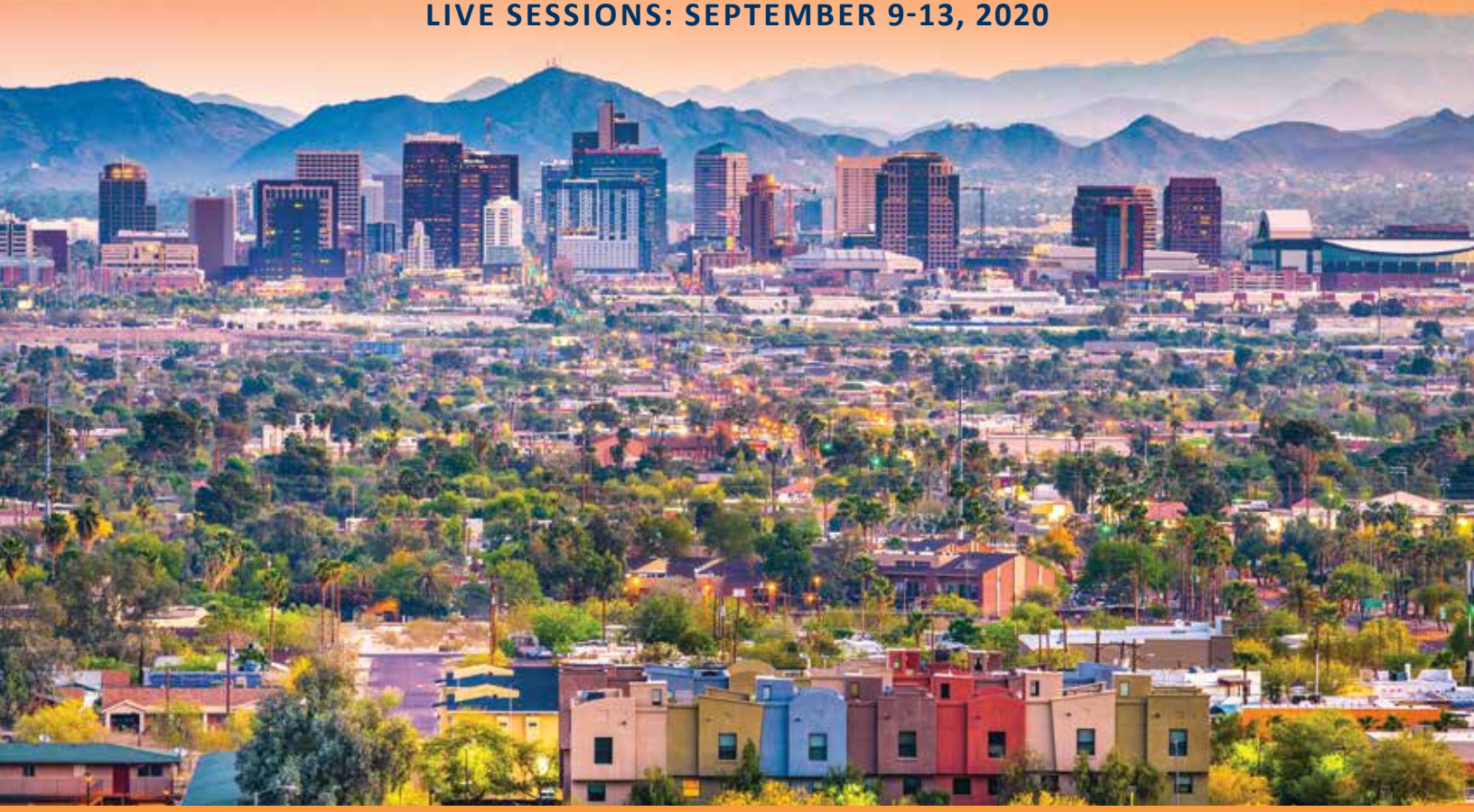
SCOLIOSIS RESEARCH SOCIETY

Virtual 55th Annual Meeting

FINAL PROGRAM

AVAILABLE ONLINE SEPTEMBER 3 THROUGH DECEMBER 31, 2020

LIVE SESSIONS: SEPTEMBER 9-13, 2020



MEETING WEBSITE: WWW.SRS.ORG/AM20

VIRTUAL MEETING PLATFORM: HTTP://SRS.BRIGHTSPACE.COM/

SRS
Scoliosis Research Society

Sponsored by the Scoliosis Research Society

www.srs.org

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Corporate Supporters

We are pleased to acknowledge and thank those companies that provided financial support to SRS in 2020.

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SRS WOULD LIKE TO THANK THE FOLLOWING SUPPORTERS WHO PROVIDED GRANT SUPPORT TO THE 55TH ANNUAL MEETING.

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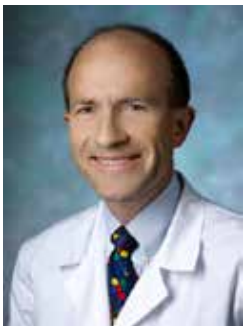
President's Message



On behalf of the Scoliosis Research Society (SRS), it is my great pleasure to welcome you to the virtual 55th Annual Meeting.

The Scoliosis Research Society Annual Meeting is one of the highlights of the year, and although we are not meeting in person, this full virtual event will continue our Society's legacy of bringing excellent education and the latest information on spinal deformity. This year the Annual Meeting will be presented virtually in two parts; the first part will include sessions presented live September 10 through September 13 and the second portion of the agenda includes a robust self-paced program that attendees will have access to through the end of the year. One of the challenges this year is clearing dedicated time for education, since we remain at home and clinical pressures intervene. I urge you to block out time for this program NOW on your schedule, when you would have been in Phoenix!

I want to thank the Annual Meeting Program Committee, Education Committee, faculty, paper presenters, corporate supporters, and staff who have risen to the unique challenges this year has brought. They truly showcase the creativity and perseverance of our Society.

This year there were 1,269 submitted abstracts; 185 were accepted for podium presentation and 75 for e-posters. Lindsay Andras, MD and the Program Committee have done masterful work in reviewing all of the submissions and putting together an outstanding program and then re-imagining it to fit within the virtual format. The Education Committee, led by Committee Chair, Baron Lonner, MD, have also done an outstanding job creating must-see programing, beginning on Wednesday, September 9 with the live Pre-Meeting Course sessions on, "Interdisciplinary Care for Optimizing Outcomes." The live agenda will continue on Wednesday with abstract presentations on Quality, Safety, Value, and Complications. In total there will be 68 abstracts presented live throughout the week and 105 abstracts that will be available in seven additional abstract sessions in the self-pace program.

Thursday's live sessions will kick off with concurrent abstracts sessions on Adolescent Idiopathic Scoliosis and Adult Spinal Deformity, followed by the Opening Ceremonies live stream. On Friday, September 11, there will be the session, "Nerves and Big Curves: Advances in Neuromonitoring and Management of Severe Spinal Deformity Abstracts" followed by this year's Harrington Lecture, presented by Gregory J. Redding, MD on "The Respiratory Impact of Early Onset Scoliosis and Current Treatments." Saturday begins with the papers selected as the Hibbs Clinical and Basic Research Award nominees and also includes the new Early Career Surgeon Session which will focus on case discussions on the topics of Selective Thoracic Fusion, T10-Pelvis Fusion, and Single Level Lumbar Stenosis. The live agenda will conclude on Sunday, September 13 with two concurrent Half-Day Course sessions, "Optimizing Value and Minimizing Complications in Adult Spinal Deformity Surgery" and "Fusion Scoliosis Correction in the Treatment of AIS."

Although the live agenda ends on Sunday, September 13; even more education will be available as a self-paced program through the end of 2020, this includes supplements to the Pre-Meeting Course and Half-Day Courses, abstract sessions with papers on the topics of Adolescent Idiopathic Scoliosis, Cervical Deformity, Early Onset Scoliosis/Syndromic, Sagittal/PJK, Spondylolisthesis/Congenital/Miscellaneous, Adult Spinal Deformity, and Basic Science. Industry Workshops, which will highlight topics and technologies selected by our corporate supporters, are also included in the self-paced program and I highly encourage attendees to watch these outstanding offerings.

It has been a pleasure and an honor to serve this year as your President of our great Society. The SRS staff, led by Executive Director, Ashtin Neuschaefer, deserves special recognition for all of their tremendous efforts. They make the work of being SRS President so much easier. I also want to especially thank my fellow Presidential Line colleagues who have made the challenges of this year easier for me and helped advance our Society; Immediate Past President, Peter O. Newton, MD; President-Elect Muharrem Yazici, MD; and Vice President, Christopher I. Shaffrey, MD.

Best wishes to all for a great meeting!

Paul D. Sponseller, MD, MBA
Scoliosis Research Society President 2019-2020

Planning Committees

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Paul D. Sponseller, MD, MBA

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Kota Watanabe, MD, Ph

Meeting Information

MEETING DESCRIPTION

The 55th Annual Meeting is a complete web-based meeting experience for the realization of the Scoliosis Research Society's mission and goals, to foster the optimal care of all patients with spinal deformities. Presentations are given by leading experts in the field and have value for health care professionals who treat spinal deformities at all levels and in all ages. Over 150 papers, faculty-led instructional courses, industry-supported workshops, e-posters on the latest research, and more will be presented on an array of topics, including adolescent idiopathic scoliosis, growing spine, kyphosis, adult deformity, trauma, neuromuscular scoliosis, and tumors for live and/or self-paced viewing.

LEARNING OBJECTIVES

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

- Analyze current research to inform best practices in clinical care.
- Implement risk stratification strategies in preoperative assessment in patients with spinal deformity.
- Incorporate multi-disciplinary teams to optimize patient outcomes.
- Identify optimal candidates for non-fusion or fusion approaches.
- Apply best practices in spinal deformity care to minimize complications and improve safety.

TARGET AUDIENCE

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

LANGUAGE

English will be the official language of the SRS Annual Meeting.

ACCREDITATION STATEMENT

The 55th Annual Meeting has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for Continuing Medical Education (ACCME) through the sponsorship of the Scoliosis Research Society (SRS). SRS is accredited by the ACCME to provide continuing medical education for physicians.

CREDIT DESIGNATION

SRS designates the live online activity, 55th Annual Meeting for a maximum of 11.50 *AMA PRA Category 1 Credits™.* SRS designates the self-paced enduring material, for a maximum of 13.75 *AMA PRA Category 1 Credits™.* Physicians should claim only the credit commensurate with the extent of their participation in each activity.

CME CERTIFICATES

CME certificates will be available online in the Annual Meeting platform upon the completion of each activity. Certificates will not be mailed or emailed. The online certificate access is the only source for this documentation. SRS asks that all Annual Meeting CME certificates be claimed no later than February 1, 2021. Please email SRS at cme@srs.org with questions.

DISCLOSURE OF CONFLICT OF INTEREST

It is the policy of SRS to insure balance, independence, objectivity and scientific rigor in all of their educational activities. In accordance with this policy, SRS identifies conflicts of interest with instructors, content managers, and other individuals who are in a position to control the content of an activity. Conflicts are resolved by SRS to ensure that all scientific research referred to, reported, or used in a CME activity conforms to the generally accepted standards of experimental design, data collection and analysis. Complete faculty disclosures are included on pages 40-66 in the final program.

FDA STATEMENT (UNITED STATES)

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

ABSTRACT VOLUME

There were 1,269 abstract submissions from 42 countries. All accepted abstracts are available in the online learning platform for live and/or self-paced viewing.

E-POSTERS

There are 75 E-Posters available for your review in the e-poster module.

The e-poster module is supported, in part, by NuVasive.

INDUSTRY WORKSHOPS

Delegates are encouraged to view the industry workshops and take part in the live workshop discussions. Each workshop is programmed by a single-supporting company and will feature presentations on topics and technologies selected by the company. Workshops are supported by DePuy Synthes; Globus Medical, Inc.; Medicrea; Medtronic; NuVasive; and Stryker. More information on the industry supported workshops can be found on pages 38-39. Please note, CME credits are not available for workshops.

EVALUATIONS

Please take time to complete the evaluations for each session you attend. Evaluations allow us to assess whether we have met your needs as a learner and what we can do to improve the next activity. After completing the evaluation surveys, CME and attendance certificates are generated.

Meeting Information

ANNOUNCEMENT BOARD

An announcement board is available in the online platform to inform learners about meeting updates and live session information.

The announcement board is supported, in part, by NuVasive.

SRS MEMBERSHIP

Attending this 55th Annual Meeting virtually will count toward membership meeting requirements. Check out the SRS Membership module for information about becoming a SRS member, upcoming meetings, and more.

EARLY CAREER SURGEONS SESSION

The Early Career Surgeons Session is a new initiative a part of SRS's recently developed, Early Career Surgeon's Program. This session offers a unique opportunity for early career members and non-members to interact closely with a panel of experts, through didactic case based discussions. All learners are invited to participate in the live session on Saturday, September 12.

The Early Career Surgeons Session is supported, in part, by a grant from Medtronic.

MEMBERS BUSINESS MEETING

All SRS members are invited to attend the virtual Member Business Meeting on Tuesday, September 8 from 09:00-09:30 US EDT/15:00-15:30 CEST/21:00-21:30 China Standard Time. Agendas will include reports from the various SRS committees, updates on SRS activities and programs, and voting.

STAY UP TO DATE WITH SRS DURING THE 55TH ANNUAL MEETING AND SHARE YOUR EXPERIENCES ON SOCIAL MEDIA WITH #SRSAM20

Guest Lectures & Award Recipients

HOWARD STEEL LECTURE

Peter MacDonald, Sr.
Navajo Code Talker and Former Leader of the Navajo Nation

At the age of 15, Peter MacDonald, a Navajo from Teecnospos, Arizona, enlisted in the U.S. Marine Corps. He went through boot camp at U.S. Marine Corps Recruit Depot (MCRD), San Diego, CA. Following regular combat and communication training at USMCB in Camp Pendleton, CA, MacDonald, along with other Navajo Marines, was secluded from other Marines for top-secret Navajo Code School. During the final phase of World War II (1944-46) MacDonald served in South Pacific as Navajo Code Talker and North China with the Sixth Marine Division.

He was honorably discharged with a rank of Corporal. He went back to his home community of Teecnospos, Arizona. After graduating from High School and Junior College in Muskogee, Oklahoma, MacDonald went on to the University of Oklahoma and graduated with an Electrical Engineering degree (BSEE). He pursued graduate studies at UCLA while working as a Project Engineer on the Polaris Missile project for (Howard) Hughes Aircraft Company. MacDonald served as Project Manager for the manufacture of the Polaris Missile Guidance System and was a member of the elite Hughes Technical Staff (MTS).

MacDonald has a long list of entrepreneurial endeavors attached to his name. Prominent among his work experience is his service as Chairman of the Navajo Nation from 1971 to 1983 and 1987 to 1991. MacDonald was re-elected to the Office of the Chairman four times—unprecedented in Navajo history. MacDonald is co-founder of the Council of Energy Resource Tribes (CERT), the National Tribal Chairman Association, the American Indian National Bank and the Native American Prep School. MacDonald also worked as Sales and Marketing Director for Cataract Engineering Company, providing engineering service for start-ups of Nuclear Power Plants and overhaul of coal-fired power plants.

Among his many honors are, Recipient of Congressional Silver Medal for heroic service to the nation as a USMC Navajo Code Talker, University of Oklahoma Engineering Hall of Fame, and Special Commendation by U.S. President Richard M. Nixon for "exceptional services to others". Chairman MacDonald also served as a civilian member of USMC Education and Training Board of Directors appointed by the Secretary of Navy. In addition, MacDonald was featured in TIME magazine as one of 200 "Rising Leaders of America" in 1974. He received Honorary Doctorate degrees from the University of Southern Utah in Cedar City and the College of Ganado (AZ). In 1978 he also received the Distinguished Service Citation from the University of Oklahoma—the institution's highest honor where he also served on the University of Oklahoma Board of Visitors and Bacone College Board of Regents.

MacDonald served on several national task forces and commissions (appointments by Presidents of the United States and Governors of Arizona and New Mexico). He now lectures at schools, colleges and universities, clubs, political organizations, government agencies and businesses. He is married and has five children and nine grandchildren. Currently he lives with his wife, Wanda, on the Navajo reservation at Tuba City, Arizona. MacDonald is currently President of the Navajo Code Talkers Association, raising funds to build National Navajo Code Talkers Museum and Veteran Center to honor Heroes of WWII, whose unique legacy, from 1942 through 1945, helped win the war transmitting top-secret messages in every major battle in the pacific theatre. Navajo Code was the only military code, in modern history, never broken by an enemy.

HARRINGTON LECTURE

Gregory J. Redding, MD
The Respiratory Impact of Early Onset Scoliosis and Current Treatments: Where Do We Go From Here?

Early onset scoliosis (EOS) often produces progressive restrictive and less often obstructive lung disease, with small lung volumes, stiff spine and chest wall, and reduced respiratory muscle motion and strength. Current surgical treatments act to distract the spine, reduce spine curvature, and promote vertebral length and in the process almost preserves lung function that exists prior to surgery. This is progress but not more is needed. New treatments should accomplish the following: 1) Preserve motion of the ribs and diaphragm, 2) Maximize function of both lungs, 3) Create space for further lung growth, and 4) Enhance respiratory muscle strength. Current treatments increase intrathoracic space alone. Improvements in treatments must salvage and/or preserve motion to maintain or improve respiratory reserve over time. This will require multiple disciplines to design the next generation surgical and non-surgical approaches to early onset spine and chest wall deformities.

Dr. Greg Redding is a professor of pediatrics at the University of Washington and Chief of the Pulmonary and Sleep Medicine Division at Seattle Children's Hospital. Dr. Redding has conducted clinical research for 40 years and has published more than 200 peer-reviewed articles, reviews, and chapters. He has received two lifetime achievement awards in pediatric respiratory medicine from the American Academy of Pediatrics and from the American Thoracic Society. He began to work in the field of spine and thoracic cage deformity in 2004 after meeting Dr. Bob Campbell. He has lectured internationally about the impact and mechanisms of impaired breathing due to spine deformities in early childhood and their functional consequences. He received the first Robert M. Campbell Jr. Award for Innovation in Early Onset Scoliosis in 2018. He remains actively conducting clinical research and recruiting more pediatric pulmonologists to collaborate with their spine colleagues throughout the world.

Guest Lectures & Award Recipients

WALTER P. BLOUNT HUMANITARIAN AWARD RECIPIENT

The Walter P. Blount Humanitarian acknowledges outstanding service to those with spinal deformity, and for generosity to the profession and society. The 2020 Walter P. Blount Humanitarian award recipient will be acknowledged during the virtual 55th Annual Meeting opening ceremonies and will be presented the award in-person at the 2021 Annual Meeting.

Francisco Javier Sánchez Pérez-Grueso Sr., MD

Dr. Francisco J. Sánchez Pérez-Grueso was born in Toledo, Spain. He completed his medical school at the Universidad de Salamanca and did his Orthopedic Surgery residency program at Hospital Universitario La Paz, Madrid. After his Residency, he joined the Spinal Deformity Unit as a staff member and soon after started a surgical program on pediatric spinal deformity surgery.

He expanded his training in spine deformity surgery visiting different specialized international centers (The Robert Jones and Agnes Hunt Orthop. Spine Disorders Dep. Oswestry, UK; Deutches Skoliosezentrum, Bad Wildungen, Germany; Hospital Saint Vincent de Paul, Paris; Hospital for Special Surgery, New York, USA). He was promoted to Chief of the Spine Unit Hospital La Paz in 2006 until his retirement in October 2018. He has been appointed Emeritus of Madrid Health System developing his research activity at Hospital La Paz.

His membership with the SRS began in 1995. He served on the Growing Spine, Global Outreach, and Globalization Committees. He became chair of the Growing Spine Committee in 2009, Director at large in the SRS Board from 2010 to 2012, and senior SRS travelling fellow in 2018.

He began working in Ghana in 2003 as part of the FOCOS initiative led by Dr. Oheneba Boachie-Adjei. For over 10 years he worked with a group of committed surgeons focused on helping children suffering from severe spine deformities. Ultimately, the Foundation was able to establish the FOCOS teaching hospital, which currently trains orthopaedic surgeons from Ghana and across West Africa.

Also alongside Dr. Boachie, they established the curriculum for the development program of spine surgeons in Sofia, Bulgaria, sponsored by the SRS. After a year of navigating administrative hurdles, the first surgery took place in 2008, working together with Dr. Steve Mardjetko. In the subsequent four years, the project helped local surgeons lead by Dr. Yablansky to achieve full autonomy in performing complex spine surgery.

In May 2017, there was a gathering to mark the 10-year anniversary of the program in Plovdid, where the founders joined local surgeons, as well as Dr. David Clements and Dr. Ahmet Alanay, who have continued with the initiative.

Throughout these years in Spain, he developed a great activity in the dissemination of new concepts and techniques in the treatment of spinal deformities. In 2004 he became the president of the Spanish Spine Society (GEER) from 2004 to 2006.

Within his research activity, his participation in different Study Groups (GSSG and ESSG) stands out. He has published more than 50 peer-reviewed papers and more than 100 podium presentation in national and international meetings.

LIFETIME ACHIEVEMENT AWARD RECIPIENTS

The Lifetime Achievement award recipients were chosen from among the SRS membership, based on long and distinguished service to the Society and spinal deformity research and care. The 2020 Lifetime Achievement award recipients will be acknowledged during the virtual 55th Annual Meeting opening ceremonies and will be presented the awards in-person at the 2021 Annual Meeting.

Jean Dubousset, MD

Jean Dubousset, born in 1936, is a pediatric orthopedic surgeon, now retired from clinical work. He received his medical education at Clermont Ferrand and Paris Universities, graduating with his MD in general surgery in 1965. He practiced pediatric orthopedics both privately and publicly in Paris until 1979, then moved to full time public practice at St. Vincent de Paul hospital for his entire remaining career, and acted as Professor of Pediatric Orthopedic surgery until 1991. He became a Member of the National Academy of Medicine and a member of the French Academy of Surgery in 2002. He was also member of the scientific committee of the Yves Cotrel Foundation at the Institut de France and is Chevalier de la Légion d'Honneur (2000).

Jean Dubousset has participated in the SRS Annual meeting almost every year beginning in 1969. He attended the meeting in Anaheim alongside Christian Salanova and Pierre Stagnara and after a 6 week tour of important scoliosis institutions in the US, he later returned to France with his new knowledge of the Halo device and the Milwaukee brace. He became a corresponding member of SRS in 1978, then Active Fellow, and is currently an Emeritus Member. He was the Harrington lecturer of the SRS at the Ottawa meeting of 1996 under the presidency of Vernon Tolo, and got the prestigious W. Blount Humanitarian award of the Society in 2010.

After reading the book of Hodgson in 1970, Jean Dubousset introduced France to wide anterior spine surgery in children. After working on paralytic pelvic obliquity in preparation for the GES (A French scoliosis Study group founded in 1969 on the model of SRS) Meeting in 1973 in Paris, he introduced the 3D basic principles for spinal pathology describing pelvic & cephalic vertebra concepts leading to economical conical balance system in humans. He is Co- inventor with Yves Cotrel of CD instrumentation for spine surgery in 1983, which describes the succession of scoliotic curves along the gravity line axis of the body with

their apical and junctional zone, and is useful for the segmental instrumentation as well as the rotation maneuver of the rods and important for the strategies for correction. He performed the first CD instrumentation in the US at the Leatherman Center in Louisville in 1985 and soon after in Boston with John Hall.

