curvature and their evolution during the first 2 postoperative years, and (2) rod material/diameter, are associated with RF; we also built a multivariable predictive model.

### Methods:

ASD patients undergoing fusion with available follow-up up to 10 years were included. Rod curvature was measured at 6 weeks, 6 months, 1 and 2 years. Analyses were performed per rod and per patient. Time-to-event modeling (Cox regression with adjustment for confounders) estimated hazard ratios (HR); discriminative ability was assessed with the c-index.

### Results:

Eighty-three patients were analyzed (mean follow-up 53.8 ± 20.9 months without RF vs 64.6 ± 23.1 with RF). The final model achieved a c-index of 0.81. Independent RF risks included: L4–S1 curvature ≥33° at 6 weeks (HR 2.03), low L1–S1 angular variation between consecutive follow-ups ≤4° (HR 3.22), and CoCr rods of 6.0 mm diameter (HR 3.81). Covariates in the model also included age (HR 0.95), preoperative relative spinopelvic alignment (HR 1.04), and the presence of a three-column osteotomy (HR 0.14).

### Conclusion:

Higher early distal curvature and minimal curvature change over the first two years are associated with increased RF risk; CoCr 6-mm rods also confer higher risk, whereas titanium appears more protective. These findings suggest that selecting more flexible constructs and avoiding excessive distal curvature may mitigate long-term mechanical failure.

### Paper #228. Automated Identification of Pedicle Screws Using Artificial Intelligence

*Julia Todderud, BS; Kellen Mulford, PhD; Andrew Pumford, BA; Christopher A. Magera, BS; A Noelle Larson, MD*

### Hypothesis:

An AI model would effectively identify unique screw types but have lower performance distinguishing screw sizes.

### Design:

Development of an automated radiograph classifier for spinal instrumentation.

### Introduction:

Applications of artificial intelligence in healthcare offer efficient and accurate tools for clinical and research settings. Characteristics such as screw thread

patterns and tulips vary with each screw type and could be used to identify patient instrumentation.

### Methods:

Patient spine radiographs were collected from our institutional image registry. 3 human annotators labeled the individual screws for model ground truth. Images were split in a 70:20:10 split for training, validation, and testing and the YoloV8 model was used for model development. 6 screw types were included: Dynesys, Expedium, Legacy, Solera, Synapse, and USS. Results are reported as precision, recall, and MAP metrics illustrating the level of overlap between screw label location by AI and human annotations.

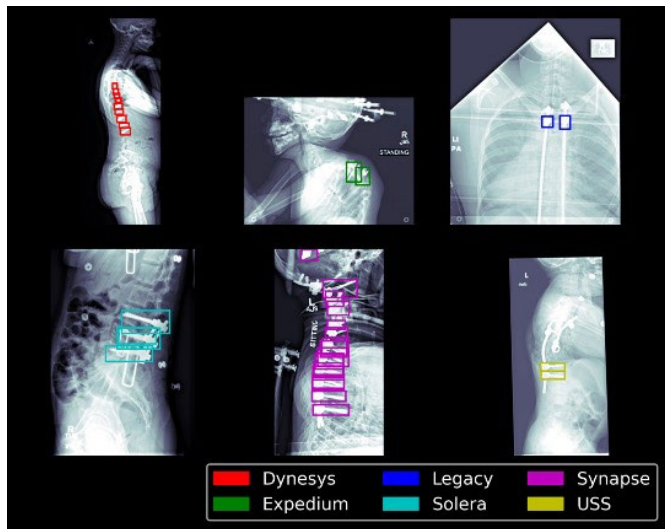
### Results:

2837 spine radiographs for 353 patients were used, with 28126 screw objects. The overall performance of the model on the test set was an mAP-50 of 0.96 across 567 images and 5829 screw objects. For individual labels, model performance was highest on Dynesys screws (mAP50=0.992, N=163 instances) and lowest on Legacy screws (mAP50=0.936, N=1020 instances). Initial images were annotated with screw type and diameter: Expedium 4.5, 5.0, and 5.5, Legacy 5.5 and 6.35, and Solera 5.5 and 6.0, in addition to Synapse, USS, and Dyensys. Model performance was uneven stratified by screw sizes, with mAP-50 metrics ranging 0.587 (Solera 6.0) to 0.99 (Expedium 5.5) and 0.875 overall.

### Conclusion:

We trained an AI model to a high degree of accuracy to classify a variety of vertebral screws in patient spine radiographs. The model excelled at identifying screw types, with more variability in classifying subtypes of screw diameters. This is likely associated with varying image sizes and screw lengths contributing to size confusion. With this deep learning model, we offer an efficient and effective resource for understanding and processing patient spine radiographs. This has potential for use in cases of patients with unknown surgical history, need for revision procedures, registry development, and research image processing.

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## Paper #229. Can Refined Indications for Vertebral Body Tethering Yield Superior Outcomes Similar to Fusion Surgery? ±

*John T. Braun, MD; Sofia Federico, BS*

### Hypothesis:

The ratio between curve flexibility and magnitude will accurately predict superior outcomes after vertebral body tethering (VBT).

### Design:

Retrospective 2019-23.

### Introduction:

While VBT has been proposed as an alternative to fusion surgery for AIS, the earliest reported outcomes for this new procedure have been disappointing. Improved indications have been suggested (curves 40-60°, flexibility ≥50%, Sanders ≤5), but these remain vague and imprecise. We analyzed a more recent series of VBT patients with the goal of refining these indications by identifying specific factors that predict superior outcomes.

### Methods:

Eighty-four AIS patients consecutively treated with VBT had ≥2 year F/U. Radiographic assessment included Cobb measurements pre-op, post-op, and final as well as fulcrum bending and hand films. Outcomes were graded as unacceptable (≥40° or revision required), acceptable (26-39°), excellent (10-25°), and outstanding (<10°) using final curve magnitude. Excellent and outstanding outcomes were considered superior.

### Results:

Eighty-four AIS patients with 121 curves (37T, 37T+TL, 10TL) were treated with VBT at age 14.5 years and Sanders 4.8 for curves 40-72°. Overall outcomes were 11% unacceptable, 37% acceptable, 44% excellent, and 8% outstanding for a total of 52% superior

outcomes. In 74/84 patients with a thoracic curve (T or T+TL), the thoracic curve determined the outcome. The outcome, in turn, was accurately predicted by the ratio of curve flexibility to curve magnitude: unacceptable outcomes had 63% flexibility/60° curves (ratio 1.0); acceptable outcomes 64%/53° (ratio 1.2); excellent 64%/48° (ratio 1.3); and outstanding had 67%/47° (ratio 1.4) (p<0.04). In 10/84 patients with single TL curves, outcomes were also accurately predicted by the flexibility/magnitude ratio but with no unacceptable outcomes: acceptable 52%/53° (ratio 1.0); excellent 72%/47° (ratio 1.5); and outstanding 77%/43° (ratio 1.8). Using these ratios, superior outcomes were predicted with high statistical significance for all curve types (p<0.01).

### Conclusion:

In this study, the ratio of curve flexibility to curve magnitude accurately predicted superior outcomes (excellent and outstanding) for both thoracic (ratio 1.3) and TL (ratio 1.5) curves with high statistical significance (p<0.01). Skeletal maturity did not have a significant impact in this study as VBT was avoided at the extremes of immaturity and maturity.

## Paper #230. L1 Pelvic Angle Can Be Predicted Using Both Morphologic and Positional Parameters

*Taryn Ludwig, MD, PhD; Chien Yew Kow, MD; Farbod Moghaddam, BS; Remi Pelletier-Roy, MD; Michael P. Kelly, MD; Fred H. Nicholls, MD*

### Hypothesis:

We hypothesize that the true and L1-S1 lumbar lordosis (LL) differ in young healthy participants. We hypothesize that the L1 pelvic angle (L1PA) can be predicted from spinopelvic and femoroacetabular parameters.

### Design:

Cross sectional

### Introduction:

Pelvic incidence (PI)-LL mismatch is a marker of sagittal balance, but lordosis frequently extends above L1 and is poorly predicted by PI alone. The L1PA is a positional sagittal alignment property, is directly affected by lordosis distribution and becomes a fixed property when the lumbar spine is fused. PI has also been shown to more reliably predict L1PA than it predicts LL.

### Methods:

Healthy volunteers with no hip or spine pathology were recruited (N=500). Full body EOS scans and 3D reconstructions of the pelvis were obtained. Femoroacetabular parameters (acetabular anteversion (AA), acetabular inclination (AI), femoral version (FV)) and spinopelvic parameters (PI, LL, L1PA, pelvic tilt (PT), sacral slope (SS)) were calculated and recorded.

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Lumbar lordosis from L1 to S1 (L1S1) and from the cranial end of the lumbar lordotic segment to S1 (trueLL) were obtained and compared to PI by linear regression. Associations between L1PA and spinopelvic and femoroacetabular parameters were tested using stepwise linear regression analyses.

### Results:

377 volunteers (age 28.90±5.1, 57% F, BMI 24.8±4.2) were included. The cranial end of LL was above L1 for 57% of participants. PI and LL-L1S1 were statistically significantly associated by linear regression ( $R^2=0.361$ ,  $p<0.001$ ), as were PI and trueLL ( $R^2=0.339$ ,  $p<0.001$ ). LL was poorly predicted by PI alone ( $R^2=0.34$ ). L1PA could be predicted by PI alone ( $R^2=0.62$ ,  $L1PA=0.47PI-18$ ), and improved with inclusion of AA in the model ( $R^2=0.67$ ,  $L1PA=0.44PI+0.34AA-22$ ). Substituting PT and SS for PI further improved predictability ( $R^2=0.79$ ,  $L1PA=0.25SS+0.75PT-12$ ).

### Conclusion:

The conventional L1-S1 measurement does not accurately capture the lordotic curvature in the majority of healthy volunteers. We identified strong relationships between morphologic spinopelvic and femoroacetabular parameters in defining sagittal balance of the young healthy spine via L1PA. The inclusion of positional parameters resulted in much improved prediction of L1PA. Future work should focus on improving understanding of factors affecting sacropelvic positioning. Our study provides a foundation for studying changes in alignment with aging and associated compensatory mechanisms.

### Paper #231. Too Young or Just in Time? Outcomes of Posterior Hemivertebra Resection Under Age Three

*Fedde Weenink, MD; Bing Wui Ng, MD; Feyzi Kilic, MD; Bayron Valenzuela C, MD; Akinbo Olaolu, MD; Elif Gizem Carus, MS; Tais Zulemyan, MS; Nuri Demirci, MD; Caglar Yilgor, MD; Altug Yucekul, MD; Ahmet Alanay, MD*

### Hypothesis:

To evaluate the safety profile, radiological outcomes, and specific technical aspects of posterior hemivertebra resection in children under the age of three.

### Design:

Retrospective review.

### Introduction:

The ideal timing for hemivertebra resection remains debated, as surgery in children under three offers potential for optimal correction but presents unique anatomical and technical challenges. This study evaluates the safety and efficacy of this early intervention strategy.

### Methods:

A retrospective review was conducted on patients who underwent hemivertebra resection before age three with a minimum 2-year follow-up. Patients with 2-rod constructs were compared to those with 3- or 4-rod constructs. The procedure was performed using modern surgical techniques, including multimodal neuromonitoring, intraoperative CT navigation, and multirod/hook-assisted stabilization.

### Results:

A total of 19 patients (23 hemivertebrae resections) were included. The mean surgical age was 23.5 ± 7.5 months, and the mean follow-up was 74.3±41.1 months. The mean coronal segmental Cobb angle was reduced from 33.0° ± 9.3° preoperatively to 5.2° ± 4.7° postoperatively and was 6.0°±6.8° at the latest follow-up. The correction rate was 85.4%±11.0% initially and was maintained at 82.8±18.4% at final follow-up. For the cranial compensatory curve, correction improved from 64.4%±31.0% to 80.0% ± 26.5%; for the caudal curve, correction was maintained from 61.1% ± 19.3% to 63.7% ± 33.2%. Mean operative time was 359.6±93.5 minutes, with a mean blood loss of 183.3 ± 124.5 ml and a hospital stay of 5 ± 2 days. Six complications were recorded in five patients, with no instances of neurological deterioration. While radiographic correction rates were comparable between 2-rod and multi-rod groups ( $p>0.05$ ), all patients with 2-rod constructs required postoperative casting, whereas none was needed for patients in the multi-rod group.

### Conclusion:

Posterior hemivertebra resection in children under three is a neurologically safe and highly effective method for deformity correction when performed with modern techniques. Early intervention offers permanent results with an acceptable complication profile. Furthermore, the use of multi-rod constructs may provide superior stability, protecting patients from the need for postoperative casting.

### Paper #232. Outcomes of Vertebral Body Tethering in Adolescent Idiopathic Scoliosis: A Prospective, Multi-Center Study

*Hans Nugraha, MD; Lawrence L. Haber, MD; Dan Hoernschemeyer, MD; Patrick J. Cahill, MD; Amer F. Samdani, MD; Firoz Miyajji, MD, FRCS(C); Peter O. Newton, MD; A. Noelle Larson, MD*

### Hypothesis:

Curve correction on first postop standing (first-erect, FE) imaging is associated with higher rates of successful correction at final follow-up.

### Design:

Prospective, multi-center

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### Introduction:

VBT for AIS is an alternative to posterior fusion. There is limited prospective, multi-center data available on VBT following U.S. FDA approval.

### Methods:

All qualifying AIS patients who underwent thoracic and lumbar VBT between 2019 and 2022 were prospectively enrolled from 9 institutions. Radiographic and clinical data were compared preoperatively, at FE, and at final follow-up with minimum of 2 years. Success was defined as major curve magnitude of  $\leq 35^\circ$  at final follow-up and no fusion surgery.

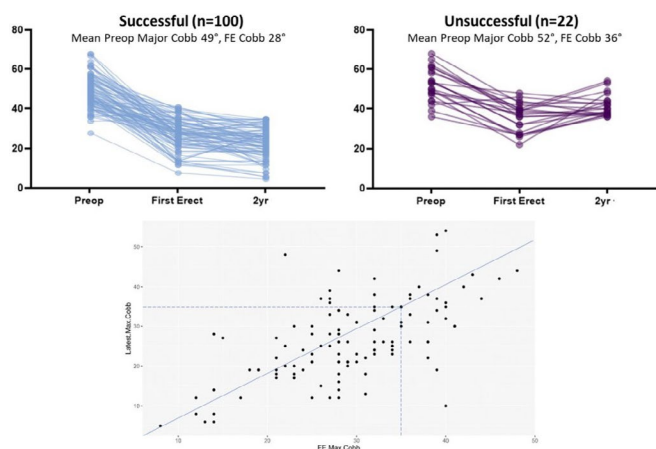
### Results:

127 patients were enrolled (79.5% female), with mean follow-up 2.4 years. Mean age-at-surgery was  $12.9 \pm 1.4$  years, most had bone-age of Sanders 4 or lower (93/112, 83.0%). In average,  $7.6 \pm 1.7$  levels were tethered. Mean preoperative major curve-magnitude was  $50 \pm 8^\circ$ , with mean initial correction at FE of  $29 \pm 8^\circ$  (%correction,  $39 \pm 18\%$ ). At final follow up, mean curve-magnitude was maintained at  $26 \pm 11^\circ$  (%correction,  $45 \pm 23\%$ ) despite 29% of tether-breakage. Patients who had mean FE curve-magnitude of  $\leq 35^\circ$  were 88% successful compared to only 60% in those with  $> 35^\circ$  on FE ( $p=0.0021$ ). Patients showed stable sagittal alignment across all timepoints. SRS-22 scores improved significantly by 2 years ( $p < 0.0001$ ). Quality of life, assessed via SRS-22 scores, improved significantly, with greatest improvement between preoperative and 2-year (mean difference = 0.46,  $p < 0.001$ ).

### Conclusion:

This is the first prospective, multi-center study to assess outcomes of VBT for AIS patients. VBT shows promise, but optimal results may depend on careful patient selection and surgical technique. FE major curve magnitude of  $\leq 35^\circ$  was associated with 88% success rate compared to only 60% success for those with poor correction.

|                          | FE Cobb $\leq 35^\circ$ | FE Cobb $> 35^\circ$ | p-value       |
|--------------------------|-------------------------|----------------------|---------------|
| Age at surgery           | $12.9 \pm 1.3$          | $13.0 \pm 1.6$       | 0.658         |
| Preop Cobb               | $48.5 \pm 7.9$          | $53.2 \pm 8.1$       | <b>0.005*</b> |
| BMI                      | $19.1 \pm 3.7$          | $19.3 \pm 4.1$       | 0.748         |
| Risser                   | $1.2 \pm 1.2$           | $1.03 \pm 1.4$       | 0.579         |
| Sanders                  | $4.2 \pm 1.7$           | $3.8 \pm 1.9$        | 0.257         |
| Time to latest follow-up | $2.4 \pm 0.4$           | $2.5 \pm 0.5$        | 0.210         |



### Paper #233. C2 Pelvic Angle Predicts Postoperative Pelvic Tilt and Cervical Alignment in Cervical Deformity: Threshold Analysis Suggests Compensation Limits

Alexandra N. Yiachos, BS; Themistocles S. Protopsaltis, MD; Frank Schwab, MD; Justin S. Smith, MD, PhD; Virginie Lafage, PhD; Renaud Lafage, MS; Christopher I. Shaffrey, MD; Eric O. Klineberg, MD; Christopher P. Ames, MD; Shay Bess, MD; International Spine Study Group

### Hypothesis:

C2 Pelvic angle (C2PA) and Pelvic Incidence (PI) can explain Pelvic Tilt (PT) patterns up to a certain threshold beyond which PT correction is limited.

### Design:

Multicenter retrospective review

### Introduction:

Persistent PT after deformity correction may reflect unrecognized compensation. In thoracolumbar deformity, C2PA and PI predict pelvic retroversion, but this has not been studied in cervical deformity (CD).

### Methods:

53 adults (mean age 62.5 years; 64.2% female) with CD who underwent cervicothoracic fusion to  $\leq T7$  were included. Linear regression assessed whether preoperative C2PA and PI predicted preoperative PT. Multivariable regression assessed whether 3-month change in C2PA and preoperative C2 slope (C2S) predicted PT correction. Additional models evaluated whether pre-op C2PA, PT, and PI could predict pre-op C2 Tilt (C2T) or the change in C2T from baseline to 1 year. Spearman correlations evaluated associations between radiographic variables and

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NDI or NSR-Neck scores at baseline, 1 year, and their change. Patients were stratified by C2PA (>19.2° vs. <19.2°), and radiographic/HRQL outcomes were compared (NDI, EQ-5D, NRS-neck) using t-tests and Mann-Whitney U (p<0.05).

## Results:

Preoperative C2PA significantly predicted preoperative PT ( $\beta = 0.79, p < 0.001$ ), while PI did not ( $\beta = 0.119, p = 0.19$ , adjusted  $R^2 = 0.699$ ). DC2PA at 3 months and pre-op C2S both significantly predicted PT correction at 3 months ( $r^2 = 0.68$  and  $-0.55$ , respectively; both  $p < 0.01$ ; adjusted  $R^2 = 0.509$ ). Pre-op C2PA, PT, and PI were not significant predictors in pre-op C2T or the change in C2T between baseline and 1-year. Preoperative C2PA was correlated with higher 1-year NDI scores ( $\Delta = 0.32, p = 0.018$ ). 1-year cSVA ( $\Delta = -0.35, p = 0.04$ ) and C2S ( $\Delta = -0.34, p = 0.02$ ) were significantly associated with a lower change in NSR Neck score from baseline to 1 year. DC2PA between baseline and 1 year was associated with lower 1-year NSR-Neck scores ( $\Delta = -0.4, p = 0.04$ ) and DNSR-Neck scores at 1 year ( $\Delta = -0.37, p = 0.04$ ). 45 patients were included in the sub-analysis. 22 patients had preop C2PA < 19.2° vs. 23 patients > 19.2°. Patients with pre-op C2PA > 19.2° had less correction in C2 Tilt ( $p = 0.012$ ) and C2S ( $p = 0.016$ ). HRQLs did not differ between groups.

## Conclusion:

PT compensates for rising C2PA only up to ~19.2°, beyond which cervical malalignment predominates. Pre-op C2PA may aid risk stratification and surgical planning.

|                    |                         | Demographics             |            |
|--------------------|-------------------------|--------------------------|------------|
|                    |                         | Age (years)              | 62.5 ± 9.4 |
|                    |                         | BMI (kg/m <sup>2</sup> ) | 29.2 ± 8.2 |
|                    |                         | Gender (% Female)        | 34 (64.2%) |
|                    |                         | Levels Fused             | 7.9 ± 2.7  |
|                    |                         | Radiographic parameters  |            |
| Preop              | C2PA (deg)              | 18.1 ± 10.7              |            |
|                    | PT (deg)                | 20.9 ± 10.0              |            |
|                    | PI (deg)                | 52.5 ± 9.9               |            |
|                    | C2 Slope (deg)          | 39.6 ± 24.9              |            |
|                    | T1 Slope (deg)          | 31.1 ± 18.7              |            |
|                    | cSVA (mm)               | 42.2 ± 26.2              |            |
|                    | Cervical lordosis (deg) | -11.2 ± 25.8             |            |
|                    | T1 PA (deg)             | 14.4 ± 10.6              |            |
|                    | C2-Tilt (deg)           | -25.6 ± 26               |            |
|                    | DIK angle (deg)         | 10.5 ± 9.5               |            |
| 3 Month            | C2PA (deg)              | 20.2 ± 11.5              |            |
|                    | PT (deg)                | 20.9 ± 9.2               |            |
|                    | PI (deg)                | 51.6 ± 9.9               |            |
|                    | C2 Slope (deg)          | 26.9 ± 16.6              |            |
|                    | T1 Slope (deg)          | 37.3 ± 19.9              |            |
|                    | cSVA (mm)               | 38.2 ± 10.7              |            |
|                    | Cervical lordosis (deg) | 7.4 ± 19.1               |            |
|                    | C2-Tilt (deg)           | 15.7 ± 16.5              |            |
|                    | T1 PA (deg)             | 16.8 ± 11.1              |            |
|                    | DIK angle (deg)         | 9.9                      |            |
| Δ3 Month and Preop | C2PA (deg)              | 3.6 ± 7.3                |            |
|                    | PT (deg)                | 0.36 ± 6.6               |            |
|                    | PI (deg)                | 0.4 ± 2.4                |            |
|                    | C2 Slope (deg)          | -12.5 ± 20.7             |            |
|                    | T1 Slope (deg)          | 7.3 ± 16.3               |            |
|                    | cSVA (mm)               | -5.7 ± 17.8              |            |
|                    | Cervical lordosis (deg) | 21.8 ± 28.7              |            |
|                    | T1 PA (deg)             | 3.7 ± 6.8                |            |
|                    | DIK angle (deg)         | 6.1                      |            |
|                    | C2-Tilt (deg)           | -11.8 ± 21.6             |            |

Table 1. Patients with Cervical deformity and fusion in Cervical and mid Thoracic regions excluding revisions

|                | C2PA < 19.2° (n=22) | C2PA > 19.2° (n=23) | p-value |
|----------------|---------------------|---------------------|---------|
| Preop          |                     |                     |         |
| C2-Tilt (deg)  | 16.9 ± 16.3         | 36.4 ± 28.6         | 0.008   |
| C2 Slope (deg) | 28 ± 17.9           | 47.8 ± 26.6         | 0.006   |
| cSVA (mm)      | 35 ± 27.8           | 49.1 ± 23.1         | 0.071   |
| PT (deg)       | 12.8 ± 5.4          | 27.2 ± 7.8          | <0.001  |
| PI (deg)       | 48.9 ± 10           | 54.9 ± 19.4         | 0.043   |
| 1 Year         |                     |                     |         |
| C2-Tilt (deg)  | 13.9 ± 13.4         | 17.8 ± 11.8         | 0.3     |
| C2 Slope (deg) | 24.1 ± 12.6         | 29.2 ± 12.6         | 0.2     |
| cSVA (mm)      | 36.6 ± 19.9         | 41.9 ± 13.5         | 0.4     |
| PT (deg)       | 13.7 ± 6.9          | 25.4 ± 10.6         | <0.001  |
| PI (deg)       | 50.5 ± 11.2         | 54.7 ± 10           | 0.2     |
| Change         |                     |                     |         |
| C2-Tilt (deg)  | -0.7 ± 14           | -20.1 ± 29.4        | 0.012   |
| C2 Slope (deg) | -1.9 ± 16.1         | -19.8 ± 27.1        | 0.016   |
| cSVA (mm)      | 0.9 ± 21.3          | 6.3 ± 29.6          | 0.7     |
| PT (deg)       | 1.2 ± 5.7           | -0.3 ± 6            | 0.1     |
| PI (deg)       | -0.5 ± 1.6          | 0.1 ± 2.2           | 0.08    |

Table 2. Comparison of radiographic parameters at baseline, 1 Year, and their change between high and low C2PA. Values are shown as mean ± standard deviation

## Hypothesis:

We hypothesized that EOS patients treated without final fusion would have satisfactory correction with few post-graduation complications across all implant types.

## Design:

Retrospective Cohort

## Introduction:

Omitting definitive surgical fusion may be an option in early onset scoliosis (EOS) patients who have satisfactory alignment at skeletal maturity. This study evaluated long-term outcomes in EOS patients without final fusion and compared outcomes across patients receiving vertical expandable prosthetic titanium ribs (VEPTR), magnetically controlled growing rods (MCGR), spinal growth guidance systems with limited apical fusion (SGGS), and traditional growing rods (TGR).

## Methods:

Using a multi-center EOS database, we identified four cohorts of patients treated with growth-friendly instrumentation who “graduated” without final fusion or implant removal: MCGR (n=14), TGR (n=94), SGGS (n=11), and VEPTR (n=78). Graduation was defined by cessation of lengthening for MCGR, TGR, and VEPTR patients and by age 16 or Risser 4 for SGGS patients. Outcomes assessed included post-graduation complication rates and changes in Cobb angle, T1-S1 height, and Early Onset Scoliosis 24-Item Questionnaire (EOSQ-24) scores. Graduation radiographic outcomes were unavailable for SGGS patients. Changes in outcomes between timepoints were assessed using paired t-tests when otherwise available. Outcomes were compared across cohorts using Fisher’s exact tests and ANOVA as appropriate. Statistical significance was set at  $p < 0.05$ .

## Results:

Cobb angle increased significantly after graduation in TGR ( $p = 0.001$ ) and VEPTR ( $p = 0.014$ ), but not MCGR patients ( $p = 0.317$ ). There were no significant post-graduation changes in T1-S1 height for MCGR ( $p = 0.501$ ), TGR ( $p = 0.389$ ), and VEPTR ( $p = 0.496$ ) patients. TGR patients had significantly worse self-reported pain/discomfort ( $p = 0.016$ ) and pulmonary function ( $p = 0.021$ ) at final follow-up compared to graduation. No other changes in EOSQ-24 scores were significant in any cohort. Post-graduation complication rates were low across all implant types, with no significant difference in the rate of complications across cohorts ( $p = 0.190$ ).

## Conclusion:

At mean follow-up of 4.6 years after graduation, all implant types had satisfactory results. Avoiding final fusion may be viable for select early onset scoliosis

## Paper #234. No Final Fusion is Viable for Early Onset Scoliosis Patients Regardless of Implant Type

*Eric Mao, BA; Kyung Park Sydney Thai, BS; Lindsay M. Andras, MD; John B. Emans, MD; John (Jack) M. Flynn, MD; Pediatric Spine Study Group Paul D. Sponseller, MD*

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patients regardless of implant type, but some loss of correction may occur with TGR.

| Outcome   | MCCR Cohort<br>n = 14 | TGR Cohort<br>n = 94 | SGGS Cohort<br>n = 11 | VEPTR Cohort<br>n = 78 | Across Cohort p-value |
|---|-----------------------|----------------------|-----------------------|------------------------|-----------------------|
| Age at Initiation of Treatment; mean ± SD                 | 6.6 ± 1.9             | 6.6 ± 2.7            | 6.7 ± 3.7             | 6.5 ± 3.5              | 0.018*                |
| Years Between Graduation and Final Follow-up; mean ± SD   | 2.9 ± 1.7             | 5.1 ± 2.7            | 2.3 ± 1.6             | 4.6 ± 2.9              | <0.001*               |
| Post-Graduation Implant Related Complications; n(%)       | 1 (7.1)               | 6 (6.4)              | 0 (0.0)               | 2 (2.6)                | 0.484                 |
| Curve Magnitude (deg); mean ± SD                          |                       |                      |                       |                        |                       |
| Graduation  | 54.3 ± 18.5           | 44.5 ± 18.7          | —                     | 61.3 ± 20.0            | <0.001*               |
| Final   | 58.4 ± 20.8           | 51.3 ± 21.4          | 39.0 ± 12.7           | 60.4 ± 23.1            | <0.001*               |
| % Curve Change from Graduation to Final; mean ± SD        | 8.2 ± 31.0            | 28.0 ± 106.7         | —                     | 10.7 ± 39.6            | 0.302                 |
| T1-S1 Height (cm); mean ± SD                              |                       |                      |                       |                        |                       |
| Graduation  | 340.1 ± 51.1          | 347.7 ± 57.7         | —                     | 319.7 ± 61.6           | 0.026*                |
| Final   | 340.5 ± 50.7          | 342.0 ± 65.0         | 350.7 ± 40.4          | 310.5 ± 50.6           | 0.021*                |
| % T1-S1 Height Change from Graduation to Final; mean ± SD | 3.7 ± 13.7            | 1.1 ± 10.4           | —                     | 0.3 ± 20.1             | 0.026*                |
| EOSQ-24 General Health; mean ± SD                         |                       |                      |                       |                        |                       |
| Graduation  | 69.4 ± 27.3           | 73.7 ± 10.3          | 84.4 ± 6.3            | 70.4 ± 18.6            | 0.018                 |
| Final   | 67.5 ± 15.8           | 68.0 ± 23.9          | 60.0 ± 16.5           | 68.3 ± 20.2            | 0.686                 |
| EOSQ-24 Pain/Discomfort; mean ± SD                        |                       |                      |                       |                        |                       |
| Graduation  | 64.2 ± 26.0           | 81.0 ± 20.6          | 78.1 ± 26.8           | 70.4 ± 22.4            | 0.018*                |
| Final   | 70.0 ± 18.8           | 67.9 ± 24.5          | 62.5 ± 31.2           | 67.1 ± 23.9            | 0.913                 |
| EOSQ-24 Pulmonary Function; mean ± SD                     |                       |                      |                       |                        |                       |
| Graduation  | 72.2 ± 29.2           | 62.6 ± 16.0          | 84.4 ± 18.8           | 78.9 ± 24.3            | 0.039*                |
| Final   | 76.3 ± 18.1           | 78.1 ± 26.6          | 87.0 ± 17.7           | 82.1 ± 23.3            | 0.609                 |
| EOSQ-24 Child Satisfaction; mean ± SD                     |                       |                      |                       |                        |                       |
| Graduation  | 47.2 ± 26.4           | 75.0 ± 25.5          | 41.7 ± 14.4           | 60.8 ± 23.4            | 0.009*                |
| Final   | 60.0 ± 29.3           | 72.7 ± 24.5          | 59.4 ± 22.9           | 57.9 ± 29.1            | 0.129                 |
| EOSQ-24 Parent Satisfaction; mean ± SD                    |                       |                      |                       |                        |                       |
| Graduation  | 53.1 ± 28.1           | 75.0 ± 26.0          | 56.3 ± 23.0           | 62.9 ± 21.8            | 0.090                 |
| Final   | 60.0 ± 29.3           | 72.0 ± 27.1          | 72.2 ± 15.0           | 61.5 ± 29.2            | 0.326                 |

## Outcomes of 197 Patients

### Paper #235. Should We Rely on Abnormal Neurological Exam and X-ray to Detect Syringomyelia/Chiari Malformation in Patients with Scoliosis?

Lucas Budd, BS; Jennifer Strahle, MD; John S. Vorhies, MD; Simon Y. Tang, PhD; Blake K. Montgomery, MD

#### Hypothesis:

Neurological exam findings, hyperkyphosis, and left-sided thoracic curves are poorly sensitive indicators of underlying Chiari malformation and syringomyelia in patients with scoliosis.

#### Design:

This was a retrospective review.

#### Introduction:

Chiari malformation and syringomyelia are known contributors to scoliosis and may necessitate neurosurgical decompression prior to corrective spinal surgery. Abnormal neurological findings or atypical curve patterns are often used to initiate advanced imaging, yet the diagnostic performance of these

criteria is unclear. This study aimed to evaluate the incidence and sensitivity of abnormal neurological exams, hyperkyphosis, and left-sided curves in patients with known neuraxial abnormalities to inform preoperative MRI guidelines.

#### Methods:

A retrospective review was conducted on pediatric scoliosis patients who underwent posterior spinal instrumentation and were diagnosed with Chiari I malformation (n=7), syringomyelia (n=25), or both (n=21). Average age at surgery was 13.06 years (16 males, 37 females). Preoperative neurological exams were reviewed for abnormalities in reflexes, motor/sensory function, gait, balance, spasticity, and muscle symmetry. Radiographic data included curve laterality and sagittal alignment. Hyperkyphosis was defined as >20° from T2-T5 and >40° from T5-T12.

#### Results:

Of 53 patients with neuraxial abnormalities, 24.5% had an abnormal neurological exam, and 41.5% had atypical radiographic features. The sensitivity of both exams was 58.5%. 33.3% (7/21) of patients with both syringomyelia and CM, 16% (4/25) of patients with only syringomyelia and 28.6% (2/7) of patients with solely CM had an abnormal neurological exam finding. There was not a reliably associated abnormality on preoperative physical exam for any group (Fisher's exact: syringomyelia (p = 0.213), CM (p = 0.555), or both conditions (p = 0.329)). Additionally, left sided curvature was not reliably associated with any group. Across all patients 41.5% of patients did not have any abnormality on physical exam or imaging and had presentation similar to AIS.

#### Conclusion:

These results indicate that neurological and radiologic examinations have low sensitivity of detecting syringomyelia and/or CM in patients with scoliosis. Understanding the utility of these exams will help inform appropriate use guidelines for preoperative MRI in patients with presumed idiopathic scoliosis.

### Paper #236. Radiological Patterns and Surgical Strategies in Degenerative Lumbar Scoliosis (DLS) with Shoulder Imbalance: A Novel Classification Approach

Junyu Li, MD; Junjie Ma, MD; Hanwen Zhang, MD; Zhuoran Sun, MD; Yongqiang Wang, MD; Miao Yu, MD; Weishi Li, MD

#### Hypothesis:

In adult DLS patients, preoperative shoulder imbalance subtypes are associated with postoperative coronal-plane and shoulder-balance outcomes.

#### Design:

A retrospective radiographic cohort study

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### Introduction:

Degenerative lumbar scoliosis (DLS) is common in the elderly. Shoulder imbalance (SI) is a major determinant of surgical outcomes, yet systematic data on radiographic features in DLS with SI are scarce, and the attainment of postoperative shoulder balance (SB) remain unclear. From radiographic review, we identified two SI subtypes with distinct clinical traits and propose a preoperative classification to guide scoliosis correction.

### Methods:

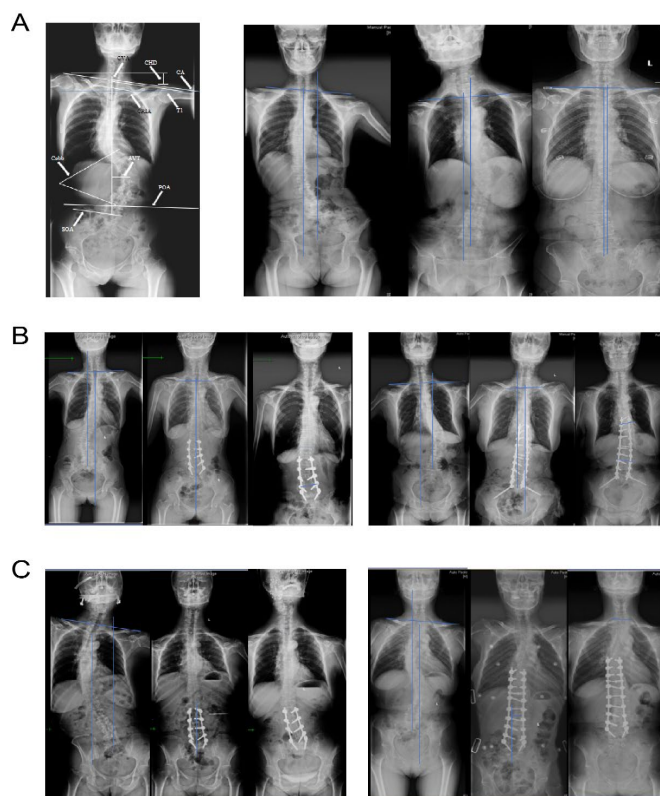
A cohort of 297 adult patients who underwent posterior scoliosis correction surgery was reviewed. Of these, 71 had coronal and shoulder imbalance ( $CA \geq 2^\circ$  and  $T1PL-CSVL \geq 20$  mm) and 117 served as balanced controls ( $CA < 2^\circ$ ,  $T1PL-CSVL < 20$  mm). Imbalanced patients were classified in two steps: first by Obeid type (I or II), then by shoulder imbalance subtype—Type I (higher clavicle on the same side as the T1PL offset) or Type II (higher clavicle on the opposite side). Group comparisons used t-tests and chi-square tests.

### Results:

In Obeid I, SI Type II showed higher postoperative T1PL-CSVL ( $p=0.014$ ) and lower last-follow-up CRIA ( $p=0.009$ ) and Cobb angle ( $p=0.041$ ). In Obeid II, SI Type I showed higher postoperative AVT ( $p=0.037$ ) and higher last-follow-up T1 tilt ( $p=0.018$ ). Versus balanced controls, Type I had larger pre-/postoperative Cobb angles ( $p=0.027$ ) and a lower correction rate ( $p=0.024$ ); Type II had higher preoperative AVT ( $p=0.01$ ), higher postoperative Cobb ( $p<0.001$ ) and AVT ( $p=0.005$ ), higher last-follow-up T1 tilt ( $p=0.008$ ), CRIA ( $p<0.001$ ), and Cobb angle ( $p<0.001$ ), and a lower correction rate ( $p=0.011$ ). Direct comparison showed Type II had higher postoperative Cobb ( $p=0.032$ ) and AVT ( $p=0.035$ ), higher last-follow-up T1 tilt ( $p=0.044$ ), CRIA ( $p=0.015$ ), and Cobb angle ( $p=0.012$ ), and greater Cobb progression ( $p<0.001$ ).

### Conclusion:

The shoulder imbalance classification stratifies prognosis: type II in Obeid I patients predicts poor coronal shift correction, while type I in Obeid II patients indicates residual apical translation. Preoperative identification is crucial for surgical planning.



Radiographic Measurement of Shoulder Balance

### Paper #237. Dystrophinopathy in the Paravertebral Muscle of Adolescent Idiopathic Scoliosis (AIS): A Prospective Case-control Study in China

*Junyu Li, MD; Xiang Zhang, MD; Zekun Li, MD; Hanwen Zhang, MD; Yingshuang Zhang, MD; Miao Yu, MD*

### Hypothesis:

Reduced dystrophin in paraspinal muscle contributes to AIS and scales with curve severity; side-specific loss of isoforms (1/2/3) correlates with vertebral rotation (Nash-Moe) and coronal curvature (Cobb angle).

### Design:

A prospective case-control study.

### Introduction:

Adolescent idiopathic scoliosis (AIS) involves vertebral rotation and lateral curvature, affecting 2–4% of children under 16; about 0.04–0.3% progress to curves  $>40^\circ$ . Its cause is unclear, but evidence implicates paraspinal muscle pathology and protein dysregulation. We conducted a prospective case-control study using histology and immunohistochemistry to map these muscle changes, relate them to curve severity, and test a neuromuscular/protein-abnormality hypothesis for AIS.

### Methods:

This study enrolled 40 patients with AIS, 20 patients with congenital scoliosis (CS), and 20 patients with

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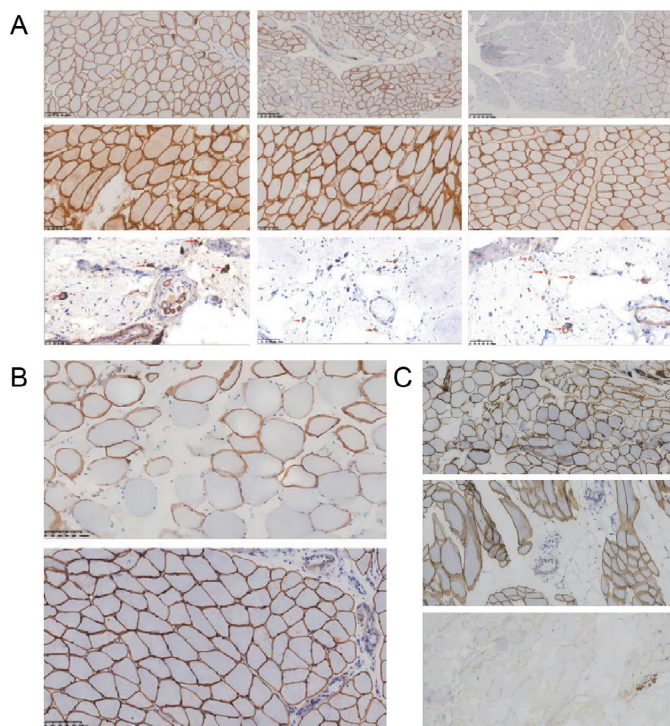
spinal degenerative disease (SDD). All patients underwent open posterior surgery in our hospital, and a paravertebral muscle (multifidus muscle) biopsy was performed intraoperatively. This study included many indexes that describe muscle, especially dystrophin staining. The above pathological results were compared among the AIS, CS, and SDD groups. The correlation between the Cobb angle and Nash–Moe classification and the above pathological results was analyzed in patients with AIS.

### Results:

Significant reductions in the dystrophin staining of dystrophin-1 ( $p < 0.001$ ), dystrophin-2 ( $p < 0.001$ ), and dystrophin-3 ( $p < 0.001$ ) were observed in the AIS group than in the CS and SDD groups. The higher the Nash–Moe classification in the AIS group, the more significant the loss of dystrophin-2 ( $p = 0.042$ ) in the convex paraspinal muscles. Additionally, a significantly positive correlation was observed between the reductions of dystrophin-2 on the concave side of the AIS group and Cobb angle ( $p = 0.011$ ).

### Conclusion:

Dystrophin protein deficiency in the paraspinal muscles plays a crucial role in AIS formation and progression. The severity of scoliosis in patients with AIS is correlated with the extent of dystrophin loss in the paravertebral muscles. Therefore, dystrophin dysfunction may be relevant to AIS occurrence and development.



*Dystrophin-Related Muscle Changes in Adolescent Idiopathic Scoliosis.*

## Paper #238. Resting State Functional MRI Brain and Effective Connectivity in Chronic Low Back Pain (cLBP) ±

*Dhruv Patel, MS; Saumyajit Basu, MS (Ortho), DNB (Ortho), FRCS (Ed); Vikas Hanasoge, MBBS, MS; Ayon Ghosh, MS*

### Hypothesis:

Changes in resting-state effective connectivity between higher and lower pain-processing brain regions are associated with chronic low back pain in individuals with negative Spine MRI and arthritic profiles.

### Design:

A prospective matched cohort study

### Introduction:

cLBP represents a significant clinical challenge in patients presenting with persistent symptoms despite a negative spine MRI and the absence of inflammatory markers. These patients possibly experience nociplastic pain—a form of pain driven by altered central processing in the absence of peripheral pathology.

### Methods:

A prospective matched cohort study was conducted at a single centre, involving 14 cLBP patients and 12 healthy controls. Participants underwent resting-state fMRI using a 3 Tesla Siemens Skyra scanner. Data preprocessing followed by time series extraction using principal component analysis and spectral dynamic causal modeling (DCM) to analyze effective connectivity between bilateral lateral frontal pole (FP1) and posterior insula (PI) regions, which were chosen for their roles in interoception and top-down cognitive control within predictive coding.

### Results:

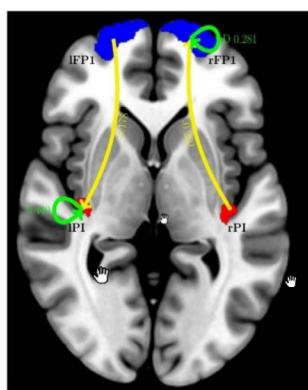
Clinical assessment revealed significantly higher pain scores (VAS and ODI) in the cLBP group compared to the control group. CLBP patients showed a distinct pattern of altered effective connectivity characterized by: (1) increased top-down inhibitory connectivity from FP1 to PI bilaterally (2) enhanced self-inhibition within both FP1 regions, and (3) increased intrinsic inhibition within the posterior insula. Leave-one-out crossvalidation analysis revealed significant predictive accuracy. Increased top-down inhibitory connectivity reflects entrenched prior expectations of pain that persist despite absent nociceptive input. The enhanced inhibition in bottom-up pathways suggests reduced precision of interoceptive prediction error signals, creating a maladaptive inference cycle where pain expectations are not effectively challenged by sensory evidence.

### Conclusion:

Our findings are suggestive of chronic pain as a “locked-in” predictive state, particularly relevant

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for nociplastic pain conditions. These findings shift understanding of CLBP from a disorder of damaged tissue to one of disordered perception, opening avenues for precision interventions targeting maladaptive top-down regulatory processes.



**Figure 4** Connections showing significant modulation in patients compared to healthy controls. Arrow colours indicate the direction of connectivity changes relative to the group mean: green for increased connectivity, yellow for decreased connectivity. Line thickness is constant and does not represent effect size. FP1: lateral frontal pole (left and right); PI: posterior insula (left and right).

## Paper #239. How a Numerical Model Can Contribute to Help the Surgical Strategy in Lumbar Zone in Lenke 1 Adolescent Idiopathic Scoliosis (AIS)?

Amandine Eon, MD, MS; Matthieu Carrere, MS; Jérôme Sales De Gauzy, MD; Mathilde Bony, MS; Joe Rassi, MD; Pascal Swider, PhD; Pauline Assemat, PhD; Tristan Langlais, MD, PhD; Emmanuelle Ferrero, MD, PhD

### Hypothesis:

A biomechanical model based on the distribution of spine energy can help the choice of the last instrumented vertebra in AIS

### Design:

Retrospective

### Introduction:

Distribution of biomechanical energy obtained from pre-operative radiographs was tested and was reliable to simulate spine alignment after arthrodesis in a AIS cohort. We have proposed a biomechanical model whose numerical implementation can help the choice of the LIV in AIS Lenke 1.

### Methods:

Twenty-four consecutive patients with Lenke 1 AIS (mean age =16yo, mean thoracic Cobb angle =52°, SD=8°) who underwent posterior spinal fusion between 2017 and 2020 and had preoperative and postoperative biplanar radiographs at three months and two years were included retrospectively. First, numerical simulation with a LIV-2, LIV-1 and LIV+1 was modeled with a in-house software. To assess frontal global balance in numerical simulation, we calculated the area (A) above (AU) and under (AD)

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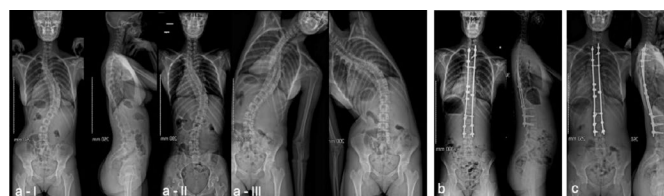
the instrumented curve after surgical correction, the distance between the apex vertebra of the free levels distally and vertical axis (ZmaxU for up and ZmaxD for down) and the angle between T1S1 line and vertical axis ( $\delta T1S1$ ). Two groups (LIV-1 compatible or incompatible) were created by two experienced surgeons who were unaware of the level of instrumentation performed. They had access to preoperative frontal and profile, bending and a suspension X-ray.

### Results:

Thirteen cases were clinically LIV-1 compatible. When we compared clinical results and numerical simulations in the compatible group, one level could have been spared when ZmaxD was less than 16.5 mm and AD was less than 1420 mm<sup>2</sup>.

### Conclusion:

This numerical model can contribute to help the surgical strategy in lumbar zone in Lenke 1 adolescent idiopathic scoliosis when used with preoperative radiographs as an additional tool for sparing an arthrodesis level.



Clinically and numerically compatible case of a 15-year-old female patient, Lenke 1A a) Preoperative radiographs I -standing ; II - supine ; III - bending b) 3 months postoperative radiographs c) 2 years postoperative radiographs d) Numerical simulation outcomes according to the LIV

## Paper #240. Analysis of Gait in Adult Spinal Deformity Patients Using Inverse Dynamics by Anybody Modeling System

Hojoong Kim, MD; Jin-Ho Park, MD; Haolin Zheng, MD; Jisoo Lee, MD; Jae Heouk Choi, MD

### Hypothesis:

Patients with adult spinal deformity (ASD) who have sagittal imbalance and fail to achieve pelvic compensation will exhibit distinct characteristics in joint moments and muscle activity during gait analysis compared with those who maintain pelvic compensation.

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### Design:

Retrospective observational study

### Introduction:

Pelvic retroversion is a key compensatory mechanism for maintaining sagittal balance in ASD. However, some patients fail to achieve adequate pelvic compensation despite marked sagittal malalignment, and the biomechanical basis remains unclear. This study examines the biomechanical characteristics of ASD patients with sagittal imbalance by comparing those with and without pelvic compensation using gait analysis and musculoskeletal simulation with the AnyBody Modeling System.

### Methods:

From August 2020 to January 2023, 154 patients who underwent ASD corrective surgery by a single surgeon were retrospectively reviewed. Of these, 52 had sagittal imbalance (SVA > 147.5 mm) and pelvic compensation failure (PT/PI < 0.68) based on standing whole spine X-rays. Eight were selected as the study group, and their gait data were analyzed with the AnyBody Modeling System to extract joint moments and muscle activity. For comparison, 21 patients with similar imbalance but preserved compensation (PT/PI ≥ 0.68) were identified, and 8 matched controls were selected via propensity score matching. Joint moments and muscle activity during gait were then compared between the groups.

### Results:

Analysis with the AnyBody Modeling System showed that the study group had significantly lower hip joint forces than controls. Hip anteroposterior force ( $4.23 \pm 2.25$  vs.  $8.96 \pm 4.39$  Nm/Bwt,  $p = 0.017$ ) and proximal force ( $41.01 \pm 15.01$  vs.  $60.64 \pm 16.75$  Nm/Bwt,  $p = 0.014$ ) were reduced. Muscle activity of the psoas major ( $1.09 \pm 1.25$  vs.  $2.71 \pm 1.68$ ,  $p = 0.046$ ) and erector spinae ( $0.96 \pm 0.63$  vs.  $2.29 \pm 1.14$ ,  $p = 0.012$ ) was also significantly decreased.

### Conclusion:

Among ASD patients with sagittal imbalance, those without pelvic compensation exhibited reduced hip extension moments compared with patients with preserved compensation, indicating a diminished ability to achieve pelvic retroversion. In addition, they demonstrated lower activity of the psoas major and erector spinae muscles, suggesting that stable contraction of these muscles is important for maintaining pelvic retroversion.

### Paper #241. An LLM-Based Delphi Study to Determine Consensus on the Clinical Diagnosis of Lumbar Spinal Stenosis: A Pilot Study

*Chuck H. Lam, BSc; Sleiman Haddad, MD, PhD, FRCS; Leo Mok, MSc; Lluís Vila Castillo, MD; Morgan Jones, FRCS, MBChB*

± = E-Point Award Nominated Paper

### Hypothesis:

Large language models, used as expert panels, can replicate the final phase of a published Delphi on the diagnosis of lumbar spinal stenosis, matching core items and achieving at least 80 percent certainty with fewer questions, faster, and at lower cost.

### Design:

Prospective computational experiment that simulated the final Delphi round with seven independent LLM panelists, benchmarked against Tomkins Lane et al. who identified seven core history items and reached at least 80 percent certainty after six items.

### Introduction:

Delphi methods are valuable but slow and resource intensive. We asked whether LLM panelists could reproduce the final phase outputs of the Tomkins Lane Delphi for lumbar spinal stenosis, while improving speed and efficiency, and maintaining agreement with the human panel.

### Methods:

Seven models, Deepseek v3, Grok 3, Claude Sonnet 4, Mistral Medium 3, Qwen 3, Llama 4, Maverick GPT 4.1. Each received ten candidate history items, returned an asking order, then estimated cumulative certainty on a five point Likert scale after each question, assuming affirmative answers. OpenRouter automation generated 280 interactions. Primary, content overlap with the seven core items. Secondary, time per round and per agent, and agreement, the proportion matching the core set.

### Results:

Ordering converged with the human panel and irrelevant items were consistently demoted. The LLM panel reached at least 80 percent certainty after two questions on average, mean 1.71. Certainty was reached after one question in 95 cases, after two in 165, and after three in 20. Total runtime was about 141 minutes, and the overall cost was under 3 USD. Percent agreement with the seven core items and per agent timing were reported as secondary outcomes.

### Conclusion:

An LLM driven Delphi reproduced key outputs of a traditional expert panel for lumbar spinal stenosis, and ran far faster at very low cost. This appears to be the first medical Delphi with a panel composed entirely of LLMs. The run finished in about two hours for under 3 USD, supporting proof of concept. Next steps include broader clinical domains, tighter prompts and bias controls, and testing hybrid human plus AI panels for rapid, reliable guideline work.

### Paper #242 has been WITHDRAWN

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### Paper #243. Composite Appearance Scoring in Scoliosis: Coupled 3D Photography and Radiographic Analysis

Zhuosong Bai, MD; Yuyan Yang, MD; Xiaohan Ye, MD; Nanze Yu, MD; Shengru Wang, MD; Xiao Long, MD; Terry Jianguo Zhang, MD

#### Hypothesis:

3D photography can quantify scoliosis back deformities and, with multivariate analysis, provide a composite score reflecting radiographic severity.

#### Design:

Prospective study.

#### Introduction:

Scoliosis patients often present with rib hump, shoulder imbalance, and trunk shift. Current assessment relies mainly on radiographs, which inadequately capture appearance and expose patients to radiation. This study evaluated appearance–radiograph associations, defined major surface deformity dimensions, and developed a composite appearance index.

#### Methods:

Twenty patients underwent 3D trunk photography and full-spine radiographs. Six appearance parameters (acromial height difference, shoulder area index, rib hump height, chest area index, waistline depth, waist area index) and four radiographic parameters (major Cobb angle, compensatory Cobb angle, radiographic shoulder height difference, trunk shift) were measured. Correlation analysis identified core appearance indicators. Principal component analysis (PCA) extracted major appearance dimensions. Two-block partial least squares (2B-PLS) examined appearance–radiograph coupling. A composite index was derived from latent variable weights.

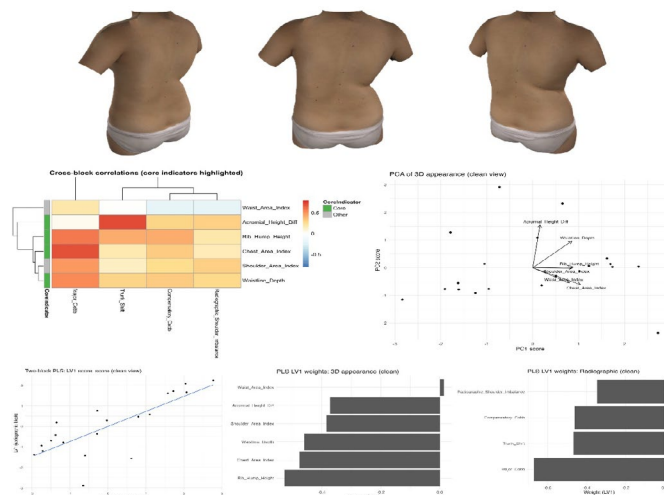
#### Results:

Four appearance indicators showed consistent associations with radiographic parameters: acromial height difference, chest area index, rib hump height, and waistline depth. PCA revealed two principal dimensions: PC1 (~60% variance) reflecting thoracolumbar asymmetry, and PC2 (~17%) representing shoulder balance. PC1 demonstrated a trend toward association with the major Cobb angle. Two-block PLS confirmed stable cross-block coupling across LV1 and LV2: rib hump height and chest area index dominated the appearance block, while the major Cobb angle contributed most in the radiographic block. The composite index based on LV1 weights reflected curve severity.

#### Conclusion:

Trunk surface deformity in scoliosis can be summarized into two key dimensions: curve severity (thoracolumbar asymmetry) and shoulder balance (acromial height difference corresponding to radio-

graphic shoulder imbalance). Three-dimensional photography combined with multivariate analysis enables a composite appearance index associated with radiographic severity, supporting its feasibility as a radiation-free assessment tool. This approach offers a reliable option for clinical follow-up, particularly in adolescents requiring dynamic monitoring.



3D Photography and Radiograph Coupling

### Paper #244. Correlating Alignment and Physical Function: Implications of Over vs Under Correction of Spine Deformity as Pertains to Specific Patient Activities

Alexandra N. Yiachos, BS; Fares Ani, MD; Akil Paturi, MD; Themistocles S. Protopsaltis, MD; Renaud Lafage, MS; Alex Soroceanu, MD, FRCS(C); Jeffrey Gum, MD; Justin S. Smith, MD, PhD; Robert K. Eastlack, MD; Gregory M. Mundis Jr., MD; Munish C. Gupta, MD, MBA; Eric O. Klineberg, MD; Lawrence G. Lenke, MD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Virginie Lafage, PhD; Frank Schwab, MD; Shay Bess, MD; International Spine Study Group

#### Hypothesis:

Overcorrected (OC) ASD Patients will have functional limitations evident in individual health related quality of life (HRQL) items compared to those who were functionally corrected (FC) or undercorrected (UC).

#### Design:

Retrospective Review of prospectively collected database

#### Introduction:

Health-related quality of life (HRQL) measures allow surgeons to evaluate patients' physical outcomes after ASD correction. Although baseline HRQL scores often improve postoperatively, spinal fusion may limit certain activities. This study investigates the impact of spinal alignment on these activity limitations.

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## Methods:

Patients with operative ASD and who were fused to the pelvis and upper-instrumented vertebrae (UIV) above T11 were included. T10PA was used to determine functional alignment, an alignment based on PI and age-appropriate physical function. OC, UC, and FC groups were determined using T10-pelvic angle (T10PA). Total scores and individual items of the SRS-22, SF36, EQ5D, LSDI, and ODI were assessed at baseline and 2 years post-operation using ANOVA with post-hoc tukey analysis. Propensity Score Matching (PSM) was used to control for age and gender. After PSM, demographics were not significantly different between the three groups, with exception to BMI.

## Results:

1,017 patients met inclusion criteria before PSM. T10PA correlated with SF36-PCS and PI (R=0.601). After PSM for age and gender, 601 patients remained: 36% FC, 29.9% OC, and 33.9% UC. At baseline, UC patients had less disability (p=0.005) and better physical functionality (p=0.01) than OC and FC. OC and FC patients reported greater difficulty walking, standing, sleeping, and poorer social life (p<0.001, p=0.003). Despite baseline disparities, total scores and changes at 2 years were similar, except for EQ5D (p=0.046). Across groups, calmness worsened at 2 years, with UC showing a larger decrease than OC (p=0.009). For ODI lifting, all groups improved, with OC and UC showing greater gains than FC (p=0.01). Work/school activity also improved, with UC showing a larger change than FC (p=0.04).

## Conclusion:

All groups achieved similar recovery outcomes regardless of their initial disparities. The significant changes in scores for individual questions suggest that UC worsened in their mental health, but improved in lifting and work level compared to FC and OC.

|   | Functionally Corrected (n=217) | Overcorrected (n=180) | Undercorrected (n=204) | p-value |
|---|--------------------------------|-----------------------|------------------------|---------|
| <b>Demographics</b>   |                                |                       |                        |         |
| Age (Years)   | 59 ± 13.6                      | 57.8 ± 15.5           | 58.7 ± 14.5            | 0.7     |
| Gender (% Female)   | 170 (78.3%)                    | 132 (73.3%)           | 151 (74%)              | 0.4     |
| BMI (kg/m <sup>2</sup> )  | 28 ± 5.80                      | ** 28.7 ± 6.3         | ** 27.1 ± 5.4          | 0.02    |
| CCI   | 1.8 ± 1.6                      | 1.96 ± 1.9            | 1.6 ± 1.9              | 0.1     |
| <b>Baseline</b>   |                                |                       |                        |         |
| ODI   | 47 ± 17.8                      | 46.9 ± 18.4           | ** 41.7 ± 17.9         | 0.005   |
| SRS 22 Total Score  | ** 2.6 ± 0.6                   | 2.7 ± 0.6             | ** 2.8 ± 0.7           | 0.01    |
| SF36 Mental Component Score   | 42.9 ± 13.7                    | 43.6 ± 14             | 45.8 ± 13.5            | 0.09    |
| SF36 Physical Component Score   | ** 29.6 ± 9.4                  | 30.7 ± 10.5           | ** 32.2 ± 10           | 0.01    |
| EQ5D  | 0.7 ± 0.07                     | 0.7 ± 0.08            | 0.8 ± 0.07             | 0.09    |
| EQ5D VAS  | 77.4 ± 143.2                   | 65 ± 103.1            | 85.9 ± 150.4           | 0.6     |
| <b>2 Year</b>   |                                |                       |                        |         |
| ODI   | 28 ± 11.7                      | 28 ± 11.5             | 24.2 ± 11.4            | 0.2     |
| SRS 22 Total Score  | 3.5 ± 0.7                      | 3.5 ± 0.8             | 3.8 ± 0.8              | 0.2     |
| SF36 Mental Component Score   | 50.6 ± 12.2                    | 49.2 ± 13             | 51.9 ± 11.2            | 0.3     |
| SF36 Physical Component Score   | 39.8 ± 10.4                    | 39.8 ± 12.2           | 41.7 ± 11.5            | 0.3     |
| EQ5D  | 0.8 ± 0.1                      | 0.8 ± 0.09            | 0.8 ± 0.1              | 0.2     |
| EQ5D VAS  | 91.3 ± 135.8                   | 111.4 ± 196.4         | 108 ± 175.7            | 0.7     |
| <b>Change in BL and 2Y</b>  |                                |                       |                        |         |
| EQ5D  | 0.05 ± 0.09                    | ** 0.04 ± 0.09        | ** 0.08 ± 0.08         | 0.046   |
| <b>Baseline ODI</b>   |                                |                       |                        |         |
| Walking   | 2.5 ± 1.3                      | 2.5 ± 1.4             | ** 2.1 ± 1.4           | <0.001  |
| Standing  | 3.2 ± 1.2                      | 3.2 ± 1.2             | ** 2.8 ± 1.3           | 0.003   |
| Sleeping  | 1.6 ± 1.5                      | 1.6 ± 1.5             | ** 1.3 ± 1.3           | <0.001  |
| Social Life   | 2.8 ± 1.4                      | 2.7 ± 1.5             | ** 2.2 ± 1.3           | <0.001  |
| <b>Change from Baseline to 2 Years SF36</b>                                   |                                |                       |                        |         |
| How much of the time during the past 4 weeks have you felt calm and peaceful? | -0.8 ± 1.1                     | ** -0.3 ± 1.1         | ** -0.4 ± 1.2          | 0.009   |
| <b>Change from Baseline to 2 Years ODI</b>                                    |                                |                       |                        |         |
| Lifting   | ** -0.2 ± 1.6                  | 0.2 ± 1.5             | -0.7 ± 1.5             | 0.01    |
| <b>Change from Baseline to 2 Years SRS 22</b>                                 |                                |                       |                        |         |
| What is your current level of work/school activity?                           | ** 0.6 ± 1.3                   | 0.6 ± 1.5             | ** 1 ± 1.4             | 0.04    |

\*\* denotes where significance lies

## Paper #245 has been WITHDRAWN

± = E-Point Award Nominated Paper

## Paper #246. Pelvic Incidence Determines Spinal Alignment in the Sitting Position

Atahan Durbas, MD; Han Jo Kim, MD; Robert N. Uzzo, MBA; Gabrielle Dykhouse, BS; Tejas Subramanian, MD; Andrea Pezzi, MD; Michael P. Kelly, MD; Francis Lovecchio, MD

## Hypothesis:

Pelvic incidence (PI)-based vertebral pelvic angle (VPA) formulas can define normative sagittal alignment in the sitting position, which can help set targets for non-ambulatory patients.

## Design:

Retrospective cross-sectional imaging study.

## Introduction:

While standing alignment with the T4-L1-Hip axis has been well defined, sitting alignment remains poorly characterized. Understanding normal sitting posture is important for surgical planning, particularly for long fusions in non-ambulatory patients. This study aimed to establish PI-based normative lumbar alignment in sitting using VPAs.

## Methods:

Adults (≥18 years) being considered for hip replacement surgery were included. Exclusion criteria were previous spinal surgery, radiographic disc degeneration (osteophyte formation, endplate sclerosis, or disc space narrowing), spondylolisthesis, severe hip osteoarthritis (Tönnis Grade 3), or coronal Cobb angle >10°. Lateral standing and sitting radiographs were reviewed. Bivariate correlations were assessed with Pearson or Spearman coefficients. Linear regression was performed to evaluate the relationship between PI, sitting pelvic tilt (PT), and VPAs.

## Results:

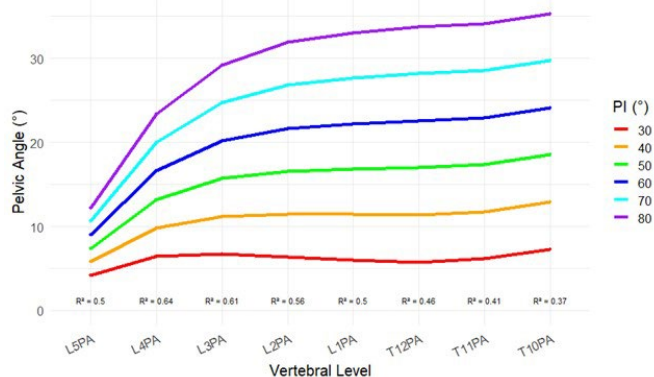
553 patients (278 females, 275 males) with a mean age of 57.5 years (±10.5), a mean BMI of 28.3 kg/m<sup>2</sup> (±5.3), and a mean PI of 55.5° (±10.8) were included. PT increased with transitioning to sitting (11.4°±7.7° to 33.6°±11.7°, p<0.001). Sitting PT was strongly correlated with sitting L1PA (r=0.79, R<sup>2</sup>=0.63, p<0.001). While PI explained only 4.9% of the variance in L1-S1 lordosis (r=0.22, R<sup>2</sup>=0.049, p<0.001), it showed a moderate association with sitting PT (r=0.46, R<sup>2</sup>=0.22, p<0.001). The following formula estimated PI-based sitting lumbar alignment: L1PA = 0.53×PI - 8.96 (R<sup>2</sup>=0.50, Figure). All VPAs with one or more intervening levels were tested, and T10PA and L1PA showed near-perfect correlation (r=0.94, R<sup>2</sup>=0.88, p<0.001), differing by ≤8.4° in 80% of cases.

## Conclusion:

This study defined a PI-based normative sitting alignment formula, consistent with established standing parameters. Previous studies of standing alignment have identified a similar proportional formula (L1PA

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=  $0.5 \times PI - 21$ ). Together, these findings provide a foundation for developing alignment targets in non-ambulatory patients.



VPA profiles across vertebral levels (T10 to L5), stratified by PI groups.

## Paper #247 has been WITHDRAWN

## Paper #248. Changes in Acetabular Abduction and Anteversion can be Predicted Following Spinal Realignment Surgery using Non-Linear Equations

*Renaud Lafage, MS; Ayman Assi, PhD; Emil Haikal, MD; Jonathan Elyse, BS; Bassel G. Diebo, MD; James Slover, MD; Virginie Lafage, PhD*

### Hypothesis:

3D geometric relationships between positional acetabular and pelvic parameters can be described using geometric non-linear equations

### Design:

Retrospective

### Introduction:

Patients with adult spinal deformity (ASD) have a high prevalence of hip osteoarthritis, that can lead to total hip replacement (THR). However, THR dislocation rates are higher in ASD due to sagittal malalignment. Previous studies suggest that acetabular anteversion increases linearly with pelvic retroversion (PT), with a 1° increase in PT leading to a 0.7–0.9° increase in acetabular anteversion. Therefore, THR cup positioning in ASD patients should account for pelvic orientation and its post-surgical changes to reduce dislocation risk.