He was an active developer of GICD study group, travelling and teaching all over the world. With his wife, Anne Marie, he spent 1987 on sabbatical in the USA, half in Miami with Harry Shufflebarger and the other half at Texas Scottish Right Hospital in Dallas with Tony Herring's team. During his sabbatical year in the USA, he did important work researching about etiology of idiopathic scoliosis and doing experimental research in chickens after a pinealectomy and the role of melatonin in its initiation which was presented at the SIROT meeting in 1988. His work continued with Masafumi Machida in Japan, later being presented and receiving awards at the 2016 SRS Annual Meeting in Prague.

He also had the opportunity during his sabbatical year in the US to develop the use of ILIZAROV system to perform salvage procedures of difficult spinal problems, elongating or shortening by compression of the pathological deformities.

Jean Dubousset was the initiator of the EOS imaging low dose radiation system, thanks to his collaboration with George Charpak (Nobel Prize winner) and Biomechanics engineers from ENSAM Paris and LIO Montreal. Creating a 3D computer reconstruction of the entire skeleton in a standing functional position, the first application was at St Vincent de Paul Hospital in Paris in 2000.

Jean Dubousset is a member of the most important scientific societies all over the world regarding pediatric orthopedics, especially spine, general pediatrics, and pediatric tumor diseases with many distinctions. He still continues to research human biomechanics focusing on Etiology of AIS and the importance of transversal plane of the body and on the consequences of ageing on the spinal alignment.

Finally Jean Dubousset's artistic activities include modern stained glass restoration of the destroyed windows of a 15th century church close to his country side family house. He also creates smaller picture pieces using original techniques.

Stuart L. Weinstein, MD

Dr. Weinstein is the Ignacio V. Ponseti Chair and Professor of Orthopaedic Surgery and Professor of Pediatrics at The University of Iowa. Dr. Weinstein received his A.B. Honors degree in Political Science and History from the University of Illinois in 1968. He received his medical degree (Alpha Omega Alpha) from the University of Iowa in 1972. After interning in Internal Medicine at The University of California San Francisco, he returned to the University of Iowa for a residency in Orthopaedic Surgery. In 1976 he joined the faculty of the Department of Orthopaedic Surgery at The University of Iowa.

Dr. Weinstein was an NIH funded researcher. He has published more than 260 scientific articles in peer review journals (including the NEJM, JAMA, The Lancet, Nature). His research work has focused on spinal deformity in children and the natural history and long-term outcome of pediatric musculoskeletal conditions. He has edited three major textbooks including The Pediatric Spine: Principles and Practice; Lovell and Winter's Pediatric Orthopaedics and Turek's Orthopaedics.

Dr. Weinstein's many contributions to orthopaedics have been recognized by his receipt of the Bristol-Myers Squibb/Zimmer Award for Distinguished Achievement in Orthopaedic Research; The Kappa Delta /Orthopaedic Research and Education Foundation Clinical Research Award (1998 and again in 2015- for the Evidence Base for the Prognosis and Treatment of Adolescent Idiopathic Scoliosis); The ABJS/CORR Nicolas Andry Award for research (2018); The Russell Hibbs Award for Clinical Research (1998, 2014, 2015) given by the Scoliosis Research Society; and The Arthur H. Heune Memorial Award, given by the St. Giles Foundation and The Pediatric Orthopaedic Society of North America. In 2005, Dr. Weinstein was the recipient of the Alfred R. Shands, Sr., MD Award, presented by the Orthopaedic Research Society and The American Orthopaedic Association for his significant contributions to orthopaedics and his devotion of a professional lifetime to furthering knowledge in the fields of musculoskeletal disease.

Dr. Weinstein received the 2000 Iowa Board of Regents Award for Faculty Excellence for sustained record of excellence across the spectrum of faculty endeavors. In 2003, he received the Ernest O. Theilen Clinical Teaching and Service Award presented by the Roy J. and Lucille Carver College of Medicine. In 2009, he received the highest award in the College of Medicine, the Distinguished Mentor Award presented by the Roy J. and Lucille Carver College of Medicine. In 2011, Dr. Weinstein received the William W. Tipton, Jr., MD Award for Outstanding Leadership in Orthopaedics from the American Academy of Orthopaedic Surgeons and the Orthopaedic Research and Education Foundation. In 2010 he received the lifetime achievement from POSNA. In 2012, he received the American Orthopaedic Association's Distinguished Contributions to Orthopaedics Award. In 2016, he was honored by the Vietnamese Government and Minister of Health and awarded the Civilian Medal for Contributions to the Development of Healthcare in Vietnam. In 2019 he received the lifetime achievement award from SOSORT.

Dr. Weinstein was a recipient of an American, British, Canadian (ABC) Traveling Fellowship in 1985. He has been honored for his contributions to Orthopaedic Surgery by honorary memberships in National Orthopaedic Associations around the world including Australia, New Zealand, Germany, Great Britain Thailand, China, Portugal, and Argentina. In 2007, he was made a Fellow of The Royal College of Surgeons of England and in 2014 he was made an Honorary Member of the European Federation of National Orthopedic Associations of Orthopaedics and Traumatology (EFORT).

Dr. Weinstein is past president of the American Academy of Orthopaedic Surgeons, The American Orthopaedic Association, The American Board of Orthopaedic Surgery, The Pediatric Orthopaedic Society of North America, The United States National Action

Guest Lectures & Award Recipients

Network of the International Bone and Joint Decade, The International Center for Orthopaedic Education (ICOE), Doctors for Medical Liability Reform (DMLR), Past Chairman of the Board of Trustees of the Journal of Bone and Joint Surgery (JBJS) and past Chairman of the American Association of Orthopaedic Surgeons Political Action Committee. He currently serves as an American College of Surgeons Children's Hospital Surgery Surveyor and a Trustee for the Orthopaedic Research and Education Foundation.

Conflict of Interest Disclosures

If noted, the relationships disclosed are as follows: a – grants/research support; b – consultant; c – stock/shareholder (self-managed); d – speaker's bureau; e – advisory board or panel; f – employee, salary (commercial interest); g – other financial or material support (royalties, patents, etc.)

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Marinus De Kleuver, MD	Netherlands	No Relationships
Ronald A. Lehman, MD	United States	Medtronic (b, g); Stryker Spine (g); Department of Defense (a)
Ferran Pellisé, MD, PhD	Spain	DePuy Synthes (a); NuVasive (b); Medtronic (a); Medtronic (b)
Gregory M. Mundis, MD	United States	K2M (b, g); NuVasive (a, b, c, e, g); SeaSpine (a, b, e); VISEON (b, e)
Peter O. Newton, MD	United States	Alphatec Spine (a); Cubist (b, g); DePuy Synthes (a, b, d, g); ElectroCore (c); EOS Imaging (a, b); K2M (a, b, g); Mazor Robotics (a); Medtronic (a); NuVasive (a); OrthoPediatrics (a, g); Thieme Publishing (g); Zimmer Biomet (a); Scoliosis Research Society (e); International Pediatric Orthopedic Think Tank (e); Harms Study Group/Setting Scoliosis Straight Foundation (e)
James O. Sanders, MD	United States	OrthoPediatrics (b); Greensun (c); Tether Implant Corporation (g); GE (c); Abbott Labs (c); Abvie (c)
Christopher I. Shaffrey, MD	United States	EOS Imaging (b); DePuy Synthes (a); K2M (a); Medtronic (a, b, g); SI Bone (b, g); NuVasive (a, b, c, g); Zimmer Biomet (g)
Suken A. Shah, MD	United States	DePuy Synthes (a, b, e, g); K2M (a, g); Globus Medical (a, b); Setting Scoliosis Straight Foundation (a, e)
John T. Smith, MD	United States	Globus Medical (b, g); NuVasive (b); SpineGuard (b); GS Medical (b); Wishbone (b); NuVasive (b)
Paul D. Sponseller, MD	United States	DePuy Synthes (a, g); Globus Medical (g); OrthoPediatrics (g)
Muharrem Yazici, MD	Turkey	No Relationships
PROGRAM COMMITTEE (IF NOT LISTED ABOVE)		
Lindsay M. Andras, MD	United States	Zimmer Biomet (b, d); Eli Lilly (c); Journal of Pediatric Orthopaedics (e); Medtronic (b, d); NuVasive (b, d); Orthobullets (g); Pediatric Orthopaedic Society of North America (e); Scoliosis Research Society (e)
Shay Bess, MD	United States	DePuy Synthes (a); Globus Medical (a); K2M (a, b, d, e); Medtronic (a); NuVasive (a); Orthofix (a); SI Bone (a); Stryker Spine (a, b, e); Zimmer Biomet (a)
Aaron J. Buckland, MBBS, FRCSA	United States	NuVasive (b); K2M (b); Medtronic (b); EOS Imaging (b)
Sébastien Charosky, MD	France	Medtronic (b); SMAIO (b)
Samuel K. Cho, MD	United States	Globus Medical (b, g); Zimmer Biomet (a, b); Medtronic (b); CGBio (b)
Lindsay Crawford, MD	United States	No Relationships
Eugenio Dema, MD	Italy	No Relationships
Hamid Hassanzadeh, MD	United States	Medtronic (d); DePuy Synthes (b); Globus Medical (d); NuVasive (b, d); Orthofix (a, b, d); Pfizer (a, b, e); Rho (a, e)
Ehsan Jazini, MD	United States	Medtronic (b); Stryker Spine (b)
Sinan Kahraman, MD	Turkey	No Relationships

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Khaled M. Kebaish, MD	United States	DePuy Synthes (b, g); Stryker Spine (g); Orthofix (b, g); SpineCraft (g)
Michael P. Kelly, MD	United States	No Relationships
Deniz Konya, MD	Turkey	No Relationships
Firoz Miyanji, MD	Canada	DePuy Synthes (b); Zimmer Biomet (b)
Joseph H. Perra, MD	United States	Medtronic (b, g); Pfizer (a)
Amer F. Samdani, MD	United States	DePuy Synthes (b); Ethicon (b); Globus Medical (b); NuVasive (b, g); Stryker Spine (b); Zimmer Biomet (b, g)
Qianyu Zhuang, MD	China	No Relationships
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Ahmet Alanay, MD	Turkey	No Relationships
Ali A. Baaj, MD	United States	DePuy Synthes (b); Stryker Spine (b)
Keith Bachmann, MD	United States	No Relationships
Saumyajit Basu, FRCS	India	No Relationships
Marco Brayda-Bruno, MD	Italy	Medtronic (a); K2M (a, b, e); Implanet (b); SpineGuard (b, g); Paradigm Spine (c)
Alexandre F. Cristante, MD, PhD	Brazil	No Relationships
Michael D. Daubs, MD	United States	DePuy Synthes (g); Pfizer (a)
Stephen G. George, MD	United States	No Relationships
Mari L. Groves, MD	United States	No Relationships
Munish C. Gupta, MD	United States	DePuy Synthes (b, e, g); Medtronic (b, e, g); Alphatec Spine (b, g); Innomed (g); Medicrea-Other-Travel (g); OMeGA-grant paid to institution for fellowship (g); AOSpine-grant paid to institution for fellowship; honorarium, travel (g); J&J (c); P&G (c); perForm Biologics (c); SRS-travel for faculty (g); Mizuho-travel (g)
Steven W. Hwang, MD	United States	Zimmer Biomet (d); NuVasive (b); Auctus (c)
Charles E. Johnston, MD	United States	Medtronic (g)
Baron Lonner, MD	United States	DePuy Synthes (a, b, d, e, g); Zimmer Biomet (b, g); Apifix (b, c, e); Spine Search (c); Paradigm Spine (c); Setting Scoliosis Straight Foundation (e)
Michael Paloski, DO, MBA	United States	DePuy Synthes (b); NuVasive (b)
Stefan Parent, MD, PhD	Canada	Spinologics Inc. (c, g); EOS Imaging (a, b, g); Setting Scoliosis Straight Foundation (a); The Canada Foundation for Innovation (a); The Natural Sciences and Engineering Research Council of Canada (a); Canadian Institute of Health Research (a); K2M (a, b); DePuy Synthes (a, b); Stryker Spine (b); Orthopediatrics (d)
Yong Qiu, MD	China	No Relationships
Justin S. Smith, MD, PhD	United States	Alphatec Spine (c); Zimmer Biomet (b, g); NuVasive (b, g); Stryker Spine (b); DePuy Synthes (a, b); Cerapedics (b); AOSpine (a); NREF (a); Thieme (g); Carlsmed (b)
Burt Yaszay, MD	United States	K2M (a, b, d, g); DePuy Synthes (a, b, d); NuVasive (a, b, d, e, g); Globus Medical (g); OrthoPediatrics (g); Biogen (b); Stryker Spine (b, d)
PROGRAM REVIEWERS (IF NOT LISTED ABOVE)		
Patrick J. Cahill, MD	United States	intellectual property for dynamic lung MRI (b); Children's Spine Study Group (a); Setting Scoliosis Straight Foundation (a)
Woojin Cho, MD, PhD	United States	No Relationships
Bassel G. Diebo, MD	United States	No Relationships
Charla R. Fischer, MD	United States	LifeSpine (b); Stryker Spine (b); Zimmer Biomet (b)

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Sumeet Garg, MD	United States	NuVasive (b); ACI Clinical (b); Medtronic (b)
Ryan C. Goodwin, MD	United States	Stryker Spine (b); OrthoPediatrics (b)
Jeffrey L. Gum, MD	United States	Medtronic (b, e, g); K2M (b, e); NuVasive (b, g); Mazor Robotics (b); DePuy Synthes (d); Acuity (g); Stryker Spine (b, e); Norton Helathcare (f)
Yong Hai, MD, PhD	China	No Relationships
Darrell S. Hanson, MD	United States	DePuy Synthes (b, d, g); Medtronic (b, d); NuVasive (b, d)
Charles Ledonio, MD, CCRP	United States	Globus Medical (f)
Jean-Marc Mac-Thiong, MD, PhD	Canada	DePuy Synthes (a); Medline (a); Medtronic (a); Spinologics (c, e, g)
Kamran Majid, MD	United States	No Relationships
Praveen V. Mummaneni, MD	United States	DePuy Synthes (b, g); Globus Medical (b); Stryker Spine (b); Spinicity/ISD (c); Spinicity/ISD (c); Thieme Publishers (g); Springer Publishers (g); ISSG (a); AO spine (a); NREF (a)
Ahmad Nassr, MD	United States	AO Spine NA (a); Premia Spine (a); Pfizer (a)
Stefano Negrini, MD	Italy	ISICO (Italian Scientific Spine Institute) (c)
Colin Nnadi, FRCS	United Kingdom	No Relationships
Masayuki Ohashi, MD, PhD	Japan	No Relationships
Bangping Qian, MD	China	No Relationships
Juan Carlos Rodriguez-Olaverri, MD	Spain	No Relationships
Cristina Sacramento Dominguez, MD	Spain	No Relationships
Ricardo A. Santos, MD	Brazil	No Relationships
Ahmed Shawky Abdelgawaad, MD, MHBA	Germany	DePuy Synthes (a); AOSpine (a)
Osamu Shirado, MD, PhD	Japan	No Relationships
Nicholas Spina, MD	United States	No Relationships
Byron F. Stephens, MD	United States	DePuy Synthes (b)
Khoi D. Than, MD	United States	Bioventus (b)
Surya Prakash Rao Voleti, MD, MS,	India	No Relationships
CME COMMITTEE(IF NOT LISTED ABOVE)		
James Bennett, MD	United States	No Relationships
David H. Clements III, MD	United States	DePuy Synthes (a, d); NuVasive (a, d, g); Stryker Spine (d)
Lori A. Dolan, PhD	United States	Green Sun Medical (b)
John Heydemann, MD	United States	OrthoPediatrics (c); Sanofi Aventis (c); Merck (c)
Naobumi Hosogane, MD, PhD	Japan	No Relationships
Patricia N. Kostial, RN, BSN	United States	No Relationships
William F. Lavelle, MD	United States	DePuy Synthes (a); Medtronic (a); K2M (a); Empirical Spine (a); Spinal Kinetics, Inc. (a); Vertebral Technologies, Inc. (a); 4-Web (c); Prosydian (c, e); Cardan Robotics (c); Innovasis (e)
Kevin Lim, FRCS, BMS, BMBS, FAMS, BMA	Singapore	No Relationships
Luke Macyszyn, MD, MA	United States	DePuy Synthes (b); Zimmer Biomet (b)
Venu M. Nemani, MD, PhD	United States	No Relationships
Anthony M. Petrizzo, DO	United States	No Relationships

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Zeeshan M. Sardar, MD	United States	Medtronic (b); Stryker Spine (b)
Vishwas R. Talwalkar, MD	United States	No Relationships
INVITED SPEAKERS (IF NOT LISTED ABOVE)		
Steve Beck, MD	United States	No Relationships
Miranda Falk, MD	United States	No Relationships
John Jerman, MD	United States	No Relationships
Jamal McClendon Jr	United States	No Relationships
Barbara McWilliams, MD	United States	No Relationships
Derek Neilson, MD	United States	No Relationships
Ayan Sen, MD	United States	No Relationships
Kristen Venuti, MD	United States	No Relationships
INVITED FACULTY (IF NOT LISTED ABOVE)		
Kariman Abelin Genevois, MD	France	Medtronic (b); Medicrea (b, e)
Christopher P. Ames, MD	United States	Stryker Spine (g); Biomet Zimmer Spine (g); DePuy Synthes (g); NuVasive (g); Next Orthosurgical (g); K2M (g); Medicrea (g); DePuy Synthes (b); Medtronic (b); Stryker Spine (b); Medicrea (b); K2M (b); Biomet Zimmer (b); Titan Spine (a); DePuy Synthes (a); ISSG (a); Operative Neurosurgery (g); ISSG (g); Global Spine Analytics (g); SRS (a)
Jennifer M. Bauer, MD	United States	DePuy Synthes (b)
Randal R. Betz, MD	United States	Abyrx (c); ApiFix (b, c); DePuy Synthes (b, d, g); Electrocore (c); Globus Medical (b, d, g); Medovex (c); Orthobond (c); SpineGuard (b, c, g); Thieme Medical Publishers (g); Wishbone Medical (b, c); Pacira (b); Addivation (b)
Oheneba Boachie-Adjei, MD	United States	K2M (a, b, e, g); WEIGAO (b, d)
Jaysson T. Brooks, MD	United States	DePuy Synthes (b); Medtronic (d); OrthoPediatrics (b)
Douglas C. Burton, MD	United States	DePuy Synthes (a, b, g); Bioventus (a); Pfizer (a); Progenerative Medical (c)
Michael S. Chang, MD	United States	Orthofix (b); Stryker Spine (b); DePuy Synthes (b); BK (b); SpineWave (b)
Robert H. Cho, MD	United States	DePuy Synthes (b, e); NuVasive (b); OrthoPediatrics (b); Prosidyan (b); Ergobaby (e)
Dean Chou, MD	United States	Globus Medical (b, g)
Ames P. Christopher, MD	United States	Stryker Spine (g); Biomet Zimmer Spine (g); DePuy Synthes (g); NuVasive (g); Next Orthosurgical (g); K2M (g); Medicrea (g); DePuy Synthes (b); Medtronic (b); Stryker Spine (b); Medicrea (b); K2M (b); Biomet Zimmer (b); Titan Spine (a); DePuy Synthes (a); ISSG (a); Operative Neurosurgery (g); SRS (a); ISSG (g); Global Spine Analytics (g)
Charles H. Crawford III, MD	United States	Alphatec Spine (g); DePuy Synthes (b); Medtronic (b, e, g); NuVasive (b, d, e, g)
Benny T. Dahl, MD, PhD, DMSc	United States	Stryker Spine (e); Stryker Spine (e)
Gokhan H. Demirkiran, MD	Turkey	No Relationships
Biren Desai, MD	United States	No Relationships
John R. Dimar, II, MD	United States	Medtronic (b, d, g); DePuy Synthes (b, d); Stryker Spine (b, g)
Sabrina Donzelli, MD	Italy	No Relationships
John P. Dormans, MD	United States	No Relationships
Ron El-Hawary, MD	Canada	DePuy Synthes (a, b); Medtronic (a, b); Globus Medical (b); OrthoPediatrics (b, c, e); Wishbone Medical (b, e)
Meric Enercan, MD	Turkey	No Relationships
Thomas J. Errico, MD	United States	K2M (b, d, g); Altus Spine (b, g)
Ryan E. Fitzgerald, MD	United States	OrthoPediatrics (d)

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John (Jack) M. Flynn, MD	United States	Zimmer Biomet (g)
Haruki Funao, MD, PhD	Japan	No Relationships
Steven D. Glassman, MD	United States	Medtronic (b, g); K2M (b); Stryker Spine (b); Norton Healthcare (f); American Spine Registry (e); NuVasive (a); Integra (a); Intellirod (a); Pfizer (a); International Spine Study Group (a); Medtronic (a)
Henry F.H. Halm, MD	Germany	NuVasive (a, b); Silony Medical (a, b)
Sajan K. Hegde, MD	India	Globus Medical (a, b, d, g)
Michael T. Hresko, MD	United States	No Relationships
Amit Jain, MD	United States	No Relationships
Han Jo Kim, MD	United States	K2M (b, g); Zimmer Biomet (b, g); ISSGF (a)
Eric O. Klineberg, MD	United States	DePuy Synthes (b); Stryker Spine (b); Medicrea (b); AOSpine (a, d)
Joseph L. Laratta, MD	United States	Stryker Spine (b); Spineart (b, g); Medtronic (a); NuVasive (a); Evolution Spine (b, g); 4Web (b); Gehrson Lehrman Group (b)
A. Noelle Larson, MD	United States	Globus Medical (b); OrthoPediatrics (b); Zimmer Biomet (b); Medtronic (b)
Lawrence G. Lenke, MD	United States	Medtronic (b); broadwater (g); EOS Imaging (a); AOSPINE (a, g); Setting Scoliosis Straight Foundation (a); quality Medical Publishing (g); Scoliosis Research Society (g); Abryx (b); Acuity Surgical (b); EOS Technologies (b)
Olavo B. Letaif, MD	Brazil	DePuy Synthes (b); NuVasive (b)
Jean-Christophe A. Leveque, MD	United States	No Relationships
John M. Caridi, MD	United States	No Relationships
David S. Marks, FRCS, FRCSOrth	United Kingdom	DePuy Synthes (g)
Morio Matsumoto, MD, PhD	Japan	NuVasive (a, b); Medtronic (a); Kyocera (a)
Emmanuel N. Menga, MD	United States	Evolution Spine (b, g)
Addisu Mesfin, MD	United States	Globus Medical (a); LES Society (a); Axiomed (c)
Dror Ovadia, MD	Israel	No Relationships
Eric C. Parent, PhD	Canada	No Relationships
Paul Park, MD	United States	Globus Medical (b, g); NuVasive (b, g); DePuy Synthes (a)
Javier Pizones, MD, PhD	Spain	DePuy Synthes (a); Medtronic (a, b)
Kwadwo Poku Yankey, MD	United States	No Relationships
David W. Polly, MD	United States	SI Bone (b); Globus Medical (d, g); Medtronic (a, g)
S. Rajasekaran, MD, PhD, FRCSA, MCh	United States	No Relationships
Gregory Redding, MD	United States	No Relationships
Dominique A. Rothenfluh, MD, PhD	United Kingdom	No Relationships
Frank J. Schwab, MD	United States	Globus Medical (b); International Spine Study Group (e); K2M (b); Medicrea (g); Medtronic (g); Zimmer Biomet (b, g)
Rajiv K. Sethi, MD	United States	K2M (b, e); Orthofix (g); Medtronic (e); Medicrea (e); Mighty Oak Medical (e)
Ajoy Prasad Shetty, MS Orth	United States	No Relationships
Eric D. Shirley, MD	United States	Assertio Therapeutics (c)
David L. Skaggs, MD	United States	CHLA Foundation (e); Grand Rounds (b); Green Sun Medical (c); Growing Spine Foundation (e); Growing Spine Study Group (e); Journal of Children's Orthopaedics (e); Medtronic (g); NuVasive (a); Orthobullets (b, c, e); Orthopedics Today (e); Spine Deformity (e); Zimmer Biomet (b, d, g); Zipline Medical Inc. (c)
Brian G. Smith, MD	United States	No Relationships