### Methods:

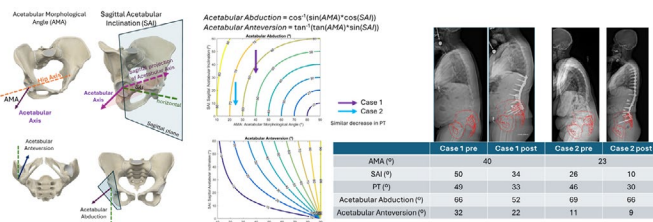
We developed 3D geometric relationships between positional acetabular parameters (abduction and anteversion), Acetabular Morphological Angle (AMA angle between the acetabular axis and the hip axis), and pelvic orientation measured using Sagittal Acetabular Inclination (SAI). These relationships were validated using postoperative data from 98 ASD patients who underwent 3D pelvic and hip reconstructions from biplanar X-rays

### Results:

Geometrical formulas were developed to calculate acetabular abduction and anteversion based on AMA and SAI (Fig.1a). Graphical analysis (Fig. 1b) demonstrates that acetabular abduction and anteversion exhibit a non-linear relationship with SAI, influenced by acetabular morphology (AMA). Specifically, for a given increase in SAI, changes in abduction and anteversion vary significantly depending on AMA. Case examples (Fig. 1c) highlight this non-linearity: two ASD patients with similar SAI variations (i.e. similar decrease in pelvic retroversion) exhibited markedly different acetabular abduction changes (-14° for case 1 vs. -3° for case 2) and anteversion changes (-10° vs. -2°). This underscores the necessity of considering patient-specific acetabular morphology when anticipating hip alignment changes following spinal realignment.

### Conclusion:

This study establishes that changes in acetabular abduction and anteversion following spinal realignment can be accurately predicted using non-linear equations incorporating patient-specific acetabular morphology. These findings are critical for spine and hip surgeons to anticipate postoperative cup orientation shifts and define new patient-specific hip “safe zones” to minimize THR dislocation risk in ASD patients.



## Paper #249 has been WITHDRAWN

## Paper #250. From Cadavers to Virtual Reality: a Carbon Footprint Analysis of Surgical Simulation for Lumbar Spine Surgery

*Léonard Chatelain, MD; Renaud Lafage, MS; Emil Haikal, MD; Blerta Budani, BS; Jonathan Elyse, BS; Max Kohn, BS; Marc Khalif, MD, MS; Emmanuelle Ferrero, MD, PhD; Virginie Lafage, PhD*

### Hypothesis:

Biological and high-fidelity simulators have the highest carbon footprints among available spine simulators.

### Design:

Descriptive life cycle analysis (LCA) study of lumbar spine surgical simulators.

± = E-Point Award Nominated Paper

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### Introduction:

While simulation is central to spine surgery training, its environmental cost remains unknown. This work evaluates the carbon footprint of the main training simulators used for lumbar spine procedures.

### Methods:

Simulators were identified through an extensive digital search and classified into three categories: biological (cadavers, animal models), synthetic (3D-printed, synthetic bones, high-fidelity simulators), and digital (screen-based, virtual reality (VR)). For each category, the most documented simulator was selected. Life cycle data were retrieved from manufacturers, or calculated using OpenLCA® software, following ISO 14040 methodology. Missing data were estimated using a national French database. Values for digital simulators were normalized per simulation. The study was set in Paris, and French carbon factor (0.059 kg CO<sub>2</sub>/kWh) was applied for electricity. The porcine model was based on a 30 kg pig at 3.41 kg CO<sub>2</sub>e/kg. Cadaver emissions included cremation (233 kg CO<sub>2</sub>e). 3D printing used 35 h at 80 Wh, with a 12,000 h device lifespan. VR consumed 12.16 Wh, with a 2,080 h lifespan. Screen-based tools and cloud services were estimated at 0.06 kg CO<sub>2</sub>e/h. Computers were considered as pre-existing equipment not specific to simulation training.

### Results:

Cadavers had the highest footprint (244.0 ± 48.8 kg CO<sub>2</sub>e), followed by porcine models (223.0 ± 44.6), and high-fidelity mannequins (36.6 ± 7.3). 3D-printed and synthetic bones models had similar footprints (8.4 ± 1.7 and 10.5 ± 2.1, respectively). Digital simulators were the least impactful (0.07 ± 0.01 kg CO<sub>2</sub>e/simulation). Main contributors to emissions were simulator production and instrument sterilization. Transport weight had limited impact (2.1%).

### Conclusion:

Cadavers and animal models remain the most carbon-intensive options. For repeated, early-stage training, low-emission solutions like virtual or 3D-printed simulators should be prioritized. Despite common assumptions, VR is among the most sustainable methods due to its reusability and lack of sterilization. High-fidelity simulators should be reserved for advanced learners given their greater environmental cost.

### Paper #251. Evaluating the Relationships of Different Metrics of Osteoporosis and Sarcopenia in Adult Spinal Deformity Surgery and Associated Complications

*Weston Wright, BS; David Chung, MD; Shahed Elhamdani, MD; Justin K. Scheer, MD; Tiffany G. Perry, MD; Alexander Tuchman; Corey T. Walker, MD*

± = E-Point Award Nominated Paper

### Hypothesis:

Psoas CSA better predicts complications than bone or fatty metrics.

### Design:

Retrospective single-institution cohort study.

### Introduction:

Osteoporosis and sarcopenia are increasingly recognized as potential drivers of complications after adult spinal deformity (ASD) surgery. Numerous radiographic metrics quantify bone and muscle quality, but their predictive value remains uncertain.

### Methods:

We retrospectively reviewed ASD patients who underwent primary thoracic-to-pelvis deformity correction at a single institution (2018–2023) with ≥2-year follow-up. Preoperative DXA, MRI, and CT were analyzed. Osteoporosis was assessed with DXA T-scores of the femoral neck, CT-based L1 Hounsfield units (HU), and MRI-derived Vertebral Bone Quality (VBQ) scores. Sarcopenia was evaluated qualitatively with Goutallier grading of paraspinal fatty infiltration and quantitatively with psoas, multifidus, and erector spinae cross-sectional area (CSA) normalized to L4 vertebral body area.

### Results:

A total of 142 patients met inclusion criteria. DXA and HU, as well as VBQ and HU, correlated significantly ( $p < 0.05$ ), but VBQ and DXA did not ( $p > 0.05$ ). No significant associations were identified between bone density metrics and sarcopenia measures. Goutallier scores failed to correlate with muscle CSA. On multivariate analysis controlling for age, BMI, and operative factors, only psoas CSA predicted mechanical complications. Patients with proximal junctional failure (PJF) had lower mean psoas CSA ratios than those without (1.25 vs. 1.46,  $p < 0.05$ ). Similarly, patients requiring reoperation for mechanical failure had lower ratios than those who did not (1.31 vs. 1.46,  $p < 0.05$ ). No other osteoporosis or sarcopenia metric was predictive.

### Conclusion:

Conventional radiographic measures of osteoporosis show poor concordance and fail to predict PJF or reoperation after ASD surgery. Likewise, radiographic sarcopenia markers based on fatty infiltration lack reliability. In contrast, psoas CSA normalized to vertebral body area emerged as a robust predictor of mechanical complications. These findings highlight the limitations of current bone and muscle metrics and underscore the need to refine radiographic assessment tools. Incorporating validated muscle-based measures into preoperative risk stratification may offer a more accurate approach to predicting outcomes and guiding surgical decision-making in ASD patients.

## E-POINT PRESENTATION ABSTRACTS

### Paper #252. Imaging Biomarkers Derived Using an Artificial Intelligence (AI) Pipeline Enhance Prognostication of Patients Undergoing Surgery for Nontraumatic Spinal Cord Injury due to Degenerative Cervical Myelopathy

*Michael G. Fehlings, MD, PhD, FRCS(C); Mohammed Ali Alvi, MD, PhD, MS; Karlo M. Pedro, MD; Raman Abaspour, BS; Mouad Elganga, BS; Yuxii Zhang*

#### Hypothesis:

Radiomic features extracted from a semi-automated imaging analysis pipeline, using baseline MRI imaging improve our ability to predict prognosis of patients with DCM undergoing surgery.

#### Design:

Retrospective

#### Introduction:

We developed a semi-automated AI-facilitated pipeline to quantify radiomic features from baseline axial T2-weighted MRI and hypothesized that integrating these features would enhance predictive model performance for 1-year postoperative outcomes.

#### Methods:

We sourced the data from two clinical trials, the CSM-I and CSM-NA study. Segmentation of the spinal cord was performed using the SpinalCordToolbox (SCT v6.5). Next, we cropped each segmented MRI at the most compressed level, and the most normal/non-compressed level. Next, each set of images was processed through the PyRadiomics pipeline to extract radiomic features. The data was then split to training (70%) and validation (30%) datasets. We applied a two-stage feature truncation process: model-based selection for outcome, yielding a target-specific reduced radiomics set and 2) applying principle component analysis (PCA) on target-specific features. We then combined radiomic features with clinical features and LightGBM and XGBoost models were independently trained and tuned using the training set. The model achieving the highest mean cross-validation performance for the relevant metric (ROC-AUC for classification, negative MAE for regression) was selected as the final model for that outcome.

#### Results:

A total of 220 patients were included in the final analysis. On the held-out test set, for minimum-clinically-important-difference (MCID) in NDI at 6-months, the highest AUC was 0.771 with clinical & NCR Radiomics while for 1 year NDI, the highest AUC (0.646) was obtained with clinical-features and CR Radiomics. For MCID in mJOA at 1-year, the model with clinical-features and all Radiomics reached 0.716. Next SHAP analysis revealed measures of grey-level co-occurrence matrix (GLCM) such as Informational Measure of Correlation 1 & 2, and maximum

correlation coefficient to be among the top 3 most important metrics.

#### Conclusion:

Combining radiomic features from compressed and non-compressed levels on baseline T2-weighted MRI via an AI-facilitated pipeline improved prognostic model performance for DCM surgical outcomes.

### Paper #253. Novel Intraoperative CT-based Technology Increases Adolescent Radiation Exposure

*Vishal Sarwahi, MD; Alexander Morledge, BA; Anabelle Cohen, BS; Brian Li, BS; Katherine Eigo, BS; Effat Rahman, BS; Yungtai Lo, PhD; Terry D. Amaral, MD*

#### Hypothesis:

Intraoperative CT-based technology significantly increases exposure to harmful radiation in adolescents during spine surgery.

#### Design:

Retrospective Chart Review

#### Introduction:

Pedicle screw insertion has classically been done using a free-hand technique or with the addition of fluoroscopy guidance. Recently, intraoperative CT-based navigation technology has been widely adopted to aid in the visualization of pedicle screw insertion to optimize for screw accuracy and improve safety during spine surgery. While technical parameters regarding the fidelity, precision, and efficiency of this technology remains a topic of debate, this study aims to analyze tangible clinical benefits while monitoring the risk of increasing radiation exposure in the vulnerable pediatric population.

#### Methods:

785 adolescent idiopathic scoliosis patients undergoing posterior spinal fusion between 2015-2025 from a single institution was performed. Patients were categorized based on the visualization/insertion technique used during their surgery. 110 patients were found operated with just CT-based technology (CT-nav group) and 407 patients were operated on utilizing a hybrid approach with CT and fluoroscopy scans (HYB-group). Surgical and clinical outcomes were compared. Kruskal-Wallis tests were used for continuous variables and Chi-Squared tests were used for categorical variables.

#### Results:

There were no significant differences in demographic or radiographic variables. CT-nav has a higher radiation dose at 21.2 mGy compared to median 15.2 dosage for HYB-group ( $p < 0.001$ ). CT-nav had significantly higher time under radiation compared to the hybrid group (21.6s versus 18.5s). Operative time in the CT-nav group was significantly higher than the Hybrid group (278.5 versus 234.0 minutes;  $p < 0.001$ ).

± = E-Point Award Nominated Paper

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There were no differences in revision rates as loss of signal occurrences between groups.

### Conclusion:

Newer technology in orthopedics often comes with touted advantages and unanticipated disadvantages. CT-based technology can theoretically give surgeons confidence in their screw placement, creating a safer and more accurate procedure. However, an increase in radiation and operative time can be harmful for adolescents, as modeled in AIS patients undergoing PSF. Adopting a hybrid approach or both fluoroscopy and CT navigation can produce balance to maximize patient benefit.

### Paper #254. Intraoperative to Postoperative Changes in T4-L1-Hip Axis Angles Occur After Fusions for Adult Spinal Deformity

*Alexander T. Yahanda, MS; Karan Joseph, BS; Tim Bui, BS; Samuel Vogl Nicholas A. Pallotta, MD, MS; Brian J. Neuman, MD; Jacob Greenberg, MD; Wilson Zachary Ray, MD; Jeffrey M. Hills, MD; Michael P. Kelly, MD; Murnish C. Gupta, MD, MBA; Camilo A. Molina, MD*

### Hypothesis:

Spinopelvic angles, thought to be fixed, may change from intra-to-postoperative measurements

### Design:

Retrospective cohort study

### Introduction:

Spinopelvic angles should theoretically remain relatively fixed independent of posture, particularly if immobilized within constructs. However, few studies have examined spinopelvic angle fidelity between intraoperative prone and postoperative standing alignment to define the magnitude of changes within/outside constructs. This study assessed changes between intra- and postoperative spinopelvic angles in patients undergoing fusions of various lengths for adult spinal deformity (ASD).

### Methods:

This was a retrospective analysis of patients receiving fusions for ASD. All patients received spinopelvic instrumentation. Pre- and 6-week postoperative spinopelvic parameters were measured on standing radiographs. Patients with intraoperative prone radiographs obtained after rod placement had spinopelvic parameters measured as able. Primary measurements were L1-pelvic angle (L1PA) and T4-pelvic angle (T4PA). Uni- and multivariable regressions were performed to identify variables associated with intra-to-postoperative L1PA or T4PA changes. Analyses were stratified by whether the construct controlled L1PA only (L1C; UIV: L2-T6) or both L1PA+T4PA (T4L1C; UIV: T5 and above).

### Results:

216 patients were analyzed (80 L1C, 136 T4L1C).

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Regardless of UIV, there were significant increases in both L1PA ( $p \leq 0.0001$ ) and T4PA ( $p < 0.0001$ ) on postoperative compared to intraoperative radiographs. L1PA changed by  $2.94 \pm 2.5^\circ$  and  $3.43 \pm 2.5^\circ$  for L1C and T4L1C, respectively. T4PA changed by  $4.62 \pm 2.8^\circ$  and  $4.23 \pm 2.9^\circ$  for L1C and T4L1C, respectively. T4PA-L1PA concordance worsened from intra- to postoperative measurements ( $p \leq 0.007$  for LIC and T4L1C). Univariable analysis identified sex, 3-column osteotomy use, osteoporosis, and lumbar interbody use as significantly associated with postoperative L1PA or T4PA changes ( $p < 0.05$  for all). These remained significant on multivariable regression with exception of osteoporosis for T4PA ( $p = 0.38$ ).

### Conclusion:

Significant changes in L1PA, T4PA, and T4PA-L1PA concordance occurred between intraoperative prone and 6-week postoperative standing radiographs, regardless of fusion length. Multiple variables may be related to these alignment changes. Our data support the notion of spinopelvic "settling" that may occur in the postoperative period.

### Paper #255. Analyzing Plastic Multilayered vs Standard Wound Closure for Non-Idiopathic Scoliosis Pediatric Patients

*Jon-Paul P. DiMauro, MD; Vishal Sarwahi, MD; Anabelle Cohen, BS; Alexander Morledge, BA; Katherine Eigo, BS; Effat Rahman, BS; Matan Grunfeld, BS; Brian Li, BS; Victor Koltenyuk, BS; Nicholas Bastidas, MD; Jeremy Nikfarjam, MD; Yungtai Lo, PhD; Terry D. Amaral, MD*

### Hypothesis:

Plastic multilayered wound closure (PMC) for Non-Idiopathic Scoliosis Pediatric Patients has improved outcomes and fewer complication rates.

### Design:

Retrospective Cohort Study

### Introduction:

PMC has been determined as beneficial in decreasing complication rates in adult spinal deformity and pediatric idiopathic patients. However, there is limited data available for the pediatric non-idiopathic patient population and perioperative outcomes regarding type of wound closure in this subset of patients. This study aims to determine whether PMC is proven to be beneficial in the pediatric population of non-idiopathic patients.

### Methods:

110 non-idiopathic scoliosis patients undergoing primary instrumentation and fusion by three senior attendings between 2015–2024 were included in our study. Clinical charts and operative reports were reviewed. Patients were stratified by plastic closure status. Demographic, radiographic, surgical, and clinical outcomes were collected and analyzed. These

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outcomes include age, BMI, sex, Cobb angles and correction, estimated blood loss (EBL), surgery and anesthesia time, ambulation outcomes, length of stay (LOS), drain output, time to drain removal, transfusion rates, morphine consumption, and complication rates. Complications include respiratory infections and infections at 90 days, one year and two-year follow up. Continuous variables were analyzed on Kruskal-Wallis tests, while categorical variables were analyzed using Chi-Square Tests.

### Results:

87 patients undergoing PMC (median 14.7 years, 61% female, median preoperative Cobb 73.0°), and 38 patients undergoing standard closure (median 14.2 years, 71% female, median preop Cobb 74.5°). There was no significant difference in age, sex, BMI or comorbidities ( $p > 0.05$ ). Of these patients, 32 in the PMC group and 28 in the standard group were non-ambulatory. Surgery time was 276 min in PMC, compared with 338 min in standard ( $p < 0.001$ ). LOS was 7 days in PMC and 6.0 in the standard group ( $p = 0.56$ ). No differences in 90-day return to ED (26.4% vs 26.3%,  $p = 0.99$ ), transfusion rates (66.2% vs. 73.7%,  $p = 0.42$ ), surgical site infections at 90 days (PMC: 13.9% vs Standard: 13.2%,  $p = 1.0$ ), or infections at 1 year (0.0% vs 2.6%,  $p = 0.12$ ). Time to drain removal was significantly longer for the PMC group (408.0 hours vs. 109.9 hours,  $p < 0.001$ ).

### Conclusion:

PMC did not decrease surgical site infection at 1 year but did prolong drain removal by roughly 4 times.

### Paper #256. SpineKit: Design and Validation of an Open-source, Modular 3D Printed Simulator for Lumbar Spine Surgery

*Léonard Chatelain, MD; Renaud Lafage, MS; Emil Haikal, MD; Blerta Budani, BS; Jonathan Elyse, BS; Max Kohn, BS; Marc Khalif, MD, MS; Emmanuelle Ferrero, MD, PhD; Virginie Lafage, PhD*

### Hypothesis:

A low-cost 3D printed TLIF simulator can provide realistic and pedagogically valuable training for orthopedic residents.

### Design:

Multicenter educational validation study.

### Introduction:

TLIF procedure requires extensive training due to its technical complexity and potential complications. Cadaver and high-fidelity simulators raise logistical, financial, and environmental concerns. We developed and evaluated a low-cost, modular, eco-friendly, and open-source 3D-printed simulator for TLIF training.

### Methods:

The simulator was designed from a L3-S1 lumbar

spine CT. L4-L5 posterior arches were separated from the pedicles via a clip-in mechanism; only these were replaced after each simulation session. Soft-tissue surroundings were constructed using a combination of organic (banana peel, blood orange) and synthetic (balloon, tissue, skin), mounted on a sturdy frame for stability. Technical metrics (printing time, weight, material cost, assembly time) were collected. Educational validation was conducted in two centers (April to October 2025). Orthopedic residents were asked to perform a full TLIF procedure on the model. Surgical parameters were the Objective Structured Assessments of Technical Skills (OSATS) score and operative time. Post-procedure questionnaire assessed realism, usability, pedagogical value, and satisfaction (5-point scale).

### Results:

The total simulator print time was 6h52 for 220 g of PLA, with a material cost of \$5.5. Assembly time between sessions was  $30 \pm 6$  seconds. The cost per resident was \$0.3. A total of 21 residents completed the simulation (PGY 1-5). Mean OSATS was  $24.4 \pm 6.7$ . There was no difference by residency year or TLIF experience. OSATS was correlated with months in spine surgery ( $\rho = 0.48$ ,  $p = 0.028$ ). Average operative time was  $21.2 \pm 6.8$  min, significantly shorter for PGY 3-5 ( $p = 0.012$ ). Questionnaire scores were high: realism  $4.5 \pm 0.6$ , usability  $4.6 \pm 0.7$ , pedagogical value  $4.8 \pm 0.4$ , satisfaction  $4.6 \pm 0.6$ , and willingness to reuse  $4.8 \pm 0.4$ . Feedback highlighted the model's value for screw trajectory and exposure training.

### Conclusion:

This TLIF simulator was successfully printed, assembled, and validated. Despite its simplicity, it provided high user satisfaction and strong educational value. Its low cost (\$0.3/session) and modularity make it ideal for repeated training, particularly in resource-limited settings.

### Paper #257 has been WITHDRAWN

### Paper #259. Quantitative CT Outperforms MRI-Based Bone Quality in Predicting Vertebral Compression Strength

*Anna-Maria Mielke, MD; Soji Tani, MD; Marco D. Burkhard, MD; Koji Ishikawa, MD, PhD; Bruno Verna, MD; Ali Guven, MD; Ek T. Tan, MD, PhD; John A. Carrino, MD; Jiaqi Zhu, Jennifer Shue, MS; Federico P. Girardi, MD; Andrew A. Sama, MD; Frank P. Cammisa Jr, MD; Alexander P. Hughes, MD*

### Hypothesis:

We hypothesized that CT-derived volumetric bone mineral density (vBMD) would be the strongest imaging predictor of finite element analysis (FEA)-derived vertebral compression strength (CS), outperforming

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MRI-based vertebral bone quality (VBQ) and abdominal aortic calcification (AAC) score.

### Design:

Retrospective cohort study at a specialized orthopedic spine center.

### Introduction:

Determining vertebral strength is essential in planning lumbar fusion, as poor bone quality increases risk of implant loosening, cage subsidence, and perioperative fracture. Imaging-based surrogate markers include CT-derived vBMD, MRI-based VBQ, and AAC on radiographs, which reflects systemic vascular disease and skeletal fragility. Their relative value for predicting vertebral compression strength (CS) is unclear. FEA provides individualized estimates of CS but is not widely available. Identifying accessible imaging predictors of FEA-derived CS is therefore clinically relevant.

### Methods:

We retrospectively reviewed lumbar fusion patients (2014-2020) with preoperative CT, MRI, and radiographs within 12 months. Exclusions were prior fusion, fracture, tumor, infection, or poor image quality. 76 patients met criteria (54% female; mean age 61±11; BMI 29.6±6.2). CT-derived vBMD at L1-L2 was calculated using scanner-specific calibration. VBQL1/2 was measured on T1 MRI as vertebral signal normalized to CSF. AAC was graded on lateral radiographs (Kauppila method). Vertebral CS was estimated by CT-based FEA with incremental compressive loading until failure. Associations with CS were tested by Spearman correlation and multivariable regression (age, sex, BMI adjusted).

### Results:

vBMD strongly correlated with CS ( $\rho=0.75$ ,  $p<0.001$ ), whereas VBQ ( $\rho=-0.20$ ,  $p=0.086$ ) and AAC ( $\rho=-0.22$ ,  $p=0.062$ ) were not significant. In regression models, vBMD was the only independent imaging predictor ( $\beta=64.9$ ,  $p<0.001$ ). Male sex was also associated with higher CS ( $\beta=2252$ ,  $p<0.001$ ). Adding VBQ or AAC to vBMD did not improve explanatory power (adjusted  $R^2=0.77$  vs. 0.76-0.78).

### Conclusion:

qCT-derived vBMD was the only imaging biomarker that reliably predicted vertebral CS, highlighting trabecular density as the key determinant of load capacity. MRI-based VBQ and AAC did not improve prediction, likely reflecting marrow or systemic factors rather than intrinsic strength. Thus, CT-based assessment remains the most robust tool for preoperative risk stratification in lumbar fusion.

**Paper #260 has been WITHDRAWN**

**Paper #261 has been WITHDRAWN**

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### Paper #262. Rod Diameter Provides Greater Protection Against Fracture Than Multi-Rod Augmentation in Adult Spinal Deformity Surgery

*Nuri Demirci, MD; Yasemin Yavuz, PhD; Munish C. Gupta, MD, MBA*

### Hypothesis:

Upsizing to larger-diameter rods reduces rod fracture (RF) risk more effectively than multi-rod augmentation in long-segment adult spinal deformity (ASD) fusion.

### Design:

Prospective cohort study of 207 ASD patients with  $\geq 7$ -level thoracic-to-pelvis fusion and  $\geq 2$  years of follow-up.

### Introduction:

RF is a frequent late complication after long ASD fusion. Multi-rod techniques, including accessory or satellite constructs, are widely used to mitigate fracture risk, but the relative benefit of rod diameter versus rod multiplicity remains unclear.

### Methods:

Patients were stratified by rod size (5.5 vs 6.35 mm), configuration (2-rod, accessory 3-rod, satellite 4-rod), and material (cobalt-chrome, titanium, stainless steel). Patient factors included age, sex, BMI, ASA class, osteoporosis/osteopenia, and revision status. Operative factors included approach, osteotomy type, UIV, BMP, allograft per level, and pre/postoperative alignment. RF was defined radiographically and clinically.

### Results:

RF occurred in 20 of 207 patients (9.7%) at a mean of 46 months, with 12 patients undergoing revision. Among 132 patients with 5.5 mm cobalt-chrome rods, 15 fractures were observed (11.4%), while 5 fractures occurred in 75 patients with 6.35 mm rods (6.7%). Patients with 6.35 mm rods had higher mean BMI (31.8±5.9 vs 28.3±5.4,  $p<0.001$ ). In the 5.5 mm group, combined anterior-posterior constructs had lower RF rates than posterior-only constructs (3-4% vs 30%). By configuration, RF was observed in 6/108 2-rod constructs (5.6%), 10/54 accessory 3-rod constructs (18.5%), and 4/45 satellite 4-rod constructs (8.9%,  $p=0.034$ ). All fractures in satellite constructs occurred at pedicle subtraction osteotomy sites. Rod material distribution corresponded with diameter, and fracture rates did not differ significantly by material ( $p=0.54$ ). Pre- and postoperative alignment parameters, BMP dose, and allograft use were similar across groups.

### Conclusion:

In this cohort, RF rates were lower with 6.35 mm rods compared with 5.5 mm rods, despite higher BMI. Multi-rod configurations did not consistently reduce

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fracture risk, particularly in posterior-only cases and at osteotomy sites. Rod diameter was more closely associated with construct durability than rod multiplicity.

### Paper #263 has been WITHDRAWN

### Paper #264. C2PA Alone Is Insufficient: Pelvic Tilt Prediction Requires Accounting for Lower-Limb Compensation

*Nuri Demirci, MD; Yasemin Yavuz, PhD; Munish C. Gupta, MD, MBA*

#### Hypothesis:

C2–pelvic angle (C2PA) predicts pelvic tilt (PT) correction, but accuracy declines with compensatory knee flexion.

#### Design:

Prospective cohort analysis

#### Introduction:

Pelvic tilt (PT) correction is vital in adult spinal deformity surgery. The C2–pelvic angle (C2PA) is a proposed geometric predictor of PT change, yet its accuracy may be altered by compensatory lower-limb (bent-knee) posture. Whether  $\Delta$ C2PA maintains predictive efficiency when such compensation is present remains unclear.

#### Methods:

Adults undergoing  $\geq 7$ -level fusion were reviewed. Of 207 eligible, 184 had complete pre- and 6-week postoperative radiographs with knee flexion angle (KFA). Patients were stratified: Low ( $\leq 5^\circ$ ), Mid (5–12.7°), High ( $> 12.7^\circ$ ). Demographic and radiographic parameters (PT, PI–LL, LL, TK, TL, T4L1PA, GAP) were compared using ANOVA with Tukey tests. Multivariable regression modeled PT change ( $\Delta$ PT= $\Delta$ C2PA+preop C2 tilt), with slope analysis testing KFA effect.

#### Results:

$\Delta$ C2PA plus preop C2 tilt predicted PT change (adj  $R^2=0.81$ ). Fit was strongest in Low flexion ( $R^2=0.86$ ), declined in Mid ( $R^2=0.79$ ), and was lowest in High ( $R^2=0.75$ ). Slope analysis showed  $\Delta$ C2PA efficiency fell from 0.82 PT/ $^\circ$ C2PA at  $0^\circ$  flexion to 0.74 at  $15^\circ$ , requiring  $\sim 10\%$  greater correction at  $15^\circ$ . Model error rose linearly with flexion ( $+0.063/^\circ$ ;  $p=0.003$ ). At 6 weeks, higher KFA was associated with larger corrections: PT decreased  $-3.0^\circ$  (Low),  $-5.0^\circ$  (Mid), and  $-8.2^\circ$  (High; High vs Low  $-5.2^\circ$ ,  $p=0.002$ ). PI–LL improved by  $-14.3^\circ$  (Low),  $-19.1^\circ$  (Mid),  $-30.9^\circ$  (High; High vs Low  $-16.6^\circ$ ,  $p<0.001$ ; High vs Mid  $-9.8^\circ$ ,  $p=0.005$ ). LL increased by  $+15.1^\circ$  (Low),  $+22.0^\circ$  (Mid),  $+32.4^\circ$  (High;  $+17.3^\circ$  vs Low,  $p<0.001$ ). GAP score improved  $-3.6$  (Low),  $-4.1$  (Mid),  $-5.8$  (High; High vs Low  $-2.2$ ,  $p=0.004$ ). Baseline TK, TL, and T4L1PA were worse with greater flexion, and their changes were similar across groups.

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#### Conclusion:

C2PA alone is insufficient for predicting pelvic tilt correction without accounting for compensatory knee flexion. Patients with bent-knee posture have worse baseline spinopelvic parameters and achieve larger absolute corrections in PT, PI–LL mismatch, LL, and GAP score after surgery. Our study shows reduced efficiency of  $\Delta$ C2PA in driving PT correction, with  $\sim 10\%$  more correction required at  $15^\circ$  of flexion. Surgical planning should explicitly incorporate knee compensation to optimize sagittal balance.

### Paper #265 has been WITHDRAWN

### Paper #266. Development and Validation of a Machine Learning–Based Model For Assessing Interbody Fusion after TLIF Using Dynamic Flexion–Extension Radiographs

*Jung Sub Lee, MD, PhD; Yoonjae Cho, MD; Joonyoung Park, MD; Ki Hun Kim, MD; Hansol Kim, MD; Tae Sik Goh, MD, PhD; Ha Young Jo, MD*

#### Hypothesis:

A machine learning–based analysis of dynamic flexion–extension radiographs can predict interbody fusion status after TLIF with accuracy comparable to or slightly better than surgeon interpretation, while maintaining good calibration against CT-defined standards

#### Design:

Retrospective diagnostic accuracy study using postoperative TLIF patient data from a single tertiary center.

#### Introduction:

Assessment of fusion after transforaminal lumbar interbody fusion (TLIF) is essential for postoperative care. Computed tomography (CT) is the gold standard but limited by radiation and cost. Flexion–extension (F/E) radiographs are accessible but less reliable. We developed and validated a machine learning (ML) model to predict fusion from F/E radiographs, using CT as reference.

#### Methods:

Patients who underwent TLIF at Pusan National University Hospital (2016–2020) were reviewed. Dynamic lumbar F/E radiographs were processed with an automated ML pipeline: vertebral and implant segmentation, extraction of motion features (angular rotation, translation, interspinous distance), and patient-level feature aggregation. Classification was performed using representative ML approaches, including gradient boosting and deep neural network–based models. Fusion was defined by Brantigan–Steffee–Fraser (BSF) grade  $\geq 3$  on CT. Motion thresholds (rotation  $\leq 3$ – $5^\circ$ , translation  $\leq 3$  mm, absence of screw loosening/breakage) were incorpo-

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rated. Performance was assessed by AUROC, AUPRC, sensitivity, specificity, accuracy, and calibration (Brier score, slope, intercept). Surgeon interpretation of F/E radiographs was also compared.

### Results:

A total of 420 patients were analyzed (mean age  $62.1 \pm 9.7$  years; nonunion 11.4%). The ML model achieved AUROC 0.89, AUPRC 0.73, sensitivity 85.7%, specificity 82.4%, and accuracy 84.1%. Calibration showed Brier score 0.112, slope 0.97, intercept  $-0.03$ . Surgeon interpretation yielded AUROC 0.84, sensitivity 78.9%, specificity 80.5%, accuracy 80.0%, and Brier score 0.158. The ML model showed better calibration and higher sensitivity for detecting nonunion.

### Conclusion:

An ML approach using F/E radiographs provided accurate and well-calibrated prediction of interbody fusion after TLIF, slightly outperforming surgeon assessment. This method could reduce CT reliance, allow earlier nonunion detection, and improve post-operative management.

### Paper #267. Sagittal Alignment Showdown: SRS-Schwab vs Age-Adjusted vs T4-L1 Hip Axis – Which is Superior?

*Jay Kumar, MD; Bryan Clampitt, BS; Kiran Kittur, BS; Chloe Chose, BS; Schahin Salmanian, BS; Mohsen Rostami, MD; Puya Alikhani, MD*

### Hypothesis:

We hypothesize that the T4-L1 hip axis sagittal alignment targets are more effective at predicting mechanical complications than the Schwab alignment targets.

### Design:

Retrospective cohort study

### Introduction:

The optimal sagittal alignment targets in adult spinal deformity (ASD) remain elusive. The SRS-Schwab, Age-Adjusted, and T4-L1 Hip Axis frameworks all offer slightly different surgical goals. We examined our institutional experience to compare these three guidelines.

### Methods:

A retrospective review was performed of 265 consecutive ASD surgeries performed at our tertiary care center between 2016 and 2023. Minimum follow up was 1 year. ASD was defined as surgeries with an upper instrumented vertebrae at L2 or higher and a lower instrumented vertebrae in the pelvis. Mismatch between pelvic incidence and lumbar lordosis (PI-LL mismatch) were compared with SRS-Schwab vs Age-Adjusted targets. The difference between the T4 pelvic angle and L1 pelvic angle (T4-L1 mismatch) was assessed (ideal  $<4^\circ$ ). Deviations from ideal

values for all 3 measures were compared with incidence of proximal junctional kyphosis using Pearson Correlations (R) and T-Tests in SPSS. Levene's test was used to determine equal variance assumptions. Patient-reported outcomes were also assessed using Visual Analog Scale (VAS) leg and back scores.

### Results:

244 patients had sufficient data for analysis. Postoperative age-adjusted PI-LL mismatch significantly correlated with PJK ( $R=0.13$ ,  $p=.03$ ), while SRS-Schwab PI-LL mismatch was less significantly correlated ( $R=0.12$ ,  $p=.06$ ). Specifically, mean PI-LL mismatch was  $8.9^\circ$  in patients without PJK, and  $13^\circ$  in patients with PJK, and  $0.7^\circ$  vs  $5.9^\circ$  in excess of age-adjusted targets respectively. T4-L1 mismatch was the most strongly correlated with rates of PJK ( $R=0.39$ ,  $p=0.0005$ ). Increase in T4-L1 mismatch was also correlated with worsening VAS Leg score ( $R=0.316$ ,  $p=0.03$ ).

### Conclusion:

Age-adjusted alignment targets may be slightly superior to standard SRS-Schwab targets in predicting PJK after ASD surgery. However, the T4-L1 hip axis targets may be more strongly correlated with risk of PJK.

### Paper #268. Relationship Between Hamstring Tightness and Change of Pelvic Tilt after Adult Spine Deformity Surgery

*Seok-In Jang, MD; HoJoong Kim, MD; Jin-Ho Park, MD; Jisoo Lee, MD; Jae Heouk Choi, MD*

### Hypothesis:

We hypothesized that hamstring tightness, by limiting the anterior pelvic tilt, contributes to reduced PT changes after adult spinal deformity (ASD) surgery.

### Design:

A retrospective cohort study.

### Introduction:

The etiology of pelvic nonresponse (PNR), which is associated with adverse postoperative clinical outcomes, remains unclear. The aim of our study was to evaluate the association between hamstring tightness (HT) and pelvic tilt (PT) change after ASD surgery for and determine whether HT contributes to proximal junctional kyphosis (PJK) after surgery.

### Methods:

Radiographic parameters including pelvic incidence (PI) - lumbar lordosis (LL) mismatch, PT, and sagittal vertical axis (SVA) were assessed preoperatively and postoperatively. The primary outcome was the degree of change in PT, which was defined as the PT/PI ratio. Secondary outcomes included incidence of PJK, proximal junctional failure (PJF), and patient-reported outcome measures (PROMs). We determined the optimal cutoff value for the popliteal angle in patients with and without PJK. Patients were classified into

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HT and non-HT groups based on the cutoff value for the popliteal angle. Radiographic spinopelvic parameters, the PJK rate, and PROMs were compared between the two groups.

### Results:

A total of 92 patients were included in this study (HT, n=18; non-HT, n=74). A popliteal angle of 40.0° was identified as the optimal cutoff threshold for predicting PJK. Postoperatively, the HT group demonstrated significant differences in PT/PI change (-0.11±0.10 vs. -0.18±0.12, P = .025) and PJK rate (11/18 [61.1%] vs. 16/74 [21.6%], P = .001). PROMs at 6 months postoperatively did not differ significantly between groups.

### Conclusion:

Patients with preoperative hamstring tightness were more likely to exhibit persistent pelvic retroversion and demonstrate an increased PJK rate after ASD surgery. The evaluation of preoperative hamstring tightness should be considered during surgical planning.

Comparison of demographic characteristics and spinopelvic parameters between HT group and Non-HT Group

|                                | HT (n=18)     | Non-HT (n=74) | P value |
|--------------------------------|---------------|---------------|---------|
| Age (years)                    | 72.2 ± 7.6    | 72.7 ± 5.9    | .809    |
| Female, n (%)                  | 14 (77.8)     | 64 (86.5)     | .197    |
| CCI                            | 0.76 ± 0.83   | 0.86 ± 0.83   | .656    |
| BMI (kg/m <sup>2</sup> )       | 26.99 ± 4.76  | 25.57 ± 3.89  | .195    |
| BMD (g/cm <sup>2</sup> )       | 0.77 ± 0.13   | 0.75 ± 0.13   | .572    |
| Pre-op spinopelvic parameters  |               |               |         |
| TK (°)                         | 20.80 ± 18.63 | 17.22 ± 15.00 | .390    |
| PT (°)                         | 29.95 ± 7.83  | 34.35 ± 10.98 | .113    |
| PI (°)                         | 52.98 ± 11.50 | 54.68 ± 13.52 | .626    |
| LL (°)                         | 9.23 ± 22.12  | 2.00 ± 18.49  | .156    |
| PI-LL (°)                      | 43.76 ± 19.15 | 52.01 ± 21.26 | .136    |
| SVA (mm)                       | 147.9 ± 100.2 | 161.7 ± 77.2  | .591    |
| PT/PI                          | 0.59 ± 0.19   | 0.63 ± 0.14   | .328    |
| Post-op spinopelvic parameters |               |               |         |
| TK (°)                         | 34.32 ± 10.80 | 29.84 ± 11.62 | .140    |
| PT (°)                         | 23.78 ± 7.46  | 24.10 ± 10.19 | .901    |
| PI (°)                         | 51.74 ± 10.85 | 53.32 ± 12.02 | .612    |
| LL (°)                         | 39.40 ± 10.61 | 33.99 ± 19.47 | .269    |
| PI-LL (°)                      | 17.74 ± 17.99 | 14.75 ± 13.94 | .399    |
| SVA (mm)                       | 57.35 ± 43.58 | 50.40 ± 62.52 | .658    |
| PT/PI                          | 0.48 ± 0.18   | 0.45 ± 0.15   | .445    |
| PJK rate, n (%)                | 11 (61.1)     | 16 (21.6)     | .001    |
| PJF rate, n (%)                | 6 (33.3)      | 13 (17.6)     | .138    |

Values are represented as mean±SD and n (%).

HT, Hamstring tightness group; Non-HT, Non hamstring tightness group; CCI, Charlson comorbidity index; BMI, Body mass index; BMD, Bone mineral density; TK, Thoracic kyphosis; PT, Pelvic tilt; PI, Pelvic incidence; LL, Lumbar lordosis; SVA, Sagittal vertical axis; ΔPT/PI was defined as postoperative PT/PI minus preoperative PT/PI; Pre-op, Preoperative; Post-op, Postoperative; PJK, Proximal junctional kyphosis; PJF, Proximal junctional failure.

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## Paper #269. Deep Learning-Based Method to Predict Long-Term Outcome of Bracing in Adolescent Idiopathic Scoliosis

*Guilin Chen, MD; Terry Jianguo Zhang, MD; Nan Wu, MD*

### Hypothesis:

The long-term outcome of the bracing for AIS patients can be predicted by deep learning-based method.

### Design:

Retrospective study.

### Introduction:

Bracing is an established method to prevent the progression of moderate adolescent idiopathic scoliosis (AIS). However, its efficacy in a specific patient remains uncertain. Deep learning can be used to predict the outcome of a certain treatment. This study is to develop a deep learning-based algorithm for predicting the long-term outcomes of bracing in AIS Patients. The algorithm was evaluated using both internal and external cohort.

### Methods:

Patients with adolescent idiopathic scoliosis (AIS) who underwent bracing were retrospectively recruited. Follow-ups for each patient were categorized into four periods: V0 represents the initial visit, V1 marks the visit when the first brace was worn, V2 indicates a short-term follow-up typically 0.5–1 year after V1, V3 refers to a long-term follow-up 1–2 years after V1. Standing full-spine coronal radiographs from V0 and V1, along with clinical information including age, sex, and Risser sign, were used as inputs. A ResNet-based algorithm was developed to predict the thoracic and lumbar angles for each patient.

### Results:

A total of 294 patients who met the inclusion criteria were recruited from two independent centers. T Cobb angles were similar between groups (24.86 ± 8.17° in cohort 2 vs. 26.51 ± 10.01° in cohort 1; P = 0.141), while TL/L angles were significantly higher in the cohort 2 (26.48 ± 7.17° vs. 23.78 ± 7.63°; P = 0.029, Mann-Whitney U test). Three-fold cross-validation was applied. The mean absolute error (MAE) of the algorithm using V0, V1, and clinical information as inputs were 4.06 for the thoracic curve (R<sup>2</sup> = 0.811) and 3.75 for the thoracolumbar/lumbar curve, respectively. Such superiority was demonstrated by comparison with existing advanced DL architectures. Classic convolutional neural networks (CNNs), such as DenseNet, ResNet, and EfficientNet, achieved MAEs ranging from 5.2° to 6.1°, with corresponding R<sup>2</sup> values between 0.59 and 0.73. Our model got the best performance.

### Conclusion:

The deep learning-based algorithm developed in this

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study demonstrated strong predictive performance for thoracic and lumbar curve angles in patients with AIS undergoing bracing. By integrating radiographic and clinical data, the model offers a promising tool to support personalized treatment planning.

## Paper #270. Patients with Severe Hip Osteoarthritis Achieve Similar Radiographic and Functional Outcomes Compared to Total Hip Arthroplasty Patients Following Adult Spine Deformity Surgery

Ahmed Sulieman, MD; Micheal Raad, MD; Bassel G. Diebo, MD; Breton Line; Renaud Lafage, MS; Virginie Lafage, PhD; Kojo D. Hamilton, MD, FAANS; Richard Hostin, MD; Peter G. Passias, MD; Eric O. Klineberg, MD; Justin S. Smith, MD, PhD; Jeffrey Gum, MD; Jeffrey P. Mullin, MD; Michael P. Kelly, MD; Alex Soroceanu, MD, FRCS(C); Robert K. Eastlack, MD; Alan H. Daniels, MD; Gregory M. Mundis Jr., MD; Themistocles S. Protopsaltis, MD; Munish C. Gupta, MD, MBA; Neel Anand, MD, Mch. Orth; David O. Okonkwo, MD, PhD; Jay D. Turner, MD, PhD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Praveen V. Mummaneni, MD; 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:

We hypothesize that total hip arthroplasty (THA) patients achieve better sagittal alignment than those with severe osteoarthritis (OA) after adult spine deformity surgery (ASD).

### Design:

Prospective multicenter study.

### Introduction:

Preoperative hip condition affects spinopelvic alignment and patient-reported outcomes (PROs) in patients with ASD. We compared sagittal alignment and PROs before and after ASD correction according to preoperative hip osteoarthritis severity and history of THA.

### Methods:

We categorized patients from a multicenter ASD surgery database into 3 groups: 1) mild osteoarthritis (mOA)(Kellgren-Lawrence [KL] <2); 2) severe osteoarthritis (sOA)(KL ≥3); and 3) THA (bilateral THA or unilateral THA with mOA). We compared pelvic incidence (PI), pelvic incidence minus lumbar lordosis (PI-LL), pelvic tilt (PT), sagittal vertical axis (SVA), and T1 pelvic angle (T1PA) between the groups postoperatively and at 1-year follow-up. PROs were compared preoperatively and at 1-year follow-up. Multivariate analyses compared SVA and PROs at 1-year follow-up between groups.

### Results:

A total of 540 patients undergoing ASD surgery were

identified. 8.9% of the cohort was in the THA group (n=48), 53.3% in the mOA group (n=288) and 37.8% in the sOA group (n=204). The sOA and THA groups were older and frailer than the mOA group. Preoperatively, PI-LL, PT, SVA, and T1PA were not different between the sOA and THA groups, and all measures but PT were higher than in the mOA group. At 1 year, SVA and T1PA did not differ between the sOA and THA groups, but both parameters were higher than in the mOA group. PT did not differ between any groups at 1 year. Hip status was independent predictor of SVA at 1 year postoperatively. Preoperatively and at 1-year follow-up, mOA patients had better physical function and less disability than the sOA and THA groups and PROs did not differ between the sOA and THA groups. sOA and THA status were independently associated with worse PROs preoperatively and at 1-year follow-up.

### Conclusion:

Preoperative hip assessment should be integral to ASD planning. Patients with mOA generally realize greater radiographic and functional gains than those with THA or sOA, for whom standard alignment targets may be unattainable.

**Table I.** Multivariable linear regression analysis\* of patient-reported outcomes preoperatively and 1 year postoperatively.

| Variable by Outcome Measure                | Preoperative         |         | 1 Year Postoperative |         |
|--|----------------------|---------|----------------------|---------|
|  | Coefficient (95% CI) | P-value | Coefficient (95% CI) | P-value |
| <b>Oswestry Disability Index</b>           |                      |         |                      |         |
| Total score                                |                      |         |                      |         |
| Severe osteoarthritis                      | 2.6 (-0.1, 5.3)      | .06     | 3.5 (-0.01, 6.9)     | .05     |
| Total hip arthroplasty                     | 4.8 (0.5, 9.0)       | .03     | 5.7 (-0.03, 11.3)    | .05     |
| <b>Standing</b>                            |                      |         |                      |         |
| Severe osteoarthritis                      | 0.1 (-0.1, 0.3)      | .26     | 0.2 (-0.1, 0.5)      | .13     |
| Total hip arthroplasty                     | 0.2 (-0.1, 0.6)      | .20     | 0.3 (-0.2, 0.7)      | .23     |
| <b>Traveling</b>                           |                      |         |                      |         |
| Severe osteoarthritis                      | -0.005 (-0.2, 0.2)   | .97     | 0.2 (-0.02, 0.4)     | .10     |
| Total hip arthroplasty                     | 0.2 (-0.2, 0.6)      | .26     | 0.3 (-0.1, 0.1)      | .14     |
| <b>Walking</b>                             |                      |         |                      |         |
| Severe osteoarthritis                      | 0.3 (0.1, 0.6)       | <.01    | 0.3 (0.02, 0.5)      | .03     |
| Total hip arthroplasty                     | 0.6 (0.2, 0.9)       | .001    | 0.7 (0.3, 1.1)       | <.01    |
| <b>PROMIS</b>                              |                      |         |                      |         |
| <b>Pain</b>                                |                      |         |                      |         |
| Severe osteoarthritis                      | -0.4 (-1.6, 0.9)     | .59     | 1.8 (0.1, 3.7)       | .04     |
| Total hip arthroplasty                     | 0.7 (-1.4, 2.7)      | .53     | 1.9 (-1.0, 4.8)      | .20     |
| <b>Physical Function</b>                   |                      |         |                      |         |
| Severe osteoarthritis                      | -0.4 (-1.7, 0.8)     | .49     | -1.4 (-2.9, 0.1)     | .07     |
| Total hip arthroplasty                     | -0.6 (-2.5, 1.4)     | .55     | -1.9 (-4.4, 0.5)     | .12     |
| <b>Scoliosis Research Society-22r</b>      |                      |         |                      |         |
| Total Score                                |                      |         |                      |         |
| Severe osteoarthritis                      | -0.1 (-0.2, 0.04)    | .22     | -0.3 (-0.2, 0.1)     | .64     |
| Total hip arthroplasty                     | -0.03 (-0.2, 0.1)    | .7      | -0.7 (-0.3, 0.2)     | .55     |
| <b>Activity</b>                            |                      |         |                      |         |
| Severe osteoarthritis                      | -0.1 (-0.2, 0.1)     | .47     | -0.1 (-0.3, 0.03)    | .12     |
| Total hip arthroplasty                     | 0.02 (-0.2, 0.2)     | .89     | -0.1 (-0.4, 0.1)     | .32     |
| <b>Pain</b>                                |                      |         |                      |         |
| Severe osteoarthritis                      | -0.05 (-0.2, 0.1)    | .54     | -1 (-0.3, 0.05)      | .14     |
| Total hip arthroplasty                     | -0.2 (-0.4, 0.04)    | .10     | -1 (-0.4, 0.2)       | .48     |
| <b>Veterans RAND 12-Item Health Survey</b> |                      |         |                      |         |
| <b>Climbing Stairs</b>                     |                      |         |                      |         |
| Severe osteoarthritis                      | -0.1 (-0.2, 0.04)    | .19     | -0.2 (-0.4, -0.1)    | .001    |
| Total hip arthroplasty                     | -0.05 (-0.3, 0.2)    | .67     | -0.3 (-0.6, -0.1)    | <.01    |
| <b>Physical Component Score</b>            |                      |         |                      |         |
| Severe osteoarthritis                      | -0.05 (-1.9, 1.8)    | .96     | -3.4 (-5.3, -1.3)    | <.01    |
| Total hip arthroplasty                     | -0.04 (-3.0, 2.9)    | .98     | -3.0 (-6.4, 0.5)     | .09     |

CI, confidence interval; PROMIS, Patient-Reported Outcomes Measurement Information System. \*Multivariate linear regression adjusted for age, gender, Charlson Comorbidity Index and Edmonton Frailty Index.

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### Paper #271. Elevated Postoperative T1 Slope Is Reflective of Poor Surgical Correction of Cervical Deformity

Akil Paturi, MD; Fares Ani, MD; Alexandra N. Yiachos, BS; Themistocles S. Protopsaltis, MD; Robert K. Eastlack, MD; Justin S. Smith, MD, PhD; Kojo D. Hamilton, MD, FAANS; Han Jo Kim, MD; Eric O. Klineberg, MD; Peter G. Passias, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Frank Schwab, MD; Virginia Lafage, PhD; Christopher P. Ames, MD; International Spine Study Group,

#### Hypothesis:

T1 slope is modifiable depending on the surgical strategy, and an increased T1 slope is associated with poor corrections of cervical deformity (CD).

#### Design:

Retrospective Multi-Center cohort analysis

#### Introduction:

High T1S is a marker of underlying thoracolumbar deformity. T1S has been proposed as a parameter to determine the cervical lordosis necessary in CD corrections. A high preoperative T1 slope is a risk factor for poor postoperative alignment. Few studies have focused on outcomes from changes in T1 slope after CD surgery.

#### Methods:

CD patients were classified as increased or decreased T1S following surgical correction. Preoperative and postoperative radiographic parameters, including in-construct angles (C2-T4 sagittal angle, C2-T10 sagittal angle), were analyzed with surgical data such as the use of 3COs, approach and fusion levels. A sub-analysis of patients with low, medium and high preoperative T1S (<24, 24-39, >40) was performed. Health-related quality of life was assessed using the NDI, mJOA, and EQ-5D. Chi-square and ANOVA analyses were used with a significance set at p<0.05.

#### Results:

Of the 106 patients included, 27(25.5%) experienced reduced T1S, while 79(74.5%) had increased T1S at one year postoperatively. Patients with reduced T1S had greater baseline deformity (cSVA, C2 slope, CTPA, in-construct angles, all p<0.05), longer fusions (p=0.001), more 3CO utilization (p=0.005), greater postoperative corrections by in-construct angles (change in C2T4 SA and C2T10 SA, p<0.001) and better postoperative alignment by C2-T10 SA (p<0.05). Patients who had longer fusions with all posterior approach and LIV below T2 had the largest decrease in T1S. In the subanalysis, as the T1S increased, there was worse baseline and postoperative cervical alignment by cSVA, C2Slope, CTPA (all p<0.001) and thoracolumbar alignment by C2PA (p<0.05). High T1S patients had less improvement in NDI than low and mid T1S (-4.99 vs -13.9 and -13.8, p<0.05).

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#### Conclusion:

T1 slope is an essential parameter in cervical deformity correction. Improvement in T1S correlated with larger corrections and better postoperative alignment. Worsening T1S resulted from insufficient corrections. Patients with a high baseline T1S had worse baseline and postoperative cervical and thoracolumbar alignment, and less improvement in NDI, demonstrating the clinical impact of this parameter.

Table 1. Main Cohort

| Measurement Units                    | Reduced T1S (n=27) | Increased T1S (n=79) | P-Value |
|--------------------------------------|--------------------|----------------------|---------|
| <b>Cervical Parameters</b>           |                    |                      |         |
| Preoperative cSVA (mm)               | 48.71 ± 19.22      | 34.40 ± 18.43        | <0.001  |
| 1-Year cSVA (mm)                     | 46.05 ± 15.47      | 38.39 ± 17.60        | 0.054   |
| Δ cSVA (mm)                          | -14.15 ± 14.53     | -2.57 ± 17.57        | 0.035   |
| Preoperative C2 Slope (°)            | 45.77 ± 26.56      | 34.60 ± 18.85        | 0.017   |
| 1-Year C2 Slope (°)                  | 29.73 ± 13.72      | 27.21 ± 12.99        | 0.491   |
| Δ C2 Slope (°)                       | -16.04 ± 23.26     | -7.39 ± 17.71        | 0.042   |
| Preoperative C2-T10 Pelvic Angle (°) | 14.95 ± 6.50       | 11.48 ± 5.04         | <0.001  |
| 1-Year C2-T10 Pelvic Angle (°)       | 13.75 ± 5.99       | 13.27 ± 5.77         | 0.722   |
| Δ C2-T10 Pelvic Angle (°)            | -0.77 ± 3.82       | 1.65 ± 3.54          | <0.001  |
| Preoperative T1 Slope (°)            | 47.69 ± 15.55      | 24.85 ± 13.49        | <0.001  |
| 1-Year T1 Slope (°)                  | 37.05 ± 14.99      | 37.02 ± 14.82        | 0.994   |
| Δ T1 Slope (°)                       | -10.64 ± 8.36      | 12.17 ± 8.35         | <0.001  |
| <b>In-Construct Angles</b>           |                    |                      |         |
| Preoperative C2-T4 Sagittal Angle    | 20.14 ± 14.82      | 4.66 ± 12.08         | <0.001  |
| 1-Year C2-T4 Sagittal Angle          | 6.19 ± 9.89        | 1.55 ± 9.43          | 0.038   |
| Δ 1-Year C2-T4 Sagittal Angle        | -13.29 ± 13.70     | -2.98 ± 11.15        | <0.001  |
| Preoperative C2-T10 Sagittal Angle   | 33.74 ± 15.42      | 21.15 ± 12.02        | <0.001  |
| 1-Year C2-T10 Sagittal Angle         | 27.85 ± 11.50      | 22.97 ± 10.20        | 0.047   |
| Δ 1-Year C2-T10 Sagittal Angle       | -5.64 ± 10.92      | 1.14 ± 7.36          | 0.001   |
| <b>Surgical Characteristics</b>      |                    |                      |         |
| Number of Levels fused               | 4.81 ± 6.48        | 1.75 ± 2.99          | 0.001   |
| 3CO                                  | 9(32.1%)           | 8(9.8%)              | 0.005   |

Table 2. Tertile groups

| Measurements              | Low T1S        | Mid T1S        | High T1S       | P-Value |
|---------------------------|----------------|----------------|----------------|---------|
| Preoperative cSVA (mm)    | 23.02 ± 13.01  | 41.32 ± 18.37  | 56.93 ± 11.39  | <0.001  |
| 1-Year cSVA (mm)          | 27.52 ± 16.08  | 44.62 ± 14.90  | 51.38 ± 13.16  | <0.001  |
| Δ cSVA (mm)               | 1.67 ± 13.64   | -5.63 ± 21.24  | -16.18 ± 14.42 | <0.001  |
| Preoperative C2 Slope (°) | 27.77 ± 14.10  | 36.94 ± 18.42  | 53.34 ± 22.19  | <0.001  |
| 1-Year C2 Slope (°)       | 21.03 ± 10.14  | 29.44 ± 14.08  | 34.13 ± 12.14  | <0.001  |
| Δ C2 Slope (°)            | -5.89 ± 14.03  | -5.61 ± 18.90  | -20.18 ± 23.44 | 0.001   |
| Δ NDI Score               | -13.92 ± 19.34 | -13.77 ± 16.87 | 4.99 ± 12.95   | 0.033   |

### Paper #272. Comparative Performance of the ISSG-Surgical Invasiveness Index versus the ESSG-Adult Deformity Surgery Complexity Index: A Retrospective Analysis

Peter G. Passias, MD; Francesca Totis, MD; Christopher I. Shaffrey, MD; Kyriakos Chatzis, BS; Peter Tretiakov, BS; Oluwatobi Onafowokan, MBBS, MS; Max Fisher

#### Hypothesis:

This study aimed to evaluate and compare the performance of ISSG-SII and ESSG-ADSCI in predicting outcomes for ASD surgery within a single database

#### Design:

Retrospective analysis

#### Introduction:

In 2018, the International Spine Study Group (ISSG) and the European Spine Study Group (ESSG) introduced surgical complexity indices for ASD: the ISSG-Surgical Invasiveness Index (SII) and the ESSG-Adult Deformity Surgery Complexity Index (ADS-

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CI). To date, no study has directly compared these indices, limiting their utility in surgical decision-making

### Methods:

A retrospective single-center study of patients who underwent surgery for ASD with complete baseline and two-year follow-up data were assessed via the ISSG-SII and the ESSG-ADSCI. The primary outcome measures for this study were intraoperative estimated blood loss (EBL), operative time, and length of stay (LOS). Secondary outcomes included the occurrence of surgical, medical, and intraoperative complications, adverse events, reoperations, and complications. We utilized receiver operating characteristic (ROC) curves while classifying outcomes into binary outcomes for use of the corresponding area under the curve (AUC) values

### Results:

A total of 693 patients who underwent surgery for ASD (mean age: 61 years; 77% female; BMI: 27kg/m<sup>2</sup>) met the inclusion criteria of this study. For our primary outcomes, both the ISSG-SII (mean: 90.0 ± 38.1) and ESSG-ADSCI (mean: 19.3 ± 7.5) were found to be a significant independent predictor of LOS, operative time, and EBL (p<0.001). The ISSG-SII outperformed the ESSG-ADSCI in predicting EBL greater than 1500 mL (AUC: 0.687 versus 0.604, p<0.001), and surgery duration over 240 minutes (AUC: 0.705 versus 0.658, p=0.036). However, there was no significant difference between the indices in predicting LOS beyond seven days (AUC: 0.687 vs. 0.654, p = 0.103). The ISSG-SII outperformed the ESSG-ADSCI in predicting overall surgical complications (AUC: 0.645 versus 0.597, p=0.018). A sub-analysis of patients who had surgery before 2017 reveals comparable outcomes, reinforcing the consistency of these findings

### Conclusion:

While both the ISSG-SII and the ESSG-ADSCI demonstrated independent predictive value for numerous invasiveness outcomes, the ISSG-SII consistently outperformed the ESSG-ADSCI among patients who had surgery for ASD. Future research is needed to corroborate our findings

### Paper #273. Pediatric Spinopelvic Fixation: Can we Place Stacked SAI Screws? ±

David W. Polly Jr, MD; Priya Jayakumar, BS; Christina K. Hardesty, MD

### Hypothesis:

Based on prior research and clinical observations, we hypothesized that stacked SAI screws can be successfully placed in pediatric patients.

### Design:

Prospective study of a single surgeon's pediatric patients who are undergoing spinopelvic fixation.

### Introduction:

Pelvic fixation can be challenging with a 22% failure rate in adults. Biomechanically, stacked SAI screws with 4 rods to the pelvis is stronger, but this has not been studied in pediatric patients. The first question is anatomic viability of stacked SAI screws in pediatric patients. This study provides insight into that possibility.

### Methods:

Pediatric patients who have undergone preoperative CT scanning for navigation comprised the cohort. Using 3D planning software, virtual screws were templated for sacroiliac trajectories. The caudal screw was placed in the tear drop just above the sciatic notch. The cephalad screw was placed just below the iliopectineal line. Maximum diameter and length were determined. Demographic data included age at time of surgery, diagnosis, height, weight, BMI, and BMI percentile.

### Results:

42 patients age 6-22 years (mean 13.5) were included. Diagnosis included cerebral palsy (n = 23, 55%), spinal muscular atrophy (n = 5, 12%), Rett syndrome (n = 4, 10%), myelomeningocele (n=2, 5%). Mean height was 1.3 m (range, 1-1.86) and mean weight was 38.4 kg (range, 16.6-120.9). Mean BMI percentile was 61.47 (range, 2-171). The caudal screw mean diameter was 8.4 mm (range, 5-10), mean length 74.7 mm (range 40-100). The cephalad mean screw diameter was 8.2 mm (range, 5-10), mean length 73.3 mm (range, 45-100). The left and right caudal screws diameter matched in 22/41 (54%) while the cephalad matched in 21/41 (51%). The left and right caudal and cephalad screws matched length in 22/41 (54%) and 17/41 (42%), respectively.

### Conclusion:

This study demonstrates the anatomic viability of stacked SAI screws in pediatric patients planned for fusion to the pelvis. The dysplastic pelvic anatomy results in different sizes and trajectories.

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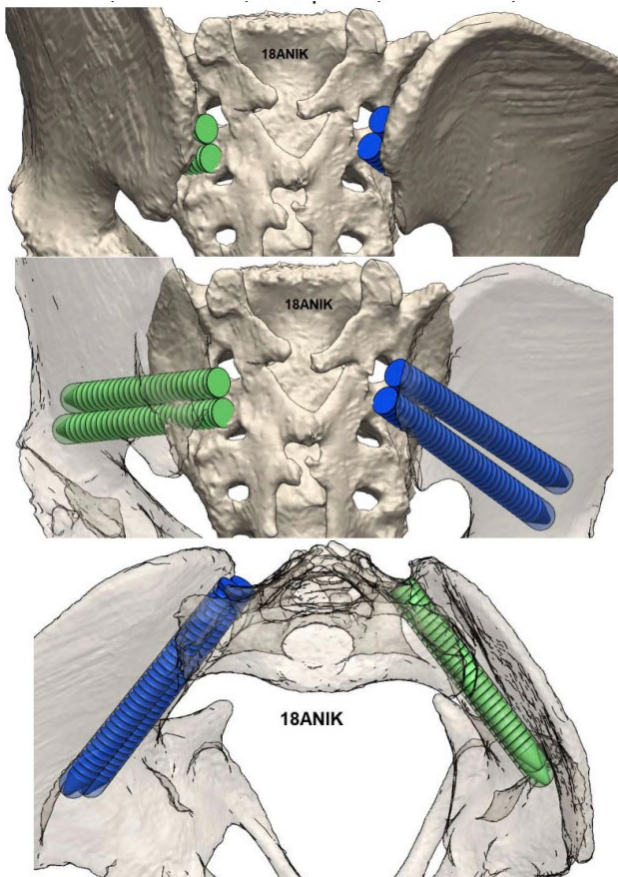


Figure 1. Stacked screws demonstrating trajectory and size mismatch in the dysplastic pelvis of a child with SMA.

## Paper #274. An Elasto-plastic Model of Spinal Rods Shows Less Deformity Correction and Implant Stresses in AIS Surgery Compared to What is Predicted From a Pure Elastic Model

Camille Pillot, MS; Xiaoyu Wang, PhD; Alexandria Mallinos, PhD; Todd F. Ritzman, MD; Lorena Floccari, MD; Richard M. Schwend, MD; Carl Eric Aubin, PhD, P.Eng

### Hypothesis:

Forces acting on spinal rods beyond their elastic limit significantly influence 3D correction and bone-screw forces during AIS surgery.

### Design:

Physics-based modeling of spinal rods in AIS instrumentation

### Introduction:

In adolescent idiopathic scoliosis (AIS) surgery, rod contouring is critical for achieving correction and sagittal alignment. However, rods often undergo plastic deformation (“bending-out”), flattening by 10–20°, which forces surgeons to routinely over-bend them in anticipation of this loss of curvature. Despite this well-recognized intraoperative phenomenon, most existing physics-based biomechanical models still

simplify rod mechanics by assuming a purely linear-elastic behavior. Such simplifications may misrepresent the true mechanical environment of the construct. In this study, we directly compared elastic versus elasto-plastic rod behavior to quantify their effects on correction and implant stresses.

### Methods:

A rod-shape modeling tool was validated using 39 surgical rod tracings. Patient-specific physics-based biomechanical spine models were created for 14 AIS cases. For each case, two primary correction simulations were performed with actual implant density and instrumented segment: (1) rods modeled as purely elastic with actual contour, diameter and material; (2) rods modeled with a simplified elasto-plastic approximation (same rod with 30% reduction of preoperative curvature,  $\sim 12^\circ \pm 5^\circ$ ). Outcomes assessed included sagittal rod shape, global 3D correction, and bone-screw forces.

### Results:

Elastic-only models consistently overestimated rod curvature ( $\sim 30\%$ ), thoracic kyphosis correction ( $+8^\circ \pm 5^\circ$  vs radiographic measurements), and apical screw pull-out forces ( $+12\%$ ) compared to elasto-plastic approximations. By contrast, elasto-plastic simulations closely reproduced postoperative rod shape ( $\pm 4^\circ$ ) while achieving equivalent global 3D correction.

### Conclusion:

Spinal rods do not exhibit purely elastic mechanical behavior during AIS correction: plasticity accounts for nearly 30% of their deformation. Neglecting this results in overestimation of correction and implant forces, whereas incorporating elasto-plasticity provides more realistic predictions and represents a key step toward tools that help surgeons better anticipate correction and optimize surgical strategies.