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Daniel J. Sucato, MD, MS	United States	No Relationships
George H. Thompson, MD	United States	OrthoPediatrics (a, b, c, e, g, ,); NuVasive (a); Wolters Kluwer (e, f); Shriner's Hospitals for Children (e, f); Wolters Kluwer (f); Scoliosis Research Society (g); Son - Bone Solutions (f)
Michael G. Vitale, MD	United States	Zimmer Biomet (b, g); Stryker Spine (b)
Kota Watanabe, MD, PhD	Japan	No Relationships
Mark Weidenbaum, MD	United States	No Relationships
Vijay Yanamadala, MD, MS, MBA	United States	No Relationships
Caglar Yilgor, MD	Turkey	No Relationships
AUTHORS (IF NOT LISTED ABOVE)		
Mark Abel, MD	United States	No Relationships
Amer Aboubakr, MD	United States	No Relationships
Emre R. Acaroglu, MD	Turkey	Medtronic (a); DePuy Synthes (a); AOSpine (d, e)
Arthur Sackeyfio, MD	Ghana	No Relationships
Nissim Ackshota, MD	Israel	No Relationships
Owoicho Adogwa, MD, MPH	United States	No Relationships
Sanjeev Agarwal, MD	United States	No Relationships
Waleed Ahmad, BS	United States	No Relationships
Tsutomu Akazawa, MD, PhD	Japan	No Relationships
Keyur Akbari, MD	India	No Relationships
Behrooz A. Akbarnia, MD	United States	NuVasive (b, g); DePuy Synthes (g); K2M (g); NociMed (c)
Harry Akoto, MD	Ghana	No Relationships
Abdullah Al Mamun, MBBS, FCPS	Bangladesh	No Relationships
Mohammed Shah Alam, MBBS, MS, FRCS, FCPS	Bangladesh	No Relationships
Alisa Alayan, MD	United States	No Relationships
Stephen A. Albanese, MD	United States	No Relationships
Christopher Alcala, MD	United States	No Relationships
Basel Sheikh Alshabab, MD	United States	No Relationships
Andressa G. Alves, MD	United States	No Relationships
Mohammed A. Alvi, MBBS	United States	No Relationships
Sze Alyssa, BA	United States	No Relationships
Abdulmajeed Alzakri, MD	Saudi Arabia	No Relationships
Terry D. Amaral, MD	United States	No Relationships
Neel Anand, MD	United States	Medtronic (b, d, g); Globus Medical (c, g); Paradigm Spine (c); Viseon (b, e); Spinal Balance (b, c, e); Bonovo (c); Spinal Simplicity (b, c, e)
Jason B. Anari, MD	United States	No Relationships
Bernardo de Andrada, MD	United States	No Relationships
Ryohei Annen, MD	Japan	No Relationships
Alexandre Ansorge, MD	Switzerland	No Relationships
Hideyuki Arima, MD, PhD	Japan	No Relationships
Vincent Arlet, MD	United States	No Relationships
Varun Arvind, BS	United States	No Relationships

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Anthony L. Asher, MD	United States	Globus Medical (b)
Rita Assaker, MD	United States	No Relationships
Nelson Astur, MD	Brazil	No Relationships
Aaron M. Atlas, BS	United States	No Relationships
Elsayed Attia, MD	United States	No Relationships
Carl-Eric Aubin, PhD	Canada	Medtronic (a, b)
Thomas Austin, MD, MS	United States	No Relationships
Catherine M. Avitabile, MD	United States	No Relationships
Binnaz Ay, MD	Turkey	No Relationships
Elif Ilgaz Aydinlar, MD	Turkey	No Relationships
Mehmet Aydogan, MD	Turkey	No Relationships
Robert Aylor, BS	United States	Boston Scientific (f)
Vigneshwara M. Badikillaya, MD	India	No Relationships
Andrei N. Baklanov, PhD	Russia	No Relationships
Nikolas Baksh, MD	United States	No Relationships
Christine Baldus, RN	United States	No Relationships
Keith Baldwin, MD	United States	No Relationships
Margaret Baldwin, MD	United States	No Relationships
Eaman Balouch, MD, PhD	United States	No Relationships
Harsha Bandaralage, MS	United States	No Relationships
Tomohiro Banno, MD, PhD	Japan	No Relationships
Dhananjay Bansal, BS	United States	No Relationships
Soraya Barchi, BSc	Canada	No Relationships
Tanvir J. Bari, MD	Denmark	No Relationships
Carrie E. Bartley, MA	United States	No Relationships
Tracey P. Bastrom, MA	United States	No Relationships
Griffin R. Baum, MD	United States	Stryker Spine (b); Medtronic (b)
Marie Beausejour, PhD	Canada	No Relationships
Sam Bemani, MD	Iran	No Relationships
Sigurd H. Berven, MD	United States	Globus Medical (e); Medtronic (b, e, g); Stryker Spine (b, g); Medicrea (b); Innovasis (b, e)
Matt Best, MD	United States	No Relationships
Graham Beutler, BS	United States	No Relationships
George A. Beyer, MS	United States	No Relationships
Erica F. Bisson, MD	United States	Stryker Spine (b); Mirus (b, c); Nview (b, c)
Afrain Boby, MS, BS	United States	No Relationships
Charlotte De Bodman, MD	Switzerland	No Relationships
Louis Boissiere, MD	France	Spineart (b); Medicrea (b); DePuy Synthes (a)
Viviana Bompadre, PhD	United States	No Relationships
Rajesh Botchu, MD	United Kingdom	No Relationships
Stephane Bourret, PhD	France	No Relationships
Daniel Bouton, MD	United States	No Relationships
Andrew J. Bowey, FRCS	United Kingdom	No Relationships
Joshua T. Bram, BS	United States	No Relationships

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Harsimran S. Brara, MD	United States	No Relationships
Keith H. Bridwell, MD	United States	No Relationships
Robert W. Bruce Jr., MD	United States	No Relationships
Jacob M. Buchowski, MD	United States	K2M (g); Globus Medical (g)
Brandon Bucklen, PhD	United States	Globus Medical (c, f)
Thomas J. Buell, MD	United States	No Relationships
David B. Bumpass, MD	United States	Medtronic (d); OrthoPediatrics (b)
Shane Burch, MD	United States	Medtronic (b, e); DePuy Synthes (b); Zimmer Biomet (b)
Kenan Burrows, MBBS	New Zealand	No Relationships
Glenn Robin Buttermann, MD	United States	FG Solco (g); Dio Medical (b)
Abdul Fettah Buyuk, MD	United States	No Relationships
John A. Buza III, MD	United States	No Relationships
Mohamad Bydon, MD	United States	No Relationships
Stephen Camer, MD	United States	No Relationships
Jeffrey Campbell, MD	United States	No Relationships
Kai Cao, MD, PhD	China	No Relationships
Leah Y. Carreon, MD	United States	Medtronic (a); Pfizer, Cerapedics, TSRH, SRS, Alan L and Jacqueline B Stuart Spine Research Foundation (a)
Patrick Carry, MS	United States	No Relationships
Alba Vila-Casademunt, MS	Spain	No Relationships
René M. Castelein, MD, PhD	Netherlands	Stryker Spine (a, d)
Alejandro Cazzulino, BA	United States	No Relationships
Paul C. Celestre, MD	United States	No Relationships
Pelin Celiker, BS	United States	No Relationships
Meghan Cerpa, MPH	United States	No Relationships
Stefano Cervellati, MD	Italy	No Relationships
Shelby P. Cerza, MA	United States	No Relationships
Ross Chafetz, PhD	United States	No Relationships
Shubhendu Chakraborty, MRCS	Bangladesh	No Relationships
Vincent Challier, MD	France	No Relationships
Andrew K. Chan, MD	United States	Orthofix (a)
Yann Philippe Charles, MD, PhD	France	Stryker Spine (a, b); Clariance (a, b)
Lu Chen, MD, PhD	China	No Relationships
Jack Chun Yiu Cheng, MD, PhD	China	No Relationships
Amy Cheung, BA	China	No Relationships
Jason Pui Yin Cheung, MD, MBBS, MS, FRCS	China	EOS Imaging (a); Amgen (a)
Kenneth Cheung, MD, MBBS, FRCS	China	Medtronic (d); Orthosmart (a); Nuvasive (a); Sciliosis Research Society (e)
J.C. Chiao, PhD	United States	No Relationships
Kazuhiro Chiba, MD, PhD	Japan	Seikgaku Corporation (b)
Brian H. Cho, BS	United States	No Relationships
Hyunmi Choi, MD	United States	No Relationships
Harman Chopra, BS	United States	No Relationships

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James Choueiry, MD	Canada	No Relationships
Amy A. Claeson, PhD	United States	Zimmer Biomet (f)
Jean-Luc Clement, MD	France	Medicrea International (b)
R. Carter Clement, MD, MBA	United States	No Relationships
Nikita Cobetto, PhD	Canada	No Relationships
Ryan Coghlan, MS	United States	BioMarin (g); Therachon (g); QED Therapeutics (g)
Franklin Coleman, BS	Ghana	No Relationships
Teresa L. Collins-Jones, PhD	United States	No Relationships
Michael Joseph Conklin, MD	United Kingdom	No Relationships
Andreas Conta	Germany	No Relationships
Daniel R. Cooperman, MD	United States	No Relationships
Domagoj Coric, MD	United States	Medtronic (b, g); Stryker Spine (b, g); Globus Medical (b, g); Spine Wave (b, c, g); Integrity Implants (g); Premia Spine (c, g); RTI (g)
Killian Coyne, BS	United States	No Relationships
Jonathan Cui, MD	United States	Merck (c, f)
Souhayl Dahmani, MD, PhD	France	No Relationships
Kenshi Daimon, MD, PhD	Japan	No Relationships
Alan H. Daniels, MD	United States	Orthofix (a, b); EOS Imaging (b); Stryker Spine (b); Spineart, Southern Spine, Springer, Medicrea, Medtronic (b)
Aina J. Danielsson, MD, PhD	Sweden	No Relationships
Kassa Darge, MD, PhD	United States	No Relationships
O Z M Dastagir, MBBS, MS, D Ortho	Bangladesh	No Relationships
Romain Dayer, MD	Switzerland	DePuy Synthes (a, d); Medtronic (a, d)
Rafael De la Garza Ramos, MD	United States	No Relationships
Elizabeth A. Demers Lavelle, MD	United States	DePuy Synthes (a); Medtronic (a); K2M (a); Empirical Spine (a); Spinal Kiinetics, Inc. (a); Vertebral Technologies, Inc. (a); 4-Web (c); Prosydian (c, e); Cardan Robotics (c); Innovasis (e)
Satoru Demura, MD, PhD	Japan	No Relationships
Francis Denis, MD	United States	Medtronic (g)
Anton Denisov, MD	Russia	No Relationships
Bhumit R. Desai, MD	United States	No Relationships
Francoise Descazeaux, MD	Chile	No Relationships
Anjaneyulu R. Devireddy, MBBS, MS	India	No Relationships
Vedat Deviren, MD	United States	Alphatec Spine (b); NuVasive (a, b, g); Zimmer Biomet (b); Seaspine (b); Medicrea (b); Omega (a)
Dennis P. Devito, MD	United States	Medicrea Spine (a, b, g); Astura spine (g); Medtronic (e); Stryker Spine (e); Sea Spine (b, g)
Devan J. Devkumar, BSA	United States	No Relationships
Theodor Di Pauli von Treuheim, BEng	United States	No Relationships
Elias Diarbakerli, PhD	Sweden	No Relationships
Rebecca J. Dieckmann, BS	United States	No Relationships
Hongtao Ding, MS	China	No Relationships

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Michael Dinizo, MD	United States	No Relationships
Colleen Ditro, RN, DNP, CPNP	United States	Biomarin (d)
Joe Doe, MD, test	United States	No Relationships
Sergei Dolgopolov, MD	United States	No Relationships
Thomas J. Dowling III, MD	United States	No Relationships
Philipp Drees, MD	Germany	No Relationships
Pingguo Duan, MD	United States	No Relationships
Michael G. Dubner, BS	United States	No Relationships
Wesley M. Durand, BS	United States	No Relationships
Lily Q. Eaker, BA	United States	No Relationships
Pablo L. Eamara, MD	Argentina	No Relationships
Robert K. Eastlack, MD	United States	Alphatec Spine (c); Aesculap (b, e, g); Globus Medical (g); Stryker Spine (e); NuVasive (a, b, c, g); SI Bone (a, b, g); Stryker Spine (e); Spine Innovation (c); Seaspine (a, b, c, g); Invuity (c); Carevature (b); Medtronic (b)
Charles C. Edwards, MD	United States	Calvary Spine (c)
Rosa M. Egea-Gámez, MD, PhD	Spain	No Relationships
Ahmed Elabd, MD	United States	No Relationships
Omar Elsemin, BSN	Canada	No Relationships
Mustafa Eltayep, MD	Turkey	No Relationships
Jonathan Elysee, MS	United States	No Relationships
John B. Emans, MD	United States	DePuy Synthes (g); Zimmer Biomet (b); Medtronic (b)
Nichelle Enata, MS	United States	No Relationships
Yigit Erdag, MD	Turkey	No Relationships
Gokhan Ergene, MD	Turkey	No Relationships
Mark A. Erickson, MD	United States	NuVasive (b, d); Medtronic (b, d)
Ernst Etienne, BS	United States	No Relationships
European Spine Study Group	Spain	DePuy Synthes (a); Medtronic (a)
Monika Fagevik Olsen, PhD	Sweden	No Relationships
Jordan Fakhoury, DO	United States	No Relationships
H Francis Farhadi, MD, PhD, FRCS(C)	United States	No Relationships
Christine L. Farnsworth, MS	United States	No Relationships
Nida Fatima, MD	United States	No Relationships
Graham T. Fedorak, MD, FRCS(C)	United States	No Relationships
David Fender, FRCS	United Kingdom	No Relationships
Nicomedes Fernández-Baíllo, MD	Spain	No Relationships
Emmanuelle Ferrero, MD, PhD	France	No Relationships
Richard G. Fessler, MD	United States	DePuy Synthes (b); Benvenue (b); InQ Innovations (g)
Michael Fields, BS	United States	No Relationships
Nicholas D. Fletcher, MD	United States	Medtronic (b, d, e); OrthoPediatrics (b, d); NuVasive (b); Zimmer Biomet (d)
Lorena Floccari, MD	United States	No Relationships
Tara Flynn, BS	United States	No Relationships
FOCOS Spine Research Group	Ghana	K2M (a)

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Kevin T. Foley, MD	United States	Medtronic (b, c, g); NuVasive (c); Discgenics (c, e); LaunchPad Medical (c, e); Fusion Robotics (c, e); Triad Life Sciences (c, e)
Liam Forbes	United Kingdom	No Relationships
Carole Fortin, PhD	Canada	No Relationships
Fox Pediatric Spinal Deformity Study	United States	No Relationships
Andrew Freeman, MS	United States	SI Bone (a); Fortus Medical (f)
Kai-Ming Gregory Fu, MD	United States	DePuy Synthes (b); Globus Medical (b); SI Bone (b)
Nobuyuki Fujita, MD, PhD	Japan	No Relationships
Federico Fusini, MD	Italy	No Relationships
Peter G. Gabos, MD	United States	DePuy Synthes (b, d)
Nirupa Galagedera, BA	United States	No Relationships
María Galán-Olleros, MD	Spain	No Relationships
Jesse Galina, BS	United States	No Relationships
Anup A. Gandhi, PhD	United States	Zimmer Biomet (f)
Rikesh A. Gandhi, MD	United States	No Relationships
(Catherine) Himo Gang, MPH	United States	No Relationships
Rui Gao, MD	China	No Relationships
Timothy A. Garvey, MD	United States	Medtronic (g)
Matthew Geck, MD	United States	Difusion (c); SpineHope (e)
Martin Gehrchen, MD, PhD	Denmark	Medtronic (a); K2M (a)
Liya Gendler, MD	United States	No Relationships
Eric Geng, BS	United States	No Relationships
Kevin George, BA	United States	No Relationships
Paul Gerdhem, MD	Sweden	No Relationships
Michael J. Gibson, FRCS	United Kingdom	No Relationships
Shawn R. Gilbert, MD	United Kingdom	No Relationships
Massimo Girardo, MD	Italy	No Relationships
Michael P. Glotzbecker, MD	United States	NuVasive (b, d); DePuy Synthes (d); Medtronic (d); Zimmer Biomet (d); orthobullets (b); PSSG, HSG (a)
Jakub Godzik, MD	United States	No Relationships
Samuel Golenbock, MS	United States	No Relationships
Rafael González-Díaz, MD, PhD	Spain	No Relationships
Carlos Miranda-Gorozarri, MD	Spain	No Relationships
Janelle Greene, MD	United States	No Relationships
Harsh Grewal, MD	United States	No Relationships
Daniel Grits, BS	United States	No Relationships
Yurong Gu, MD	China	No Relationships
Jian Guan, MD	United States	No Relationships
Pierre Guigui, MD	France	No Relationships
Tenner Guillaume, MD	United States	Zimmer Biomet (b, d); NuVasive (b, d)
Jeremy Guinn, BS	United States	No Relationships
Ndeye F. Guisse, MS	United States	No Relationships
Kern H. Guppy, MD, PhD	United States	No Relationships

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Kavish Gupta, BS	United States	No Relationships
Seray G. Gur, MD	Turkey	No Relationships
Ipek Ege Gurel	Turkey	No Relationships
Bijjawara H Mahesh, MBBS, MS	India	No Relationships
Alexander Haddad, BS	United States	No Relationships
Ram Haddas, PhD	United States	No Relationships
Regis W. Haid Jr., MD	United States	Medtronic (g); Globus Medical (c, g); NuVasive (b, c, g); Paradigm Spine (c); SpineWave (c); Vertical Health (SpineUniverse) (c)
Dawit T Haile, MD	United States	No Relationships
Dennis W. Hallager, MD, PhD	Denmark	No Relationships
Matthew Halsey, MD	United States	No Relationships
D. Kojo Hamilton, MD	United States	NuVasive (a); Pfizer (a)
Kim W. Hammerberg, MD	United States	No Relationships
Azmi Hamzaoglu, MD	Turkey	Medtronic (a, b)
Chaofan Han, MD, PhD	China	No Relationships
Makoto Handa, MD	Japan	No Relationships
Lars V. Hansen, MD	Denmark	No Relationships
Arun R. Hariharan, MD	United States	No Relationships
Katsumi Harimaya, MD, PhD	Japan	No Relationships
Harms Study Group	United States	DePuy Synthes (a); EOS Imaging (a); NuVasive (a); K2M (a); Medtronic (a); Medicrea (a); Globus Medical (g); Misonix (g); Zimmer Biomet (a); Green Sun Medical (g); SeaSpine (g); UNYQ (g)
Jessica Harris, MS	United States	No Relationships
Robert A. Hart, MD	United States	DePuy Synthes (b); Globus Medical (b); Medtronic (b); Seaspine (b); Orthofix (b)
Sayyida Hasan, BS	United States	No Relationships
Kazuhiro Hasegawa, MD, PhD	Japan	No Relationships
Tomohiko Hasegawa, MD, PhD	Japan	No Relationships
Irem Havlucu	Turkey	No Relationships
Gregory Hawryluk, MD	Canada	No Relationships
Daniel Hedequist, MD	United States	No Relationships
Michael J. Heffernan, MD	United States	No Relationships
Brett Heldt, BS	United States	No Relationships
Ilkka J. Helenius, MD	Finland	Medtronic (a, b); K2M (a, b)
Linda Helenius, MD	Finland	Medtronic (a); K2M (a)
Isobella Henzell, MBBS	New Zealand	No Relationships
Javier Alonso Hernández, MD	Spain	OrthoPediatrics (d)
Shea Hesselbacher	United States	No Relationships
Hwee Weng Dennis Hey, MD	Singapore	No Relationships
Tricia St. Hilaire, MPH	United States	No Relationships
Jeffrey M. Hills, MD	United States	No Relationships
Bruce F. Hodgson, MBBS, FRCS	New Zealand	No Relationships
Victor Ho-Fung, MD	United States	No Relationships
Brian Hollenbeck, MD	United States	No Relationships

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Daniel Hong, MD	United States	No Relationships
Michio Hongo, MD, PhD	Japan	No Relationships
Yusuke Hori, MD	Japan	No Relationships
William Horton, MD	United States	Biomarin (b); Ascendis Rx (b); Theracon Rx (b); QED Rx (b); Relay Rx (b)
Richard Hostin, MD	United States	No Relationships
Christopher Howard, MBA	United States	Medical Sensor Systems, Inc. (c)
Zongshan Hu, PhD	China	No Relationships
Carlos Huaiquilaf, MD	Chile	No Relationships
Jichen Huang, MD	China	No Relationships
Jae Hwan Cho, MD, PhD	South Korea	No Relationships
Koichiro Ide, MD	Japan	No Relationships
Shiro Ikegawa, MD, PhD	Japan	No Relationships
Brice Ilharreborde, MD, PhD	France	Implanet (b); Medtronic (b); Zimmer Biomet (b); EOS Imaging (b)
Kenneth D. Illingworth, MD	United States	No Relationships
Kazuhide Inage, MD, PhD	Japan	No Relationships
Satoshi Inami, MD, PhD	Japan	No Relationships
International Spine Study Group	United States	DePuy Synthes (a); K2M (a); Medtronic (a); Globus Medical (a); NuVasive (a); Orthofix (a); SI Bone (a); Allosource (a)
Ken Ishii, MD, PhD	Japan	No Relationships
Yoshinori Ishikawa, MD, PhD	Japan	No Relationships
Norihiro Isogai, MD	Japan	No Relationships
Manabu Ito, MD, PhD	Japan	No Relationships
Sravisht Iyer, MD	United States	Globus Medical (b); Healthgrades (e); Innovasis (a)
Siddharth Jadhav, MD	United States	No Relationships
Sarwar Jahan, MBBS, FCPS	Bangladesh	No Relationships
Sreenath R. Jakinapally, MD	France	No Relationships
M. Burhan Janjua, MD	United States	No Relationships
Julio Jauregui, MD	United States	No Relationships
Heng Jiang, MD	China	No Relationships
Abhinav Jogani, MS	India	No Relationships
Erica Johnson, BS	United States	No Relationships
Sharif A. Jonayed, MBBS, MS, FCPS	Bangladesh	No Relationships
Julie Joncas, RN	Canada	No Relationships
Rushikesh S. Joshi, BS	United States	No Relationships
Thomas J. Joyce, PhD	United Kingdom	No Relationships
Chang Ju Hwang, MD, PhD	South Korea	No Relationships
Florence Julien-Marsollier, MD	France	No Relationships
Joseph Kahan, MD	United States	No Relationships
Sheila Kahwaty, PA-C	United States	No Relationships
Takashi Kaito, MD, PhD	Japan	No Relationships
Kenichiro Kakutani, MD, PhD	Japan	No Relationships
Michel Kanas, MD	Brazil	No Relationships
Göksu Kandemir, MSc	United Kingdom	No Relationships