## Paper #275. Identifying High-Risk Patients in Adult Spinal Deformity Surgery: Leveraging Predictive Analytics to Assess Drivers of Increase Risk of Surgical Complications

Peter G. Passias, MD; Francesca Totis, MD; Max Fisher; Kyriakos Chatzis, BS; Peter Tretiakov, BS; Khoi D. Than, MD; Nima Alan, MD; Christopher I. Shaffrey, MD; Oluwatosi Onafowokan, MBBS, MS; Paul Park, MD

### Hypothesis:

To identify baseline patient characteristics and surgical factors that predict which adult spinal deformity (ASD) patients are at elevated risk for surgical complications

### Design:

Retrospective cohort study of a prospective ASD database

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## Introduction:

High-risk committees have recently been established in many hospitals to reduce operative risks through multidisciplinary collaboration. However, there remains limited consensus on which specific patient characteristics and surgical parameters warrant pre-operative discussion, making it challenging to standardize risk assessment and optimize care pathways

## Methods:

ASD patients meeting operative criteria (Cobb >20°, SVA >5 cm, PT >25°, or TK >60°) with available baseline and 2-year radiographic and HRQL data were included. Surgical risk was assessed based on surgical complications. High surgical risk was defined as experiencing a major surgical complication or revision surgery, also accompanied by negative clinical outcomes, specifically failure to meet the MCID for the ODI. A conditional inference tree machine learning model identified threshold cutoffs for continuous variables, while multivariable logistic regression models were used to develop predictive scores for both medical and surgical risk

## Results:

464 ASD patients were included (mean age 60.5, 80% female, BMI 27.1, CCI 1.7, mASD-FI 6.8). High surgical risk was predicted by age >70, ODI >56, BMI >34, frailty >5, SVA >15 cm, C7PL >7 cm, PI-LL >25, prior fusion, >16 levels fused, 3CO, instrumentation removal, and >3 interbodies (AUC 93%, accuracy 94%). Increasing risk factors correlated with higher odds of intraoperative/major complications, PJK (all time points), and PJF by 2Y, along with lower likelihood of achieving BCO in ODI and SRS-22r, and higher likelihood of WCO across timepoints

## Conclusion:

Identifying patient-specific and surgical factors associated with a high risk of major complications and poor clinical outcomes enables surgeons to better profile patients who may benefit from multidisciplinary collaboration

Table 1. Surgical High-Risk Cohorts

| Odd of Experiencing  | Surgical Risk Index |                                     |                                     |                                     |                                     |                                      |
|--|---------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|--------------------------------------|
|  | 0                   | ≥1                                  | ≥2                                  | ≥3                                  | ≥4                                  |                                      |
| Overall Complication   | Reference           | 1.77<br>[1.29 - 2.42]<br>p < 0.001* | 2.24<br>[1.60 - 3.15]<br>p < 0.001* | 2.34<br>[1.60 - 3.41]<br>p < 0.001* | 2.79<br>[1.78 - 4.37]<br>p < 0.001* | 3.70<br>[2.03 - 6.72]<br>p < 0.001*  |
| Overall Surgical Complication                                  | Reference           | 1.95<br>[1.43 - 2.66]<br>p < 0.001* | 2.42<br>[1.75 - 3.36]<br>p < 0.001* | 2.41<br>[1.69 - 3.44]<br>p < 0.001* | 2.42<br>[1.62 - 3.62]<br>p < 0.001* | 2.66<br>[1.63 - 4.34]<br>p < 0.001*  |
| Intraoperative Surgical Complication                           | Reference           | 1.86<br>[1.15 - 3.02]<br>p = 0.012* | 2.32<br>[1.41 - 3.79]<br>p < 0.001* | 2.45<br>[1.45 - 4.12]<br>p < 0.001* | 2.60<br>[1.48 - 4.56]<br>p < 0.001* | 2.79<br>[1.47 - 5.30]<br>p = 0.002*  |
| Intraoperative Major Surgical Complication                     | Reference           | 4.92<br>[1.76 - 13.7]<br>p = 0.002* | 5.59<br>[1.98 - 15.8]<br>p = 0.001* | 5.01<br>[1.72 - 14.6]<br>p = 0.003* | 5.68<br>[1.88 - 17.2]<br>p < 0.001* | 5.51<br>[1.65 - 18.4]<br>p = 0.005*  |
| Surgical Complication Prior to Discharged                      | Reference           | 1.71<br>[1.10 - 2.65]<br>p = 0.017* | 2.06<br>[1.32 - 3.20]<br>p = 0.001* | 2.11<br>[1.18 - 3.51]<br>p = 0.001* | 2.31<br>[1.37 - 3.89]<br>p = 0.002* | 2.64<br>[1.45 - 4.77]<br>p = 0.001*  |
| Major Surgical Complication Prior to Discharged                | Reference           | 5.25<br>[2.06 - 13.3]<br>p < 0.001* | 4.88<br>[1.86 - 12.8]<br>p < 0.001* | 5.43<br>[1.99 - 14.8]<br>p < 0.001* | 6.06<br>[2.07 - 17.7]<br>p < 0.001* | 10.85<br>[3.08 - 38.2]<br>p < 0.001* |
| Surgical Complication Within 90 Days of Discharged             | Reference           | 1.61<br>[1.10 - 2.36]<br>p = 0.015* | 1.89<br>[1.28 - 2.81]<br>p = 0.002* | 1.92<br>[1.26 - 2.93]<br>p = 0.003* | 2.11<br>[1.33 - 3.36]<br>p = 0.002* | 2.41<br>[1.41 - 4.14]<br>p = 0.001*  |
| Major Surgical Complication Within 90 Days of Discharged       | Reference           | 4.41<br>[2.01 - 9.68]<br>p < 0.001* | 4.81<br>[2.17 - 10.7]<br>p < 0.001* | 4.37<br>[1.91 - 10.0]<br>p < 0.001* | 4.73<br>[1.99 - 11.2]<br>p < 0.001* | 5.55<br>[2.19 - 14.1]<br>p < 0.001*  |
| Surgical Complication Within 2 Year of Discharged              | Reference           | 1.71<br>[1.22 - 2.41]<br>p = 0.002* | 2.06<br>[1.44 - 2.94]<br>p < 0.001* | 1.89<br>[1.29 - 3.78]<br>p = 0.003* | 1.98<br>[1.29 - 3.03]<br>p = 0.002* | 2.00<br>[1.21 - 3.33]<br>p = 0.005*  |
| Major Surgical Complication Within 2 Year of Discharged        | Reference           | 3.39<br>[1.87 - 6.15]<br>p < 0.001* | 3.51<br>[2.15 - 7.20]<br>p < 0.001* | 3.34<br>[1.99 - 7.02]<br>p < 0.001* | 4.02<br>[2.06 - 7.85]<br>p < 0.001* | 3.36<br>[1.82 - 8.20]<br>p < 0.001*  |
| Overall Reoperation  | Reference           | 1.76<br>[1.18 - 2.61]<br>p = 0.005* | 2.02<br>[1.34 - 3.04]<br>p < 0.001* | 2.25<br>[1.46 - 3.47]<br>p < 0.001* | 2.10<br>[1.30 - 3.40]<br>p < 0.001* | 2.39<br>[1.37 - 4.17]<br>p = 0.002*  |
| Reoperation due to Surgical Complication Prior to Discharged   | Reference           | 3.99<br>[1.21 - 13.1]<br>p = 0.023* | 4.42<br>[1.33 - 14.7]<br>p = 0.016* | 5.27<br>[1.55 - 18.0]<br>p = 0.008* | 4.29<br>[1.33 - 15.9]<br>p = 0.007* | 6.49<br>[1.68 - 25.0]<br>p = 0.007*  |
| Reoperation due to Surgical Complication within 90D Discharged | Reference           | 2.56<br>[1.30 - 5.05]<br>p = 0.007* | 2.62<br>[1.31 - 5.26]<br>p = 0.007* | 2.83<br>[1.37 - 5.85]<br>p = 0.005* | 2.21<br>[0.99 - 4.96]<br>p = 0.054  | 2.96<br>[1.23 - 7.10]<br>p = 0.015*  |
| Reoperation due to Surgical Complication within 2Y Discharged  | Reference           | 1.69<br>[1.12 - 2.54]<br>p = 0.013* | 1.97<br>[1.29 - 3.01]<br>p = 0.002* | 2.18<br>[1.39 - 3.42]<br>p < 0.001* | 1.97<br>[1.19 - 3.24]<br>p = 0.008* | 2.07<br>[1.16 - 3.70]<br>p = 0.014*  |

\*Unadjusted Univariate Logistic Regression Models

## Paper #276. Hybrid Junctional Rod (HJR™): A Novel Implant Strategy for Preventing Proximal Junctional Kyphosis in Spinal Deformity Surgery – Clinical and Biomechanical Outcomes

*Ercan Bal, MD; Fatma B. Saylak, MD*

### Hypothesis:

The Hybrid Junctional Rod (HJR™) reduces proximal junctional kyphosis (PJK) after long-segment deformity surgery by enabling stiffness transition, graded load sharing, and preservation of posterior soft tissues.

### Design:

Prospective clinical series with integrated biomechanical testing.

### Introduction:

PJK is a common complication after long-segment spinal deformity correction, reported up to 35%. Existing preventive measures, including tethering, hooks, spacers, and cement augmentation, show limited effectiveness and may increase complexity or cost. The HJR™ was developed as a novel implant strategy to reduce PJK through gradual stiffness modulation and load sharing while maintaining posterior ligamentous integrity.

### Methods:

Seventeen patients (mean age 22, range 13–48; 9 males, 8 females) underwent posterior long-segment instrumentation with HJR™. Diagnoses included Scheuermann kyphosis (n=11), congenital (n=2), neuromuscular (n=1), degenerative (n=1), and syndromic (n=2). Preoperative values: thoracic kyphosis 80°, thoracolumbar kyphosis 29°, lumbar lordosis 67°,

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GAP score 5. The construct combined a distal titanium rod, a transitional rod with single-screw connection, and proximal polyethylene-terephthalate bands tensioned from T2–T4 in graded fashion. Pedicle screws were placed at T6 and below, transitional screw at T5, and monoaxial screws at T2–T4. Posterior ligamentous structures were preserved. Static and cyclic biomechanical testing up to 1100 N compared HJR™ with titanium rods. Outcomes included correction, PJK/PJF incidence, implant complications, and patient-reported measures (SRS-22, VAS) at 18-month follow-up.

### Results:

Mean kyphosis correction was 56%. No PJK, PJF, or implant failures occurred. SRS-22 improved by +1.2, VAS pain decreased by –3.5. Radiographs showed stable sagittal alignment without junctional progression (Figure 1). Biomechanical testing confirmed superior load distribution, durability, and resistance to cyclic failure versus titanium constructs.

### Conclusion:

HJR™ is a safe, cost-neutral, and reproducible technique to reduce PJK by modulating stiffness and preserving soft tissues. Clinical and biomechanical results are encouraging; multicenter studies with long-term follow-up are warranted.

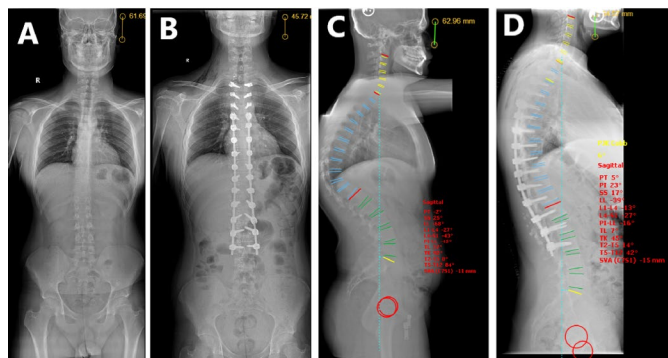


Figure 1.

## Paper #277. Machine Learning Driven Nomogram to Predict Risk of Revision Surgery in Adult Spine Deformity

Ahmed Sulieman, MD; Indeevar Beeram, MD; Renaud Lafage, MS; Virginie Lafage, PhD; Breton Line; Justin S. Smith, MD, PhD; Peter G. Passias, MD; Kojo D. Hamilton, MD, FAANS; Richard Hostin, MD; Bassel G. Diebo, MD; Eric O. Klineberg, MD; Jeffrey Gum, MD; Jeffrey P. Mullin, MD; Michael P. Kelly, MD; Alex Soroceanu, MD, FRCS(C); Robert K. Eastlack, MD; Alan H. Daniels, MD; Gregory M. Mundis Jr., MD; Themistocles S. Protopsaltis, MD; Munish C. Gupta, MD, MBA; Neel Anand, MD, Mch. Orth; David O. Okonkwo, MD, PhD; Jay D. Turner, MD, PhD; Adam S. Kanter, MD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Praveen V. Mummaneni, MD; 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:

Using machine learning, a predictive nomogram for revision surgery can be developed and validated.

### Design:

Prospective Multicenter study

### Introduction:

Machine learning (ML) algorithms have demonstrated potential in predicting outcomes after adult spine deformity (ASD) surgery by recognizing patterns in complex datasets. This study aimed to utilize a machine learning algorithm to identify key predictors of revision surgery and develop a nomogram based on these predictors

### Methods:

A multicenter prospective ASD database was utilized. Patient who underwent revision surgery were identified. Revision surgeries for infection and neurological complications were excluded from the analysis. Demographics, radiographic measurements, patient reported outcomes and operative factors were collected. A Random Forest algorithm was used to identify predictors of revision surgery. These predictors were then entered into a ridge regression model to address multicollinearity and overfitting. Variables with non-negligible coefficients in the ridge model were subsequently included in a multivariable logistic regression, which was used to construct a nomogram. The model was trained on 80% of the dataset and validated on the remaining 20% to assess accuracy and generalizability

### Results:

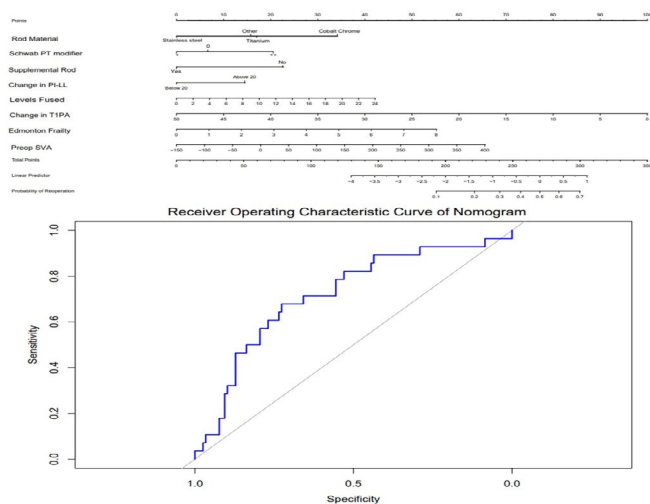
A total of 1,358 patients with a minimum 2-year follow-up were included. The median age was 64, with 73% being female. Revision surgery was performed in 16.1% (n=219) of patients. The Random Forest model achieved an AUC of 0.81, identifying 20 important predictors of revision surgery. Ridge regres-

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sion selected 8 predictors, which were incorporated into a logistic regression model achieving an AUC of 0.76 in the training set. A nomogram based on this model was validated on the testing data with an AUC of 0.75 and an accuracy of 0.83. Key predictors in the nomogram included baseline frailty, supplemental rod use, levels fused, rod material, preoperative sagittal vertical axis, preoperative Schwab pelvic tilt modifier, change in T1 pelvic angle and pelvic incidence-lumbar lordosis mismatch.

### Conclusion:

This study effectively merged machine learning with traditional statistics to create a nomogram that predicts the probability of revision surgery in ASD patients. This may aid in planning for more personalized long-term follow-up for those at higher risk for revision surgery. Further studies are needed for external validation of this nomogram.



### Paper #278. AI Models of Vertebral Body, Posterior, and Transverse Regions for Early Identification of Non-Responders in Spinal Tuberculosis

*Pankaj Kandwal, MD, MS; Anil Kumar, MD; Kaustubh Ahuja, MD; Amritpal Singh, MBBS*

#### Hypothesis:

To develop and validate AI models using baseline MRI features from distinct vertebral subregions to predict non-response to anti-tubercular therapy (ATT) in Spinal tuberculosis (STB).

#### Design:

Retrospective study

#### Introduction:

STB remains a major health challenge with treatment decisions between (ATT) and surgery often based on subjective assessment. Disease involvement differs across vertebral regions—body, posterior elements, transverse processes; affecting treatment response. Region-specific MRI features may provide early,

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biologically informed indicators to identify patients unlikely to respond to ATT and guide timely surgical intervention.

#### Methods:

127 patients with STB underwent baseline sagittal T2-weighted MRI prior to ATT. Vertebral structures were automatically segmented using pre-trained nnUNet and features were extracted from vertebral body, posterior elements and transverse processes to capture region-specific pathology. Four predictive models were developed: three focused on individual regions and fourth integrating all regions. Model performance was evaluated on holdout set using AUC, accuracy and standard clinical metrics. Outcome Measures: Non-response to ATT and identification of patients requiring surgical intervention based on MRI derived features

#### Results:

Among 127 patients with spinal tuberculosis, 54 required surgery after failing ATT. Region-specific analysis revealed distinct predictive patterns: the vertebral body model was most sensitive (83%, AUC 0.70), highlighting marrow and endplate changes as early indicators of non-response. The posterior process model was more specific (~79%, AUC 0.68) but less sensitive (46%), reflecting the cortical and posterior element involvement as reliable but late markers. Transverse process model showed modest performance (sensitivity 58%, specificity 61%, AUC 0.62), and fused model integrating all regions did not outperform individual subregions (AUC 0.61, accuracy 64%). These findings suggest vertebral body changes are most sensitive early markers, while posterior element changes provide higher specificity, guiding timely surgical decision-making.

#### Conclusion:

Region-specific MRI features can predict non-response to ATT in STB, with vertebral body changes being most sensitive and posterior elements most specific, guiding timely surgical intervention.

### Paper #279. Adolescent Idiopathic Scoliosis Patients Benefit from Minimally Invasive Surgery in Terms of Safety and Cost

*Vishal Sarwahi, MD; Alexander Morledge, BA; Anabelle Cohen, BS; Effat Rahman, BS; Katherine Eigo, BS; Sayyida Hasan, BS; Keshin Visahan, BS; Brian Li, BS; Sarah Trent, MD; Alex Ngan, MD; Terry D. Amaral, MD; Yungtai Lo, PhD*

#### Hypothesis:

Minimally invasive surgery (MIS) in AIS has better functional outcomes, lower OR costs, and similar radiographic corrections compared to traditional open Posterior Spinal Fusion (PSF).

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### Design:

Retrospective chart review

### Introduction:

In AIS patients undergoing corrective PSF, MIS is an innovative technique that is known to be comparable to the standard open posterior approach in terms of measurable (radiographic) outcomes. Using a matched case-controlled design, we aim to further evaluate MIS value-based, intraoperative, and postoperative outcomes against a conventional PSF benchmark.

### Methods:

296 AIS patients who had undergone PSF at a single institution between 2015-2024 were included. 148 MIS-PSF ("MIS") patients were matched with 148 open PSF controls based on age, BMI, levels fused, and Pre-Op Cobb angle. Charts and x-rays were reviewed for intra- and postop measurements. Cumulative OR costs (implants, equipment, blood products, etc.) were calculated for each surgery. Wilcoxon signed-rank tests and McNemar's tests were used to assess for significant differences between the two surgical modalities.

### Results:

MIS patients had significantly fewer fixation points (18 vs 22 points,  $p < 0.001$ ), but a longer surgical time (median 288 vs 259 mins,  $p < 0.001$ ). There was significantly less EBL for MIS patients (median 300 vs 500 mL,  $p < 0.001$ ), lower transfusion rates (2% MIS versus 16.2% PSF) ( $p < 0.001$ ), and shorter length of stay ( $p = 0.003$ ). Cobb corrections (%) and complication rates were not significant ( $p = 0.739$  and  $0.346$ ). Available OR costs in USD were significantly lower in the MIS (median \$36,174) group than the control PSF (median \$37,518) ( $p = 0.007$ ).

### Conclusion:

Minimally invasive scoliosis surgery has comparable radiographic outcomes and similar, if not more desirable short-term clinical outcomes when compared to standard PSF approach (complication rates and LOS respectively). While being an overall lengthier procedure, MIS allows for significant cost savings, potentially due in part to fewer blood transfusions and fixation points. Altogether, the findings indicate that MIS may represent on average not only a safer but also more economic surgical option for qualifying AIS patients requiring PSF. Future steps include repeating analyses on a larger database and tracking long term outcomes such as complications and reoperation rate.

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### Paper #280. Back Pain is a Negative Predictor for Rapid Improvement Following Primary One- and Two-Level Lumbar Laminectomy

*Eric Zhao, BS; Gregory Kazarian, MD; Jung Mok, MD; Christopher Yoo, BS; Mihir Dekhne, MD; Tomoyuki Asada, MD, PhD; Atahan Durbas, MD; Adin Ehrlich, BS; Serreen Halayqeh, MD; Adrian Lui, MBBS; Sheeraz Qureshi, MD; Todd J. Albert, MD; Sravisht Iyer, MD*

### Hypothesis:

Rapid improvers (RI) will achieve significant Oswestry Disability Index (ODI) improvement between consecutive postoperative timepoints

### Design:

Retrospective

### Introduction:

Literature suggests recovery after lumbar laminectomy occurs mostly within 3-6 months; however, some patients improve more rapidly. We compared rapid-improvers with non-rapid improvers after lumbar laminectomy using a novel definition of improvement based on global rating of change (GRC) improvement between consecutive postoperative timepoints.

### Methods:

Patients > 18 years undergoing primary 1- and 2-level lumbar laminectomy were included. Rapid improvers (RI) achieved significant Oswestry Disability Index (ODI) improvement between consecutive postoperative timepoints in the short-term (2 or 6 weeks), but not mid-term (3 or 6 months) or late-term (1 or 2 years). ODI improvement was defined by optimal cutoff of receiver operating characteristic (ROC) curve using change in ODI to predict GRC improvement between consecutive timepoints. Variables assessed included ODI, visual analog scale (VAS) for back and leg pain, Patient-Reported Outcomes Measurement Information System Physical Function (PROMIS-PF), sagittal alignment, muscle health, and Goutallier. Poor muscle health was defined by lowest gender-specific quartile of L3-L4 cross-sectional area (CSA)/height-squared (psoas) and CSA/body mass index (paralumbars). Logistic regression covariates were determined using  $p < 0.20$  on univariate analyses and clinical relevance.

### Results:

234 patients (RI = 38, non-RI = 196) were included. AUC was 0.76. Optimal cutoff for ODI improvement was 4.1. There were no demographic differences. The RI cohort had significantly lower preoperative ODI, VAS back and leg. At 12 weeks and 6 months, the RI cohort had significantly lower ODI and VAS leg. There were no differences in muscle health or Goutallier. Logistic regression including age, sex, preoperative ODI, VAS back, VAS leg, and paralumbar muscle health showed that preoperative VAS back

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was a negative predictor for rapid improvement (OR 0.78 [0.64 - 0.95],  $p = 0.012$ ).

### Conclusion:

Increased preoperative back pain in patients undergoing 1- or 2- level lumbar decompression may be a negative predictor for rapid postoperative improvement. This information may aid spine surgeons with perioperative patient counseling.

### Paper #281. Improving Early Scoliosis Detection with a Low-Dose Mobile Imaging and Automated Measurement Platform: A Cross-Sectional Screening Study ±

*Guilin Chen, MD; Terry Jianguo Zhang, MD; Nan Wu, MD*

### Hypothesis:

The referral-to-diagnosis rate can be maximized by the new workflow with decreased screening-to-diagnosis interval and radiation dosage.

### Design:

Cross-sectional study.

### Introduction:

Adolescent idiopathic scoliosis (AIS) is a complex, three-dimensional deformity of the spine, affecting approximately 1-3% of adolescents aged 10-18 years old. The school-based screening program was designed to identify adolescents with early-stage scoliosis. However, referring positive individuals for school-based scoliosis screening is difficult, time-consuming, and associated with high radiation exposure due to the low specificity. We developed and implemented a decentralized scoliosis screening workflow that enables on-site diagnosis and referral decision-making immediately following initial screening, which is supported by a mobile, low-dose full-spine imaging platform.

### Methods:

We conducted a cross-sectional, decentralized diagnostic evaluation study to assess the real-world performance of a school-based scoliosis screening workflow. The workflow was implemented between September 2024 and May 2025 across 20 cities in China. All procedures following physical screening were completed on-site using a mobile, AI-integrated low-dose imaging platform. The study was approved by the institutional review board of Peking Union Medical College Hospital (Number I-22PJ976), and electronic informed consent was obtained from all participants or their legal guardians.

### Results:

Between April 2023 and June 2025, 44,821 adolescents were included in the school-based screening program in 20 schools in 9 cities across China. The referral-to-diagnosis rate increase from 14.86% to 95.03% with the new workflow. For the diagnosis

interval between screening and diagnosis. The mean diagnosis time of the new workflow and tradition workflow was  $131.70 \pm 266.12$  min ( $n = 1560$ ) and  $12433.45 \pm 7617.79$  min ( $n = 113$ ) ( $p < 10^{-60}$ ), respectively. Based on standardized physical measurements using a calibrated dosimeter across representative patient body types and projection protocols, the estimated typical Dose Area Product (DAP) per full-spine AP exposure was  $300 \text{ mGy}\cdot\text{cm}^2$  (KV = 95, mAs = 8.8) in the new workflow, which in tradition workflow is  $2656.7 \text{ mGy}\cdot\text{cm}^2$ .

### Conclusion:

The referral-to-diagnosis rate can be optimized through the new workflow, which shortens the screening-to-diagnosis interval while lowering radiation dosage.

### Paper #282. Balancing Rod Contouring and Implant Density to Optimize Correction in Lenke 1 AIS ±

*Alexandria Mallinos, PhD; Camille Pillot, MS; Carl Eric Aubin, PhD, P.Eng; Richard M. Schwend, MD; Todd F. Ritzman, MD; Lorena Floccari, MD*

### Hypothesis:

Exceeding a concave rod angulation threshold reduces correction efficiency while lower screw density patterns increase apical bone-screw forces despite reduced implant use.

### Design:

Deterministic patient-specific computational modeling.

### Introduction:

In the posterior spinal fusion of adolescent idiopathic scoliosis (AIS) patients, differential rod contouring (DRC) and implant density patterns critically influence correction and implant loading. Aggressive rod angulation may lead to diminishing returns, while variations in screw density can alter force distribution. This study examines how these factors interact to affect correction efficiency and screw loading, with emphasis on the law of diminishing return in surgical correction.

### Methods:

Ten Lenke 1 AIS cases were modeled from pre-operative radiographs (MT Cobb  $62.5^\circ \pm 7.1^\circ$ ; MT kyphosis  $17.3^\circ \pm 12.1^\circ$ ). Simulations in MSC Adams used the concave rod first technique with 5.5 mm cobalt-chrome rods. Concave rod angulations of  $35^\circ$ ,  $55^\circ$ ,  $75^\circ$ , and  $85^\circ$  were paired with a  $15^\circ$  convex rod. Screw density patterns consisted of alternate, convex alternate, convex peri-apical dropout, and segmental.

### Results:

MT Cobb correction declined significantly when the concave rod exceeded  $55^\circ$  ( $p < 0.05$ ) (Figure 1).

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Sagittal correction improved with increasing angulation, demonstrating a coronal-sagittal trade off. Axial rotation correction was unaffected ( $p > 0.05$ ). Implant density minimally altered correction but strongly influenced apical bone-screw forces. The lower density alternate implant density pattern, produced larger bone-screw forces compared to higher density constructs, reflecting greater load sharing demands.

### Conclusion:

DRC is most effective when concave rod angulation is limited to  $55^\circ$ , achieving balanced coronal and sagittal correction without excessive implant stress. Lower density patterns reduce implant use but increase apical bone-screw forces, whereas higher density patterns better distribute loads. These findings highlight the need to balance rod contouring with implant configuration to optimize surgical outcomes in AIS patients.

### Paper #283 has been WITHDRAWN

### Paper #284. Does Navigation Allow for Placement of Larger S2AI Screws Compared with Freehand Technique? ±

*Kari Odland, DAT, ATC; Saurabh Rawall, MBBS; David W. Polly Jr, MD*

### Hypothesis:

In patients undergoing ASD surgery with pelvic fixation, we sought to compare navigation-assisted vs. freehand screw placement regarding: 1) screw length and 2) screw width.

### Design:

Retrospective cohort study

### Introduction:

S2-alar-iliac (S2AI) screws are critical for sacropelvic fixation in adult spinal deformity (ASD) surgery, with screw length influencing biomechanical stability. It is unknown if screw method placement – navigation vs. freehand – affects screw size.

### Methods:

A dual-institution, retrospective cohort study (2009-23) of patients undergoing ASD surgery with instrumentation to pelvis was undertaken. Patients were stratified into: 1) navigation-assisted placement with 4 pelvic screws—all screws placed with navigation, and 2) freehand placement with 2 pelvic screws—a single x-ray taken to ensure the screw was above the sciatic notch. Primary outcome was the average S2AI screw length and width. For patients with 4 pelvic screws, length and width of the caudal screw were evaluated.

### Results:

Of 229 patients, (mean age:  $66.0 \pm 11.1$  years; 65.9% females), 107 (46.7%) used intraoperative navigation use and 122 (53.3%) had freehand screw placement. Mean screw length and width were  $86.2 \pm 11.5$  mm

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and  $8.8 \pm 1.0$  mm, respectively. The navigation group had significantly longer S2AI screws as compared with the freehand group ( $95.1 \pm 44.4$  mm vs  $78.3 \pm 9.0$  mm,  $p < 0.001$ ). Similarly, the mean screw width was larger in the navigation group ( $9.8 \pm 0.3$  mm vs  $8.1 \pm 0.6$  mm,  $p < 0.001$ ). Additionally, the navigation group had a significantly larger population with screw length greater than 100 mm (41.1% vs. 2.5%,  $p < 0.001$ ) and screw with greater than 10 mm (45.8% vs. 0.0%,  $p < 0.001$ ). The longest and the widest screw in the navigation group were 110 mm and 10.5 mm, respectively, compared to 100 mm and 9.5 mm in the freehand group. On multivariable linear regression, average screw length ( $\beta = 17.2$ , 95%CI: 15.0-19.5,  $p < 0.001$ ) and screw width ( $\beta = 1.8$ , 95%CI: 1.6-1.9,  $p < 0.001$ ) were significantly larger in the navigation group.

### Conclusion:

Navigation-assisted placement of S2AI screws during ASD surgery allowed for the insertion of significantly longer and wider S2AI screws compared with freehand technique. These findings suggest that intraoperative navigation facilitates more optimal sacropelvic fixation by enabling the use of larger-diameter and longer screws, potentially enhancing construct stability and fixation strength.

### Paper #285. Rethinking S1 Screws: Equivalent Outcomes in Pelvic Fixation for Neuromuscular Scoliosis

*Hannah Hoopes, MD; Tega Diejomaoh, BS; Amit Jain, MD, MBA; Daniel J. Sucato, MD, MS; John S. Vorhies, MD; Judy-Mae Lima, BS; Amer F. Samdani, MD; Jaysson T. Brooks, MD; Harms NonFusion Study Group*

### Hypothesis:

S1 screws will not significantly affect deformity correction, pelvic obliquity, complication rates, or patient-reported outcomes in children with NMS.

### Design:

Retrospective query of a multi-center database with patients aged 8-21 years who underwent primary PSFs with pelvic fixation for NMS, with a minimum 2-year follow-up.

### Introduction:

Children with neuromuscular scoliosis (NMS) often require long fusion constructs extending into the pelvis. The most common pelvic fixation constructs include bilateral iliac screws (IS) or bilateral sacral-alar-iliac (SAI) screws with or without S1 pedicle screws. Equipoise exists on how beneficial the inclusion S1 screws are in long fusion constructs. This study looks to evaluate how the presence or absence of S1 screws effects deformity correction, pelvic obliquity, complication rates, and patient-reported outcomes in children with NMS.

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### Methods:

Patients were grouped by presence or absence of S1 screws in addition to bilateral IS or SAI screws. Radiographs were assessed preoperatively and at 2-year follow-up. Patient-reported outcomes included the Health Utilities Index (HUI), with a score of 1 indicating good health and scores less than 1 indicating worsening health; and the CPCHILD instrument. Medical and distal fixation-related complications were recorded.

### Results:

362 patients were included with mean age of  $14 \pm 2.7$  years. The majority (79%) of patients had spastic cerebral palsy with 90% of patients classified as GMFCS Level IV or V. No preoperative differences were observed between groups in major curve magnitude or pelvic obliquity. At 2-year follow-up, patients with pelvic fixation constructs including S1 screws had statistically significant but clinically insignificant improved pelvic obliquity at  $8^\circ \pm 8^\circ$  vs patients without S1 pedicle screws at  $10.4^\circ \pm 9^\circ$  ( $p=0.007$ , Figure 1). There was no significant difference in complications related to the distal fixation between the S1 and no S1 screw cohorts. Patients without S1 screws did have significantly more medical complications. There was no significant difference in CPCHILD scores between the S1 and no S1 screw cohorts at 2-years of follow-up. However, patients without S1 screws did have worse HUI scores 2 years postoperatively.

### Conclusion:

S1 pedicle screws in long fusion constructs in children with NMS does not result in any clinically relevant differences in deformity correction, pelvic obliquity, or patient reported outcomes.

| Variable  | N   | S1 Group                | N   | No S1 Group              | p-value |
|---|-----|-------------------------|-----|--------------------------|---------|
| GMFCS Level   |     |                         |     |                          |         |
| 1-3   | -   | 16 (5%)                 | -   | 6 (0.02%)                | N/A     |
| 4   | -   | 38 (11%)                | -   | 33 (9%)                  |         |
| 5   | -   | 77 (22%)                | -   | 183 (52%)                |         |
| PreOp Major Curve Angle                                       | 139 | $86^\circ \pm 22^\circ$ | 230 | $83^\circ \pm 24^\circ$  | 0.230   |
| PreOp Pelvic Obliquity  | 123 | $29^\circ \pm 15^\circ$ | 158 | $28^\circ \pm 15^\circ$  | 0.617   |
| Length of Surgery (min)                                       | 137 | $363 \pm 147$           | 224 | $448 \pm 150$            | <0.0001 |
| EBL (cc)  | 139 | $1507 \pm 1126$         | 229 | $1278 \pm 973$           | 0.040   |
| 2YR PostOp Major Curve Angle                                  | 139 | $29^\circ \pm 16^\circ$ | 230 | $32^\circ \pm 17^\circ$  | 0.146   |
| 2YR PostOp Pelvic Obliquity                                   | 126 | $8^\circ \pm 8^\circ$   | 214 | $10.4^\circ \pm 9^\circ$ | 0.007   |
| Complications   |     |                         |     |                          |         |
| Infections  | 12  | 8.63                    | 13  | 5.65                     | 0.270   |
| Pseudoarthrosis   | 0   | 0                       | 1   | 0.43                     | 1       |
| Medical   | 2   | 1.44                    | 21  | 9.13                     | 0.003   |
| Distal Instrument Related                                     | 4   | 2.88                    | 18  | 7.83                     | 0.067   |
| Reoperation   | 2   | 1.44                    | 6   | 2.61                     | 0.715   |
| PreOp Health Utility Index (HUI) Score                        | 106 | $-0.016 \pm 0.25$       | 160 | $-0.13 \pm .22$          | 0.019   |
| 2YR PostOp HUI Score  | 104 | $-0.03 \pm 0.24$        | 153 | $-0.11 \pm 0.20$         | 0.006   |
| PreOp CPCHILD Positioning, Transferring, Mobility Domain      | 99  | $35.73 \pm 16.60$       | 186 | $32.98 \pm 16.99$        | 0.191   |
| 2YR PostOp CPCHILD Positioning, Transferring, Mobility Domain | 89  | $43.97 \pm 19.14$       | 144 | $41.73 \pm 16.90$        | 0.332   |
| PreOp CPCHILD Total Score                                     | 104 | $50.22 \pm 15$          | 190 | $49.77 \pm 15$           | 0.805   |
| 2YR PostOp CPCHILD Total Score                                | 95  | $57.1 \pm 17$           | 175 | $57.2 \pm 14$            | 0.976   |

$\pm$  = E-Point Award Nominated Paper

### Paper #286. The Utility of Traction X-ray Under General Anesthesia (TRUGA) in Preserving One More Mobile Segment for Selection of the Lowest Instrumented Vertebra in the Surgical Treatment of Adult Idiopathic Scoliosis

Hamisi M. Mraja, MD; Burak Abay, MD; Bugra Ayaz, MD; Ahmet Hamdi Olcar, MD; Sinan Kahraman, MD; Meric Enercan, MD; Selhan Karadereler, MD; Azmi Hamzaoglu, MD

### Hypothesis:

TRUGA-based LIV selection will preserve more mobile segments without increasing mechanical complications in surgical treatment of adult idiopathic scoliosis.

### Design:

Retrospective

### Introduction:

Selecting the LIV in adult idiopathic scoliosis (AdIS) surgery aims to achieve optimal alignment while minimizing the number of fused segments. Prior studies suggested using the last vertebra touching the CSVL on standing x-rays as the LIV. This study compares radiologic and clinical outcomes when LIV is chosen based on standing x-ray vs traction x-ray under general anesthesia (TRUGA).

### Methods:

60 AdIS pts (age 21–48 yrs) who underwent posterior spinal fusion with  $\geq 2$  yrs of f/up. Patients requiring lumbosacral fusion were excluded. Group A ( $n=27$ ) had LIV defined as the last vertebra touching the CSVL on standing x-rays. Group B ( $n=33$ ) had LIV defined as the vertebra bisected by or medial to the CSVL on TRUGA. Coronal and sagittal parameters were measured preoperatively and at final f/up. ODI was used for quality-of-life assessment. Paired t-tests evaluated differences.

### Results:

The mean preoperative was curve  $62^\circ$ ; LIV levels were between T12–L5. Mean f/up was 11 yrs (range, 2–24). Trunk shift decreased from 31 mm to 15 mm at final f/up, and C7–CSVL distance improved from 28 mm to 10 mm. Both groups demonstrated significant coronal and sagittal alignment improvements. No cases of distal adding-on, distal junctional kyphosis, or revision surgery occurred. Group A showed greater improvement in LIV–CSVL distance ( $p<0.05$ ). Distal disc angles were  $<5^\circ$  in both groups. At final f/up, C7–CSVL distance and MT curve correction were comparable. Group B had greater TL/L curve magnitudes preoperatively, resulting in higher residual values postoperatively, though correction rates were similar between groups. ODI improved significantly in both groups; Group B, which preserved one additional mobile segment, showed higher ODI

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improvement, although the difference was not statistically significant.

### Conclusion:

TRUGA-based selection of LIV allows preservation of one more mobile segment without increasing mechanical complications or revision rates compared with standing x-rays. While ODI improvements favored TRUGA, differences were not significant. TRUGA may offer an advantage in optimizing LIV selection in adult coronal deformities.

### Paper #287. Sarcopenic Obesity: An Underrated Phenomenon Impacting Adult Spinal Deformity Intervention Outcomes

*Peter G. Passias, MD; Francesca Totis, MD; Kyriakos Chatzis, BS; Peter Tretiakov, BS; Alan H. Daniels, MD; Oluwatobi Onafowokan, MBBS, MS; Max Fisher*

### Hypothesis:

SO may impact ASD surgery outcomes and better characterize the health of important surrounding structural tissue that is key to alignment

### Design:

Retrospective cohort review of a prospectively enrolled database

### Introduction:

The amount and quality of tissue do not always positively correlate, as is the case with sarcopenic obesity (SO). As the population of elderly people with adult spinal deformity (ASD) continues to increase, sarcopenia (decreased muscle mass) and obesity continue to soar in prevalence, although sarcopenia is underacknowledged.

### Methods:

Operative ASD patients with complete baseline and two-year radiographic, and health related quality of life (HRQL) data were included. Sarcopenia was defined based on the validated European Working Group of Sarcopenia in Older People (EWGOSOP2). Obesity was classified via traditional BMI categories. The cohort with SO was compared to a cohort of patients without SO

### Results:

529 ASD patients were included (mean age 60.2, BMI 27.1, CCI 1.6, mASD-FI 6.5). Mean operative time was 414 min, EBL 1566 mL, and 10.9 levels fused. SO was present in 206 patients (38.9%), who were older, more comorbid, and frailer (all  $p < .05$ ). At baseline, SO patients had lower extremity motor scores, greater PI-LL mismatch, pelvic tilt, vertebral pelvic angles, and GAP disproportionality. SO was associated with higher rates of cardiac events, infection, pseudoarthrosis, reoperation, and instrumentation failure (all  $p < .05$ ). PJK prophylaxis reduced screw breakage and mechanical complications in SO patients. SO inde-

pendently predicted instrumentation failure (OR 1.7), whereas obesity and sarcopenia alone did not. SO patients also less often achieved age-adjusted goals and reported higher pain scores through 2 years

### Conclusion:

SO appears to significantly hamper outcomes after ASD, and awareness of the patient's muscle quality could guide operative decision-making as well as serve as a valuable target for preoperative optimization through measures such as nutritional counseling and prehabilitation

### Paper #288. Comparison of the Clinical and Radiologic Outcomes between Upper Thoracic versus Mid-Thoracic Upper Instrumented Vertebra in Long Fusions Down to the Pelvis for Adult Spinal Deformity

*Ahmet Hamdi Olcar, MD; Burak Abay, MD; Bugra Ayaz, MD; Hamisi M. Mraja, MD; Sinan Kahraman, MD; Selhan Karadereler, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD*

### Hypothesis:

Selecting UIV at upper thoracic level in long fusions would result in lower rates of PJK and mechanical failures

### Design:

Retrospective

### Introduction:

Selection of upper instrumented vertebra (UIV) in long fusions for adult spinal deformity (ASD) remains challenging. Previous studies suggest that mid-thoracic levels may be associated with higher mechanical complications. We hypothesized that choosing an upper thoracic (UT, T2-T4) or T9 level as the UIV would reduce the risk of proximal junctional kyphosis (PJK) and mechanical failures compared with T10.

### Methods:

203 ASD pts who underwent posterior fusion from UT or MT levels down to the pelvis was performed. Patients were divided into three groups: UT (T2-T4, 79 patients), T9 (62 patients), and T10 (62 patients). Radiographs were assessed preoperatively, post-operatively, and at final follow-up for coronal and sagittal parameters, including PJK and mechanical failures. Clinical outcomes were measured using SRS-22r and ODI.

### Results:

Mean age was 67 years (range, 40-75) in the UT group and 71 years (41-88) in the MT groups. Mean follow-up was 74 months (28-144) for UT and 68 months (24-182) for MT. Preoperatively, the UT group demonstrated greater thoracic kyphosis (TK), sagittal vertical axis (SVA), T4 pelvic angle (T4PA), and T4-L1 pelvic angle mismatch compared with T9

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and T10 groups. Postoperatively, all groups achieved similar sagittal alignment correction. PJK occurred in 11 patients (14%) in the UT group, 6 (4.8%) in the T9 group, and 12 (19%) in the T10 group. Proximal junctional failure (PJF) requiring revision was observed in 5 patients (6.3%) in the UT group, 4 (3%) in the T9 group, and 7 (12%) in the T10 group. SVA and T4PA correction was greater in the UT group. At final follow-up, clinical scores were comparable among groups: SRS-22r total scores UT 3.8, T9 3.9, T10 3.8; ODI UT 31, T9 29, T10 31.

### Conclusion:

UIV selection in ASD surgery depends on patient alignment. Fusion to T10 was associated with the highest rates of PJK and PJF, whereas T9 demonstrated the lowest rates. The UT group had higher PJK (14%) and PJF (6.3%) rates than T9 but lower than T10. These findings suggest that T9 (mid-thoracic) or T2-T4 (upper thoracic) levels are preferable to T10 as UIVs to minimize junctional complications and revision surgery, while clinical outcomes were similar across groups.

### Paper #289. Delineation of Alignment Goals for Adult Cervical Deformity Correction for Optimal Clinical and Functional Outcomes

*Peter G. Passias, MD; Francesca Totis, MD; Kyriakos Chatzis, BS; Peter Tretiakov, BS; Oluwatobi Onafowokan, MBBS, MS; Max Fisher; Paul Park, MD*

### Hypothesis:

Determine radiographic alignment targets associated with optimal clinical/functional outcomes in CD Patients

### Design:

Retrospective analysis of a prospectively enrolled, single-center database

### Introduction:

Surgical correction of cervical deformity (CD) can restore alignment and function but carries higher risk of complications and subsequent failure. It remains unclear which baseline and postoperative radiographic parameters correlate with improved HRQL metrics and minimized complications

### Methods:

Operative CD patients with a UIV above C7 and with pre-(BL) and at least 2-year (2Y) postoperative radiographic/HRQL data were included. CD defined as  $\geq 1$  of: C2-C7 lordosis  $< -15^\circ$ , TS-CL  $> 35^\circ$ , segmental cervical kyphosis  $> 15^\circ$  across any three vertebrae between C2-T1, C2-C7 SVA  $> 4$  cm, McGregor's slope  $> 20^\circ$ , or CBVA  $> 25^\circ$ . An optimal outcome defined as no DJF and meeting Virk et al.'s criteria for good clinical outcome [ $\geq 2$  of NDI  $< 20$  or meeting MCID, mild myelopathy (mJOA  $\geq 14$ ), NRS-Neck  $\leq 5$  or improved by  $\geq 2$  points from BL]. Regression analysis and Chi-squared

Automatic Interaction Detector (CHAID) identified BL and 3-month postoperative radiographic thresholds predictive of an optimal outcome

### Results:

340 patients were included (mean age 57.5, 48% female, BMI 29.1, CCI 0.8; mean fusion levels 5.0, EBL 496 mL, OR time 277 min). Baseline alignment showed near-neutral PI-LL ( $-0.3^\circ$ ) and SVA (0.1 mm), with T1S  $29.2^\circ$  and cSVA 29.0 mm. Baseline HRQLs included NRS back 6.0, NRS neck 7.3, NDI 56.3, mJOA 12.9, EQ5D 5.8. At 1Y, 23.2% achieved optimal outcomes, and 16.2% at 2-3Y. CHAID regression identified thresholds predictive of optimal outcome: BL T1S  $\leq 18.3^\circ$  (OR 3.2,  $p < .001$ ), 3M T1S  $\leq 31^\circ$  (OR 16.3,  $p = 0.012$ ), and 3M C7-S1 SVA  $\leq 38^\circ$  (OR 44.4,  $p = 0.001$ )

### Conclusion:

This study suggests novel baseline radiographic thresholds and postoperative realignment goals associated with favorable functional/clinical outcomes in patients undergoing surgery for CD

### Paper #290. Developing a Spinal Model for Gait Analysis: A Technical Feasibility Study of a Dynamic Sagittal Alignment Model

*Tim Bui, BS; Karan Joseph, BS; Alexander T. Yahanda, MS; Samuel Vogl Miguel Ruiz Cardozo, MD; Christopher Diaz, BS; Brian J. Neuman, MD; Camilo A. Molina, MD*

### Hypothesis:

Dynamic spinal gait analysis will provide analogous metrics as traditional radiographic spinopelvic parameters.

### Design:

Prospective Cohort

### Introduction:

Advanced methods of measuring spinopelvic alignment have been increasingly used in adult spinal deformity (ASD). Due to its novelty, few models have been developed for spinal gait analysis. Our objective was to develop a spine model for gait analysis and evaluate the relationship between skin-surface marker measurements and traditional radiographic spinopelvic parameters.

### Methods:

A spine model for gait analysis was developed to evaluate spinal geometry of ASD patients, inspired by T1PA, L1PA, PT, C7-SVA, C7-T12 TK, and L1-L5 LL. Markers were placed along anatomical landmarks on the skin surface where the sacrum, bilateral anterior superior iliac spine (ASIS), bilateral temporomandibular joint (TMJ), and spinous processes for C7, T6, T9, T12, and L3 could be palpated. Hip-joint positioning was mathematically calculated based on pelvic depth and skin markers. A Video Gait lab was used to record these markers while static and in ambulation.

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## Results:

The correlation between radiographic spinopelvic parameters and the static measurements from our developed model were as follows: 0.69 (p=0.006) for C7-SVA, 0.22 (p=0.5) for TK, -0.27 (p=0.3) for LL, -0.23 (p=0.4) for PT, -0.36 (p=0.2) for L1-PA, and 0.60 (p=0.02) for T1PA. The correlation between radiographic parameters and gait measurement from our developed spine model were as follows: 0.71 (p=0.004) for C7-SVA, 0.20 (p=0.5) for TK, -0.32 (p=0.3) for LL, -0.06 (p=0.8) for PT, -0.05 (p=0.9) for L1PA, and 0.57 (p=0.04) for T1PA.

## Conclusion:

Correlation between gait and radiographic models of sagittal spinopelvic parameters were strongest for C7-SVA and T1PA, while correlation was weak for TK, LL, L1PA and PT. Weakly correlated parameters were likely affected by variables introduced from using skin-surface markers (body habitus) or breakdown of compensatory mechanisms throughout the fatiguing gait collection process and require additional study.

| Spinopelvic Parameter  | Radiographic Defn  | Defn Model Definition  | 2-Var Static Correlation | Static Dynamic Correlation |
|------------------------|--|--|--------------------------|----------------------------|
| Pelvic Tilt (PT)       | Angle formed by a vertical reference line, and vertical through the femoral head | Angle formed by the vertical reference line, and vertical through the femoral head | 0.23 (p=0.1)             | 0.66 (p<0.001)             |
| C7-SVA                 | Horizontal distance between C7 and sacral midpoint                               | Horizontal distance between C7 vertebra process marker and sacral midpoint         | 0.69 (p<0.0001)          | 0.71 (p<0.0001)            |
| C7 Pelvic Angle (C7PA) | Angle formed by C7, hip joint, and sacral midpoint                               | Angle formed by the C7 process marker, hip joint, and sacral midpoint              | 0.60 (p<0.0001)          | 0.57 (p<0.0001)            |
| L1 Pelvic Angle (L1PA) | Angle formed by L1, hip joint, and sacral midpoint                               | Angle formed by the L1 process marker, hip joint, and sacral midpoint              | -0.36 (p<0.2)            | -0.06 (p=0.8)              |
| Thoracic Kyphosis (TK) | Cobb's angle between C7-T12  | Angle between superior of T12 & inferior of C7                                     | 0.22 (p=0.5)             | 0.20 (p=0.5)               |
| Lumbar Lordosis (LL)   | Cobb's angle between L1-S1   | Angle between superior of L1 & inferior of S1                                      | -0.27 (p=0.3)            | -0.32 (p=0.3)              |

Spinopelvic parameters with distinct definitions and correlations between traditional radiographic methods and the newly developed spine gait model.

## Paper #291. Biomechanical Basis of Proximal Junction Vulnerabilities with T4-L1 Hip Axis Malalignment: A Finite Element Analysis of Instrumentation and Disc Stress

*Luke Mugge, MD; Anna O. Sawa, MS; Robert Rudy, MD; Aydin Salek, BS; Sarah McBryan, MS; Juan S. Uribe, MD; Brian Kelly, PhD; Jay D. Turner, MD, PhD*

### Hypothesis:

Proximal rod and disc stress is elevated after a fusion when L1PA/T4PA alignment goals are not met.

### Design:

Finite element modeling of a synthetic spine with a T10 to pelvis construct to evaluate rod and disc stress.

### Introduction:

Proximal junctional kyphosis and mechanical failures remain common complications for adult spinal deformity (ASD). Sagittal alignment has become a central focus to ameliorate complications associated with ASD surgery. L1 and T4 pelvic angles have been proposed to define normative sagittal alignment. Achieving these normative targets in ASD patients is associated with decreased mechanical complications.

## Methods:

T4 to pelvis FEM was created with instrumentation spanning T10-pelvis. Using CAD, vertebrae were repositioned to obtain spinal alignment representing L1PA at target (T) and undercorrected (U) curves. (T) was established such that L1PA and T4PA were at goal (L1PA=(0.5\*PI)-19 and T4PA=L1PA ±1-4). For (U), the vertebral bodies were adjusted so L1PA was undercorrected and the T4 vertebral body was ventral to the L1. Load conditions were 100N compression (vertical load) applied at the proximal level's center of mass (Comp), followed by 5 Nm flexion +100N Comp (FL+Comp). Two rod materials were compared: titanium [Ti] and cobalt-chrome [CoCr], as were max stresses across rods at all levels and the upper adjacent level disc (T9-T10).

## Results:

For proximal disc stress, significantly higher levels of stress developed across the T9-T10 disc space for U compared to T under both conditions and for both types of rods (Comp [Ti]: 21.4 MPa vs. 3.9 MPa; Comp [CoCr]: 18 MPa vs. 3.6 MPa; FL+Comp [Ti]: 125.1 MPa vs. 7.4 MPa; and FL+Comp [CoCr]: 119.2 MPa vs. 6.8 MPa. For rod stress, significantly higher rod stresses were observed both proximally (T10-T11) and distally (S1-ilium) for U vs T for both load conditions and rod materials: [Ti rods-Comp] 206MPa vs 28MPa and 1039MPa vs 274MPa, respectively, [Ti rods Comp+FL] 304MPa vs 130MPa and 1442MPa vs 235MPa, respectively. Comp [CoCr]: 306 MPa vs 39MPa and 1028MPa vs 257MPa, respectively, Comp [CoCr]: 456MPa vs 201MPa and 1423MPa vs 250MPa, respectively.

## Conclusion:

Our study demonstrates proximal disc stress and rod stress are significantly higher with global malalignment as defined by normative L1PA/T4PA. We provide the first biomechanical evidence supporting the use of L1PA/T4PA as alignment goals.

## Paper #292. Is an Inspiratory Hold Necessary to Compare Respiratory Parameters in NMS?

*Zaid Elsabbagh, BS; Jessica Siragusa, MBA; William ElNemer, BS; Paul D. Sponseller, MD*

### Hypothesis:

Due to the limited tidal volumes in patients with neuromuscular scoliosis (NMS), standardization of diaphragm position via a breath-hold is not necessary for assessment of diaphragmatic position in these patients.

### Design:

Retrospective reliability study of diaphragm position metrics on serial postoperative radiographs in children with cerebral palsy (CP) undergoing posterior spinal fusion (PSF).

± = E-Point Award Nominated Paper

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### Introduction:

Diaphragm position has emerged as a valuable radiographic marker in patients with NMS, offering insight into thoracic volume and postoperative respiratory status. However, the reliability of these measurements across repeated imaging—particularly without standardization of respiratory phase—has not been validated. This is especially relevant in NMS, where consistent inspiratory effort is often limited. We sought to evaluate the stability of two commonly used diaphragm-based radiographic metrics—Diaphragm Intrusion Index (DII) and Diaphragm Vertebral Level (DVL)—across serial upright radiographs obtained without breath-hold standardization

### Methods:

We retrospectively reviewed 147 patients with CP who underwent PSF at a single academic center. Inclusion required at least two upright thoracoabdominal radiographs within five days postoperatively. 20 patients had two radiographs, 32 had three, 14 had four, and 81 had five. All eligible radiographs (maximum of five per patient) were assessed. DII and DVL were measured bilaterally by a single reviewer (Fig.1). Intraclass correlation coefficients (ICCs) quantified reliability, and repeated measures ANOVA evaluated within-patient variability.

### Results:

All four diaphragm metrics showed excellent consistency. ICCs were 0.993 (95% CI: 0.991–0.995) for right DII, 0.992 (0.989–0.995) for left DII, 0.967 (0.954–0.977) for right DVL, and 0.969 (0.958–0.979) for left DVL (all  $P < 0.001$ ). No significant within-patient variability was detected by ANOVA (DII right  $P = 0.9346$ , DII left  $P = 0.9526$ , DVL right  $P = 0.9541$ , DVL left  $P = 0.9015$ ).

### Conclusion:

DII and DVL remain stable across repeated upright radiographs even without inspiratory breath-hold. These findings validate their reliability in patients with limited respiratory control and support their use in longitudinal assessment of diaphragm position following PSF in the NMS population.

### Paper #293. Change In Pelvic Incidence Following Primary Sacroiliac Joint Fusion

*Clayton Hoffman, MD; Jonathan Layne, BS; Christopher J. Kleck, MD*

### Hypothesis:

Pelvic incidence may change after primary sacroiliac joint fusion, indicating that PI is not a fixed parameter.

### Design:

Retrospective

### Introduction:

Sacroiliac joint dysfunction can be successfully treated ± = E-Point Award Nominated Paper

ed through sacroiliac joint fusion (SIFJ). One of the considerations of SIFJ is motion through the sacroiliac joint. This motion is reflected in the spinopelvic radiographic parameter known as pelvic incidence(PI), a measurement integral to the assessment and treatment of spinal deformity. Pelvic incidence has traditionally been viewed as a fixed relationship however multiple recent analyses suggest this may not always be true. In this investigation, we sought to examine if SIFJ can result in significant changes in postoperative PI.

### Methods:

Retrospective analysis was performed on patients aged 18-85 who underwent primary SIFJ at a single institution. Those who underwent surgery for purposes of revision, trauma, cancer, or infection were excluded. Patients who had concurrent lumbar fusion were included. Pelvic incidence, sacral slope, and pelvic tilt were measured by two independent evaluators on standing lateral radiographs before and after SIFJ. Postoperative measurements were performed on the patient's most recent follow-up radiograph. Interobserver reliability was assessed using the Band-Altman method.

### Results:

A total of 104 patients were deemed eligible. Absolute change of  $>5^\circ$  of PI occurred in 11/104 (10.6%) of patients. Preoperative demographic factors did not predict changes in PI  $>5^\circ$ . Interobserver risk of measurement bias ( $R^2$ ) ranged from  $<0.001$  to 0.017 (low).

### Conclusion:

We identified that PI significantly changed by  $>5^\circ$  in 10.6% of patients after primary SIFJ. This would suggest that PI is not a static parameter. Our observed change is consistent with other studies that have demonstrated PI can change with flexion/extension of the spine or those undergoing long-construct adult spinal deformity surgery. Additional investigations are needed to help identify preoperative demographic factors that may predict change in PI as well as the clinical significance of those who experience change. Based on our study, PI can significantly change after SIFJ. These findings suggest that surgeons performing SIFJ should be mindful of fusion positioning and potential for SIFJ to impact PI. Such changes may influence overall spinopelvic alignment which could in turn affect concurrent lumbar fusion planning or instigate new/existing spinal deformity.

### Paper #294. Comparison between Modified Growth Guidance System (MGGS) and Apical Control Technique with Traditional Growing Rods (ACT-TGR)

*You Du, MD; Xiangjian Song, MD; Jianguo T. Zhang, MD*

## E-POINT PRESENTATION ABSTRACTS

### Hypothesis:

MGGS has the similar correction ability as the ACT-TGR with less surgeries.

### Design:

Retrospective Study

### Introduction:

There are two major modifications of MGGS: The buttress were used between the fixed screws and sliding screws in concave side, to maintain the distraction forces of concave side of the curve, prevent the sliding-back phenomenon. Three column osteotomy was performed in rigid severe early onset scoliosis(EOS), to acquire ultimate correction. ACT-TGR combined apical control techniques with traditional growing rods. There were two kind of ACTs: three column osteotomy and apical controlled screws, depended on the magnitude and rigidity of the curve.

### Methods:

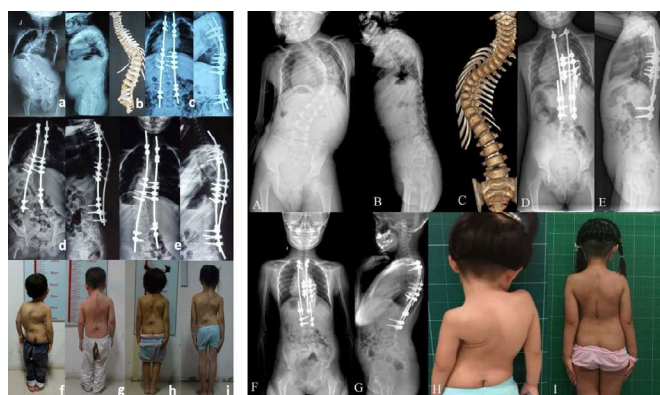
A case matched retrospective study of EOS patients was conducted in two center in China. Patients were divided into 2 groups according to the different treatment approaches: the MGGS group and the ACT-TGR group. Two groups were matched with age ( $\pm 2$  years) and Cobb angle ( $\pm 5^\circ$ ). Demographic information, radiographic parameters, surgeries records and complications were compared.

### Results:

Thirty patients were enrolled in this study, fifteen patients in each groups. Index surgery age (MGGS:  $6.87 \pm 1.81$  years; ACT-TGR:  $7.08 \pm 2.48$  years;  $p=0.790$ ), follow-up ( $5.04 \pm 1.57$  vs.  $5.28 \pm 1.97$  years;  $p=0.723$ ), sex, curve type, and diagnosis showed no differences ( $p>0.05$ ). Preoperative main Cobb angles ( $69.84 \pm 18.57^\circ$  vs.  $70.73 \pm 15.03^\circ$ ;  $p=0.886$ ), post index-operation ( $24.87 \pm 11.01^\circ$  vs.  $25.60 \pm 9.93^\circ$ ;  $p=0.851$ ), and final follow-up ( $28.31 \pm 17.57^\circ$  vs.  $26.87 \pm 11.36^\circ$ ;  $p=0.792$ ) were similar. Correction rates were equivalent (initial: 65% vs. 64%,  $p=0.974$ ; final: 60% vs. 62%,  $p=0.713$ ). Preoperative sagittal parameters were comparable, final follow-up showed no differences except LL ( $39.61 \pm 8.27^\circ$  vs.  $54.94 \pm 8.98^\circ$ ;  $p<0.001$ ). Preoperative T1-T12 ( $16.30 \pm 2.23$  vs.  $15.53 \pm 3.80$  cm;  $p=0.509$ ) were similar, final total gains were equivalent (T1-T12:  $5.36 \pm 2.22$  vs.  $6.02 \pm 2.56$  cm,  $p=0.464$ ). Annual growth rate was higher in ACT-TGR ( $0.44 \pm 0.45$  vs.  $0.77 \pm 0.56$  cm/year;  $p=0.018$ ). Number of surgeries was significantly lower in MGGS ( $1.33 \pm 0.49$  vs.  $5.87 \pm 1.30$ ;  $p<0.001$ ). Complications and revisions surgeries were similar.

### Conclusion:

MGGS matches ACT-TGR in coronal correction and spinal growth for EOS, with fewer surgeries, and comparable complications.



*3y/f Congenital scoliosis(T9 HV) underwent MGGS and 3y/f Congenital scoliosis(T8 HV) underwent ACT-TGR*

### Paper #295. Impact of Global Sagittal Alignment on Pelvic Fixation Failure: A Matched Case-Control Study

*Karan Joseph, BS; Samuel Vogl Alexander T. Yahanda, MS; Miguel Ruiz Cardozo, MD; Tim Bui, BS; Nicholas A. Pallotta, MD, MS; Munish C. Gupta, MD, MBA; Brian J. Neuman, MD; Jacob Greenberg, MD; Wilson Zachary Ray, MD; Camilo A. Molina, MD*

### Hypothesis:

Deviations in global sagittal balance are associated with pelvic fixation failure

### Design:

retrospective case control

### Introduction:

Pelvic fixation failure (PFF) is a rare yet underrecognized mechanical complication that follows surgical management of adult spinal deformity (ASD). Prior studies have shown that residual malalignment may increase mechanical stress, but the role of global radiographic parameters in predicting PFF remains poorly defined. Our study aims to identify radiographic predictors of PFF using a matched control design while evaluating the time-dependent relationship between residual deformity and rates of PFF.

### Methods:

This was a single-center, retrospective, matched case-control study of ASD patients who underwent surgical management with pelvic fixation from 2016-2024 and had  $>1$  year of follow-up. PFF was defined as any reoperation for pelvic screw or rod failure, and patients were matched in a 1:4 ratio by age and sex. Global radiographic outcome measures were collected, and multivariable logistic regression and Cox proportional hazard models were used to assess PFF predictors and time-to-failure.

### Results:

31 (5.99%) of 517 eligible patients experienced PFF, and 94 patients were included after propensity matching with 63 eligible controls. Postoperative C2

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Tilt (C2T) (OR = 1.15, p=0.013) and  $\Delta$ C7-Coronal Vertical Axis ( $\Delta$ C7-CVA) (OR=1.66, p=0.007) were associated with increased PFF risk, and T1-Pelvic Angle (T1PA) trended toward significance. Time-to-event analysis confirmed these findings and identified a C2T cutoff for hazard ratio >1 of 6.9°.

### Conclusion:

Residual global deformity malalignment, specifically elevated postoperative C2T and  $\Delta$ C7-CVA, are significant predictors of PFF and accelerated time-to-failure. This highlights the importance of achieving global alignment intraoperatively to improve long-term construct durability and prevent PFF complications in ASD surgery.

### Paper #296. Spatiotemporal Gait Parameters are Independently Associated with Disability at Presentation in Adult Spinal Deformity Patients

*Rahul Sastry, MD; Alexa M. Semonche, MD; Conor Grady, MD; Adrian Fu Aaron J. Clark, MD, PhD; Vedat Deviren, MD; Christopher P. Ames, MD*

### Hypothesis:

That adult spinal deformity patients (ASD) present with significant abnormalities in spatiotemporal gait and that these abnormalities contribute significantly to pre-operative disability

### Design:

Retrospective review of prospectively collected data

### Introduction:

ASD patients may present with significant disability, which is partially attributable to derangements of static spinal alignment. Across many health conditions, however, the relationship between abnormal gait and quality of life, functional status, and risk of injury is well established. As such, we sought to characterize baseline gait parameters and assess their relationship to pre-operative disability in ASD patients

### Methods:

A retrospective study of all outpatient ASD patients who underwent gait analysis in the lead author's (CPA) clinic from 2023 to 2025 were included. Summary statistics were calculated after assessing skewness of distributions. Principal component analysis (PCA) was used to reduce the dimensionality of 25 available gait parameters. All components with eigenvalues greater than 1 were retained. Multivariable linear regression utilizing these principal components as well as age, skeletal muscle index (SMI), pelvic tilt (PT), C7 sagittal vertical axis (SVA), knee flexion (KF) as predictors of Oswestry Disability Index (ODI) was then conducted using multiple imputation by chained equations (m = 5).

### Results:

79 patients met inclusion criteria. Median age was

69.4 years old. Static deformity parameters were notable for mean PT of 27.7deg (SD: 9.66deg), mean SVA of 8.1 cm (SD: 5.3 cm), and mean KF of 11.5deg (SD: 9.0deg). Mean SMI was 7.6 kg/m<sup>2</sup> (SD: 1.5 kg/m<sup>2</sup>) and mean ODI was 48.9% (SD: 17.7%). Mean gait velocity was 67.2 cm/sec (SD: 24.21 cm/sec) and median gait cadence was 95.7 steps/min (IQR: 86.25-101.95 steps/min). 71 (90.0%) and 44 (55.7%) patients had gait speeds below thresholds of 100 cm/sec and 70 cm/sec, respectively. PCA yielded 5 parameters with eigenvalues greater than 1 (87% variance explained). In multiple imputation analysis, two of these gait principal components along with knee flexion were significantly associated with increased disability, as measured by ODI.

### Conclusion:

ASD patients present with markedly abnormal gait parameters, with 56% of patients failing to ambulate at even 70 cm/sec. Gait parameters were associated with ODI at presentation even when controlling other factors.

Table 1 – Baseline Patient Characteristics

|  | Overall               | Missing |
|--|-----------------------|---------|
| n  | 79                    |         |
| Age (median [IQR])                                   | 69.46 [63.59, 74.07]  | 0       |
| Pelvic Incidence (median [IQR])                      | 53.00 [45.25, 60.00]  | 11.4    |
| Sacral Slope (mean (SD))                             | 26.61 (12.44)         | 11.4    |
| Pelvic Tilt (mean (SD))                              | 27.74 (9.66)          | 11.4    |
| Pelvic Obliquity (median [IQR])                      | 4.00 [2.00, 8.00]     | 11.4    |
| Pelvic Axial Rotation (median [IQR])                 | 0.00 [-2.00, 2.00]    | 11.4    |
| C7 Central Sacral Line (median [IQR])                | 15.00 [7.00, 31.75]   | 11.4    |
| C7 Sagittal Vertical Axis (mean (SD))                | 80.93 (52.75)         | 11.4    |
| T1 Tilt (mean (SD))                                  | -1.00 (5.84)          | 11.4    |
| T9 Tilt (mean (SD))                                  | 10.21 (6.86)          | 11.4    |
| Knee Flexion (mean (SD))                             | 11.48 (8.96)          | 12.7    |
| Gait Speed (cm/sec) (mean (SD))                      | 67.21 (24.21)         | 0       |
| Gait Speed < 100 cm/sec                              | 71 (89.9)             | 0       |
| Gait Speed < 70 cm/sec                               | 44 (55.7)             | 0       |
| Cadence (Steps/Min) (median [IQR])                   | 95.70 [86.25, 101.95] | 0       |
| Step Time Differential (sec) (median [IQR])          | 0.03 [0.02, 0.07]     | 0       |
| Step Length Differential (cm) (median [IQR])         | 2.26 [0.69, 4.75]     | 0       |
| Single Support Time (% of Gait Cycle) (median [IQR]) | 33.90 [30.25, 35.65]  | 0       |
| Double Support Time (% of Gait Cycle) (median [IQR]) | 31.95 [28.12, 39.50]  | 0       |
| Skeletal Muscle Index (mean (SD))                    | 7.62 (1.45)           | 24.1    |
| Oswestry Disability Index (mean (SD))                | 48.88 (17.74)         | 15.2    |

### Paper #297. A Novel Hemivertebra Automatic Segmentation and Recognition Algorithm: Development and Validation

*You Du, MD; Shuang Song, PhD; Terry Jianguo Zhang, MD*

### Hypothesis:

The novel algorithm achieves automatically segmentation and recognition of the hemivertebra in CT scan with high accuracy and efficiency.

### Design:

AI algorithm development and clinical validation.

### Introduction:

Hemivertebra, a congenital spine anomaly, poses challenges in accurate segmentation and recognition in CT imaging due to its structural complexity

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and variability. Precise segmentation of hemivertebrae and surrounding vertebrae is critical for clinical diagnosis and treatment planning. Existing end-to-end segmentation models often struggle to balance accuracy and preservation of adjacent vertebral structures. This study proposes a novel three-stage algorithm to address these challenges, aiming to achieve superior segmentation accuracy while maintaining the integrity and independence of surrounding vertebrae.