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Adam S. Kanter, MD	United States	NuVasive (b, g); Zimmer Biomet (b, g)
Selhan Karadereler, MD	Turkey	No Relationships
Alexa J. Karkenny, MD	United States	No Relationships
Michelle Kars, MD	United States	No Relationships
Yuji Kasukawa, MD, PhD	Japan	No Relationships
Satoshi Kato, PhD	Japan	No Relationships
Yoshihiro Katsuura, MD	United States	No Relationships
Chhavi Katyal, MD	United States	No Relationships
Harleen Kaur, BS	United States	No Relationships
Noriaki Kawakami, MD, PhD	Japan	EOS Imaging (a); Medtronic (b); Kisco (b); Japan Spinal Deformity Institute (g)
Lukas Keil, MD	United States	No Relationships
Brian P. Kelly, PhD	United States	No Relationships
Daniel Kent	United States	No Relationships
Paul Kent, MD	United States	No Relationships
Suzanne E. Kent, BS	United States	No Relationships
Swapnil Keny, MS	India	No Relationships
Panagiotis Kerezoudis, MD, MS	United States	No Relationships
Babak Khandehroo, MD	United States	No Relationships
James Kho, MD	United Kingdom	No Relationships
Duhan Kilickan	Turkey	No Relationships
David Kim, BS	United States	No Relationships
Eun Kim, BA	United States	No Relationships
Jun Kim, MD	United States	No Relationships
Kyunghyun Kim, MD	South Korea	No Relationships
Stanley Kisinde, MD	United States	No Relationships
Ryo Kitagawa, MD	Japan	No Relationships
Gunilla Kjellby-Wendt, PhD	Sweden	No Relationships
Frank S. Kleinstueck, MD	Switzerland	No Relationships
John J. Knightly, MD	United States	No Relationships
Sho Kobayashi, MD, PhD	Japan	No Relationships
Sergey Kolesov, MD, PhD	Russia	Zimmer Biomet (b); DePuy Synthes (b); Stryker Spine (b)
Heiko Koller, MD	Germany	No Relationships
Dimitriy Kondrashov, MD	United States	SI Bone (a, b); Spineart (b, g); Tryptich Surgical (c, g)
Christopher Kong, MD	United States	No Relationships
Emre Korkmaz, MD	Turkey	No Relationships
Tyler Koski, MD	United States	NuVasive (b, c, g); Medtronic (b, g); spinewave (g)
Thomas Kosztowski, MD	United States	No Relationships
Toshiaki Kotani, MD, PhD	Japan	No Relationships
Joseph Ivan Krajbich, MD	United States	No Relationships
Walter F. Krengel III, MD	United States	No Relationships
Moyo C. Kruyt, MD, PhD	Netherlands	No Relationships
Daisuke Kudo, MD, PhD	Japan	No Relationships
Swamy Kurra, MD	United States	No Relationships

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Kenny Kwan, MD	China	No Relationships
Hubert Labelle, MD	Canada	Spinologics Inc (c, g); Rodin4D (g)
Renaud Lafage, MS	United States	Nemaris (c)
Virginie Lafage, PhD	United States	Globus Medical (b); NuVasive (g); International Spine Study Group (e); European Spine Journal (e); DePuy Synthes (d); The permanente Group (d)
Tsz Ping Lam, PhD	China	No Relationships
Ben Lane, MS	United States	No Relationships
Darryl Lau, MD	United States	No Relationships
Scott M. LaValva, BA	United States	No Relationships
Jean-Charles Le Huec, MD	France	No Relationships
Sylvie Le May, PhD	Canada	No Relationships
Jeremi Leasure, MS	United States	No Relationships
David E. Lebel, MD, PhD	Canada	No Relationships
Dong-Ho Lee, MD, PhD	South Korea	No Relationships
Nathan J. Lee, MD	United States	No Relationships
Jennifer N. Lehrman, MS	United States	No Relationships
Justin V. Lemans, MD	Netherlands	No Relationships
Carlos Leon, BE	United States	No Relationships
Eric Leung, BS	United States	No Relationships
Stephen J. Lewis, MD, FRCS(C)	Canada	Medtronic (a, d); Stryker Spine (b, d); DePuy Synthes (a); L&K Biomed (b); AO Spine (a, d)
Bo Li, MD	United States	No Relationships
Chengxin Li, PhD	China	No Relationships
Don Li, PhD	United States	No Relationships
Eric Li	United States	No Relationships
Guoan Li, PhD	United States	No Relationships
Jiong Li, MD	China	No Relationships
Benita Liao, MD	United States	No Relationships
Takahiro Iida, MD, PhD	Japan	No Relationships
Isador H. Lieberman, MD	United States	Globus Medical (b); Medtronic (b); Misonix (b); SI Bone (b)
Yasushi Iijima, MD, PhD	Japan	No Relationships
James D. Lin, MD	United States	No Relationships
Antoinette W. Lindberg, MD	United States	NuVasive (g)
Breton G. Line, BS	United States	International Spine Study Group (b)
Gabriel KP Liu, MD	Singapore	No Relationships
Zhen Liu, MD	China	No Relationships
Yungtai Lo, PhD	United States	No Relationships
Joseph M. Lombardi, MD	United States	No Relationships
Carina Lott, MS	United States	No Relationships
Francis C. Lovecchio, MD	United States	No Relationships
John P. Lubicky, MD	United States	No Relationships
Scott John Luhmann, MD	United States	Stryker Spine (b, d, g); OrthoPediatrics (b, d, g); Wishbone medical (b); Globus Medical (g); Lippincott (g); Medtronic (g)
Jon D. Lurie, MD, MS	United States	Spinol (c, e); UptoDate (g)

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Jun Ma, MD	China	No Relationships
Lacey Magee, BA	United States	No Relationships
Constance Maglaras, PhD	United States	No Relationships
Mohammad E. Majd, MD	United States	No Relationships
Melvin C. Makhni, MD	United States	No Relationships
Ali Mansour, MD	United States	No Relationships
Noorullah Maqsoodi, MS	United States	No Relationships
Damon Mar, PhD	United States	No Relationships
Gerard F. Marciano, MD	United States	No Relationships
Jonathan S. Markowitz, MD	United States	No Relationships
Michelle Claire Marks, PT	United States	Setting Scoliosis Straight (f)
Majd Marrache, MD	United States	No Relationships
Ginny Martin, RN	New Zealand	No Relationships
Carmen Martínez-González, MD	Spain	No Relationships
Delio E. Martins, MD, PhD	Brazil	No Relationships
Jeffrey E. Martus, MD	United States	No Relationships
Sergei Masevnin, MD, PhD	Russia	No Relationships
Smitha Mathew, MBBS, MS	United States	No Relationships
Akira Matsumura, MD, PhD	Japan	No Relationships
Yukihiro Matsuyama, MD, PhD	Japan	No Relationships
Rory R. Mayer, MD	United States	No Relationships
Ali Maziad, MD, PhD	Egypt	No Relationships
Steven J. Mcanany, MD	United States	Titan (b); Stryker Spine (b); NuVasive (b); Medicrea (b)
Richard E. McCarthy, MD	United States	OrthoPediatrics (b, e); Medtronic (b)
Anna McClung, RN, BSN	United States	No Relationships
Tyler C. McDonald, MD	United States	No Relationships
Joseph M. McDonough, MS	United States	No Relationships
Kelley McGowan, BS	United States	No Relationships
Amy L. McIntosh, MD	United States	NuVasive (b)
Emmanuel McNeely, MS	United States	No Relationships
Amir A. Mehbod, MD	United States	Zimmer Biomet (g); Stryker Spine (g)
Ratnesh N. Mehra, MD	United States	No Relationships
Charmie Mehta, BS	United States	No Relationships
Jwalant S. Mehta, MD, FRCS (Orth), MCh (Orth), MS (Orth), D Orth	United Kingdom	Stryker Spine (a, b, g); DePuy Synthes (a); NuVasive (a, g); POSNA (a); FDA (a); Growing Spine Foundation (a); Childrens' Spine Foundation (a); Elite Health Services (c); AO Spine (d)
Nishank Mehta, BA	United States	No Relationships
Anil Mendiratta, MD	United States	No Relationships
Yichen Meng, MD	China	No Relationships
Richard P. Menger, MD	United States	No Relationships
James Meyers, BA	United States	No Relationships
Alexander Mihas, BS	United States	No Relationships
Christopher Mikhail, MD	United States	No Relationships
Dmitrii Mikhailov, MD, PhD	Russia	No Relationships

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Lotfi Miladi, MD	France	EUROS Company (g)
Todd A. Milbrandt, MD, MS	United States	Medtronic (b); OrthoPediatrics (b); Zimmer Biomet (b); Viking Scientific (c); Nview (b)
Daniel J. Miller, MD	United States	No Relationships
Freeman Miller, MD	United States	No Relationships
Patricia E. Miller, MS	United States	No Relationships
Shohei Minami, MD, PhD	Japan	No Relationships
Amy Minnema, MS	United States	No Relationships
Brendon Mitchell, MD	United States	No Relationships
Ashish Mittal, MD	United States	No Relationships
Naohisa Miyakoshi, MD, PhD	Japan	No Relationships
Andrew Z. Mo, MD	United States	No Relationships
Kush Mody, BS	United States	No Relationships
Marina Moguilevtch, MD	United States	No Relationships
Alaa Mohammed, MPH	United States	No Relationships
David J. Moller, MD	United States	No Relationships
Lucía Moreno-Manzanaro, BS	Spain	No Relationships
Christian Morin, MD	France	No Relationships
Natalia Morozova, MD, PhD	Russia	No Relationships
Simon Morr, MD	United States	No Relationships
William Z. Morris, MD	United States	No Relationships
Cole Morrissette, BS	United States	No Relationships
Thomas Mroz, MD	United States	No Relationships
Alana Munger, MD	United States	No Relationships
Joshua S. Murphy, MD	United States	DePuy Synthes (b); OrthoPediatrics (a, b)
Robert F. Murphy, MD	United States	No Relationships
Ayhan Mutlu, MD	Turkey	No Relationships
Naveed Nabizadeh, MD	Iran	No Relationships
Sara Naessig, BS	United States	No Relationships
Narihito Nagoshi, MD, PhD	Japan	No Relationships
Imad S. Nahle, MD	Canada	No Relationships
Salem Najjar, BA	United States	No Relationships
Masaya Nakamura, MD, PhD	Japan	No Relationships
Keita Nakayama, MD, PhD	Japan	No Relationships
Takashi Namikawa, MD, PhD	Japan	No Relationships
Unni G. Narayanan, MBBS, FRCS(C), MSc	Canada	No Relationships
Wataru Narita, MD	Japan	No Relationships
Luigi A. Nasto, MD	Canada	No Relationships
Suresh Nayar, MD	United States	No Relationships
Ryan Nazar, MD	United States	No Relationships
Jacob Neary, BS	United States	No Relationships
Geraldine I. Neiss, PhD	United States	No Relationships
Brian J. Neuman, MD	United States	DePuy Synthes (a)

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Anna S. Newcomb, MS	United States	No Relationships
Jie C. Nguyen, MD, MS	United States	No Relationships
Michael Nguyen, BS	United States	No Relationships
Anthony Nicholson, BS	United States	No Relationships
Christopher J. Nielsen, MD	Canada	No Relationships
Thomas Niemeyer, MD	Germany	No Relationships
Kotaro Nishida, MD, PhD	Japan	No Relationships
Makoto Nishiyama, MD, PhD	Japan	No Relationships
Dolores Njoku, MD	United States	No Relationships
Heidi R. Nocka, BA	United States	No Relationships
Sung Hyun Noh, MD	South Korea	No Relationships
Edward K. Nomoto, MD	United States	DePuy Synthes (b); NuVasive (b); Seaspine (g)
Elizabeth P. Norheim, MD	United States	No Relationships
Satoshi Nori, MD, PhD	Japan	No Relationships
Pierce D. Nunley, MD	United States	Amedica (c); K2M (b, d, g); Zimmer Biomet (b, d, g); Paradigm Spine (c); Spineology (b, c, d); Vertiflex (b); Camber Spine (b, c, d, g); Integrity Spine (b, g); Centinel Spine (b)
Derrick Owusu Nyantakyi	Ghana	No Relationships
Ibrahim Obeid, MD	France	Alphatec Spine (g); DePuy Synthes (a, b); Medtronic (b); Spineart, Medicrea (g)
Peter Obid, MD	Germany	No Relationships
Alex Soroceanu, MD, FRCS(C), MPH	Canada	No Relationships
Khalid Odeh, MD	United States	No Relationships
Shin Oe, MD	Japan	Medtronic (g); Japan Medical Dynamic Marketing (g); Jyuzen Memorial Hospital (g)
Ender Ofluoglu, MD	Turkey	No Relationships
Henry Ofori Duah, RN, BSN, MPH	Ghana	No Relationships
Gerhard Ofori-Amankwah, MD	Ghana	No Relationships
Yoji Ogura, MD, PhD	Japan	No Relationships
Tetsuya Ohara, MD	Japan	No Relationships
Seiji Ohtori, MD	Japan	No Relationships
Eijiro Okada, MD, PhD	Japan	No Relationships
David O. Okonkwo, MD	United States	NuVasive (b, g); Zimmer Biomet (b, g)
Hanna Oksanen, RN	Finland	No Relationships
Norihiro Oku, MD	Japan	No Relationships
Ismail Oltulu, MD	Turkey	No Relationships
Nicholas A. O'Malley, BS	United States	No Relationships
Adan Omar, MD	United States	No Relationships
Keith Orland, MD	United States	No Relationships
Nicole Orozco, BSN	United States	No Relationships
Joseph A. Osorio, MD, PhD	United States	No Relationships
Nao Otomo, MD	Japan	No Relationships
Mabel A. Owiredu,	Ghana	No Relationships

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Gulsen Oztosun	Turkey	No Relationships
Huseyin Ozturk, MD	Turkey	No Relationships
Joshua M. Pahys, MD	United States	DePuy Synthes (b); NuVasive (b); Zimmer Biomet (b)
Olli T. Pajulo, MD	Finland	No Relationships
Robert C. Palmer, MD	United States	No Relationships
Matteo Palmisani, MD	Italy	No Relationships
Rosa Palmisani, MD	Italy	No Relationships
Aixing Pan, MD, PhD	China	No Relationships
Zhimin Pan, MD, PhD	China	No Relationships
Andrey Panteleyev, MD	Russia	No Relationships
Bernd Pape, PhD	Finland	No Relationships
Amit Parekh, DO	United States	No Relationships
Carlos Pargas, MD	United States	No Relationships
Jae Woo Park, MD	South Korea	No Relationships
Paul J. Park, MD	United States	No Relationships
Sehan Park, MD	South Korea	No Relationships
Saba Pasha, PhD	United States	No Relationships
Peter G. Passias, MD	United States	Zimmer Biomet (b); Allosource (g); CSRS (a); Globus Medical (g); Medicrea (b); SpineWave (b)
Neil Patel, BS	United States	No Relationships
Carl B. Paulino, MD	United States	No Relationships
Jeff Pawelek, BS	United States	No Relationships
Pediatric Spine Study Group	United States	NuVasive (a); DePuy Synthes (a); Pediatric Orthopaedic Society of North America (a); Growing Spine Foundation (a); Children's Spine Foundation (a); Food and Drug Administration (a)
Tuna Pehlivanoglu, MD	Turkey	No Relationships
Glenn Pelletier, MD	United States	No Relationships
Brenton Pennicooke, MD	United States	McKinsey & Company (e)
Jacquelyn S. Pennings, PhD	United States	No Relationships
Francisco Javier S. Perez-Grueso, MD	Spain	No Relationships
Sebastien Pesenti, MD, PhD	France	No Relationships
Maty Petcharaporn, BS	United States	No Relationships
Joseph Petfield, MD	United States	No Relationships
Logan Petit, MD	United States	No Relationships
Katherine E. Pierce, BS	United States	No Relationships
Jonathan Poli, MS	United States	No Relationships
Kiley F. Poppino, BS	United States	No Relationships
D. Dean Potter, MD	United States	No Relationships
Eric Potts, MD	United States	Medtronic (b, g)
Joseph Pourtabib, BS	United States	No Relationships
Niyathi Prasad, BS	United States	No Relationships
Themistocles S. Protopsaltis, MD	United States	Globus Medical (b); Medicrea (b); K2M (b); NuVasive (b); Innovasis (b); Altus (g)

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Dmitrii Ptashnikov, MD, PhD	Russia	No Relationships
Catherine Qiu, MS	United States	No Relationships
Hannah Quick, BA	United States	No Relationships
Edward Quilligan, BS	United States	No Relationships
Alejandro Quinonez, BS	United States	No Relationships
Sheeraz Qureshi, MD	United States	AMOpportunities (g); Avaz Surgical (c); Globus Medical (b, d); Healthgrades (e); Lifelink.com (e); Minimally Invasive Spine Surgery Group (e); Paradigm Spine (b); RTI Surgical Inc. (b); Spinal Simplicity, LLC (e); Stryker Spine (b, g); Vital 5 (c); Zimmer Biomet (b, g)
Shayan U. Rahman, MD	United States	No Relationships
Tina Raman, MD	United States	No Relationships
Subaraman Ramchandran, MD	United States	No Relationships
Brandon A. Ramo, MD	United States	No Relationships
Patricia Rampy, MS, CNIM	United States	No Relationships
Frank Rand, MD	United States	No Relationships
Raghavendra Rao, MBBS, MS	United States	No Relationships
Tushar N. Rathod, MS	India	No Relationships
Barkin Erdogan	Turkey	No Relationships
Jay S. Reidler, MD	United States	No Relationships
Tom Reinsel, MD	Turkey	No Relationships
Hend Riahi, MD	Tunisia	No Relationships
B. Stephens Richards, MD	United States	No Relationships
Ron I. Riesenburger, MD	United States	No Relationships
K. Daniel Riew, MD	United States	Medtronic (g); NuVasive (g); Biomet (g); KASS, CSRS, AOSpine, JBJS Spine (e); Benvenue, Amedica, PSD, Spinal Kinetics, Osprey, Paradigm, AxioMed, Spineology, Vertiflex, Expanding Orthopedics (c); DePuy, Johnson & Johnson (d)
Joshua Rivera	United States	No Relationships
Bruno B. Roberto, MD	Brazil	No Relationships
Brett Rocos, MD	Canada	No Relationships
Kenneth J. Rogers, PhD	United States	No Relationships
Karin Romberg, PhD	Sweden	No Relationships
Alexander Rompala, BS	United States	No Relationships
Alexander Rosinski, MS	United States	No Relationships
Marjolaine Roy-Beaudry, MSc	Canada	No Relationships
Benjamin D. Roye, MD	United States	No Relationships
Kathryn E. Royse, PhD, MPH, MSPH	United States	No Relationships
Paul T. Rubery, MD	United States	Johnson and Johnson (c)
Vincent Ruggieri, BS	United States	No Relationships
Paul R. Rushton, FRCS	United Kingdom	No Relationships
Tracy Ruska, NP	United States	No Relationships
Rahul Sachdev, BS	United States	No Relationships
Comron Saifi, MD	United States	NuVasive (g)
Toshiki Saito, MD, PhD	Japan	No Relationships

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Wataru Saito, MD, PhD	Japan	No Relationships
Tsuyoshi Sakuma, MD, PhD	Japan	No Relationships
Andre M. Samuel, MD	United States	No Relationships
Solomon Samuel, D. Eng.	United States	No Relationships
Jose Miguel Sánchez-Márquez, MD, PhD	Spain	No Relationships
Milan Sandhu, BS	United States	No Relationships
Tunay Sanli, MA	Turkey	No Relationships
Ender Sarioglu, MD	Turkey	No Relationships
Natalya Sarkisova, BS	United States	No Relationships
Vishal Sarwahi, MD, MBBS	United States	DePuy Synthes (b); Medtronic (b); NuVasive (b); Precision Spine (g)
Yutaka Sasao, MD, PhD	Japan	No Relationships
Samuel Sassine, BS	Canada	No Relationships
Ashwin Sathe, MS	India	No Relationships
Alexander M. Satin, MD	United States	No Relationships
Kosuke Sato, MD	United States	No Relationships
Tatsuya Sato, MD, PhD	Japan	No Relationships
Vijay Sawlani, MD	United Kingdom	No Relationships
Jeffrey R. Sawyer, MD	United States	Elsevier (g); Republic Spine (b); DePuy Synthes (d)
Michael L. Schmitz, MD	United States	Stryker Spine (b); Children's Healthcare of Atlanta (f); OrthoPediatrics (b)
William Schreiber-Stainthorp, BS	United States	No Relationships
John T. Schwartz, BS	United States	No Relationships
Jarren Section, MD	United States	No Relationships
Julieanne P. Sees, MD	United States	No Relationships
Dale Segal, MD	United States	No Relationships
Frank A. Segreto, BS	United States	No Relationships
Jonathan N. Sembrano, MD	United States	NuVasive (a); Orthofix (a)
Sahin Senay, MD	Turkey	No Relationships
Cristina Madrid de la Serna, MD	Spain	No Relationships
Miquel Serra-Burriel, PhD	Spain	No Relationships
Mark E. Shaffrey, MD	United States	No Relationships
Neil V. Shah, MD, MS	United States	No Relationships
Ronit Shah, BS	United States	No Relationships
Kenneth A. Shaw, DO	United States	No Relationships
Benjamin W. Sheffer, MD	United States	No Relationships
Jesse Shen, MD, MSc	Canada	No Relationships
Jinhui Shi, MD	China	No Relationships
Hideki Shigematsu, MD, PhD	Japan	No Relationships
Yoichi Shimada, MD, PhD	Japan	No Relationships
Takaki Shimizu, MD	Japan	No Relationships
Takayoshi Shimizu, MD, PhD	Japan	No Relationships
Kazuya Shinmura, PhD	Japan	No Relationships
M. Wade Shrader, MD	United States	No Relationships
Harry L. Shufflebarger, MD	United States	Stryker Spine (b, d, g)

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Brenda A. Sides, MA	United States	No Relationships
J. Alex Sielatycki, MD	United States	BalancedBack (c)
Susan Sienko, PhD	United States	No Relationships
Matthew E. Simhon, BS	United States	No Relationships
Byron H. Simmons, MD	United States	No Relationships
Benjamin Sinder, PhD	United States	No Relationships
Devender Singh, PhD	United States	No Relationships
Wafa Skalli, PhD	France	EOS Imaging (g); Stryker Spine (a); Clariance (a); Cousin Biotech (a)
Richard L. Skolasky, PhD	United States	No Relationships
Jonathan R. Slotkin, MD	United States	Stryker Spine (b)
Brian Smith, MD	United States	No Relationships
Jeremy Smith, MD	United States	NuVasive (a, b)
Simon L. Smith, PhD	United Kingdom	No Relationships
Brian D. Snyder, MD, PhD	United States	No Relationships
Federico Solla, MD	France	Medicrea (a); Euros (a)
Shardul Soman, MBBS, MS	India	No Relationships
Bryant Song, BS	United States	No Relationships
Steven P. Sparagana, MD	United States	No Relationships
Jesse Spencer-Smith, PhD	United States	No Relationships
Maarten Spruit, MD	Netherlands	No Relationships
William H. Stafford, BS	United States	No Relationships
Ashley Startzman, MD	United States	No Relationships
Portia A. Steele, RN	United States	No Relationships
Alyssa Steinbaum, BS	United States	No Relationships
Stephen Stephan, MD	United States	No Relationships
Carolyn Stickley, BS	United States	No Relationships
John Stokes, MD	United States	Genesys spine (g); Difusion (c); Summit Medventures (c)
Joseph Stone, MD	United States	OrthoPediatrics (b)
Peter F. Sturm, MD	United States	DePuy Synthes (b, e); NuVasive (b); Green Sun Medical (c)
Pramod Sudarshan, MD	India	No Relationships
Hideki Sudo, MD, PhD	Japan	No Relationships
Patrick W. Suen, MD	United States	No Relationships
Ryo Sugawara, MD, PhD	Japan	No Relationships
Maki Sugimoto, MD, PhD	Japan	Holoeyes Inc (f)
Hamdi Sukkarieh, MD	United States	No Relationships
Brian T. Sullivan, MD	United States	No Relationships
Aron Sulovari, BS	United States	No Relationships
Gonzalo Sumarriva, MD	United States	No Relationships
Xu Sun, MD	China	No Relationships
Choon Sung Lee, MD, PhD	South Korea	No Relationships
Satoshi Suzuki, MD, PhD	Japan	No Relationships
Teppei Suzuki, MD, PhD	Japan	No Relationships
Ishaan Swarup, MD	United States	No Relationships