### Methods:

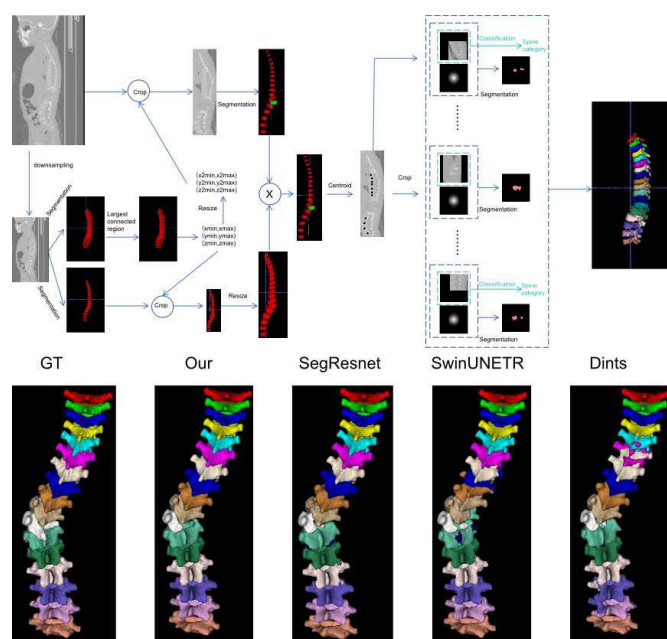
The proposed method consists of three stages: (1) segmentation of the entire spine from hemivertebra CT images, employing a binary segmentation network to localize the region of interest (ROI) and exclude the sacrum for centroid extraction preparation, followed by dual-target segmentation of normal spine and hemivertebra; (2) calculation of vertebral centroids using topological methods to serve as markers; and (3) extraction of image sub-blocks based on centroids, followed by segmentation using a SegResNet-based network and spatial stitching to obtain complete hemivertebra segmentation. The method was evaluated on 82 annotated hemivertebra CT images using five-fold cross-validation, with 58 training, 8 validation, and 16 test samples per fold. Performance was compared against end-to-end models: SegResNet, SwinUNETR, and Dints.

### Results:

Figure demonstrate that the proposed method effectively segments hemivertebra structures while preserving the integrity and independence of adjacent vertebrae. Quantitative results show superior performance, with a DICE score of 0.89 and a 95% Hausdorff Distance of 2.94 mm, outperforming SegResNet (0.80, 13.56 mm), SwinUNETR (0.80, 12.18 mm), and Dints (0.78, 9.95 mm). These results highlight the proposed method's enhanced accuracy and robustness in hemivertebra segmentation.

### Conclusion:

The proposed three-stage algorithm significantly improves hemivertebra segmentation accuracy and preserves surrounding vertebral structures, outperforming existing end-to-end models.



Flowchart of the proposed method and comparison results by the proposed method and other models

### Paper #298. Functional Gait Analysis in Lumbar Degenerative Kyphosis: Insights from Butterfly Diagram and Three-Foot-Zone Evaluation

JungHee Lee, MD, PhD; Ki Young Lee, MD, PhD; Woo-Jae Jang, MD; Hong-Sik Park, MD

### Hypothesis:

We hypothesized that lumbar degenerative kyphosis (LDK) patients would show characteristic gait dysfunctions by butterfly diagram and three-foot-zone analysis.

### Design:

Retrospective comparative study

### Introduction:

LDK, a subtype of adult spinal deformity (ASD) with sagittal malalignment, presents with stooping and walking difficulty. A typical feature is the "hands-on-thigh" posture after walking, which static radiographs cannot capture. To assess such dynamic features, we performed treadmill-based gait analysis in LDK patients and compared them with controls.

### Methods:

We retrospectively analyzed LDK patients and controls who underwent treadmill gait analysis. Spinopelvic parameters was analyzed. Gait was evaluated in three domains: (1) spatiotemporal parameters (step/stride length, width, cadence, velocity, gait phases); (2) CoP trajectories, visualized by butterfly diagrams to evaluate line length, variability, symmetry, and anterior-posterior excursion; and (3) plantar pressure distribution, analyzed by the three-foot-zone method for heel-to-forefoot transfer and regional loading.

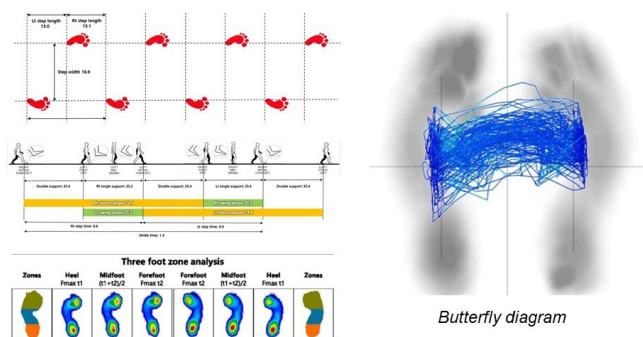
## E-POINT PRESENTATION ABSTRACTS

### Results:

We studied 371 LDK patients and 72 controls. LDK patients had shorter step (44 vs 53 cm) and stride (88 vs 106 cm), slower cadence (112 vs 127 steps/min) and velocity (3.0 vs 4.8 km/h), and wider step width (15 vs 13 cm). Stance phase was longer (65% vs 60%) and stride time increased (1.1 vs 0.9 sec), while swing (33% vs 40%) and single-limb support (33% vs 40%) were reduced. CoP trajectories showed shorter gait line (257 vs 362 mm), reduced support line (130 vs 236 mm), decreased anterior-posterior excursion (190 vs 262 mm), and greater variability, producing a flattened butterfly pattern. Three-foot-zone analysis showed delayed heel-to-forefoot transfer (0.3 vs 0.2 sec), more midfoot load, and lower forefoot pressure (24 vs 35 kPa), indicating impaired progression and weak push-off.

### Conclusion:

Butterfly diagram and three-foot-zone analysis revealed disease-specific gait dysfunctions in LDK. These included shorter steps, slower speed, wider base, reduced swing, and diminished single-limb support. Midfoot-dominant loading, reduced forefoot push-off, and flattened CoP trajectories were distinctive. Such functional assessments complement radiographs and may aid diagnosis and rehabilitation planning in ASD.



Characteristic gait patterns in LDK: flattened butterfly and mid-foot-dominant pressure.

### Paper #299. Detailed Analysis of Episode-Of-Care Inpatient Costs in Adult Spinal Deformity Surgery

Andrew H. Kim, MD; Ahmed Sulieman, MD; Breton Line; Shay Bess, MD; Richard Hostin, MD; Jeffrey Gum, MD; Renaud Lafage, MS; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Peter G. Passias, MD; D (deleted) Hamilton (Deleted), MD; Bassel G. Diebo, MD; Eric O. Klineberg, MD; Jeffrey P. Mullin, MD; Michael P. Kelly, MD; Alex Soroceanu, MD, FRCS(C); Robert K. Eastlack, MD; Alan H. Daniels, MD; Gregory M. Mundis Jr., MD; Themistocles S. Protopsaltis, MD; Munish C. Gupta, MD, MBA; Neel Anand, MD, Mch. Orth; David O. Okonkwo, MD, PhD; Jay D. Turner, MD, PhD; Frank Schwab, MD; Christopher I. Shaffrey, MD; Stephen J. Lewis, MD, FRCS(C); Praveen V. Mummaneni, MD; Christopher P. Ames, MD; Lawrence G. Lenke, MD; Sang Hun Lee, MD, PhD; Khaled M. Ke-baish, MD; International Spine Study Group,

### Hypothesis:

To provide reference points regarding direct costs associated with adult spinal deformity (ASD) surgery for surgeon and administrative education.

### Design:

Multi-center prospective study.

### Introduction:

ASD surgery is associated with costs that vary between surgeons and institutions. The purpose of this study was to provide a detailed analysis characterizing episode-of-care (EOC) costs and identify cost-drivers associated with the most common types of ASD surgery.

### Methods:

A total of 137 patients who underwent ASD surgery from 2018-2023 were analyzed. Cost modeling was performed on the most common ASD surgeries (T3- and T10-pelvis). Direct costs for each surgery were collected from hospital administrative records. Itemized charges were mapped into 1 of 4 categories: implants, biologics, inpatient services, and room and floor (R&F). Multivariable regression was performed to assess for factors contributing to total direct costs while controlling for age, sex, procedure, ASA grade, and length of stay (LOS).

### Results:

Among 137 patients, 67.2% (92/137) were female with mean age of 63.81 years and 12.80 levels fused. Median total direct costs for T3-pelvis (T3P) and T10-pelvis (T10P) were \$77,360.91 and \$55,966.59 respectively. Instrumentation accounted for the largest portion of EOC costs in both T3P and T10P surgeries (38.34% and 36.78%), followed by R&F (28.88% and 33.50%), and biologics (24.27% and 20.42%). After factoring for null charges, median total implant cost per level fused among all ASD surgeries was \$1,846.92, with pedicle screws, interbody cages, rods, and hooks accounting for 79.78%, 18.85%,

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2.56%, and 3.10% of total implant cost per segment fused, respectively. Adjusted multivariable regression revealed a significant relationship between total direct cost and number of levels fused and LOS ( $p < 0.001$ ), with each additional level increasing EOC costs by \$2,230.27 and each additional day spent inpatient increasing costs by \$2,186.78. Age, sex, and prep ASA grade had no significant impact on total costs ( $p > 0.05$ ).

## Conclusion:

Greater number of levels fused, and longer inpatient LOS are associated with increasing total EOC costs following ASD surgery. Characterizing potential cost-drivers of ASD surgery can allow surgeons to identify strategies to minimize expenditures while optimizing cost-effectiveness.

|                                 | T3 to Pelvis     |                              |                 | T10 to Pelvis    |                              |                 |
|---------------------------------|------------------|------------------------------|-----------------|------------------|------------------------------|-----------------|
|                                 | Median           | IQR                          | % of Total Cost | Median           | IQR                          | % of Total Cost |
| Pedicle Screws                  | 23,757.58        | 20,375.05 - 26,781.92        | 30.71           | 17,676.70        | 14,243.61 - 19,916.94        | 31.58           |
| Interbody Cages                 | 851.20           | 0.00 - 3,080.17              | 1.10            | 3,222.86         | 0.00 - 5,183.28              | 5.76            |
| Rods                            | 819.00           | 578.71 - 1,197.76            | 1.06            | 511.56           | 397.72 - 842.35              | 0.91            |
| Hooks                           | 972.17           | 906.72 - 1,226.37            | 1.26            | 0.00             | 0.00 - 0.00                  | 0.00            |
| <b>Total Implant</b>            | <b>29,657.38</b> | <b>25,481.68 - 31,757.39</b> | <b>38.34</b>    | <b>20,584.94</b> | <b>18,099.36 - 23,664.00</b> | <b>36.78</b>    |
| BMP                             | 14,756.24        | 13,678.40 - 15,045.00        | 19.07           | 7,233.74         | 7,156.59 - 10,135.92         | 12.93           |
| DBM                             | 3,727.62         | 2,928.43 - 7,272.38          | 4.82            | 3,231.34         | 2,154.22 - 5,447.92          | 5.77            |
| <b>Total Biologicals</b>        | <b>18,772.62</b> | <b>15,536.89 - 21,694.91</b> | <b>24.27</b>    | <b>11,428.10</b> | <b>9,348.56 - 16,825.38</b>  | <b>20.42</b>    |
| Pharmaceutical                  | 1,747.19         | 1,311.24 - 2,801.18          | 2.26            | 1,479.12         | 1,204.81 - 1,754.35          | 2.64            |
| Labs                            | 2,718.28         | 1,988.94 - 3,632.16          | 3.51            | 1,762.42         | 671.59 - 2,941.48            | 3.15            |
| Therapy                         | 601.71           | 396.31 - 792.04              | 0.78            | 626.50           | 372.21 - 940.55              | 1.12            |
| Radiology                       | 304.83           | 242.84 - 422.32              | 0.39            | 339.19           | 244.65 - 531.32              | 0.61            |
| Blood Products                  | 0.00             | 0.00 - 46.17                 | 0.00            | 0.00             | 0.00 - 58.63                 | 0.00            |
| <b>Total Inpatient Services</b> | <b>5,789.57</b>  | <b>4,598.64 - 7,083.77</b>   | <b>7.48</b>     | <b>4,429.45</b>  | <b>3,305.70 - 5,725.02</b>   | <b>7.91</b>     |
| Operating Room                  | 10,989.77        | 8,782.76 - 12,409.41         | 14.21           | 8,995.02         | 7,625.65 - 10,755.91         | 16.07           |
| Hospital Floor                  | 7,621.09         | 5,969.14 - 10,134.93         | 9.85            | 6,607.45         | 4,604.54 - 8,858.51          | 11.81           |
| SICU                            | 3,267.55         | 0.00 - 6,066.32              | 4.22            | 2,856.41         | 210.50 - 4,931.28            | 5.10            |
| <b>Total Room and Floor</b>     | <b>22,343.08</b> | <b>19,087.13 - 25,782.48</b> | <b>28.88</b>    | <b>18,747.97</b> | <b>15,141.89 - 23,727.61</b> | <b>33.50</b>    |
| <b>Total Costs</b>              | <b>77,360.91</b> | <b>70,38.36 - 80,673.69</b>  | <b>-</b>        | <b>55,966.59</b> | <b>49,824.68 - 63,568.61</b> | <b>-</b>        |

\*Values represented in United States dollars; IQR = interquartile range; BMP = bone morphogenetic protein; DBM = demineralized bone matrix; SICU = surgical intensive care unit.

Table 1. Itemized direct costs by procedure type

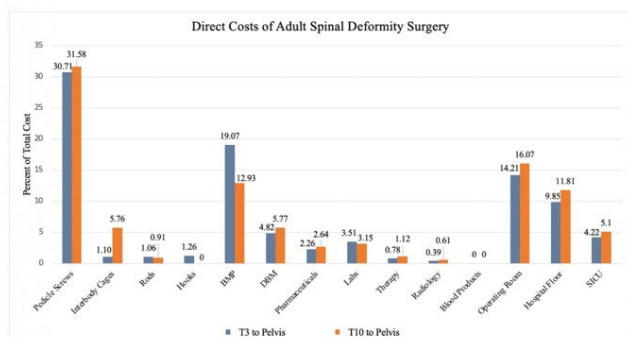


Figure 1. Percent breakdown of itemized direct costs of the most common adult spinal deformity surgeries

## Paper #300. Outcomes After Vertebral Body Tethering for AIS: A Comparison of Ideal Versus Acceptable Indications ±

John T. Braun, MD; Sofia Federico, BS

### Hypothesis:

Patients with ideal indications will have better outcomes than patients with 1, 2, or 3 risk factors.

### Design:

Retrospective 2010-23.

### Introduction:

Though vertebral body tethering (VBT) has been

proposed as an alternative to fusion surgery for AIS, ideal versus acceptable indications for this novel procedure have yet to be established. This study compared outcomes after VBT in AIS patients with ideal indications versus those with acceptable indications and 1, 2, or 3 risk factors.

### Methods:

One-hundred forty consecutive AIS patients treated with VBT for thoracic and thoracolumbar curves 33-72° had 2-11 year follow-up data. Four groups were analyzed: 1 group with ideal indications and no risk factors and 3 groups with acceptable indications and 1, 2, or 3 risk factors. Patients considered to have ideal indications had a curve magnitude of 40-60°, curve flexibility  $\geq 50\%$ , and skeletal maturity graded at Risser 0-2 or Sanders 3-5. Those patients considered to have acceptable indications had 1, 2, or 3 risk factors because they failed to meet 1, 2, or 3 of the ideal criteria. Radiographic outcomes were graded as excellent for curves  $\leq 25^\circ$ , good 26-39°, fair  $\geq 40^\circ$ , or poor  $\geq 50^\circ$  or if fusion was required.

### Results:

One-hundred forty AIS patients (118F/22M) with 199 curves were treated with VBT. Patients with ideal indications ( $n=42$ ) demonstrated 95% good or excellent outcomes despite a 27% overall tether rupture rate and 2% revision surgery. Patients with acceptable indications and 1 risk factor ( $n=72$ ) had 86% good or excellent outcomes with a 36% overall tether rupture rate and 15% revision surgery. Those with 2 risk factors ( $n=21$ ) had 67% good or excellent outcomes with a 33% overall tether rupture rate and 19% revision surgery. And those with 3 risk factors ( $n=5$ ) had 40% good or excellent outcomes with a 40% overall tether rupture rate and 40% revision surgery.

### Conclusion:

Outcomes after VBT for AIS were better in patients with ideal versus acceptable indications. Though the chance of a good or excellent outcome was best in patients with ideal indications (95%), this dropped steadily with the accumulation of 1 (86%), 2 (67%), or 3 (40%) risk factors ( $p < 0.001$ ). The risk of complications and revision surgery, especially fusion, was also the lowest in patients with ideal indications but steadily increased with the accumulation of risk factors.

± = E-Point Award Nominated Paper

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### Paper #301. Opioid Prescribing Mandate in Opioid Naïve Patients Can Translate to Improved Outcomes in the Opioid Non-Naïve Patients in Anterior Cervical Surgery: A Michigan Spine Surgery Improvement Collaborative (MSSIC) Study

*Anisse Chaker, MD; Michael Melhem, MD; Geoff Kahn, PhD; Jianhui Hu, PhD; Kari Jarabek, BSN, RN; Heegook Yeo, MD; Bhargav Ayloo, BS; Trevor Ruesch, BS; Adam Junn, BS; Jad G. Khalil, MD; Kevin Taliaferro, MD; Kenneth Easton, MD; Richard Easton, MD; Doris Tong, MD, MSc; Miguelangelo PerezCruet, MD; Noojan Kazemi, MD; Ilyas Aleem, MD; Muwaffak Abdulhak, MD; David Nerenz, PhD; Victor Chang, MD*

#### Hypothesis:

We hypothesize that implementation of a multi-institutional postoperative opioid prescribing limit would have a transitive effect in reducing long-term opioid use in opioid non-naïve patients undergoing anterior cervical surgery.

#### Design:

Retrospective cohort study using a multi-institutional registry.

#### Introduction:

We have previously demonstrated promise in utilizing multi-institutional prescribing guidelines to reduce opioid use in elective cervical surgeries. However, their impact on patients chronically dependent on opioids pre-operatively has not been analyzed. The goal of this study was to evaluate whether changes in prescribing patterns in the opioid naïve population would also translate to the non-naïve populations.

#### Methods:

The MSSIC database was queried from January 2022 to December 2024 for patients across 29 hospitals and ASCs who underwent 1-2 level anterior cervical surgery and had a pre-operative history of opioid use. Patients were grouped based on compliance with the MSSIC morphine milliequivalent (MME) cutoff for the cervical spine: MME  $\leq$  225 (averaged over 7 days). Outcomes analyzed included continued opioid use, post-operative complications, and patient reported outcomes (PROs). A multivariate analysis was conducted to control for confounders.

#### Results:

A total of 6,401 patients were included in this analysis. Prior to implementation of the mandate, only 44% of opioid non-naïve patients were prescribed 225 MME or less compared to 65% after. Opioid non-naïve patients who were compliant with the MME cutoff were less likely to have continued opioid use at 90 days compared to opioid non-naïve patients who were not MME cutoff compliant (OR 0.70; CI 0.55-0.88,  $p=0.001$ ). There was no significant difference in complications, ED visits, readmission,

± = E-Point Award Nominated Paper

or achieving minimal clinically important difference (MCID) in neck or arm pain.

#### Conclusion:

In a large, multi-institutional cohort, compliance with a postoperative opioid prescribing cutoff in the opioid naïve population had an observed benefit in the opioid non-naïve patients without adversely affecting outcomes. This demonstrates the feasibility and potential benefit of utilizing an opioid cutoff in both opioid naïve and non-naïve populations.

| Multivariate Outcomes of Patients after Anterior Cervical Surgery (n=6401) |                           |                 |
|--|---------------------------|-----------------|
| Outcome  | RR (95% CI)               | p-value         |
| Neck pain MCID, 90 days  | 1.15 (0.87 – 1.52)        | >0.05           |
| Arm pain MCID, 90 days   | 1.09 (0.80 – 1.49)        | >0.05           |
| Physical functioning MCID, 90 days   | 0.92 (0.70 – 1.20)        | >0.05           |
| Satisfied, 90 days   | 1.08 (0.79 – 1.48)        | >0.05           |
| Opioid use, 90 days  | <b>0.70 (0.55 – 0.88)</b> | <b>0.001</b>    |
| Return to work, 90 days  | 1.11 (0.69 – 1.76)        | >0.05           |
| Neck pain MCID, 1 year   | 0.87 (0.63 – 1.22)        | >0.05           |
| Arm pain MCID, 1 year  | 0.83 (0.58 – 1.20)        | >0.05           |
| Physical functioning MCID, 1 year  | 0.85 (0.61 – 1.19)        | >0.05           |
| Satisfied, 1 year  | 1.03 (0.73 – 1.44)        | >0.05           |
| Opioid use, 1 year   | 0.99 (0.74 – 1.31)        | >0.05           |
| Return to work, 1 year   | 0.95 (0.49 – 1.84)        | >0.05           |
| Readmission  | 1.09 (0.75 – 1.60)        | >0.05           |
| ED visit   | <b>0.76 (0.59 – 0.99)</b> | <b>&lt;0.05</b> |
| Any complication   | 1.02 (0.76 – 1.37)        | >0.05           |
| Return to OR   | 1.38 (0.73 – 2.59)        | >0.05           |

### Paper #302. Outcomes Following a Two-Year Implementation of a Multi-Institutional Enhanced Recovery After Surgery (ERAS) for Elective Spine Surgery: The Michigan Spine Surgery Improvement Collaborative (MSSIC) Experience

*Anisse Chaker, MD; Kylie Springer, MS; Kari Jarabek, BSN, RN; Michael Melhem, MD; Heegook Yeo, MD; Jianhui Hu, PhD; Kevin Taliaferro, MD; Jad G. Khalil, MD; Kenneth Easton, MD; Richard Easton, MD; Doris Tong, MD, MSc; Miguelangelo PerezCruet, MD; Noojan Kazemi, MD; Ilyas Aleem, MD; Muwaffak Abdulhak, MD; David Nerenz, PhD; Victor Chang, MD*

#### Hypothesis:

We hypothesize that implementation of a multi-institutional Enhanced Recovery After Surgery (ERAS) protocol for spine surgery would improve patient outcomes follow elective spine surgery.

#### Design:

Retrospective cohort study using a multi-institutional registry.

#### Introduction:

ERAS protocols are widely used across surgical specialties to improve perioperative outcomes, yet

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evidence in spine surgery on a institutional scale remains limited.

### Methods:

The Michigan Spine Surgery Improvement Collaborative (MSSIC) was queried for patients undergoing elective cervical or lumbar surgery between January 2022 and December 2024. Patients treated following ERAS protocols were compared to those who were not. Outcomes included discharge destination, length of stay, 30-day readmissions, complications, return to work, and achievement of minimal clinically important difference (MCID) in functional status. Multivariate analysis was utilized to control for confounders.

### Results:

15,633 patients were analyzed, including 10,816 lumbar and 4,817 cervical cases. Among lumbar patients, ERAS participation was associated with higher likelihood of home discharge (RR 1.06, 95% CI 1.03–1.09,  $p < 0.001$ ), return to work at 90 days (RR 1.24, 95% CI 1.01–1.52,  $p = 0.041$ ), and achievement of MCID in PROMIS functional score at 90 days (RR 1.11, 95% CI 1.00–1.24,  $p = 0.043$ ). Lumbar ERAS patients were also less likely to experience prolonged length of stay (RR 0.82, 95% CI 0.72–0.93,  $p = 0.003$ ). In the cervical cohort, ERAS was associated with increased home discharge (RR 1.11, 95% CI 1.07–1.15,  $p < 0.001$ ) and reduced risk of prolonged length of stay (RR 0.82, 95% CI 0.69–0.98,  $p = 0.032$ ), readmission (RR 0.65, 95% CI 0.43–0.98,  $p = 0.039$ ), and any complication (RR 0.71, 95% CI 0.54–0.94,  $p = 0.016$ ).

### Conclusion:

Implementation of a statewide ERAS protocol for elective spine surgery was associated with reduced hospitalization, lower complication and readmission rates, and better patient reported outcomes. These results highlight that ERAS pathways can be successfully scaled across diverse institutions and represent a practical model for enhancing spine quality of care.

| ERAS vs. No ERAS Outcomes Lumbar<br>(n=10,816) | RR          | [95% Conf. Interval] | p-value          |
|--|-------------|----------------------|------------------|
| Any Complication                               | 0.90        | 0.76-1.07            | 0.231            |
| Urinary Retention                              | 0.74        | 0.50-1.10            | 0.133            |
| SSI  | 0.82        | 0.50-1.34            | 0.432            |
| Readmission                                    | 1.11        | 0.89-1.39            | 0.364            |
| LOS 3+ days                                    | <b>0.82</b> | <b>0.72-0.93</b>     | <b>0.003</b>     |
| Discharge Home                                 | <b>1.06</b> | <b>1.03-1.09</b>     | <b>&lt;0.001</b> |
| Return to Work at 90 days                      | <b>1.24</b> | <b>1.01-1.52</b>     | <b>0.041</b>     |
| Patient Reported Outcomes at 90 days           |             |                      |                  |
| PROMIS MCID                                    | <b>1.11</b> | <b>1.00-1.24</b>     | <b>0.043</b>     |
| Satisfaction                                   | 1.04        | 0.99-1.09            | 0.134            |
| Leg Pain MCID                                  | 1.06        | 1.00-1.13            | 0.052            |
| Back Pain MCID                                 | 1.02        | 0.97-1.07            | 0.412            |

| ERAS vs. No ERAS Outcomes Cervical<br>(n=4,817) | RR          | [95% Conf. Interval] | p-value          |
|---|-------------|----------------------|------------------|
| Any Complication                                | <b>0.71</b> | <b>0.54-0.94</b>     | <b>0.016</b>     |
| Urinary Retention                               | 0.86        | 0.38-1.95            | 0.713            |
| Readmission                                     | <b>0.67</b> | <b>0.48-0.95</b>     | <b>0.023</b>     |
| Return to OR                                    | <b>0.58</b> | <b>0.38-0.90</b>     | <b>0.014</b>     |
| ED Visit  | <b>1.44</b> | <b>1.03-2.01</b>     | <b>0.033</b>     |
| LOS 3+ days                                     | <b>0.82</b> | <b>0.69-0.98</b>     | <b>0.032</b>     |
| Discharge Home                                  | <b>1.11</b> | <b>1.07-1.15</b>     | <b>&lt;0.001</b> |
| Patient Reported Outcomes at 90 days            |             |                      |                  |
| PROMIS MCID                                     | 1.07        | 0.85-1.34            | 0.560            |
| Satisfaction                                    | 1.04        | 0.99-1.09            | 0.103            |
| Arm Pain MCID                                   | 1.00        | 0.85-1.17            | 0.997            |

# EXHIBITORS

We encourage you to visit the exhibits throughout the meeting to learn more about their technological advances.

The IMAST Exhibit Hall is located in Constitution Hall 106.

## VISIT THE SRS MEMBERSHIP BOOTH

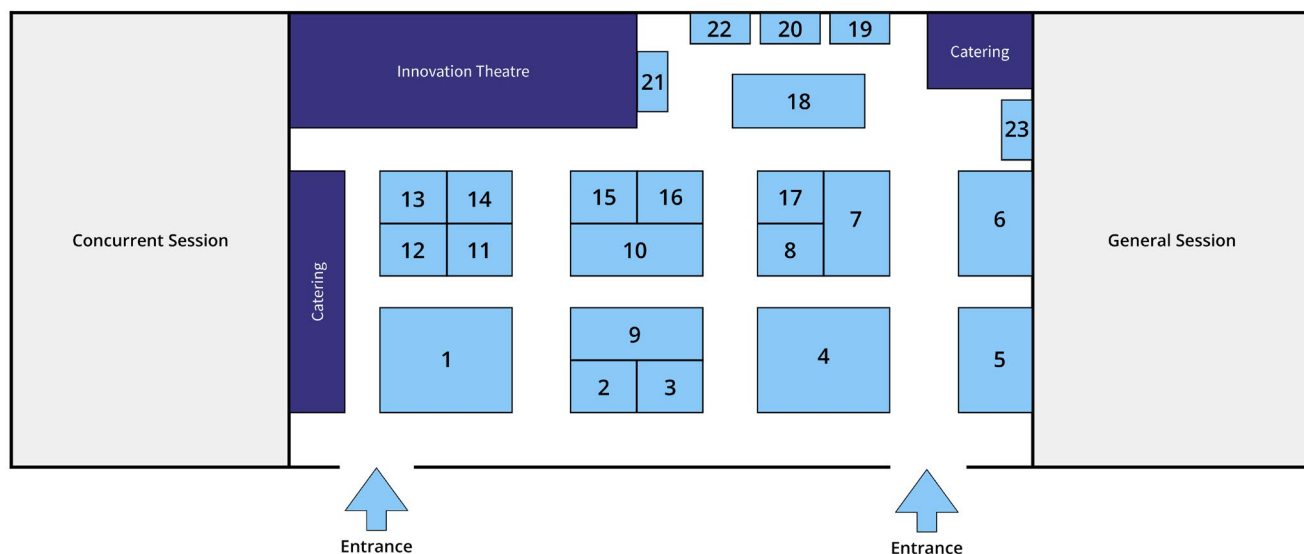
Stop by the SRS Booth (#23) in the Exhibit Hall for information about becoming an SRS member, upcoming meetings, and more.

### Hours:

Wednesday, April 15 18:00 - 20:00 (Welcome Reception 18:00 - 20:00)

Thursday, April 16 08:30 - 17:30

Friday, April 17 08:30 - 16:30



| Company Name     | Booth # |
|------------------|---------|
| Medtronic        | 1       |
| SI-BONE          | 2       |
| Enovis           | 3       |
| Globus Medical   | 4       |
| ATEC Spine       | 5       |
| Orthofix         | 6       |
| DePuy Synthes    | 7       |
| Mdus.ai          | 8       |
| VB Spine         | 9       |
| 8i Robotics Inc. | 10      |
| Isto Biologics   | 11      |
| Carlsmed         | 12      |

| Company Name                             | Booth # |
|--|---------|
| Brainlab                                 | 13      |
| ForeThought Medical Technology Co., Ltd. | 14      |
| Woven Orthopedic Technologies            | 15      |
| Momentum Health                          | 16      |
| MRIguidance                              | 17      |
| Highridge Medical                        | 18      |
| Canadian Spine Society                   | 19      |
| Higgy Bears                              | 20      |
| UpSurgeOn                                | 21      |
| Cresco Spine                             | 22      |
| SRS Membership                           | 23      |

## EXHIBITOR DESCRIPTIONS

### 8i Robotics Inc. | Booth #10

451-3550 Victoria Park Ave  
Toronto, ON M2H 2N5, Canada  
[www.8irobotics.com](http://www.8irobotics.com)

8i Robotics Inc. is pioneering the future of spine and orthopedic surgery through the development of a revolutionary multi-arm humanoid robot system. By integrating state-of-the-art multi-arm robotics with electromagnetic navigation and high-resolution optical imaging, we provide a modular platform designed for unprecedented surgical precision and safety. The system features multiple 7+ degree-of-freedom robotic arms capable of operating under direct surgeon feedback. These arms utilize interchangeable end-effectors for various payloads, including ultrasonic cutting knives and pedicle screwdrivers. Our industry-first electromagnetic navigation allows for real-time, submillimeter tracking of instruments without requiring a direct line-of-sight, ensuring minimal disruption to existing surgical workflows. Further enhancing clinical clarity, our humanoid "head" utilizes LIDAR and high-zoom cameras to provide near-instantaneous optical measurements and a crystal-clear view of the surgical field. This is supported by a built-in preoperative planning module.

Guided by a team of industry veterans with a proven track record in surgical technology, 8i Robotics is committed to reducing complications such as neurovascular injury and hardware failure. Our mission is to redefine the surgical landscape by offering automated solutions that improve patient outcomes and enhance case throughput.

Implanet is the leader in sublaminar band technology with >10 years of success with the Jazz Band System in pediatric deformity surgery and now offers the latest in ultrasonic bone cutting technology, the Olea Ultrasonic Osteotome, and a full line posterior fixation system, the Jazz Spinal System.

Disclaimer: The 8i Robotics' system is currently not approved for sale in the USA or Canada.

### ATEC Spine | Booth #5

1950 Camino Vida Robles  
Carlsbad, CA 92008 USA  
[www.atecspine.com](http://www.atecspine.com)

ATEC is a medical device company dedicated to revolutionizing the approach to spine surgery through innovation. ATEC's Organic Innovation Machine™ is the greatest concentration of spine knowhow in the industry and committed to the creation of clinical distinction. Leveraging 100% spine focus and expertise, we seek to improve spine surgery by rethinking, redesigning and seamlessly integrating the technologies required from the ground up. The innovation that results from that process is being rapidly adopt-

ed because, like us, spine surgeons covet informatic and procedural sophistication that enables more predictable, more reproducible care. Our vision is to be the standard bearer in spine. Visit our website for more information: [www.atecspine.com](http://www.atecspine.com)

### Brainlab | Booth #13

5 Westbrook Corporate Ctr  
Westchester, IL 60154  
[www.brainlab.com](http://www.brainlab.com)

At Brainlab, we digitize medical workflows from diagnosis to therapy, and our innovative ecosystem forms the basis for modern healthcare technology. We help healthcare providers build three-dimensional patient-specific models with data that is structured, mapped and aggregated with industry-leading artificial intelligence. This builds the basis of our navigation system for the human body, clinicians can safely remove brain tumors, place screws in the spine precisely, and irradiate breast tumors with millimetric precision.

Our robotics and mixed reality technologies and expertise allow users to connect and innovate between the digital and physical worlds. In addition, Brainlab technologies power the collection of structured long-term data and medical registries. Through the neuroscience of play, Brainlab advances clinical training and education, promoting the adaptation to technological advances and creating digital models of complete interventions. Our digital ecosystem is an open interface and forms a framework for third parties to accelerate innovation in other clinical areas as well.

Brainlab systems are established in around 4000 hospitals in 120 countries to offer doctors and patients better treatment possibilities. At the forefront of health technology for over 35 years, the company headquarters are in Munich, and we employ around 2000 people of 87 nationalities in 25 locations.

For more information, visit [Brainlab](http://Brainlab) or follow us on [LinkedIn](https://www.linkedin.com/company/brainlab), [Facebook](https://www.facebook.com/brainlab) and [Instagram](https://www.instagram.com/brainlab).

### Canadian Spine Society | Booth #19

PO Box 1053  
Markdale ON N0C 1H0  
[spinecanada.ca](http://spinecanada.ca)

The Canadian Spine Society (CSS), for twenty-six years, has been a collaborative national society for spine care in Canada, bringing together orthopaedic surgeons, neurosurgeons, researchers and allied spine professionals with a shared commitment to excellence in patient care, research, and education. Guided by a vision to be key opinion leaders in spine care, research, and education, CSS comprises surgeons working alongside physiatrists, physiotherapists, chiropractors, researchers and other experts in

## EXHIBITOR DESCRIPTIONS

a truly multidisciplinary environment. CSS represents a distinctly Canadian model—collegial, evidence-driven, and built on collaboration across specialties within a modern single payer healthcare system.