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David S. Tager, MD	United States	Johnson and Johnson (c)
Yohei Takahashi, MD, PhD	Japan	No Relationships
Kazuki Takeda, MD, PhD	Japan	No Relationships
Gloria Talavera, MD	Spain	No Relationships
Ronan Talty, BS	United States	No Relationships
Divya Talwar, PhD	United States	No Relationships
Yongyao Tan, MS	Canada	No Relationships
Hiroshi Taneichi, MD, PhD	Japan	No Relationships
Peter Tang, MD	United States	No Relationships
Yuki Taniguchi, MD, PhD	Japan	No Relationships
Amir Taree, BS	United States	No Relationships
Ryoji Tauchi, MD, PhD	Japan	No Relationships
Chikashi Terao, MD, PhD	Japan	Actelion (a); ONO PHARMACEUTICAL CO., LTD. (d); Asahi Kasei Pharma (d); asteras (d); Tanabe-Mitsubishi (d)
Ravindra Thimmaiah, MD, FRCS Tr & Orth	United Kingdom	No Relationships
James Joseph Thomas, MD	United States	No Relationships
David C. Thornberg, BS	United States	No Relationships
Earl D. Thuet, BS	United States	No Relationships
Hallie A. Tiburzi, BS	United States	No Relationships
Laura Tillman, DNP	United States	No Relationships
Vernon T. Tolo, MD	United States	Journal of Bone and Joint Surgery - American (g); Wolters Kluwer Health - Lippincott Williams & Wilkins (g)
Yubing Tong, PhD	United States	No Relationships
Upasana Topiwala, BS	United Kingdom	No Relationships
Drew A. Torigian, MD, MA	United States	Quantitative Radiology Solutions LLC (c, e)
Dong-Phuong Tran, MS	United States	No Relationships
Ensor E. Transfeldt, MD	United States	Medtronic (g); Stryker Spine (g)
Michael J. Troy, BS	United States	No Relationships
Eeric Truumees, MD	United States	Doctoral research group (c); Stryker Spine (g); NASS (e); Medtronic (a); Relievant Medsystem (a); Kuros (a); Seikagaku Corporation (a)
Hiroyuki Tsuchiya, PhD	Japan	No Relationships
Osahiko Tsuji, MD, PhD	Japan	No Relationships
Taichi Tsuji, MD, PhD	Japan	No Relationships
Isabelle Turgeon, BSc	Canada	No Relationships
Jay D. Turner, MD	United States	NuVasive (a, b); SeaSpine (a, b)
Jayaram K. Udupa, PhD	United States	Quantitative Radiology Solutions, LLC (c)
Koki Uno, MD, PhD	Japan	No Relationships
Vidyadhar V. Upasani, MD	United States	DePuy Synthes (b); EOS Imaging (a); Globus Medical (b); NuVasive (d); OrthoPediatrics (a, b, g)
Bidre Upendra, MBBS, MS	India	Medtronic (a)
Hikari Urakawa, MD	United States	No Relationships
Atahan Durbas	Turkey	No Relationships
Juan S. Uribe, MD	United States	NuVasive (a, b, c, g); Misonix (b); SI Bone (b)

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Stephanie Urigüen, LPN	United States	No Relationships
Hiroki Ushirozako, MD, PhD	Japan	No Relationships
Avani S. Vaishnav, MBBS	United States	No Relationships
John L. Valentino, BS	United States	No Relationships
Aly A. Valliani, BS	United States	No Relationships
V.N. Ravi Varma, MBBS, MS	United States	No Relationships
Majella Vaughan, MPH	United States	No Relationships
Ryne J. Veenema, MS	United States	No Relationships
Muralidharan Venkatesan, MD	India	No Relationships
Bram P. Verhofste, MD	United States	No Relationships
Shaleen Vira, MD	United States	No Relationships
Michael S. Virk, MD, PhD	United States	DePuy Synthes (b, g); Globus Medical (b); Brainlab Inc (b)
Sohrab Virk, MD	United States	No Relationships
Ella Virkki, MD	Finland	No Relationships
Andrew C. Vivas, MD	United States	Nference (b)
Catphuong L. Vu, MD	United States	No Relationships
Meghana Vulapalli	United States	No Relationships
Marcelo Wajchenberg, MD, PhD	Brazil	No Relationships
Wenbing Wan, MD, PhD	China	No Relationships
Ce Wang, MD	China	No Relationships
Michael Y. Wang, MD	United States	K2M (b); Stryker Spine (b); DePuy Synthes (b, g); Spineology (b); ISD (c); Medical Device Partners (c)
Minghao Wang, MD, PhD	United States	No Relationships
Shengru Wang, MD	China	No Relationships
Wenhai Wang, PhD	United States	Globus Medical (f)
John Wanner, MD	United States	No Relationships
Spencer Warshauer, MS	United States	No Relationships
Kei Watanabe, MD, PhD	Japan	No Relationships
Yuh Watanabe, MD	Japan	No Relationships
Benjamin M. Weisenthal, MD	United States	No Relationships
Karen A. Weissmann, MD	Spain	Medyssey (b); Helico (b); Promedon (b); OrthoPediatrics (b)
Michelle C. Welborn, MD	United States	DePuy Synthes (b, d, e); K2M (b, d); NuVasive (b, d)
Sebastian E. Welling, BS	United States	No Relationships
Stephen F. Wendolowski, BS	United States	No Relationships
Shi Wenyuan, PhD	United States	No Relationships
Klane K. White, MD	United States	No Relationships
Sebastiaan P. Wijdicks, MD	Netherlands	No Relationships
Kerry Wilder, PhD	United States	No Relationships
Tyler Wilps, BS	Ghana	No Relationships
Robert Winkelman, MS	United States	No Relationships
Zhu Winnie, PhD	United States	No Relationships
Adam J. Wolfert, BS	United States	No Relationships
Hee-Kit Wong, FRCS	Singapore	SpineGuard (e)
Yat Wa Wong, MD, MBBS	China	No Relationships

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Thaddeus Woodard, BS	United States	No Relationships
Regina Woon, MPH	United States	No Relationships
Patrick B. Wright, MD	United States	No Relationships
Caiyun Wu, MS	United States	No Relationships
Hao-Hua Wu, MD	United States	No Relationships
Irene Wulff, MD	Ghana	No Relationships
Enjie Xu, MD	China	No Relationships
Liang Xu, MD	China	No Relationships
Zhuo Xi, MD	United States	No Relationships
Wen-Bin Xuan, MD	China	No Relationships
Mitsuru Yagi, MD, PhD	Japan	No Relationships
Pinar Yalinay Dikmen, MD	Turkey	No Relationships
Tomohiro Yamada, MD	Japan	No Relationships
Yu Yamato, MD, PhD	Japan	No Relationships
Joshua Yang, BA	United States	No Relationships
Elizabeth L. Yanik, PhD	United States	No Relationships
Ziming Yao, PhD	China	No Relationships
Reza Yassari, MD, MS	United States	No Relationships
Tatsuya Yasuda, MD	Japan	No Relationships
Yasemin Yavuz, PhD	Turkey	No Relationships
Jichao Ye, MD	China	No Relationships
Samrat Yeramaneni, PhD	United States	No Relationships
Tsung-Cheng Yin, MD	Taiwan	No Relationships
Ikuho Yonezawa, MD, PhD	Japan	No Relationships
Noritaka Yonezawa, MD	Japan	No Relationships
Eric Yoon, BS	United States	No Relationships
Petya Yorgova	United States	No Relationships
Go Yoshida, MD, PhD	Japan	No Relationships
Anthony Yu, MS	United States	No Relationships
Honggui Yu, MD, PhD	China	No Relationships
Altug Yucekul, MD	Turkey	No Relationships
Nikita Zaborovskii, MD, PhD	Russia	No Relationships
Karina Zapata, PhD, DPT	United States	No Relationships
Reinhard D. Zeller, MD, FRCS(C)	Canada	Spinevision (g); Stryker Spine (g)
Hongqi Zhang, MD	China	No Relationships
Jianguo Zhang, MD	China	No Relationships
Teng Zhang, PhD	China	No Relationships
Xuejun Zhang, MD	China	No Relationships
Jack R. Zhong, BS	United States	No Relationships
Rongping Zhou, MD, PhD	China	No Relationships
Xuhui Zhou, MD	China	No Relationships
Zhenhai Zhou, MD, PhD	China	No Relationships
Zezhang Zhu, MD	China	No Relationships

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Scott Zuckerman, MD	United States	No Relationships
Tais Zulemyan, MD	Turkey	No Relationships
STAFF		
Sinais Alvarado, MA	United States	No Relationships
Lily Atonio	United States	No Relationships
Alysha B. Chapman, CNP	United States	No Relationships
Ann D'Arienzo, CMP	United States	No Relationships
Jenifer Heller	United States	No Relationships
Courtney Kissinger	United States	No Relationships
Ashtin Neuschaefer, CAE	United States	No Relationships
Laura Pizur	United States	No Relationships
Shawn Storey	United States	No Relationships

Meeting Outline

Times are provided in three different time zones: US Eastern Daylight Time, Central European Summer Time, and China Standard Time.

US EASTERN DAYLIGHT TIME		
DATE	**TIME**	**SESSION**
Tuesday, September 8	9:00-9:30	Member Business Meeting*
Wednesday, September 9	8:00-10:10 10:20-12:00	Pre-Meeting Course Scientific Program
Thursday, September 10	9:00-10:30 10:30-11:35	Scientifc Program (2 Concurrent Sessions) Opening Ceremonies*
Friday, September 11	9:00-11:15	Scientific Program and Harrington Lecture
Saturday, September 12	9:00-10:50 10:50-11:30 11:30-12:40	Hibbs Basic Science and Clinical Research Award Nominees 2021 Preview, Scientific Awards & Transfer of Presidency* Early Career Surgeons Session*
Sunday, September 13	9:00-11:00	Half-Day Courses (2 Concurrent Sessions)
CHINA STANDARD TIME		
DATE	**TIME**	**SESSION**
Tuesday, September 8	21:00-21:30	Member Business Meeting*
Wednesday, September 9	20:00-22:10 22:20-00:00	Pre-Meeting Course Scientific Program
Thursday, September 10	21:00-22:30 22:30-23:35	Scientifc Program (2 Concurrent Sessions) Opening Ceremonies*
Friday, September 11	21:00-23:15	Scientific Program and Harrington Lecture
Saturday, September 12	21:00-22:50 22:50-23:30 23:30-00:40	Hibbs Basic Science and Clinical Research Award Nominees 2021 Preview, Scientific Awards & Transfer of Presidency* Early Career Surgeons Session*
Sunday, September 13	21:00-23:00	Half-Day Courses (2 Concurrent Sessions)
CENTRAL EUROPEAN SUMMER TIME		
DATE	**TIME**	**SESSION**
Tuesday, September 8	15:00-15:30	Member Business Meeting*
Wednesday, September 9	14:00-16:10 16:20-18:00	Pre-Meeting Course Scientific Program
Thursday, September 10	15:00-16:30 16:30-17:35	Scientifc Program (2 Concurrent Sessions) Opening Ceremonies*
Friday, September 11	15:00-17:15	Scientific Program and Harrington Lecture
Saturday, September 12	15:00-16:50 16:50-17:30 17:30-18:40	Hibbs Basic Science and Clinical Research Award Nominees 2021 Preview, Scientific Awards & Transfer of Presidency* Early Career Surgeons Session*
Sunday, September 13	15:00-17:00	Half-Day Courses (2 Concurrent Sessions)
SELF-PACED CONTENT		
Pre-Meeting Course Supplement Half-Day Course Abstract Supplements: Adult & Pediatric Abstract Sessions Membership Information Session* Industry Workshops*		

**Denotes non-CME session*

Live Session Agenda

Session times are listed in US Eastern Daylight Time.

Tuesday, September 8, 2020

9:00-9:30 US EDT / 21:00-21:30 CST / 15:00-15:30 CEST

Member Business Meeting*

All SRS members are invited to join the virtual Member Business Meeting. Agendas will include reports from the various SRS committees, updates on SRS activities and programs, and voting.

Wednesday, September 9, 2020

8:00-10:10 US EDT / 20:00-22:10 CST / 14:00-16:10 CEST

Pre-Meeting Course: Interdisciplinary Care for Optimizing Outcomes in the Patient with Spinal Deformity

The Pre-Meeting Course is supported, in part, by a grant from Globus Medical, Inc.

Course Chair: Baron S. Lonner, MD; Course Co-Chairs: Michael S. Chang, MD and Gregory R. White, MD

Organizing Committee: Stefan Parent, MD, PhD; Amer F. Samdani, MD; Suken A. Shah, MD; Paul D. Sponseller, MD, MBA; Burt Yaszay, MD

Section 1: Interdisciplinary Clinical Support and Perioperative Optimization

Moderators: Michael S. Chang, MD & Gregory R. White, MD

8:00-8:02 **Course Welcome**
Baron S. Lonner, MD

8:02-8:10 **Anesthesia Optimization: Pediatric**
Steve Beck, MD

8:10-8:18 **Anesthesia Optimization: Adult**
Lee Kimball, MD

8:18-8:26 **Pulmonary Assessment**
Gregory J. Redding, MD

8:26-8:34 **When to Seek a Genetics Consult**
Derek Neilson, MD

8:34-8:39 **Two-Surgeon Teams to Improve Outcomes**
Jamal McClendon Jr., MD

8:39-8:44 **Two-Surgeon Teams to Improve Outcomes**
Jaysson T. Brooks, MD

8:44-8:49 **Debate: Access Surgeons are Beneficial to the Team**
Kenneth Fang, MD, FACS

8:49-8:54 **Debate: Access Surgeons are Unecessary Resources**
Stefan Parent, MD, PhD

8:54-9:04 **Discussion**

Moderators: Samuel K. Cho, MD and Suken A. Shah, MD

9:04-9:12 **Role of the Intensivist: How is Intensive Care Best Incorporated Into the Care Paradigm?**
Ayan Sen, MD

9:12-9:20 **Post-Operative Pain Management: Minimizing Opioids and Complications**
John Jerman, MD

9:20-9:26 **Nursing: Improving Patient Outcomes and Satisfaction**
Kristen Venuti, CRNP

9:26-9:32 **Hospital Team: Improving Patient Outcomes and Satisfaction**
Miranda Falk, PA-C

9:32-9:37 **The Patient's Perspective in Shared Surgical Decision Making: Pediatric**
Eric D. Shirley, MD

**Denotes non-CME session*

Live Session Agenda - Wednesday, September 9

Session times are listed in US Eastern Daylight Time.

9:37-9:42 **The Adult Patient's Perspective in Shared Surgical Decision Making**
Ferran Pellisé, MD, PhD

9:42-9:52 **Utilizing the C-Suite**
Barbara McWilliams, RN, BSN, MBA

9:52-10:10 **Discussion**

10:10-10:20 **Break**

10:20-12:00 US EDT / 22:20-00:00 CST / 16:20-18:00 CEST

Session 1: Quality/Safety/Value/Complications

Moderators: Suken A. Shah, MD & David L. Skaggs, MD

10:20-10:24 **Paper #13: Use of Predictive Machine Learning Models at the Population Level Has the Potential to Save Cost by Directing Economic Resources to Those Likely to Improve Most: A Simulation Analysis Stratified by Risk in Largest Combined US/European ASD Registry**
Rushikesh S. Joshi, BS; Miquel Serra-Burriel, PhD; Ferran Pellisé, MD, PhD; Darryl Lau, MD; Justin S. Smith, MD, PhD; Michael P. Kelly, MD; Ahmet Alanay, MD; Emre R. Acaroglu, MD; Francisco Javier S. Perez-Grueso, MD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD; Douglas C. Burton, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Christopher P. Ames, MD

10:24-10:28 **Paper #14: Clinical Review of Spine Surgery Patient Safety Indicators Avoids CMS Payment Reductions**
John A. Buza III, MD; Ryan Nazar, MD; Portia A. Steele, RN; Leah Y. Carreon, MD; Joseph L. Laratta, MD; Steven D. Glassman, MD; Jeffrey L. Gum, MD

10:28-10:32 **Paper #15: The Impact of Early Physical Therapy on Resource Utilization and Spending in First Time Presenters of Low Back Pain**
Majd Marrache, MD; Niyathi Prasad, BS; Suresh Nayar, MD; Matt Best, MD; Richard L. Skolasky, PhD

10:32-10:41 **Discussion**

10:41-10:45 **Paper #16: Critical Analysis of Anterior/Posterior Staged vs. Same Day Surgery in Patients Undergoing Identical Corrective Surgery for Adult Spinal Deformity**
Waleed Ahmad, BS; Peter G. Passias, MD; Renaud Lafage, MS; Virginie Lafage, PhD; Breton G. Line, BS; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Pierce D. Nunley, MD; D. Kojo Hamilton, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Christopher P. Ames, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; Eric O. Klineberg, MD

10:45-10:49 **Paper #17: Does a Dedicated "Scoliosis Team" and Surgical Standardization Improve Outcomes in AIS Surgery and is it Reproducible?**
Vishal Sarwahi, MD, MBBS; Sayyida Hasan, BS; Jesse Galina, BS; Aaron M. Atlas, BS; Michelle Kars, MD; Benita Liao, MD; Yungtai Lo, PhD; Terry D. Amaral, MD

10:49-10:53 **Paper #18: Ultrasonic Bone Scalpel Does Not Reduce Blood Loss in Adolescent Idiopathic Scoliosis: Randomized Clinical Trialr**
Sumeet Garg, MD; James Joseph Thomas, MD; Hannah Quick, BA; Patrick Carry, MS; Eun Kim; Mark A. Erickson, MD

10:53-11:02 **Discussion**

11:02-11:06 **Paper #19: The Necessity and Risk Factors of Subsequent Fusion After Decompression Alone for Lumbar Spinal Stenosis with Lumbar Spondylolisthesis: 5-Year Follow-Up in 2 Large Populations**
Hikari Urakawa, MD; Andre M. Samuel, MD; Avani S. Vaishnav, MBBS; Yoshihiro Katsuura, MD; Sravisht Iyer, MD; Steven J. Mcanany, MD; Todd J. Albert, MD; (Catherine) Himo Gang, MPH; Sheeraz Qureshi, MD

11:06-11:10 **Paper #20: Predicting Mechanical Complications After Adult Spinal Deformity Surgery: Modified Global Alignment and Proportion Scoring with Body Mass Index and Bone Mineral Density (GAPB) vs Global Alignment and Proportion (GAP) Score in Each Categorical Comparative**
Sung Hyun Noh, MD; Kyunghyun Kim, MD

**Denotes non-CME session*

Live Session Agenda - Wednesday, September 9

Session times are listed in US Eastern Daylight Time.

11:10-11:14 **Paper #21: Lower Extremity Motor Scores (LEMS) After Complex Adult Spinal Deformity Surgery: 5-Year Follow-Up of the Scoli-Risk-1 Studyr**
Lawrence G. Lenke, MD; Meghan Cerpa, MPH; Scott Zuckerman, MD; Zeeshan M. Sardar, MD; Yong Qiu, MD; Christopher I. Shaffrey, MD; Leah Y. Carreon, MD; Kenneth Cheung, MD, MBBS, FRCS; Michael P. Kelly, MD; Ames P. Christopher, MD; Frank J. Schwab, MD; Oheneba Boachie-Adjei, MD; Yukihiro Matsuyama, MD, PhD; Khaled M. Kebaish, MD

11:14-11:23 **Discussion**

11:23-11:27 **Paper #22: The Additional Economic Burden of Frailty in Adult Spinal Deformity Patients Undergoing Surgical Intervention**
Peter G. Passias, MD; Waleed Ahmad, BS; Renaud Lafage, MS; Virginie Lafage, PhD; Khaled M. Kebaish, MD; Alan H. Daniels, MD; Eric O. Klineberg, MD; Alex Soroceanu, MPH; Jeffrey L. Gum, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Richard Hostin, MD; Shay Bess, MD

11:27-11:31 **Paper #23: Rates of Loosening, Failure, and Revision of Iliac Fixation in Adult Deformity Surgery**
Robert K. Eastlack, MD; Alex Soroceanu, MPH; Gregory M. Mundis, MD; Alan H. Daniels, MD; Justin S. Smith, MD, PhD; Breton G. Line, BS; Peter G. Passias, MD; Pierce D. Nunley, MD; David O. Okonkwo, MD; Khoi D. Than, MD; Juan S. Uribe, MD; Praveen V. Mummaneni, MD; Dean Chou, MD; Khaled M. Kebaish, MD; Christopher I. Shaffrey, MD; Shay Bess, MD

11:31-11:35 **Paper #24: Prolonged Post-Operative Intubation Following Spinal Fusion in Cerebral Palsy: Are there Modifiable Risk Factors and Associated Consequences?**
Scott M. LaValva, BA; Keith Baldwin, MD; Ishaan Swarup, MD; John M. Flynn, MD; Joshua M. Pahys, MD; Burt Yaszay, MD; Mark Abel, MD; Keith Bachmann, MD; Suken A. Shah, MD; Paul D. Sponseller, MD, MBA; Harms Study Group; Patrick J. Cahill, MD

11:35-11:44 **Discussion**
Paper #25: has been withdrawn

11:44-11:48 **Paper #26: Patient Centered Interdisciplinary Medical Optimization Clinic Decreases Surgical Site Infection (SSI) Risk in Pediatric Neuromuscular and Syndromic Scoliosis Patients.**
Amy L. McIntosh, MD; Kerry Wilder, PhD

11:48-11:52 **Paper #27: Surgical Site Infection Incidence in Neuromuscular Posterior Spinal Fusion: Comparing Incidence Before and After the Implementation of the 2013 Best Practice Guideline**
Stephen Stephan, MD; Kenneth D. Illingworth, MD; Kavish Gupta, BS; David L. Skaggs, MD; Lindsay M. Andras, MD

11:52-12:00 **Discussion**

**Denotes non-CME session*

Live Session Agenda - Thursday, September 10

Session times are listed in US Eastern Daylight Time.

Thursday, September 10, 2020

9:00-9:05 **Meeting Welcome**
Lindsay C. Andras, MD and Paul D. Sponseller, MD, MBA

9:05-10:30 US EDT / 21:05-22:30 CST / 15:05-16:30 CEST

Session 2A: Adolescent Idiopathic Scoliosis I: From Assessing Skeletal Maturity to Managing Pain *(Runs Concurrently with Session 2B)*

Moderators: Kenneth MC Cheung, MD & Laurel C. Blakemore, MD

9:05-9:09 **Paper #1: Refining the Proximal Humerus Ossification System Using Medial Physeal Closure**
Don Li, PhD; Logan Petit, MD; Joseph Kahan, MD; Elsayed Attia, MD; Ashley Startzman, MD; Eric Li ; Siddharth Jadhav, MD; Alana Munger, MD; Ahmed Elabd, MD; Janelle Greene, MD; Jonathan Cui, MD; Ronan Talty, BS; Brett Heldt, BS; Daniel R. Cooperman, MD; Brian G. Smith, MD

9:09-9:13 **Paper #2: Multi-Site Assessment of Pediatric Bone Age Using Deep Learning**
Aly A. Valliani, BS; John T. Schwartz, BS; Eric Geng, BS; Varun Arvind, BS; Christopher Mikhail, MD; Jun Kim, MD; Samuel K. Cho, MD

9:13-9:17 **Paper #3: Comparison between Low-Dose Slot Scanning and Conventional Radiography for Hand Bone Age: Imaging Quality and Radiation Dose**
Jie C. Nguyen, MD, MS; Andressa G. Alves, MD; Anthony Nicholson, BS; Liya Gendler, MD; Victor Ho-Fung, MD; Sze Alyssa, BA; Michael Nguyen, BS; Zhu Winnie, PhD; Divya Talwar, PhD; Kassa Darge, MD, PhD; John (Jack) M. Flynn, MD; Patrick J. Cahill, MD

9:17-9:26 **Discussion**

9:26-9:30 **Paper #4: MOBI (My Orthopedic Brace Inventory): A New Reliable and Valid Questionnaire to Identify Factors Associated with Poor Adherence to Brace Treatment in AIS**
Omar Elsemin, BSN; Marie Beausejour, PhD; Samuel Sassine; Julie Joncas, RN; Soraya Barchi, BSc; Sylvie Le May, PhD; Nikita Cobetto, PhD; Carole Fortin, PhD; Carl-Eric Aubin, PhD; Stefan Parent, MD, PhD; Hubert Labelle, MD

9:30-9:34 **Paper #5: AIS Patients with Pain Catastrophizing Have Worse SRS Scores 1 Year Postoperatively**
Kiley F. Poppino, BS; Shelby P. Cerza, MA; Teresa L. Collins-Jones, PhD; Brandon A. Ramo, MD

9:34-9:38 **Paper #6: The Effects of Obesity and Poverty on Perioperative Complications in Adolescent Idiopathic Scoliosis: A Multi-Center Analysis**
Tyler C. McDonald, MD; Michael J. Heffernan, MD; Bryant Song, BS; Hamdi Sukkarieh, MD; Lawrence L. L. Haber, MD; Michael Joseph Conklin, MD; Shawn R. Gilbert, MD; Benjamin W. Sheffer, MD; William H. Stafford, BS; Jeffrey E. Martus, MD; Charles H. Crawford III, MD; Leah Y. Carreon, MD; John P. P. Lubicky, MD; David S. Tager, MD; David B. Bumpass, MD; Killian Coyne, BS; Brandon A. Ramo, MD; Patrick B. Wright, MD; Jaysson T. Brooks, MD

9:38-9:47 **Discussion**

9:47-9:51 **Paper #7: Comparison of Four Different Methods of Correction for Adolescent Idiopathic Scoliosis: Results from A National Cohort Study**
Sebastien Pesenti, MD, PhD; Federico Solla, MD; Yann Philippe Charles, MD, PhD; Brice Ilharreborde, MD, PhD; Christian Morin, MD; Jean-Luc Clement, MD

9:51-9:55 **Paper #8: What Factors are Associated with Greater Apical Derotation? Is Single or Dual Rod Derotation Better?**
Steven W. Hwang, MD; Joshua M. Pahys, MD; Tracey P. Bastrom, MA; Peter O. Newton, MD; Suken A. Shah, MD; Stefan Parent, MD, PhD; Harms Study Group; Amer F. Samdani, MD

9:55-9:59 **Paper #9: Perioperative Steroid Use in Patients Undergoing PSF for AIS**
Tracy Ruska, NP; Thomas Austin, MD, MS; Ndeye F. Guisse, MS; Robert W. Bruce Jr., MD; Joshua S. Murphy, MD; Nicholas D. Fletcher, MD

9:59-10:08 **Discussion**

10:08-10:12 **Paper #10: Parents Anxiety Predicts Child's Narcotic Use**
Natalya Sarkisova, BS; Lindsay M. Andras, MD; Joshua Yang, BA; Vernon T. Tolo, MD; David L. Skaggs, MD

**Denotes non-CME session*

Live Session Agenda - Thursday, September 10

Session times are listed in US Eastern Daylight Time.

10:12-10:16 **Paper #11: Zero PCA is an Achievable Target for Postoperative Rapid Recovery Management of AIS Patients**
Vishal Sarwahi, MD, MBBS; Sayyida Hasan, BS; Michelle Kars, MD; Benita Liao, MD; Jesse Galina, BS; Yungtai Lo, PhD; Terry D. Amaral, MD

10:16-10:20 **Paper #12: Can Opioid Free Anesthesia (OFA) Reduce Postoperative Pain After Adolescent Idiopathic Scoliosis Surgery?**
Florence Julien-Marsollier, MD; Rita Assaker, MD; Souhayl Dahmani, MD, PhD; Brice Ilharreborde, MD, PhD

10:20-10:30 **Discussion**

9:05-10:30 US EDT / 21:05-22:30 CST / 15:05-16:30 CEST

Session 2B: Adult Spinal Deformity I *(Runs Concurrently with Session 2A)*

Moderators: Ehsan Jazini, MD & Praveen V. Mummaneni, MD

9:05-9:09 **Paper #43: Dubousset Functional Test (DFT): The First Application on Spine Patients and Asymptomatic Volunteers**
Bassel G. Diebo, MD; David Kim, BS; Michael G. Dubner, BS; Neil Patel, BS; Sanjeev Agarwal, MD; Harleen Kaur, BS; George A. Beyer, MS; Neil V. Shah, MD, MS; Renaud Lafage, MS; Carl B. Paulino, MD; Peter G. Passias, MD; Vincent Challier, MD; Frank J. Schwab, MD; Virginie Lafage, PhD

9:09-9:13 **Paper #44: Relationships Between Radiographic Parameters and Spinopelvic Muscles in Adult Spinal Deformity Patients**
Emmanuelle Ferrero, MD, PhD; Pierre Guigui, MD; Wafa Skalli, PhD; Virginie Lafage, PhD

9:13-9:17 **Paper #45: Risk Factors for Rapid Curve Progression in De Novo Degenerative Lumbar Scoliosis**
Dmitrii Ptashnikov, MD, PhD; Sergei Masevnin, MD, PhD; Dmitrii Mikhailov, MD, PhD; Nikita Zaborovskii, MD, PhD; Anton Denisov, MD

9:17-9:26 **Discussion**

9:26-9:30 **Paper #46: Efficacy of Adult Spinal Deformity Surgical Decision Making (ASD-SDM) Score in Patients Over 40 Years as an Indication for Surgical Management.**
Sreenath R. Jakinapally, MD; Louis Boissiere, MD; Ferran Pellisé, MD, PhD; Francisco Javier S. Perez-Grueso, MD; Frank S. Kleinstueck, MD; Emre R. Acaroglu, MD; Ahmet Alanay, MD; Ibrahim Obeid, MD

9:30-9:34 **Paper #47: Identifying Subsets of Adult Spinal Deformity Patients that Maintained a Positive Response to Non-Operative Management**
Peter G. Passias, MD; Waleed Ahmad, BS; Frank A. Segreto, BS; Renaud Lafage, MS; Virginie Lafage, PhD; Alex Sorocanu, MPH; Alan H. Daniels, MD; Jeffrey L. Gum, MD; Breton G. Line, BS; Robert A. Hart, MD; Douglas C. Burton, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Richard Hostin, MD; Shay Bess, MD

9:34-9:38 **Paper #48: When Not to Operate in Spinal Deformity: Identifying Subsets of Patients with Simultaneous Clinical Deterioration, Major Complications, and Reoperation**
Peter G. Passias, MD; Katherine E. Pierce, BS; Renaud Lafage, MS; Virginie Lafage, PhD; D. Kojo Hamilton, MD; Gregory M. Mundis, MD; Han Jo Kim, MD; Richard Hostin, MD; Alan H. Daniels, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Christopher P. Ames, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; Eric O. Klineberg, MD

9:38-9:47 **Discussion**

9:47-9:51 **Paper #49: The Effect of Intraoperative Prone Cross-table Lateral X-ray on Surgical Treatment of Adult Spinal Deformity**
Ayhan Mutlu, MD; Mustafa Eltayep, MD; Seray G. Gur, MD; Huseyin Ozturk, MD; Sinan Kahraman, MD; Tunay Sanli, MA; Selhan Karadereler, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD

9:51-9:55 **Paper #50: Opioid Use Prior to Adult Spine Deformity (ASD) Surgery is Associated with Decreased Cost Effectiveness; A Matched Cohort Analysis**
Breton G. Line, BS; Shay Bess, MD; Samrat Yeramaneni, PhD; Richard Hostin, MD; Christopher P. Ames, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Douglas C. Burton, MD; Eric O. Klineberg, MD; Munish C. Gupta, MD; Robert K. Eastlack, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Robert A. Hart, MD; Khaled M. Kebaish, MD; Han Jo Kim, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD

**Denotes non-CME session*

Live Session Agenda - Thursday, September 10

Session times are listed in US Eastern Daylight Time.

9:55-9:59 **Paper #51: Recovery Kinetics of Post-operative Opiate Usage in Adult Spinal Deformity Corrective Surgery: Is There an Optimal Time Frame For Cessation?**
Waleed Ahmad, BS; Peter G. Passias, MD; Renaud Lafage, MS; Virginie Lafage, PhD; Eric O. Klineberg, MD; Michael P. Kelly, MD; Jeffrey L. Gum, MD; Breton G. Line, BS; Mitsuru Yagi, MD, PhD; Robert A. Hart, MD; Douglas C. Burton, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Richard Hostin, MD; Shay Bess, MD

9:59-10:08 **Discussion**

10:08-10:12 **Paper #52: Decompression Alone, Limited Fusion, or Full Correction of Adult Scoliosis: Outcomes and Morbidity with Minimum 2-Year Follow-Up**
Minghao Wang, MD, PhD; Gregory Hawryluk, MD; Praveen V. Mummaneni, MD; Darryl Lau, MD; Ratnesh N. Mehra, MD; Rory R. Mayer, MD; Dean Chou, MD; Bo Li, MD

10:12-10:16 **Paper #53: Cost Effectiveness of Adult Lumbar Scoliosis Surgery: An As-treated Analysis from the Adult Symptomatic Scoliosis Surgery Trial with Five Year Follow-Upr**
Steven D. Glassman, MD; Leah Y. Carreon, MD; Christopher I. Shaffrey, MD; Michael P. Kelly, MD; Charles H. Crawford III, MD; Elizabeth L. Yanik, PhD; Jon D. Lurie, MD, MS; Shay Bess, MD; Christine Baldus, RN; Keith H. Bridwell, MD

10:16-10:20 **Paper #54: Adverse Events Occurring up to 5-years after Complex Adult Spinal Deformity Surgery: A Scoli-Risk-1 Analysisr**
Meghan Cerpa, MPH; Scott Zuckerman, MD; Lawrence G. Lenke, MD; Zeeshan M. Sardar, MD; Eric Leung, BS; Meghana Vulapalli ; Joseph M. Lombardi, MD; Ferran Pellisé, MD, PhD; Khaled M. Kebaish, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Yukihiro Matsuyama, MD, PhD; Leah Y. Carreon, MD; Yong Qiu, MD; Kenneth Cheung, MD, MBBS, FRCS; Michael P. Kelly, MD; Ames P. Christopher, MD; Frank J. Schwab, MD; Oheneba Boachie-Adjei, MD

10:20-10:30 **Discussion**

10:30-11:35 US EDT / 22:30-23:35 CST / 16:30-17:35 CEST

Opening Ceremonies

10:30-10:50 **Welcome & Presidential Address**
Paul D. Sponseller, MD, MBA

10:50-10:52 **Announcement of Biedermann & Cotrel Award**
Paul D. Sponseller, MD, MBA

10:52-11:07 **Acknowledgement of Corporate Supporters**
Peter O. Newton, MD, Past President & Corporate Relations Committee Chair

11:07-11:10 **Acknowledgement of the 2020 Blount Humanitarian & Lifetime Achievement Award Winners**
Paul D. Sponseller, MD, MBA

11:10-11:12 **Introduction of Howard Steel Lecturer**
Paul D. Sponseller, MD, MBA

11:12-11:32 **Howard Steel Lecture: Navajo Code Talker and Former Leader of the Navajo Nation**
Peter MacDonald, Sr.

11:32-11:35 **Closing Remark**
Paul D. Sponseller, MD, MBA

**Denotes non-CME session*

Live Session Agenda - Friday, September 11

Session times are listed in US Eastern Daylight Time.

Friday, September 11, 2020

9:00-10:40 US EDT / 21:00-22:40 CST / 15:00-16:40 CEST

Session 3: Nerves and Big Curves: Advances in Neuromonitoring and Management of Severe Spinal Deformity

Moderators: Christopher P. Ames, MD & Lawrence G. Lenke, MD & Kota Watanabe, MD, PhD

9:00-9:04 **Paper #109: Review of New Neurological Injuries and Prognosis Associated with Idiopathic Scoliosis Surgeries Utilizing the Scoliosis Research Society Morbidity and Mortality (SRS M&M) Database**
Swamy Kurra, MD; Harman Chopra, BS; Jinhui Shi, MD; Stephen A. Albanese, MD; Elizabeth A. Demers Lavelle, MD; William F. Lavelle, MD

9:04-9:08 **Paper #110: Intraoperative Neuromonitoring Practice Patterns in Spinal Deformity Surgery**
Pinar Yalinay Dikmen, MD; Altug Yucekul, MD; Matthew Halsey, MD; Irem Havlucu; Tais Zulemyan, MD; Caglar Yilgor, MD; Ahmet Alanay, MD

9:08-9:12 **Paper #111: A Wireless Intraoperative Neuromonitoring System is as Reliable and Accurate as the Traditional Wired Systems for AIS Surgery**
Shi Wenyuan, PhD; J.C. Chiao, PhD; Steven P. Sparagana, MD; Patricia Rampy, CNIM; Kiley F. Poppino, BS; Daniel J. Sucato, MD, MS

9:12-9:21 **Discussion**

9:21-9:25 **Paper #112: Prospective Validation of The Spinal Cord Shape Classification System (SCSCS) to Assess the Risk of Intraoperative Neuromonitoring Data Loss with Thoracic Deformity Correction**
Meghan Cerpa, MPH; J. Alex Sielatycki, MD; Scott Zuckerman, MD; Earl D. Thuet, BS; Griffin R. Baum, MD; Zeeshan M. Sardar, MD; Paul J. Park, MD; Joseph M. Lombardi, MD; Eric Leung, BS; Meghana Vulapalli; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

9:25-9:29 **Paper #113: How a Compressed Spinal Cord is Rejuvenated in Spinal Tuberculosis:A Case Series of Surgical Approaches on 715 Patients**
Md Shah Alam, FCPS; Sharif A. Jonayed, FCPS; Sarwar Jahan, FCPS; Abdullah Al Mamun, FCPS; O Z M Dastagir, D Ortho; Shubhendu Chakraborty, MRCS

9:29-9:33 **Paper #114: Better Late than Never: Neurological Outcomes of Surgical Decompression in Neglected Tuberculosis Spine with Neurodeficit**
Tushar N. Rathod, MS; Ashwin Sathe, MS; Swapnil Keny, MS; Abhinav Jogani, MS

9:33-9:42 **Discussion**

9:42-9:46 **Paper #115: The Contribution of Preoperative Halo-Pelvic Traction to Correcting Severe Rigid Scoliosis**
Kai Cao, MD, PhD; Lu Chen, MD, PhD; Honggui Yu, MD, PhD; Zhenhai Zhou, MD, PhD; Rongping Zhou, MD, PhD; Wenbing Wan, MD, PhD; Zhimin Pan, MD, PhD

Paper #116: has been withdrawn

9:46-9:50 **Paper #117: Intraoperative and Early Postoperative Complications After Surgery for Severe Pediatric Spinal Deformity Have a High Rate of Resolution at 2 Years but Affect Outcome Scores**
Munish C. Gupta, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; David B. Bumpass, MD; Mark A. Erickson, MD; Sumeet Garg, MD; Richard E. McCarthy, MD; Peter O. Newton, MD; Joshua M. Pahys, MD; Amer F. Samdani, MD; Suken A. Shah, MD; Harry L. Shufflebarger, MD; Paul D. Sponseller, MD, MBA; Daniel J. Sucato, MD, MS; Burt Yaszay, MD; Brenda A. Sides, MA; Mi . Allograft Reconstructed Iliac Bone-graft Donor Site Remodels to Viable Bone and Its Preliminary Clinical Effectiveness in Revision Fusionchael P. Kelly, MD; Fox Pediatric Spinal Deformity Study

9:50-9:59 **Discussion**

9:59-10:03 **Paper #118: Surgical Treatment of Severe Pediatric Spinal Deformity Significantly Improves Pulmonary Function**
Munish C. Gupta, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; David B. Bumpass, MD; Mark A. Erickson, MD; Sumeet Garg, MD; Richard E. McCarthy, MD; Peter O. Newton, MD; Joshua M. Pahys, MD; Amer F. Samdani, MD; Suken A. Shah, MD; Harry L. Shufflebarger, MD; Paul D. Sponseller, MD, MBA; Daniel J. Sucato, MD, MS; Burt Yaszay, MD; Brenda A. Sides, MA; Michael P. Kelly, MD; Fox Pediatric Spinal Deformity Study

**Denotes non-CME session*

Live Session Agenda - Friday, September 11

Session times are listed in US Eastern Daylight Time.

10:03-10:07 **Paper #119: The Influence of Rib Resection on Pulmonary Function After Vertebral Column Resection in the Thoracic Spine**
Satoru Demura, MD, PhD; Satoshi Kato, PhD; Kazuya Shinmura, PhD; Noritaka Yonezawa, MD; Takaki Shimizu, MD; Norihiro Oku, MD; Ryo Kitagawa, MD; Makoto Handa, MD; Ryohei Annen, MD; Hiroyuki Tsuchiya, PhD

10:07-10:11 **Paper #120: Vertebral Column Resection by Concave Pedicle Drilling in Severe Kyphoscoliosis**
Anjaneyulu R. Devireddy, MBBS, MS; Bijjawara H Mahesh, MBBS, MS; Bidre Upendra, MBBS, MS; Raghavendra Rao, MBBS, MS; Ravi Varma VN, MBBS, MS

10:11-10:20 **Discussion**

10:20-10:24 **Paper #121: Medical Complications and Health Related Quality of Life in Complex Pediatric Spine Deformities Exceeding 100 Degrees or Treated By 3CO.**
Kwadwo Poku Yankey, MD; Henry Ofori Duah, MPH; Arthur Sackeyfio, MD; Lawrence G. Lenke, MD; Paul D. Sponseller, MD, MBA; Suken A. Shah, MD; Mark A. Erickson, MD; Brenda A. Sides, MA; Peter O. Newton, MD; David B. Bumpass, MD; Irene Wulff, MD; Munish C. Gupta, MD; Oheneba Boachie-Adjei, MD

10:24-10:28 **Paper #122: Reducing Revision Rates following 3-Column Osteotomy Surgery:A Single-Center Experience of Trends Over Seven Years**
Tanvir J. Bari, MD; Dennis W. Hallager, MD, PhD; Lars V. Hansen, MD; Benny T. Dahl, DMSc; Martin Gehrchen, MD, PhD

10:28-10:40 **Discussion**

10:40-11:15 US EDT / 22:40-23:15 CST / 16:40-17:15 CEST

Harrington Lecture

10:40-10:45 **Harrington Lecture Introduction**
Paul D. Sponseller, MD, MBA

10:45-11:15 **Harrington Lecture: The Respiratory Impact of Early Onset Scoliosis and Current Treatments: Where Do We Go From Here?**
Gregory J. Redding, MD

**Denotes non-CME session*

Live Session Agenda - Saturday, September 12

Session times are listed in US Eastern Daylight Time.

Saturday, September 12, 2020

9:00-9:40 US EDT / 21:00-21:40 CST / 15:00-15:40 CEST

Session 4A: Hibbs Basic Science Research Award Nominees

Moderators: A. Noelle Larson, MD & Stefan Parent, MD, PhD & Ferran Pellisé, MD, PhD

9:00-9:04 **Welcome**
Lindsay M. Andras, MD

9:04-9:08 **Paper #55: Genetic Prediction of Onset and Progression of Adolescent Idiopathic Scoliosis**
Nao Otomo, MD; Kazuki Takeda, MD, PhD; Yoji Ogura, MD, PhD; Yohei Takahashi, MD, PhD; Shohei Minami, MD, PhD; Koki Uno, MD, PhD; Noriaki Kawakami, MD, PhD; Manabu Ito, MD, PhD; Kei Watanabe, MD, PhD; Takashi Kaito, MD, PhD; Hiroshi Taneichi, MD, PhD; Katsumi Harimaya, MD, PhD; Yuki Taniguchi, MD, PhD; Hideki Shigematsu, MD, PhD; Takahiro Iida, MD, PhD; Satoru Demura, MD, PhD; Ryo Sugawara, MD, PhD; Nobuyuki Fujita, MD, PhD; Mitsuru Yagi, MD, PhD; Eijiro Okada, MD, PhD; Naobumi Hosogane, MD, PhD; Kazuhiro Chiba, MD, PhD; Toshiaki Kotani, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Tsutomu Akazawa, MD, PhD; Teppei Suzuki, MD, PhD; Kotaro Nishida, MD, PhD; Kenichiro Kakutani, MD, PhD; Taichi Tsuji, MD, PhD; Tatsuya Sato, MD, PhD; Satoshi Inami, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Shiro Ikegawa, MD, PhD; Chikashi Terao, MD, PhD; Kota Watanabe, MD, PhD

9:08-9:12 **Paper #56: Correlation of Collagen X Biomarker (CXM) with Peak Height Velocity and Radiographic Measures of Growth in Idiopathic Scoliosis**
Michelle C. Welborn, MD; Ryan Coghlan, MS; James O. Sanders, MD; Vishwas R. Talwalkar, MD; Amer F. Samdani, MD; Joseph Stone, MD; Daniel Bouton, MD; William Horton, MD; Susan Sienko, PhD

9:12-9:16 **Paper #57: Does Implant Density Matter in the Surgical Outcomes of Severe Kyphoscoliosis Exceeding 100 Degrees or Treated by 3CO?**
Oheneba Boachie-Adjei, MD; Henry Ofori Duah, MPH; Arthur Sackeyfio, MD; Kwadwo Poku Yankey, MD; Lawrence G. Lenke, MD; Paul D. Sponseller, MD, MBA; Amer F. Samdani, MD; Daniel J. Sucato, MD, MS; Brenda A. Sides, MA; Peter O. Newton, MD; Suken A. Shah, MD; Harry Akoto, MD; Munish C. Gupta, MD

9:16-9:25 **Discussion**

9:25-9:29 **Paper #58: A Novel Imaging Study to Quantify Respiratory Function in Early Onset Scoliosis-Introducing Quantitative Dynamic Magnetic Resonance Imaging (QdMRI)**
Yubing Tong, PhD; Jayaram K. Udupa, PhD; Joseph M. McDonough, MS; Caiyun Wu, MS; Catherine Qiu, MS; Carina Lott, MS; Nirupa Galagedera, BA; Jason B. Anari, MD; Drew A. Torigian, MA; Patrick J. Cahill, MD

9:29-9:33 **Paper #59: Prospective Study of Intraoperative MEP Monitoring to Identify Lumbosacral Nerve Root Motor Deficits**
Kelley Wichman, BS; Hyunmi Choi, MD; Anil Mendiratta, MD; Earl D. Thuet, BS; Paul Kent, MD; Meghan Cerpa, MPH; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

9:33-9:40 **Discussion**

9:40-10:50 US EDT / 21:40-22:50 CST / 15:40-16:50 CEST

Session 4B: Hibbs Clinical Science Research Award Nominees

Moderators: Lindsay M. Andras, MD & Peter O. Newton, MD & Colin Nnadi, FRCS (Orth)

9:40-9:44 **Paper #60: Moderate Scoliosis Continues to Progress at 30-Year Follow-Up. A Call for Concern?**
Christopher Alcala, MD; Amir A. Mehbod, MD; Francis Denis, MD; Timothy A. Garvey, MD; Joseph H. Perra, MD; Ensor E. Transfeldt, MD

9:44-9:48 **Paper #61: Complications Following Posterior Surgical Treatment of Adolescent Idiopathic Scoliosis: Prospective 10-Year Follow-Up Study**
Arun R. Hariharan, MD; Suken A. Shah, MD; Margaret Baldwin, MD; Joseph Petfield, MD; Burt Yaszay, MD; Peter O. Newton, MD; Baron Lonner, MD; Firoz Miyanji, MD; Paul D. Sponseller, MD, MBA; Amer F. Samdani, MD

9:48-9:54 **Discussion**

**Denotes non-CME session*

Live Session Agenda - Saturday, September 12

Session times are listed in US Eastern Daylight Time.