A major strength of CSS is its prospective registry, CSORN, the Canadian Spine Outcomes and Research Network. Through multicentre research and a national outcomes registry, CSORN evaluates both surgical and non-operative management across a wide range of spinal conditions, generating the kind of real-world evidence that advances quality, informs best practice, and elevates Canada's voice internationally. With more than 18,500 patients prospectively enrolled, 23 participating centres, and 86 publications to date, CSORN gives CSS exceptional research depth and a powerful platform for global engagement.

The CSS has also led the recent development of the world's first post-graduate Spine Surgery Diploma (Area of Advanced Competency) with the Royal College of Physicians and Surgeons of Canada.

The CSS is a society where scientific rigor and practical experience come together to shape better care for patients with spinal disorders in Canada and worldwide.

### Carlsmed | Booth #12

1800 Aston Ave. Suite 100  
Carlsbad, CA 92008 USA  
[www.carlsmed.com](http://www.carlsmed.com)

Carlsmed is a high-growth medical technology leader and pioneer in the personalized spine surgery market. The company is transforming spine surgery to improve outcomes and decrease the cost of healthcare for spine surgery and beyond. Carlsmed's mission is to revolutionize the standard of care in spine surgery by providing cutting-edge solutions tailored to the unique needs of each patient. The Company's innovative aprevo® Technology Platform combines proprietary AI-driven software with patient-specific fusion devices designed for better surgical results, reduced revisions and improved long-term outcomes. aprevo® empowers surgeons to personalize procedures to align with their unique preferences while addressing each patient's individual needs. The platform supports a broad spectrum of surgical techniques, offering precision solutions for anterior, posterior, and lateral approaches.

### Cresco Spine | Booth #22

Havenstraat 30  
Schiedam, 3115 HD Netherlands  
[www.cresco-spine.com](http://www.cresco-spine.com)

Cresco Spine develops growth-friendly dynamic implant solutions for early onset scoliosis (EOS) and adolescent scoliosis.

Our flagship technology, the Spring Distraction System (SDS™), is a proprietary implant, providing continuous dynamic spinal distraction and physiologically guiding spinal growth while correcting scoliosis three-dimensionally and supporting thoracic development.

Unlike conventional growth systems that require repeated surgical or non-surgical lengthening interventions, SDS™ provides integrated corrective distraction that preserves spinal mobility and promotes normal growth and thoracic expansion. Including in the most complex scoliosis cases.

A prospective cohort of over 150 EOS patients, with up to 10 years of follow-up, demonstrates superior spinal growth, significantly fewer complications, and a reduced surgical burden compared to existing systems. This translates into fewer hospital visits, improved quality of life for patients and families, and substantially lower healthcare costs. Recent studies also demonstrated intervertebral disc height preservation and spinal mobility at graduation, emphasizing the longer term positive impact of SDS™.

The U.S. Food and Drug Administration (FDA) granted SDS Breakthrough Device Designation and recently cleared SDS™ through the 510(k) pathway. Orthopedics This Week recognized SDS™ with its Best Technology in Spine Award. First clinical cases outside the Netherlands are planned in the US and Canada.

Cresco Spine's mission is to set a new standard in scoliosis care, significantly improving the clinical outcome and quality of life, as well as lowering the burden of disease for these young patients and their parents.

For more information, visit [www.cresco-spine.com](http://www.cresco-spine.com) or connect with us on LinkedIn @CrescoSpine.

### Depuy Synthes | Booth #7

325 Paramount Drive  
Raynham, MA 02767 USA  
<https://www.jnjmedtech.com/en-US/companies/depuy-synthes>

DePuy Synthes provides one of the most comprehensive orthopaedics portfolios in the world that helps heal and restore movement for the millions of patients we serve. DePuy Synthes solutions, in specialties including joint reconstruction, trauma, extremities, craniomaxillofacial, spinal surgery and sports medicine, in addition to the VELYS™ Enabling Tech portfolio, are designed to advance patient care while delivering clinical and economic value.

## EXHIBITOR DESCRIPTIONS

### Enovis | Booth #3

2900 Lake Vista Drive, Suite 200  
Lewisville, TX 75067 USA  
[www.enovis.com](http://www.enovis.com)

We're Enovis—a global medical technology innovator dedicated to improving lives by developing clinically differentiated solutions that enhance patient outcomes and restore motion for life. We strive to make each day better by partnering with the brightest minds in health to advance care that is smarter, personalized, and more effective, while improving operational efficiency for surgeons and clinicians around the world. We do this through our extraordinary talent, a relentless focus on innovation, strategic acquisitions, and a common culture of continuous improvement.

### Forethought Medical Technology Co., Ltd. | Booth #14

19F, Building, ShanJin Financial Plaza, No.1198, Yang-ShuPu Road, Yangpu District  
Shanghai, China  
[www.forethoughtmed.com](http://www.forethoughtmed.com)

Guard your health, Create the Future

Forethought (Shanghai) Medical Technology Co., Ltd. is a high-tech company that has long been committed to the research, development, production, sales and service of intelligent, portable and innovative medical devices.

The company has a research and development team of dozens of scientists, including medical research experts, clinical medicine experts, electrical engineering PhD, algorithmic research computer PhD, experts in the field of medical rehabilitation, etc., with a strong strength of cutting-edge scientific and technological research and development of medical devices.

Forethought Medical is committed to developing intelligent and portable medical high-tech products. Our independent research and development include revolutionary smart optical sensing technology, precise terrain scanning technology, multi-sensor data fusion technology, and leading digital twin technology. We've created "ScoliMatrix 3D Detection System" making spinal detection simpler, safe and lighter than ever before.

### Globus Medical | Booth #4

2560 General Armistead  
Audubon, PA 19403 USA  
[www.globusmedical.com](http://www.globusmedical.com)

Globus Medical Company Description - Globus Medical, Inc. is a leading musculoskeletal technology company based in Audubon, PA. The company was founded in 2003 by an experienced group of

engineers and business leaders who believed that significantly better patient outcomes in spine surgery were possible. Today Globus Medical is committed to creating products that enable surgeons to promote healing in patients with musculoskeletal disorders. At Globus Medical, listening to customers and responding with action is paramount, and the company is relentlessly focused on solving unmet customer and patient needs with world class engineering and technology.

### Higgy Bears | Booth #20

Kalamazoo, MI, USA  
[Higgybears.com](http://Higgybears.com)

Higgy Bears is a global support initiative founded by scoliosis patient Lauren Higginson—built on a simple mission: making scoliosis bearable. Created from her own experience of feeling alone as a child navigating diagnosis, Higgy Bears provides comfort, connection, and community to kids and families around the world. A Higgy Bear is a teddy bear designed to reflect a child's journey—each one includes either a mini scoliosis back brace or a surgical scar, helping kids feel seen, understood, and less alone. Today, Higgy Bears has donated nearly 70,000 free mini bears to kids and teens in over 200 countries, serving as an entry point into something much bigger than a stuffed animal.

Each Higgy Bear represents connection, understanding, and belonging. Through Higgy Bears and the broader community, children and families are introduced to others who truly understand the emotional and social challenges of scoliosis—helping reduce isolation, build confidence, and improve overall well-being alongside medical care. This connection often becomes a turning point in how a child copes with diagnosis, treatment, and daily life.

Higgy Con, now the largest gathering of scoliosis patients in the world, brings this mission to life. What began with 160 attendees has grown to over 600 already registered (as of March), with an expected 1,000 participants, including international families traveling from around the world. The event brings together kids, teens, parents, and experts for two days of connection, education, and shared experience. Families consistently describe Higgy Con as life-changing—many meeting someone like them for the very first time. We also offer Higgy Friends, with over 30 local support groups (primarily across the U.S.), providing in-person opportunities for kids to build friendships and connect within their own communities.

Higgy Bears exists to support the emotional side of scoliosis, which is just as critical as physical treatment. By fostering connection, community, and confidence, we help patients feel seen, supported,

## EXHIBITOR DESCRIPTIONS

and stronger throughout their journey—and partner with providers to help make scoliosis more bearable for the patients you care for every day.

### Highridge Medical | Booth #18

10225 Westmoor Drive  
Westminster, CO 80021 USA  
[www.highridgemedical.com](http://www.highridgemedical.com)

Highridge Medical is committed to improving spine care by partnering with the surgeon community to drive innovation. The company has a strong portfolio supported by extensive clinical evidence, with solutions for complex spine that include the comprehensive Vital™ thoracolumbar and Virage® OCT spinal fixation systems and The Tether™ vertebral body tethering (VBT) system, a non-fusion application for pediatric scoliosis. The compelling motion preservation platform features the Mobi-C® cervical disc and the activL® lumbar disc. Additionally, Highridge provides solutions for treating degenerative spine conditions, with support for minimally invasive surgery, including the FlareHawk® expandable cage, and the TrelOss® family of porous titanium interbody cages. The portfolio is supported by a suite of biologics and enabling technologies, such as the PathKeeper optical navigation system, designed to improve surgical workflows and clinical outcomes. For more information on Highridge products, our best-in-class surgeon training and education programs, or our committed commercial team, visit [www.highridgemedical.com](http://www.highridgemedical.com).

### Isto Biologics | Booth #11

42 South St. Ste. 1  
Hopkinton, MA 01748, USA  
[www.istobiologics.com](http://www.istobiologics.com)

Isto Biologics is a 100% biologics-focused company dedicated to helping patients heal faster. With a portfolio comprised of the market leading autologous concentration device as well as a differentiated bone grafting portfolio that offers functional solutions to meet patient and procedural challenges, Isto is equipped to offer a range of customizable options to surgeons of varying specialties.

### Mdus.ai | Booth #8

114 S 1st Street  
Brooklyn, NY 11249  
[www.mdus.ai](http://www.mdus.ai)

[MDus.ai](http://www.mdus.ai) transforms how doctors communicate with patients through personalized medical avatars, medically reviewed content, and AI-powered video experiences. We turn complex medical information into clear, scalable, and patient-specific videos that improve patient understanding, reduce repeated explanations, and extend care beyond the clinic visit.

### Medtronic | Booth #1

1800 Pyramid Pl.  
Memphis, TN 38738 USA  
[www.medtronic.com](http://www.medtronic.com)

We are redefining spine and cranial surgery through the convergence of data, AI-driven planning, navigation, imaging, robotics, and implants to reduce surgical variability and deliver personalized care. Through the AiBLE™ smart ecosystem, we optimize every phase of care—before, during, and beyond surgery—to achieve more predictable, patient-specific outcomes. Our goal is to set new standards in spine and cranial surgery, so patients can return to fuller, more active lives with confidence.

### Momentum Health | Booth #16

2727 Rue Saint Patrick Street  
Montréal, QC H4C2M6, Canada  
[momentum.health](http://momentum.health)

Momentum Health is a Montreal-based medical technology company bringing objective, functional assessment to spine care. Co-founded by a spine surgeon, the company's FDA-cleared platform, Momentum Spine, generates photorealistic 3D digital twins of the patient's body from a 45-second smartphone video — capturing spinal alignment, posture, predicted radiographic parameters, and dynamic movement metrics without radiation or specialized equipment.

Clinicians use the platform to inform patient selection, surgical planning, and longitudinal outcome tracking. Remote monitoring capabilities allow care teams to follow patients between visits through at-home functional assessments and patient-reported outcomes delivered within the mobile app.

Deployed across leading academic spine centers in North America and internationally, Momentum Health is working to establish a new standard for how spine care is measured, monitored, and delivered. To learn more about Momentum Spine, visit our website at [momentum.health](http://momentum.health)

### MRIGuidance | Booth #17

Maliesingel 23  
Utrecht 3581 BG, Netherlands  
[www.mriguidance.com](http://www.mriguidance.com)

MRIGuidance is a Dutch MedTech company pioneering radiation-free bone imaging with BoneMRI, the world's first software that creates 3D CT-like images of the hip and spine from MRI scans. Designed for adolescents and adults, BoneMRI enhances diagnostics and improves surgical planning and navigation, all without harmful radiation while improving workflow efficiencies.

## EXHIBITOR DESCRIPTIONS

### Orthofix | Booth #6

5770 Armada Drive  
Carlsbad, CA 92008 USA  
[www.seaspine.com](http://www.seaspine.com)

Orthofix is a global medical technology company headquartered in Lewisville, Texas. By providing medical technologies that heal musculoskeletal pathologies, we deliver exceptional experiences and life-changing solutions to patients around the world. Orthofix offers a comprehensive portfolio of spinal hardware, bone growth therapies, specialized limb reconstruction solutions, biologics and enabling technologies, including the 7D FLASH™ navigation system. To learn more, visit [Orthofix.com](http://Orthofix.com) and follow on [LinkedIn](#).

### SI-BONE | Booth #2

471 El Camino Real  
Santa Clara, CA 95050 USA  
[www.si-bone.com](http://www.si-bone.com)

SI-BONE, Inc. is a global leading medical device company specializing in *Sacropelvic Solutions*™. SI-BONE utilizes its *iFuse Technology*® to develop products to treat SI joint dysfunction, spinopelvic fixation, and pelvic trauma. The *iFuse Implant System*®, a proprietary minimally invasive surgical implant system to fuse the sacroiliac joint, was launched in 2009 to treat sacroiliac joint dysfunction. The *iFuse Implant System* portfolio has expanded to include *iFuse Bed-rock Granite*® to provide a solid foundation in spinal deformity surgery, and *iFuse TORQ*® for treatment of pelvic trauma including sacral fragility and insufficiency fractures.

### SRS Membership | Booth #23

555 E Wells St. Suite 1100  
Milwaukee, WI 53202 USA  
[www.srs.org/membership](http://www.srs.org/membership)

Stop by for information about becoming an SRS member, upcoming meetings, and more.

### UpSurgeOn | Booth #21

Via Cascina Venina 7  
20057 Assago (MI), Italy  
[www.upsurgeon.com](http://www.upsurgeon.com)

UpSurgeOn is a surgical simulation company founded in 2017, with the mission of making surgical excellence accessible globally. By offering cutting-edge hyper-realistic simulators and immersive VR/AR experiences, it specializes in fields such as Neurosurgery, Spine Surgery, Plastic Surgery, and others. UpSurgeOn helps professionals enhance their psychomotor skills, improve patient safety, and reduce costs for healthcare providers.

### VB Spine | Booth #9

600 Hope Parkway  
Leesburg, VA 20175 USA  
[www.strykerspine.com](http://www.strykerspine.com)

VB Spine is the largest privately held spine company and among the largest family-owned medical technology companies in the world. Guided by the belief that everything starts with the patient, we focus on delivering thoughtful solutions that support surgeons and care teams every day.

### Woven Orthopedic Technologies | Booth #15

750 E. Main Street, Suite 620  
Stamford, CT 06902 USA  
[www.wovenorthopedics.com](http://www.wovenorthopedics.com)

Woven Orthopedic Technologies is a medical device company focused on improving fixation in spine surgery through a simple, practical approach to challenges associated with compromised pedicle screw fixation.

The company's flagship solution, the Ogmend® Implantable Sleeve, is designed to augment the bone-implant interface for pedicle screws without the need for cement augmentation or expandable hardware. The device is intended for use in cases where pedicle screw fixation has been compromised, such as loosening, back-out, or breakage.

Developed with surgeon workflow in mind, the sleeve is designed to integrate with standard surgical techniques. When implanted, it utilizes principles of interference fit, surface area contact, and pressure distribution to help restore stability at the screw-to-bone interface and support subsequent healing.

Woven Orthopedics has supported its technology with extensive biomechanical testing, animal studies, and a prospective clinical trial with published results. The system is currently being used across a growing number of spine centers, with over 1400 sleeves implanted in the United States, and thousands more internationally.

## HANDS-ON WORKSHOPS

IMAST delegates are encouraged to attend the Hands-On Workshops (HOWs). Each workshop is programmed by a single-supporting company and will feature presentations on topics and technologies selected by the company. Catering will be served at each Workshop.

Please note: CME credits are not available for Hands-On Workshops.

|                | Thursday, April 16, 2026 | Friday, April 17, 2026 |
|----------------|--------------------------|------------------------|
| <b>MORNING</b> | <b>07:30 - 08:30</b>     |                        |
| Room 104 B     | Cresco Spine             |                        |
| Room 104 C     | ATEC Spine               |                        |
| Room 104 D     | Highridge Medical        |                        |
| <b>LUNCH</b>   | <b>12:00 - 13:00</b>     | <b>12:00 - 13:00</b>   |
| Room 104 A     | Orthofix                 |                        |
| Room 104 B     | Globus Medical           |                        |
| Room 104 C     | DePuy Synthes            | ATEC Spine             |
| Room 104 D     | Medtronic                | Highridge Medical      |

Meeting room locations are subject to change

### THURSDAY, APRIL 16 | 07:30 - 08:30

#### **CRESCO SPINE** | ROOM 104B

##### **What Happens When You Let the Spine Move? A Decade of Continuous Dynamic Distraction in EOS**

Faculty: René M. Castelein, MD, PhD, Tom P.C. Schlösser, MD, PhD

What if surgical treatment of Early Onset Scoliosis could optimize growth potential, preserve spinal mobility, reduce surgical burden, and maintain correction without repeated interventions? Our faculty Rene Castelein and Tom Schlösser share 25+ years of research and a decade of clinical experience with the Spring Distraction System (SDS™) at UMC Utrecht. From scoliosis etiology to long-term outcomes, and a look at an exciting next phase in research that may reshape how we approach spinal deformity correction.

#### **ATEC SPINE** | ROOM 104C

##### **Beyond Implants: Advancing Pediatric Spine Patient Positioning**

Faculty: Kenneth Illingworth, MD and Lionel Metz, MD

Join Drs. Lionel Metz and Ken Illingworth for a case-based discussion on advancements in patient positioning for pediatric spine surgery. The session will explore the evolution of positioning strategies designed to address the unique anatomy and surgical objectives of pediatric patients. Discussion will include current approaches as well as future opportunities to improve procedural workflow, support surgical goals, and ultimately enhance patient outcomes.

#### **HIGHRIDGE MEDICAL** | ROOM 104D

##### **Integrating Efficiency, Technology and AI into your Practice**

Faculty: Han Jo Kim, MD, Rajiv Sethi, MD, Suken Shah, MD

This workshop is designed for surgeons seeking to strategically integrate efficiency-driven workflows, emerging technologies, and artificial intelligence into modern clinical practice. Using complex spine deformity surgery as the central framework, the session will examine how data-driven decision-making, AI-enabled planning, and technology integration are reshaping outcomes, economics, and surgical execution.

### THURSDAY, APRIL 16 | 12:00 - 13:00

#### **ORTHOFIX** | ROOM 104A

##### **Predictive Planning Meets Machine Vision**

Faculty: Eric Klineberg, MD, Camilo Molina, Gregory Mundis, MD, Venu Nemani, MD, PhD

The session will demonstrate how SMAIO predictive alignment and rod contouring strategies perfectly set the stage for execution using 7D FLASH Navigation and Orthofix Fixation systems.

# HANDS-ON WORKSHOPS

**THURSDAY, APRIL 16 | 12:00 - 13:00**

**GLOBUS MDEICAL | ROOM 104B**

## Current Controversies in Adult and Pediatric Deformity

*Moderator: Hamid Hassanzadeh, MD*

*Faculty: Noelle Larson, MD, Rajiv Sethi, MD*

This engaging workshop will be focused on discussing cases and techniques involving current controversies in the treatment of adult and pediatric deformity. The talks will include planning, interoperative deformity correction techniques and pediatric techniques such as vertebral body tethering.

**DEPUY SYNTHES | ROOM 104C**

## Architects of the New Era: Driving Innovation in Complex Spine

*Moderator: Suken A. Shah, MD*

*Faculty: Amit Jain, MD, MBA, Isador Lieberman, MD, Alekos Theologis, MD*

Discover how innovation is redefining what's possible in complex spine surgery. This dynamic IMAST workshop brings together leading surgeons to showcase the real-world impact of active robotics, navigation, and cutting-edge surgical techniques across pediatric and adult deformity. Through case discussions and interactive audience engagement, our expert faculty will highlight how technology is opening new pathways to cervical and thoracic care, with increased precision and the potential for better patient outcomes. Join us for an energizing, future-focused session that blends expert insights with practical, case-based learning.

**MEDTRONIC | ROOM 104D**

## Transformational Advances in Posterior Spinal Fixation

*Moderator: Reg Haid, MD*

*Faculty: David Polly, MD, Jeff Gum, MD, Lawrence Lenke, MD, and Christopher Shaffrey, MD*

Join a panel of world-renowned spine surgeons for a dynamic 60-minute discussion highlighting the latest transformational advances in posterior spinal fixation. This expert-led session will explore innovations across cervical, thoracic, and thoracolumbar applications, including next-generation pedicle screw technologies, reduction strategies, deformity correction, and the evolving role of navigation and robotics. Moderated by leading experts in the field, this Lunch and Learn offers a comprehensive look at where posterior fixation is today, and where it is headed.

**FRIDAY, APRIL 17 | 12:00 - 13:00**

**ATEC SPINE | ROOM 104C**

## EOS Insight for Surgical Decision Making: Aligning Clinical Judgment and Data Science

*Faculty: Han Jo Kim, MD, Darryl Lau, MD, Eric Oermann, MD, and Kevin Vincent, PhD*

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.

**HIGHRIDGE MEDICAL | ROOM 104D**

## VBT: Defining indications and Redefining Outcomes

*Faculty: Amer Samdani, MD, Firoz Miyanji, MD, Kevin Smit, MD*

This case-based workshop is designed for surgeons seeking to refine decision-making and technical execution in Vertebral Body Tethering (VBT). Faculty will lead an in-depth discussion centered on patient selection criteria and the key indications that influence VBT candidacy. Emphasis will be placed on identifying specific clinical and radiographic parameters that guide preoperative planning and more predictable outcomes.

The session is structured to provide practical, experience-based insights that surgeons can directly integrate into their deformity practice, reducing a learning curve

# INNOVATION UPDATES

Please join SRS industry partners for updates on innovations by the sponsoring company. Innovation Updates take place in the Innovation Theatre which is located in the Exhibit Hall.

*Please note: CME credits are not available for Innovation Updates.*

## THURSDAY, APRIL 16

### 08:30 - 08:40 | ENOVIS

#### A Novel Hybrid Brace for AIS: Spinamic

Spinamic™ rethinks traditional bracing by integrating dynamic support with structural control — designed to provide in-brace correction while supporting improved wearability for adolescents with idiopathic scoliosis. Presented by Dr. Sam Yeol Chang MD, Associate Professor, Seoul National University Hospital, South Korea.

### 09:35 - 09:45 | CARLSMED

#### aprevo® AI-Enabled Planning and Personalized Interbody Devices: Two-Year Reoperation Rates in Adult Deformity

Join our Tech Talk with Zeeshan M. Sardar, MD, who will present two-year reoperation rates in adult deformity patients treated using aprevo® AI-enabled surgical planning and patient-specific interbody devices.

This session will explore how personalized planning and patient-specific devices are being used to support surgical decision-making and potentially improve long-term outcomes in complex spine deformity cases.

### 11:45 - 11:55 | HIGHRIDGE MEDICAL

#### United Healthcare Policy Update: What this means for VBT patients and families

Effective April 1, one of the largest healthcare providers will update its policy to reflect positive coverage for VBT, using The Tether™. Join Dr. John T. Braun to learn how patients and families may be impacted and what free resources are available for patients currently working through the pre-authorization process.

## FRIDAY, APRIL 17

### 11:40 - 11:50 | GLOBUS MEDICAL

#### Elevating Efficiency: Navigated Oscillation with DuraPro™ and Excelsius® Technology

Join us for a dynamic look at how the DuraPro™ Oscillating System—now integrated with Excelsius® navigation (ExcelsiusGPS and ExcelsiusHub)—is helping to reshape procedural efficiency. This next-gen platform is designed to enable controlled bone cutting, powered disc removal, and robotic pilot hole creation—all with real-time visualization. Learn how leading Spine surgeons are using DuraPro to bolster efficiency, confidence, and surgical accuracy.

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## ABOUT SRS

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 1,600 health care professionals.

### MISSION STATEMENT

The purpose of the Scoliosis Research Society is to foster the optimal care of all patients with spinal deformities.

### MEMBERSHIP

SRS is open to orthopaedic surgeons, neurosurgeons, researchers and allied health professionals who have a practice that focuses on spinal deformity.

**Candidate Fellowship (membership)** is open to orthopaedic surgeons, neurosurgeons and to researchers in all geographic locations who are willing to commit to a clinical practice which includes at least 20% spinal deformity. Candidate Fellows stay in that category for three- five years, during which time they must demonstrate their interest in spinal deformity and in the goals of the Scoliosis Research Society. Candidate Fellows may serve on SRS committees. After a minimum three years, those who complete all requirements are eligible to apply for Active Fellowship in the Society. Candidate Fellowship does not include the right to vote or hold office.

**Active Fellowship (membership)** requires the applicant to have fulfilled a minimum three-year Candidate Fellowship and have a practice that is 20% or more in spinal deformity. Only Active Fellows may vote and hold elected offices within the Society.

**Associate Fellowship (membership)** is for distinguished members of the medical profession including nurses, physician assistants, as well as orthopaedic surgeons, neurosurgeons, scientists, engineers and specialists who have made a significant contribution to scoliosis or related spinal deformities who do not wish to assume the full responsibilities of Active Fellowship. Associate Fellows may not vote or hold office, but may serve on committees.

Visit [www.srs.org/membership](http://www.srs.org/membership) for membership requirement details.

## PROGRAMS AND ACTIVITIES

SRS is focused primarily on education and research that include the Annual Meeting, the International Meeting on Advanced Spine Techniques (IMAST), Worldwide Conferences, a Global Outreach Program, 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 [www.srs.org](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. For more information, please visit the SRS website at [www.srs.org](http://www.srs.org).

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**61<sup>st</sup> SYDNEY** October 6-10, 2026  
ANNUAL MEETING *Australia*



*Powered by the Scoliosis Research Society*

**International Meeting on  
Advanced Spine Techniques**

# MEETING OVERVIEW

All IMAST sessions take place at the Metro Toronto Convention Centre (MTCC), Level 100

| WEDNESDAY, APRIL 15, 2026 |  | LOCATION   |
|---------------------------|--|--|
| 12:30 - 18:30             | Registration Open  | Level 100 Foyer                                      |
| 13:00 - 18:00             | Speaker Ready Room Open  | Room 103 B   |
| 18:00 - 20:00             | Exhibit Hall Open  | Constitution Hall 106                                |
| 14:30 - 15:40             | <b>Session 1</b>   Mastering Early Practice: Lessons Learned with Grey Hair  | Constitution Hall 105                                |
| 16:00 - 18:00             | Cases & Cocktails Sessions ( <i>concurrent sessions</i> )<br><b>C&amp;C 1</b>   Adult Spinal Deformity<br><b>C&amp;C 2</b>   Pediatric Deformity<br><b>C&amp;C 3</b>   Cervical Deformity  | Room 104 B<br>Room 104 C<br>Room 104 D               |
| 18:00 - 20:00             | Welcome Reception & Exhibitor Viewing*   | Constitution Hall 106                                |
| THURSDAY, APRIL 16, 2026  |  | LOCATION   |
| 07:00 - 18:30             | Registration Open  | Level 100 Foyer                                      |
| 08:00 - 18:30             | Speaker Ready Room Open  | Room 103 B   |
| 08:30 - 17:30             | Exhibit Hall Open  | Constitution Hall 106                                |
| 07:30 - 08:30             | Hands-On Workshops* ( <i>includes breakfast</i> )<br><b>A TEC Spine</b>   Beyond Implants: Advancing Pediatric Spine Patient Positioning<br><b>Highridge Medical</b>   Integrating Efficiency, Technology and AI into your Practice<br><b>Cresco Spine</b>   What Happens When You Let the Spine Move? A Decade of Continuous Dynamic Distraction in EOS                 | Room 104 C<br>Room 104 D<br>Room 104 B               |
| 08:30 - 08:40             | <b>Innovation Update*: Enovis</b><br>A Novel Hybrid Brace for AIS: Spinamic  | Innovation Theatre                                   |
| 08:40 - 09:30             | <b>Session 2</b>   Panel Discussion: Design Thinking and Innovation in Spine Surgery   | Constitution Hall 107                                |
| 09:30 - 09:45             | Refreshment Break & Exhibit Viewing*   | Constitution Hall 106                                |
| 09:35 - 09:45             | <b>Innovation Update*: Carlsmid</b><br>aprevo® AI-Enabled Planning and Personalized Interbody Devices: Two-Year Reoperation Rates in Adult Deformity   | Innovation Theatre                                   |
| 09:45 - 11:45             | <b>Abstract Session 3</b>   Whitecloud Award Nominated Papers  | Constitution Hall 105                                |
| 11:45 - 12:00             | Lunch Pick-Up*   | Room 104 Foyer                                       |
| 11:45 - 11:55             | <b>Innovation Update*: Highridge Medical</b><br>United Healthcare Policy Update: What this means for VBT patients and families   | Innovation Theatre                                   |
| 12:00 - 13:00             | Hands-On Workshops* ( <i>concurrent sessions</i> )<br><b>DePuy Synthes</b>   Architects of the New Era: Driving Innovation in Complex Spine<br><b>Globus Medical</b>   Current Controversies in Adult and Pediatric Deformity<br><b>Medtronic</b>   Transformational Advances in Posterior Spinal Fixation<br><b>Orthofix</b>   Predictive Planning Meets Machine Vision | Room 104 C<br>Room 104 B<br>Room 104 D<br>Room 104 A |
| 13:00 - 13:30             | Exhibit Viewing*   | Constitution Hall 106                                |
| 13:15 - 14:00             | <b>Innovation ICL Session*</b>   Innovations in Value Based Care   | Innovation Theatre                                   |
| 13:30 - 15:00             | Sessions 4A & 4B ( <i>concurrent sessions</i> )<br><b>Abstract Session 4A</b>   Adult Spinal Deformity<br><b>Abstract Session 4B</b>   Adolescent Idiopathic Scoliosis   | Constitution Hall 105<br>Constitution Hall 107       |
| 15:00 - 15:30             | Refreshment Break & Exhibit Viewing*<br><b>E-Point Award Nominated Papers 1*</b>   | Constitution Hall 106<br>Innovation Theatre          |
| 15:30 - 17:00             | Sessions 5A & 5B ( <i>concurrent sessions</i> )<br><b>Abstract Session 5A</b>   Artificial Intelligence & Emerging Concepts<br><b>Session 5B*</b>   The Great Canadian Debates and Controversies   | Constitution Hall 105<br>Constitution Hall 107       |
| 15:45 - 16:30             | <b>Innovation ICL Session*</b>   MIS Deformity: State-of-the-Art   | Innovation Theatre                                   |
| 17:00 - 17:30             | Exhibit Viewing*<br><b>E-Point Award Nominated Papers 2*</b>   | Constitution Hall 106<br>Innovation Theatre          |
| 17:30 - 18:30             | <b>Session 6*</b>   Learning Curve & Master Techniques   | Constitution Hall 105                                |
| 18:30 - 19:30             | Women in Spine Reception*  | Room 104 A   |

\*Denotes Non-CME Session or Event

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All IMAST sessions take place at the Metro Toronto Convention Centre (MTCC), Level 100

| FRIDAY, APRIL 17, 2026 |  | LOCATION                                       |
|------------------------|--|--|
| 07:00 - 17:30          | Registration Open  | Level 100 Foyer                                |
| 07:00 - 17:00          | Speaker Ready Room Open  | Room 103 B                                     |
| 08:30 - 16:30          | Exhibit Hall Open  | Constitution Hall 106                          |
| 07:30 - 08:30          | <b>Session 7</b>   Making Adult Deformity Correction More Predictable  | Constitution Hall 107                          |
| 08:30 - 09:00          | Refreshment Break & Exhibit Viewing*<br><b>E-Point Award Nominated Papers 3*</b>   | Constitution Hall 106<br>Innovation Theatre    |
| 09:00 - 11:05          | <b>Abstract Session 8*</b>   Quality & Safety  | Constitution Hall 105                          |
| 11:05 - 11:30          | <b>Keynote Speaker*</b>   From Surgeon-Scientist to Surgeon-Entrepreneur: The Unexpected Journey That Led Us to Produce the Top-Ranked Helmet in the NFL                                   | Constitution Hall 105                          |
| 11:30 - 12:00          | Lunch Pick-Up*   | Room 104 Foyer                                 |
| 11:30 - 12:00          | Exhibit Viewing*   | Constitution Hall 106                          |
| 11:40 - 11:50          | <b>Innovation Update:* Globus Medical</b><br>Elevating Efficiency: Navigated Oscillation with DuraPro™ and Excelsius® Technology   | Innovation Theatre                             |
| 12:00 - 13:00          | Hands-On Workshops* (concurrent sessions)  |  |
|                        | <b>A TEC Spine</b>   EOS Insight for Surgical Decision Making: Aligning Clinical Judgment and Data Science<br><b>Highridge Medical</b>   VBT: Defining Indications and Redefining Outcomes | Room 104 C<br>Room 104 D                       |
| 13:00 - 13:15          | Exhibit Viewing*   | Constitution Hall 106                          |
| 13:15 - 14:30          | Sessions 9A & 9B (concurrent sessions)   |  |
|                        | <b>Abstract Session 9A</b>   Early Onset & Pediatric Scoliosis<br><b>Session 9B*</b>   Integrating New Technologies & Techniques   | Constitution Hall 105<br>Constitution Hall 107 |
| 13:30 - 14:15          | <b>Innovation ICL Session*</b>   Practical Tips for Using AI to Improve Clinical Care  | Innovation Theatre                             |
| 14:30 - 15:00          | Refreshment Break & Exhibit Viewing*   | Constitution Hall 106                          |
| 15:00 - 16:15          | Sessions 10A & 10B (concurrent sessions)   |  |
|                        | <b>Abstract Session 10A</b>   Cervical Spine<br><b>Abstract Session 10B</b>   Tumors, Infection, & Miscellaneous   | Constitution Hall 105<br>Constitution Hall 107 |
| 15:00 - 15:45          | <b>Innovation ICL Session*</b>   From Napkin to Commercialization: Device Development  | Innovation Theatre                             |
| 16:15 - 16:30          | Exhibit Viewing*   |  |
|                        | <b>SRS Membership Information Session*</b>   | Constitution Hall 106<br>Innovation Theatre    |
| 16:30 - 17:35          | <b>Session 11</b>   Understanding the Past and Conquering the Future   | Constitution Hall 105                          |
| 17:35 - 19:00          | <b>Innovation Celebration*</b> (ticket required)   | Azure (InterContinental Toronto Centre hotel)  |

\*Denotes Non-CME Session or Event