9:54-9:58 **Paper #62: Comparison of Clinical and Functional Outcomes of Vertebral Body Tethering to Posterior Spinal Fusion in Patients with Adolescent Idiopathic Scoliosis and Evaluation of Quality of Life**
Tuna Pehlivanoglu, MD; Ismail Oltulu, MD; Emre Korkmaz, MD; Yigit Erdag , MD; Ender Sarioglu, MD; Ender Ofluoglu, MD; Mehmet Aydogan, MD

9:58-10:02 **Paper #63: Anterior Vertebral Body Tethering in Idiopathic Scoliosis: A Prospective, Multicenter Analysis**
Firoz Miyanji, MD; Paul R. Rushton, FRCS; Isabelle Turgeon, BSc; Luigi A. Nasto, MD; Jeff Pawelek, BS; Stefan Parent, MD, PhD

10:02-10:06 **Paper #64: Spring Distraction System to Correct Early Onset Scoliosis: 2-Year Follow-Up Results From 22 Patients.**
Justin V. Lemans, MD; Sebastiaan P. Wijdicks, MD; René M. Castelein, MD, PhD; Moyo C. Kruyt, MD, PhD

10:06-10:15 **Discussion**

10:15-10:19 **Paper #65: Operative Versus Nonoperative Treatment for Adult Symptomatic Lumbar Scoliosis at 5-6 Year Follow-Up: Outcomes and Impact of Related Serious Adverse Events**
Justin S. Smith, MD, PhD; Michael P. Kelly, MD; Elizabeth L. Yanik, PhD; Christine Baldus, RN; Thomas J. Buell, MD; Jon D. Lurie, MD, MS; Charles C. Edwards, MD; Steven D. Glassman, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; Jacob M. Buchowski, MD; Leah Y. Carreon, MD; Charles H. Crawford III, MD; Stephen J. Lewis, MD, FRCS(C); Tyler Koski, MD; Stefan Parent, MD, PhD; Virginie Lafage, PhD; Munish C. Gupta, MD; Han Jo Kim, MD; Christopher P. Ames, MD; Shay Bess, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Keith H. Bridwell, MD

10:19-10:23 **Paper #66: Realistic Radiographic Lordosis Achieved in Pedicle Subtraction Osteotomies (PSO) and 3-Level Posterior Column Osteotomies (PCO) in Adult Spinal Deformity (ASD) Patients with 2-Year Follow-Up**
Joshua Rivera; Praveen V. Mummaneni, MD; Jeremy Guinn, BS; Hao-Hua Wu, MD; Minghao Wang, MD, PhD; Pingguo Duan, MD; Zhuo Xi, MD; Bo Li, MD; Rory R. Mayer, MD; Shane Burch, MD; Sigurd H. Berven, MD; Dean Chou, MD

10:23-10:27 **Paper #67: Quality Metrics in Adult Spinal Deformity (ASD) Surgery Over the Last Decade: A Combined Analysis of the Largest Prospective Multicentric Datasets**
Ferran Pellisé, MD, PhD; Miquel Serra-Burriel, PhD; Alba Vila-Casademunt, MS; Justin S. Smith, MD, PhD; Ibrahim Obeid, MD; Douglas C. Burton, MD; Frank S. Kleinstueck, MD; Shay Bess, MD; Javier Pizones, MD, PhD; Virginie Lafage, PhD; Francisco Javier S. Perez-Grueso, MD; Frank J. Schwab, MD; Jeffrey L. Gum, MD; Eric O. Klineberg, MD; Christopher I. Shaffrey, MD; Ahmet Alanay, MD; Christopher P. Ames, MD

10:27-10:36 **Discussion**

10:36-10:40 **Paper #68: Automated Measurement of Spinopelvic Parameters on Lateral Lumbar Radiographs Using Deep Learning**
John T. Schwartz, BS; Varun Arvind, BS; Brian H. Cho, BS; Aly A. Valliani, BS; Eric Geng, BS; Peter Tang, MD; Jun Kim, MD; Samuel K. Cho, MD

10:40-10:44 **Paper #69: Outcomes of Neurologic Deficit and Use of Intraoperative Neuromonitoring for Lower Cervical and Upper Thoracic Three Column Osteotomies for Deformity Correction**
Darryl Lau, MD; Alexander Haddad, BS; Vedat Deviren, MD; Christopher P. Ames, MD

10:44-10:50 **Discussion**

10:50-11:30 US EDT / 22:50-23:30 CST / 16:50-17:30 CEST

2021 Preview, Scientific Awards & Transfer of Presidency*

10:50-10:54 **2021 IMAST Preview**
David L. Skaggs, MD, MMM

10:54-10:58 **2021 Annual Meeting Preview**
Michael P. Kelly, MD

10:58-11:05 **Scientific Award Presentations: Russell A. Hibbs, Louis A. Goldstein, John H. Moe**
Presented by: Lindsay M. Andras, MD

11:05-11:10 **Introduction of the 2021 President**
Paul D. Sponseller, MD, MBA

**Denotes non-CME session*

Live Session Agenda - Saturday, September 12

Session times are listed in US Eastern Daylight Time.

11:10-11:30 **Transfer of Presidency**
Muharrem Yazici, MD

11:30-12:40 US EDT / 23:30-00:40 CST / 17:30-18:40 CEST

Early Career Surgeons Session*

The Early Career Surgeons Session is supported, in part, by a grant from Medtronic.

Discussion Leaders: Kariman Abelin-Genevois, MD, PhD; Laurel C. Blakemore, MD; Louis Boissiere, MD; Robert H. Cho, MD; Kenny Kwan, BMBCh(Oxon), FRCSEd; Javier Pizones, MD, PhD; Christopher I. Shaffrey, MD; Brian G. Smith, MD; Justin S. Smith, MD; Paul D. Sponseller MD, MBA; Muharrem Yazici, MD; Caglar Yilgor, MD

11:30-11:40 **Introduction to Early Career Surgeon's Program**
Paul D. Sponseller, MD, MBA

11:40-11:55 **Case Discussion: Selective Thoracic Fusion**
Altug Yucekul, MD

11:55-12:10 **Case Discussion: T10-Pelvis Fusion**
Pierre Grobost, MD

12:10-12:25 **Case Discussion: Single Level Lumbar Stenosis**
Timothy O'Connor, MD

12:25-12:40 **Details of SRS Mentorship Program**
Brian G. Smith, MD

**Denotes non-CME session*

Live Session Agenda - Sunday, September 13

Session times are listed in US Eastern Daylight Time.

Sunday, September 13, 2020

9:00-11:00 US EDT / 21:00-23:00 CST / 15:00-17:00 CEST

Half-Day Course 1: Optimizing Value and Minimizing Complications in Adult Spinal Deformity Surgery: The Roles of Teams, Risk Stratification, and Technology *(Runs Concurrently with Half-Day Course 2)*

Course Chairs: Han Jo Kim, MD; Rajiv K. Sethi, MD & Mark Weidenbaum, MD

Section 1: Methods for Improving Care

Moderators: Rajiv K. Sethi, MD & Mark Weidenbaum, MD

9:00-9:03 **Safety and Value in ASD Surgery in 2020. Where Are We?**
Rajiv K. Sethi, MD

9:03-9:08 **What Are the Current Definitions of Risk Stratification Debate: Committee Better than Computer**
Jean-Christophe A. Leveque, MD

9:08-9:13 **What Are the Current Definitions of Risk Stratification Debate: Computer Better than Committee**
Ferran Pellisé, MD, PhD

9:13-9:18 **Methods Used for Pre-operative Optimization at a Tertiary Spine Center in the United States**
David W. Polly Jr., MD

9:18-9:23 **Is It All About Pre-op Optimization? How About Intra-operative and Post-operative Strategies**
Khaled M. Kebaish, MD

9:23-9:27 **Moderator Led Discussion**
Rajiv K. Sethi, MD

9:27-9:38 **Panel Discussion: Obstacles to Risk Stratification in a Large Medical Center**
Moderator: Mark Weidenbaum, MD

Panelists: Christopher P. Ames, MD; Benny T. Dahl, MD, PhD, DMSci; Eric O. Klineberg, MD; Dominique A. Rothenfluh, MD, PhD

Section 2: Multidisciplinary Approaches to Risk Mitigation

Moderators: Han Jo Kim, MD & Rajiv K. Sethi, MD

9:38-9:43 **Building and Advocating Dedicated Spine Teams: Anesthesia and OR**
Lawrence G. Lenke, MD

9:43-9:48 **Building and Advocating Dedicated Spine Teams: Medical**
Marinus de Kleuver, MD, PhD

9:48-9:53 **Own the Bone: The Importance of Osteoporosis Management Prior to Adult Spinal Deformity**
John R. Dimar II, MD

9:53-9:58 **How Do You Form a Standard Work Protocol and Make it the Language of the Team?**
Douglas C. Burton, MD

9:58-10:02 **Moderator Led Discussion**
Han Jo Kim, MD

10:02-10:13 **Panel Discussion: Obstacles We Have Faced in the Formation of Dedicated Teams**
Moderator: Han Jo Kim, MD

Panelists: Todd J. Albert, MD; John P. Dormans, MD; Morio Matsumoto, MD, PhD; Venu M. Nemani, MD, PhD; Paul D. Sponseller, MD, MBA

Section 3: Technology and Safety: Often at Odds?

Moderators: Rajiv K. Sethi, MD & Mark Weidenbaum, MD

10:13-10:18 **Free-Hand Placement of Pedicle Screws Will Always Be the Gold Standard**
Peter O. Newton, MD

10:18-10:23 **Current State of Robotics and Navigation at a Large Center: USA**
Frank J. Schwab, MD

**Denotes non-CME session*

Live Session Agenda - Sunday, September 13

Session times are listed in US Eastern Daylight Time.

10:23-10:28 **Current State of Robotics and Navigation at a Large Center: Japan**
Kota Watanabe, MD, PhD

10:28-10:33 **Occupational Risks in Spinal Surgery:Will Technology Help Us Reduce Intraoperative Overuse Injuries and Radiation Risks**
Baron S. Lonner, MD

10:33-10:38 **Is Robotics and Navigation Possible in the Developing World with Cost Pressures?**
Sajan K. Hegde, MD

10:38-10:42 **Moderator Led Discussion**
Mark Weidenbaum, MD

10:42-10:58 **Panel Discussion: How Do I Justify Adding Expensive Technology to Hospital Administrators?**
Moderator: Rajiv K. Sethi, MD

Panelists: Meric Enercan, MD; Christopher I. Shaffrey Sr., MD; Michael G. Vitale, MD, MPH; Vijay Yanamadala, MD

10:58-11:00 **Close and Final Comments**
Han Jo Kim, MD; Rajiv K. Sethi, MD; Mark Weidenbaum, MD

9:00-11:00 US EDT / 21:00-23:00 CST / 15:00-17:00 CEST

Half-Day Course 2: Non-Fusion Scoliosis Correction in the Treatment of AIS: Fundamentals and Future *(Runs Concurrently with Half-Day Course 1)*

Course Chairs: Baron S. Lonner, MD; Firoz Miyanji, MD; Peter O. Newton, MD; Amer F. Samdani, MD
Moderators: Baron S. Lonner, MD & Peter O. Newton, MD

9:00-9:05 **Introduction and Patient's Perspective**
Baron S. Lonner, MD

9:05-9:10 **Growth Modulation: Developing the Basic Science Case**
John T. Braun, MD

9:10-9:15 **Regulatory Requirements in the United States**
Patrick J. Cahill, MD

9:15-9:20 **Indications for VBT**
A. Noelle Larson, MD

9:20-9:25 **Simulating/Predicting Growth Modulation**
Stefan Parent, MD, PhD

9:25-9:35 **Discussion**

Moderators: Ahmet Alanay, MD & Amer F. Samdani, MD

9:35-9:40 **Video Review: Anterior and Thoracoscopic Surgical Approach**
Randal R. Betz, MD

9:40-9:45 **VBT Basics of the Implants and Technical Considerations**
Firoz Miyanji, MD, FRCSC

9:45-9:50 **VBT Outcomes**
Amer F. Samdani, MD

9:50-9:55 **VBT Complications: What Happens When Things Go Bad?**
Peter O. Newton, MD

9:55-10:05 **Discussion**

Moderators: Firoz Miyanji, MD, FRCSC & Per D. Trobisch, MD

10:05-10:10 **Indications, Rationale, and Current Evidence for Posterior Dynamic Distraction**
Biren Desai, MD

10:10-10:15 **Complications of PDD and Technique Tips to Avoid**
Ron El-Hawary, MD

**Denotes non-CME session*

Live Session Agenda - Sunday, September 13

Session times are listed in US Eastern Daylight Time.

10:15-10:20 **Discussion**

10:20-11:00 **Case Presentations for Fusion, PDD, and Tether**
Panelists: Ahmet Alanay, MD; Randal R. Betz, MD; John T. Braun,MD; Biren Desai, MD; Ron El-Hawary, MD; A. Noelle Larson, MD; Baron S. Lonner, MD; Peter O. Newton, MD; Stefan Parent, MD, PhD; Amer F. Samdani, MD; Daniel J. Sucato, MD, MS

**Denotes non-CME session*

Self-Paced Program

September 3-December 31, 2020

Self-paced content will be available to all registered attendees through December 31, 2020. Once all content in the self-paced program is completed, additional CME can be claimed.

Pre-Meeting Course Supplement

Section 2: Practice Management and Managing Practice

Moderators: Stefan Parent, MD, PhD & Burt Yaszay, MD

How We Deal with Complications: To Err is Human
David S. Marks, FRCS, FRCS(Orth)

Organizing a Team Panel: How It Changed My Practice
Moderator: Stefan Parent, MD, PhD
Panelists: John M. Flynn, MD; David S. Marks, FRCS, FRCS(Orth); Firoz Miyanji, MD, FRCSC; David L. Skaggs, MD, MMM

Section 3: Resource Management Panel: Accessing Tools and Infrastructure for the Patient

Moderators: Brian Hsu, MD & Baron S. Lonner, MD

The Indian Experience
S. Rajasekaran, MD, FRCS, MCh, PhD

The LA Experience
David L. Skaggs, MD, MMM

Managing the Patient Without ICU
Daniel J. Sucato, MD, MS

The Brazilian Experience
Olavo Biraghi Letaif, MD, MSc

Setting Up a Hospital in a Developing Country
Oheneba Boachie-Adjei, MD, DSc

Telemedicine in the Age of COVID-19
Suken A. Shah, MD

HALF-DAY COURSE ABSTRACT SUPPLEMENT (ADULT)

Moderators: Rajiv K. Sethi, MD

The Patient Demographics, Radiographic Index, and Surgical Invasiveness for Mechanical Failure (PRISM) Model Established for Adult Spinal Deformity Surgery
Mitsuru Yagi, MD, PhD; Satoshi Suzuki, MD, PhD; Eijiro Okada, MD, PhD; Satoshi Nori, MD, PhD; Osahiko Tsuji, MD, PhD; Narihito Nagoshi, MD, PhD; Nobuyuki Fujita, MD, PhD; Naobumi Hosogane, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Kota Watanabe, MD, PhD

Artificial Intelligence Clustering of Adult Spinal Deformity Morphology Predicts Surgical Characteristics, Alignment, and Outcomes
Wesley M. Durand, BS; Renaud Lafage, MS; D. Kojo Hamilton, MD; Peter G. Passias, MD; Han Jo Kim, MD; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Jeffrey L. Gum, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Khaled M. Kebaish, MD; Alex Soroceanu, MPH; Richard Hostin, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Alan H. Daniels, MD

Enhanced Perioperative Protocols Can Improve Infection Outcomes in Adult Spinal Deformity (ASD) Surgery
Suzanne E. Kent, BS; Daniel Kent ; Brian Hollenbeck, MD; Samuel Golenbock, MS; Stephen Camer, MD; Frank Rand, MD

The Impact of Metabolic Disorders of Bone Mineralization on Long Term Outcomes Following Surgery for Adult Spinal Deformity Surgery: Analysis of 2-year Surveillance
Bassel G. Diebo, MD; George A. Beyer, MS; Alexander Rompala, BS; Neil V. Shah, MD, MS; Adam J. Wolfert, BS; Frank A. Segreto, BS; Salem Najjar, BA; Peter G. Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Carl B. Paulino, MD

Not So Sweet: Determining Hemoglobin A1C Cut-offs in Diabetic Patients Prior to Posterior Spinal Fusion
Nicholas A. O'Malley, BS; Charmie Mehta, BS; Eaman Balouch, MD, PhD; Carolyn Stickley, BS; Jack R. Zhong, BS; Carlos Leon, BE; Constance Maglaras, PhD; Aaron J. Buckland, MBBS, FRCSA

Self-Paced Program

September 3-December 31, 2020

Self-paced content will be available to all registered attendees through December 31, 2020. Once all content in the self-paced program is completed, additional CME can be claimed.

Complication Rate in Obese vs Non-Obese Patients Undergoing Minimally Invasive Surgery for Correction of Adult Spinal Deformity: Evaluation of 2 Year Prospective Data
Richard G. Fessler, MD; Kai-Ming Gregory Fu, MD; Paul Park, MD; Dean Chou, MD; Robert K. Eastlack, MD; Gregory M. Mundis, MD; Khoi D. Than, MD; Neel Anand, MD; David O. Okonkwo, MD; Michael Y. Wang, MD; Adam S. Kanter, MD; Pierce D. Nunley, MD; Praveen V. Mummaneni, MD

High Radiation Burden of Minimally Invasive Approaches for Adult Spinal Deformity
Jakub Godzik, MD; Gregory M. Mundis, MD; Jay D. Turner, MD; Juan S. Uribe, MD; Robert K. Eastlack, MD

3D-Printed Spine Model Improves the Efficiency and Safety of the Severe Congenital Spine Deformity Correction Surgery
Yong Hai, MD, PhD; Hongtao Ding, MS; Aixing Pan, MD, PhD

Power-Assisted Pedicle Screw Technique Protects Against Risk of Surgeon Overuse Injury: A Real-Time EMG Study
David L. Skaggs, MD; Amy A. Claeson, PhD; Frank J. Schwab, MD; Anup A. Gandhi, PhD

HALF-DAY COURSE ABSTRACT SUPPLMENT (PEDIACTRIC)

Moderators: Baron S. Lonner, MD, Firoz Miyanji, MD, FRCSC, Peter O. Newton, MD & Per D. Trobisch, MD

Does Intraoperative Correction during Anterior Vertebral Body Tethering Predict Correction Seen on 1st Erect Radiograph?
Abdul Fettah Buyuk, MD; Todd A. Milbrandt, MD, MS; Smitha Mathew, MBBS, MS; D. Dean Potter, MD; A. Noelle Larson, MD

Rate of Scoliosis Correction Correlates with Height Velocity and Slows Substantially at 2 Years After Anterior Spinal Growth Tethering (ASGT) for AIS
Yohei Takahashi, MD, PhD; Wataru Saito, MD, PhD; Burt Yaszay, MD; Carrie E. Bartley, MA; Tracey P. Bastrom, MA; Peter O. Newton, MD

The Clinical Significance of Tether Breakages in Anterior Vertebral Body Growth Modulation: A Two–Year Post-Operative Analysis
Jesse Shen, MSc; Julie Joncas, RN; Marjolaine Roy-Beaudry, MSc; Isabelle Turgeon, BSc; Imad S. Nahle, MD; Stefan Parent, MD, PhD

Vertebral Body Tethering Compared to the Gold Standard Spinal Fusion: Matched Analysis 2 Years Post-Operatively
Lily Q. Eaker, BA; Jonathan S. Markowitz, MD; Baron Lonner, MD

Anterior Vertebral Body Tethering for Adolescent Idiopathic Scoliosis Preserves Trunk Motion Compared to Posterior Spinal Fusion at Two Year Follow-Up
Joshua M. Pahys, MD; Amer F. Samdani, MD; Steven W. Hwang, MD; Spencer Warshauer, MS; Ross Chafetz, PhD

Comparative Analysis of Post-op Motion between Spinal Fusion and VBT
Firoz Miyanji, MD; Michelle Claire Marks, PT; Amer F. Samdani, MD; Suken A. Shah, MD; Maty Petcharaporn, BS; Tracey P. Bastrom, MA; Peter O. Newton, MD

Anterior Vertebral Body Tethering for Immature Idiopathic Scoliosis: Results on Patients Reaching Skeletal Maturity
Amer F. Samdani, MD; Joshua M. Pahys, MD; Solomon Samuel, D. Eng.; Erica Johnson, BS; Alejandro Quinonez, BS; Glenn Pelletier, MD; Harsh Grewal, MD; Steven W. Hwang, MD

Shoulder Balance in Lenke Type 1 and 2 Idiopathic Scoliosis Following Anterior Vertebral Body Tethering of the Spine
Firoz Miyanji, MD; Michael G. Vitale, MD; Ron El-Hawary, MD; Joshua S. Murphy, MD; Michael Fields, BS; Hiroko Matsumoto, PhD; David L. Skaggs, MD; Stefan Parent, MD, PhD

Reoperations after Anterior Vertebral Body Tethering: Analysis of a Cohort of 218 Patients
Amer F. Samdani, MD; Joshua M. Pahys, MD; Solomon Samuel, D. Eng.; Erica Johnson, BS; Alejandro Quinonez, BS; Firoz Miyanji, MD; Steven W. Hwang, MD

Session 3: Adolescent Idiopathic Scoliosis II

Moderators: John Flynn, MD & Masayuki Ohashi, MD

Paper #28: Three Dimensional Changes are Predictors of Brace Effectiveness in Patients with Idiopathic Scoliosisr
Kenny Kwan, MD; Amy Cheung, BA; Kenneth Cheung, MD, MBBS, FRCS

Paper #29: In-Brace Axial Rotation Magnitude and Improvement is Associated with Lower Rates of Curve Progression in AISr
Matthew E. Simhon, BS; Hiroko Matsumoto, PhD; Michael Fields, BS; Gerard F. Marciano, MD; Afrain Boby, MS, BS; Benjamin D. Roye, MD; Michael G. Vitale, MD

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Paper #30: Realities of a Multi-Site Randomized Schroth-Based Trial for AIS <25°r
Karina Zapata, DPT; Rebecca J. Dieckmann, BS; Steven D. Glassman, MD; Michael T. Hresko, MD; Brian G. Smith, MD; Paul D. Sponseller, MD, MBA; Michael G. Vitale, MD; Daniel J. Sucato, MD, MS

Paper #31: Variability in Anesthetic Practices in Surgical Treatment of Adolescent Idiopathic Scoliosis
Niyathi Prasad, BS; Majd Marrache, MD; Dolores Njoku, MD; Paul D. Sponseller, MD, MBA; Amit Jain, MD

Paper #32: Bone Graft Substitutes and Extenders are Associated with a Higher Rate of Wound Complications
Dhananjay Bansal, BS; Majd Marrache, MD; Paul D. Sponseller, MD, MBA; Suken A. Shah, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD; Baron Lonner, MD; Michelle Claire Marks, PT; Peter O. Newton, MD; Thomas J. Errico, MD; Amit Jain, MD

Paper #33: Sinister! The High Preop Left Shoulder is Less Likely to be Balanced at 2 Years Postop
Joshua T. Bram, BS; Nishank Mehta, BA; Jason B. Anari, MD; Burt Yaszay, MD; Joshua M. Pahys, MD; Harms Study Group; Patrick J. Cahill, MD

Paper #34: Selective vs. Non-Selective Thoracic Fusion for Lenke Type 1-4C Curves: Which Has More Complications at 5-Year Follow-Up?
Jay S. Reidler, MD; Scott Zuckerman, MD; Joseph M. Lombardi, MD; Jun Kim, MD; Andrew C. Vivas, MD; Meghan Cerpa, MPH; Peter O. Newton, MD; Lawrence G. Lenke, MD

Paper #35: Preoperative LIV Translation and LIV Tilt are Risk Factors for Adding-On in Lenke 1/2AR Curves
Brendon Mitchell, MD; David L. Skaggs, MD; Lawrence G. Lenke, MD; Tracey P. Bastrom, MA; Carrie E. Bartley, MA; Peter O. Newton, MD

Paper #36: Fusions Ending Above The Sagittal Stable Vertebrae in Adolescent Idiopathic Scoliosis: Does it Matter?
Dale Segal, MD; Keith Orland, MD; Eric Yoon, BS; Tracey P. Bastrom, MA; Harms Study Group, N/A; Nicholas D. Fletcher, MD

Paper #37: Sagittal Considerations and Implications in Lenke 5 Curves
Majd Marrache, MD; Patrick J. Cahill, MD; Baron Lonner, MD; Peter O. Newton, MD; Paul D. Sponseller, MD, MBA

Paper #38: Surgical Treatment of Lenke Type 5 Curves Using Vertebral Body Tethering with Double Screw-Double Cord Fixation. Radiological and Clinical Outcomes.
Azmi Hamzaoglu, MD; Mustafa Eltayep, MD; Huseyin Ozturk, MD; Seray G. Gur, MD; Ayhan Mutlu, MD; Sinan Kahraman, MD; Tunay Sanli, MA; Selhan Karadereler, MD; Meric Enercan, MD

Paper #39: Coronal and Sagittal Parameters that Affect Disc and Facet Joint Degeneration in Lenke 5 Curves after Selective Posterior Lumbar Fusion: a MRI Study with 10-Year Follow-up
Seray G. Gur, MD; Mustafa Eltayep, MD; Huseyin Ozturk, MD; Tunay Sanli, MA; Ayhan Mutlu, MD; Selhan Karadereler, MD; Tom Reinsel, MD; Sinan Kahraman, MD; Meric Enercan, MD; Azmi Hamzaoglu, MD

Paper #40: Junctional Segment Degeneration 20 Years Following Posterior Instrumented Fusion for Adolescent Idiopathic Scoliosis (AIS): Comparative Analysis of Lumbar Vertebral Tilt, Sagittal Balance and Patient Outcome.
Isobella Henzell, MBBS; Kenan Burrows, MBBS; Bruce F. Hodgson, MBBS, FRCS; Ginny Martin, RN

Paper #41: Repeat Surgical Interventions Following "Definitive" Instrumentation and Fusion for Idiopathic Scoliosis: A 30-Year Update
William Z. Morris, MD; Kiley F. Poppino, BS; Dong-Phuong Tran, MS; Brandon A. Ramo, MD; B. Stephens Richards, MD

Paper #42: Ultralong Follow-Up of Spinal Fusion for Adolescent Idiopathic Scoliosis: Harrington Instrumentation Versus Uninstrumented Fusion. Minimum 53-Year Follow-Up
Noorullah Maqsoodi, MS; Aron Sulovari, BS; Adan Omar, MD; Jarren Section, MD; Emmanuel N. Menga, MD; James O. Sanders, MD; Paul T. Rubery, MD; Addisu Mesfin, MD

Session 6: Cervical Deformity

Moderators: Michael P. Kelly, MD & Suken Shah, MD

Paper #70: Postoperative Axial Neck Pain (ANP) and its Associated Radiographic Parameters in the Surgically Treated AIS Patients
Akira Matsumura, MD, PhD; Takashi Namikawa, MD, PhD; Yusuke Hori, MD

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Paper #71: Restoration of Thoracic Kyphosis and Higher T1 Slope Angle Impacts Cervical Alignment after Posterior Spinal Fusion in Hypokypotic Adolescent Idiopathic Scoliosis: A Retrospective Study with Minimum Five-year Follow-Up
Ayhan Mutlu, MD; Mustafa Eltayep, MD; Seray G. Gur, MD; Huseyin Ozturk, MD; Tunay Sanli, MA; Selhan Karadereler, MD; Tom Reinsel, MD; Meric Enercan, MD; Sinan Kahraman, MD; Azmi Hamzaoglu, MD

Paper #72: Cervical Radiographic Parameters and Patient Reported Outcomes Following Harrington Instrumentation: A Minimum 35-Year Follow-Up
Noorullah Maqsoodi, MS; Aron Sulovari, BS; Adan Omar, MD; Jarren Section, MD; Emmanuel N. Menga, MD; Paul T. Rubery, MD; Addisu Mesfin, MD

Paper #73: More Than 10-Year Clinical Outcome After Pedicle Screw Fixation for Cervical Kyphosis in Athetoid Cerebral Palsy Patients.
Satoru Demura, MD, PhD; Satoshi Kato, PhD; Kazuya Shinmura, PhD; Noritaka Yonezawa, MD; Takaki Shimizu, MD; Norihiro Oku, MD; Ryo Kitagawa, MD; Makoto Handa, MD; Ryohei Annen, MD; Hiroyuki Tsuchiya, PhD

Paper #74: The Surgical Treatment of Severe Cervical Kyphosis in Diastrophic Dysplasia
John Heydemann, MD; William G. Mackenzie, MD; Colleen Ditro, RN, DNP, CPNP; Kenneth J. Rogers, PhD; Jeffrey Campbell, MD; Suken A. Shah, MD; William G. Mackenzie, MD

Paper #75: Radiological and Clinical Outcome of Surgery for Basilar Invagination: What Holds the Key to Success in this Difficult Terrain
Shardul Soman, MBBS, MS

Paper #76: When Can we Expect Global Sagittal Alignment to Reach a Stable Value Following Cervical Deformity Surgery?
Renaud Lafage, MS; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Peter G. Passias, MD; Christopher I. Shaffrey, MD; Gregory M. Mundis, MD; Themistocles S. Protopsaltis, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Jonathan Elysee, MS; Han Jo Kim, MD; Shay Bess, MD; Frank J. Schwab, MD; Virginie Lafage, PhD

Paper #77: Failure Mechanisms and Revision Strategies for DJK Following Cervical Deformity Correction
Themistocles S. Protopsaltis, MD; Eaman Balouch, MD, PhD; William Schreiber-Stainthorp, BS; Robert K. Eastlack, MD; Justin S. Smith, MD, PhD; D. Kojo Hamilton, MD; Alan H. Daniels, MD; Eric O. Klineberg, MD; Brian J. Neuman, MD; Robert A. Hart, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Christopher P. Ames, MD

Paper #78: Optimizing Cervicothoracic Junction Biomechanics After C7 Pedicle Subtraction Osteotomy: a Cadaveric Study of Stability and Rod Strain
Jakub Godzik, MD; Jennifer N. Lehrman, MS; Bernardo de Andrada, MD; Christopher P. Ames, MD; Heiko Koller, MD; Anna S. Newcomb, MS; Jay D. Turner, MD; Brian P. Kelly, PhD

Session 7: Early Onset Scoliosis/Syndromic

Moderators: Colin Nnadi, FRCS

Paper #79: Urgent Field Safety Notice Concerning Locking Pin Fracture from Manufacturer of Magnetically Controlled Growing Rods: How Does Data from an Independent Explant Centre Compare?
Thomas J. Joyce, PhD; Simon L. Smith, PhD; Göksu Kandemir, MSc; Paul R. Rushton, FRCS; David Fender, FRCS; Andrew J. Bowey, FRCS; Michael J. Gibson, FRCS

Paper #80: Spinal Lengthening with Magnetically Controlled Growing Rods: Data from the Largest Series of Explanted Devices
Paul R. Rushton, FRCS; Simon L. Smith, PhD; Göksu Kandemir, MSc; Liam Forbes ; David Fender, FRCS; Andrew J. Bowey, FRCS; Michael J. Gibson, FRCS; Thomas J. Joyce, PhD

Paper #81: Exo Corporal Evaluation of Magnetic Spinal Growth Rods (MSGR) in Patients Treated by the Protocol of Frequent Small Increments Lengthenings
Joseph Ivan Krajbich, MD; Michelle C. Welborn, MD; Daniel Bouton, MD

Paper #82: How to Select the Lower Instrumented Vertebra (LIV) in Traditional Growing Rods (TGR) Index Surgery
Federico Fusini, MD; Javier Pizones, MD, PhD; Lucía Moreno-Manzanaro, BS; Jose Miguel Sánchez-Márquez, MD, PhD; Gloria Talavera, MD; Nicomedes Fernández-Baíllo, MD; Francisco Javier S. Perez-Grueso, MD

Paper #83: The Effect of Magnetically Controlled Growing Rod Lengthening on Kyphosis
Michelle C. Welborn, MD; Nikolas Baksh, MD; Joseph Ivan Krajbich, MD; Daniel Bouton, MD

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Paper #84: Does the Law of Diminishing Returns Exist in Early Onset Scoliosis with Connective Tissue Disorders?
Majd Marrache, MD; Klane K. White, MD; A. Noelle Larson, MD; Tricia St. Hilaire, ; Majella Vaughan, ; Regina Woon, MPH; Paul D. Sponseller, MD, MBA

Paper #85: Comparison of Results and Complications: Hybrid Technique of Posterior Osteotomy with Short Segmental Fusion and Dual Growing Rod Technique VS Traditional Dual Growing Rod (TGR) Technique
Jianguo Zhang, MD; Shengru Wang, MD

Paper #86: Surgical Treatment for Congenital Scoliosis Patients Aged from 9 to 11 years Old: Is Growth-friendly Treatment Superior to One-Stage Fusion?
Liang Xu, MD; Xu Sun, MD; Zhen Liu, MD; Zezhang Zhu, MD; Bangping Qian, MD; Yong Qiu, MD

Paper #87: Revision Rates of 5-Year Minimum Graduates of Growth Friendly Surgery for Early Onset Scoliosis
Robert F. Murphy, MD; John B. Emans, MD; Paul D. Sponseller, MD, MBA; David S. Marks, FRCSOrth; David L. Skaggs, MD; George H. Thompson, MD; John (Jack) M. Flynn, MD; Behrooz A. Akbarnia, MD; John T. Smith, MD; Jeffrey R. Sawyer, MD

Paper #88: Spinal Mobility and Muscle Function in Middle-Aged Patients Treated for Early Onset Idiopathic Scoliosis Compared with Untreated and Treated Adolescent Onset Patients
Karin Romberg, PhD; Aina J. Danielsson, MD, PhD; Monika Fagevik Olsen, PhD; Gunilla Kjellby-Wendt, PhD

Paper #89: Mental Health Consequences of Serial Mehta Casting: Negative Correlation with Behavioral Development
Nishank Mehta, BA; Lacey Magee, BA; Heidi R. Nocka, BA; Peter F. Sturm, MD; Joshua M. Pahys, MD; Sumeet Garg, MD; Robert F. Murphy, MD; Pediatric Spine Study Group; Patrick J. Cahill, MD

Paper #90: Pulmonary Hypertension (PH) and Thoracic Cage Function in Patients with Early Onset Scoliosis: Assessment with Quantitative Dynamic Magnetic Resonance Imaging (QdMRI)
Yubing Tong, PhD; Jayaram K. Udupa, PhD; Joseph M. McDonough, MS; Caiyun Wu, MS; Catherine Qiu, MS; Carina Lott, MS; Nirupa Galagedera, BA; Catherine M. Avitabile, MD; Jason B. Anari, MD; Drew A. Torigian, MA; Patrick J. Cahill, MD

Paper #91: Nusinersin does not Mitigate Spine Pathoanatomy in Spinal Muscular Atrophy Patients
Michael J. Troy, BS; Patricia E. Miller, MS; Carina Lott, MS; Catherine Qiu, MS; Jason B. Anari, MD; Brian D. Snyder, MD, PhD

Paper #92: Is the Sagittal Profile of the Spine Modified in Patients with Achondroplasia after the Lower Limb Lengthening Surgery?
Rosa M. Egea-Gámez, MD, PhD; María Galán-Olleros, MD; Cristina Madrid de la Serna, MD; Javier Alonso Hernández, MD; Carlos Miranda-Gorozarri, MD; Carmen Martínez-González, MD; Rafael González-Díaz, MD, PhD

Paper #93: Prospective Spine at Risk Program for Prevalence of Intracanal Spine Lesions in Pediatric Hereditary Multiple Osteochondromas
Catphuong L. Vu, MD; Antoinette W. Lindberg, MD; Viviana Bompadre, PhD; Klane K. White, MD; Jennifer M. Bauer, MD

Session 8: Sagittal/PJK

Moderators: Khaled Kebaish, MD & Eric O. Klineberg, MD

Paper #94: Age- and Gender-Based Normative Values of Whole-body Sagittal Alignment: A Large Cohort Study of 584 Chinese Adults Aged from 20 to 89
Zongshan Hu, PhD; Zhen Liu, MD; Tsz Ping Lam, PhD; Zezhang Zhu, MD; Yong Qiu, MD; Jack Chun Yiu Cheng, MD, PhD

Paper #95: Increase in Thoracic Kyphosis with Aging is the Main Factor that Leads to Positive Sagittal Balance: Results of the Multi-ethnic Alignment Normative Study (MEANS) of Asymptomatic Adults
Zeeshan M. Sardar, MD; Meghan Cerpa, MPH; Jean-Charles Le Huec, MD; Stephane Bourret, PhD; Kazuhiro Hasegawa, MD, PhD; Hee-Kit Wong, FRCS; Gabriel KP Liu, MD; Hwee Weng Dennis Hey, MD; Hend Riahi, MD; Michael P. Kelly, MD; Lawrence G. Lenke, MD

Paper #96: Correlation Between Degenerative Diseases of the Lumbar Spine and Types of Lumbar Lordosis
Nelson Astur, MD; Bruno B. Roberto, MD; Delio E. Martins, MD, PhD; Michel Kanas, MD; Marcelo Wajchenberg, MD, PhD

Paper #97: A Patient-specific Approach to Alignment Goals and Assessing Proximal Junctional Kyphosis Risk after Adult Spinal Deformity Surgery
Jeffrey M. Hills, MD; Benjamin M. Weisenthal, MD; Jacquelyn S. Pennings, PhD; John Wanner, MD; Byron F. Stephens, MD

Paper #98: Is Chin-Brow Vertical Angle Always the Reliable Parameter for Correction Planning in Ankylosing Spondylitis Patients with Thoracolumbar Kyphosis?
Bangping Qian, MD; Wen-bin Xuan, MD; Yong Qiu, MD; Jichen Huang, MD

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Paper #99: C2 SVA: When Angles are Too Complicated and the X-Ray is Too Small
Simon Morr, MD; Meghan Cerpa, MPH; Joseph A. Osorio, MD, PhD; James D. Lin, MD; Zeeshan M. Sardar, MD; Richard P. Menger, MD; Eric Leung, BS; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Paper #100: The Posterior Cranial Vertical Line (PCVL): A Novel Predictor for Proximal Junctional Kyphosis in Spinal Deformity Surgery
Griffin R. Baum, MD; Meghan Cerpa, MPH; Paul J. Park, MD; Joseph A. Osorio, MD, PhD; Nathan J. Lee, MD; Eric Leung, BS; Meghana Vulapalli ; Ronald A. Lehman, MD; K. Daniel Riew, MD; Lawrence G. Lenke, MD

Paper #101: Is the Distance from the Upper Instrumented Vertebrae (UIV) to the Gravity Line Associated with Proximal Junctional Kyphosis (PJK) after Adult Spinal Deformity (ASD) Correction?
Pingguo Duan, MD; Praveen V. Mummaneni, MD; Jeremy Guinn, BS; Minghao Wang, MD, PhD; Zhuo Xi, MD; Bo Li, MD; Hao-Hua Wu, MD; Rory R. Mayer, MD; Joshua Rivera ; Shane Burch, MD; Sigurd H. Berven, MD; Dean Chou, MD

Paper #102: has been withdrawn

Paper #103: Low Pelvic Incidence (PI) Patients are at High Risk of Over Correction Following ASD Surgery
Alex Soroceanu, MPH; Themistocles S. Protopsaltis, MD; Gregory M. Mundis, MD; Justin S. Smith, MD, PhD; Michael P. Kelly, MD; Alan H. Daniels, MD; Eric O. Klineberg, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Munish C. Gupta, MD

Paper #104: Understanding Sagittal Compensation in Adult Spinal Deformity Patients: Relationship Between Pelvic Tilt and Lower Extremity Position
Takayoshi Shimizu, MD, PhD; Meghan Cerpa, MPH; Eric Leung, BS; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Paper #105: What is Actually Happening Inside the "Cone of Economy": Compensatory Mechanisms During a Dynamic Balance Test
Ram Haddas, PhD; Alexander M. Satin, MD; Isador H. Lieberman, MD

Paper #106: has been withdrawn

Paper #107: Achieving Harmonious Sagittal Profile Prevents from PJK in Adolescents with Idiopathic Scoliosis
Sebastien Pesenti, MD, PhD; Federico Solla, MD; Brice Ilharreborde, MD, PhD; Christian Morin, MD; Yann Philippe Charles, MD, PhD; Jean-Luc Clement, MD

Paper #108: Upper Instrumented Vertebral Pelvic Angle and Risk of Proximal Junctional Kyphosis at Two-year Follow-Up
Hao-Hua Wu, MD; Dean Chou, MD; Jeremy Guinn, BS; Joshua Rivera ; Pingguo Duan, MD; Minghao Wang, MD, PhD; Zhuo Xi, MD; Bo Li, MD; Shane Burch, MD; Praveen V. Mummaneni, MD; Sigurd H. Berven, MD

Session 10A: Spondylolisthesis/Congenital/Miscellaneous

Moderators: Samuel K. Cho, MD & Michael Vitale, MD

Paper #123: Can Surgery Restore Normal Quality of Life After Failed Conservative Treatment of Pediatric Low-Grade Spondylolisthesis?
Jean-Marc Mac-Thiong, MD, PhD; Julie Joncas, RN; James Choueiry, MD; Stefan Parent, MD, PhD; Soraya Barchi, BSc; Hubert Labelle, MD

Paper #124: Does Meyerding Slippage Reduction in Spondylolisthesis Correlate with Patient Outcomes?
Rory R. Mayer, MD; Dean Chou, MD; Brenton Pennicooke, MD; Praveen V. Mummaneni, MD

Paper #125: Health-Related Quality of Life (HRQOL) of Instrumented Reduction with Circumferential Arthrodesis for Pediatric Spondylolisthesis. A Comparison with Age and Gender Matched Healthy Controls
Ella Virkki, MD; Hanna Oksanen, RN; Linda Helenius, MD; Olli T. Pajulo, MD; Elias Diarbakerli, PhD; Paul Gerdhem, MD; Bernd Pape, PhD; Ilkka J. Helenius, MD

Paper #126: Complications of the Surgical Treatment of Pediatric High-grade Spondylolisthesis: A Prospective Multicenter Studyr
Jean-Marc Mac-Thiong, MD, PhD; Michael T. Hresko, MD; Abdulmajeed Alzakri, MD; Stefan Parent, MD, PhD; Daniel J. Sucato, MD, MS; Lawrence G. Lenke, MD; Michelle Claire Marks, PT; Hubert Labelle, MD

Paper #127: What is the Optimal Surgical Method for Achieving Successful Symptom Relief in Paediatric High Grade Spondylolisthesis?
Brett Rocos, MD; Reinhard D. Zeller, MD, FRCS(C); Stephen J. Lewis, MD, FRCS(C); Yongyao Tan, MS; David E. Lebel, MD, PhD

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Paper #128: Types, Timing, Impact, and Predictors of Reoperations Following Surgery for Lumbar Spondylolisthesis
Andrew K. Chan, MD; Erica F. Bisson, MD; Mohamad Bydon, MD; Kevin T. Foley, MD; Steven D. Glassman, MD; Christopher I. Shaffrey, MD; Michael Y. Wang, MD; Paul Park, MD; Eric Potts, MD; Mark E. Shaffrey, MD; Domagoj Coric, MD; John J. Knightly, MD; Kai-Ming Gregory Fu, MD; Jonathan R. Slotkin, MD; Anthony L. Asher, MD; Michael S. Virk, MD, PhD; Panagiotis Kerezoudis, MD, MS; Mohammed A. Alvi, MBBS; Jian Guan, MD; Regis W. Haid Jr., MD; Praveen V. Mummaneni, MD

Paper #129: Congenital Scoliosis Patients Can Attain Similar Curve Correction and Perioperative Outcomes to AIS Patients without the Need for Hemivertebra Excision
Vishal Sarwahi, MD, MBBS; Jesse Galina, BS; Jordan Fakhoury, DO; Thomas J. Dowling III, MD; Sayyida Hasan, BS; Yungtai Lo, PhD; Terry D. Amaral, MD

Paper #130: Failure of Initial Curve Correction Increases the Risk of Postoperative Curve Progression in Patients with Congenital Scoliosis: Mean 16-year Follow-Up
Noriaki Kawakami, MD, PhD; Hiroko Matsumoto, PhD; Toshiki Saito, MD, PhD; Ryoji Tauchi, MD, PhD; Tetsuya Ohara, MD

Paper #131: Reconstruction After Total En Bloc Spondylectomy: Does Bony Fusion Mean Long-term Stability?
Yat Wa Wong, Dr; Kenny Kwan, MD

Paper #132: Does Thoracic Paravertebral Block Improve Postoperative Pain Scores in Scoliosis Patients Undergoing Anterior Vertebral Body Tethering?
Smitha Mathew, MBBS, MS; Todd A. Milbrandt, MD, MS; D. Dean Potter, MD; Dawit T Haile, MD; A. Noelle Larson, MD

Paper #133: Radiation Exposure with Use of Intraoperative CT Guidance in Spinal Deformity Surgery
Bhumit R. Desai, MD; Gonzalo Sumarriva, MD; Alaa Mohammed; Paul C. Celestre, MD

Paper #134: An Audit of the Radiation Exposures in Children and Adults During the Treatment of Spinal Deformities.
Jwalant S. Mehta, FRCS (Orth), MCh (Orth), MS (Orth), D Orth; Ravindra Thimmaiah, FRCS Tr & Orth; James Kho, MD; Upasana Topiwala; Vijay Sawlani, MD; Rajesh Botchu, MD

Session 10B: Adult Spinal Deformity II

Moderators: Marinus de Kleuver, MD, PhD & Han Jo Kim, MD

Paper #135: A Propensity-score Matched Comparison of National vs. Single-institution Databases: Analysis of Unplanned Readmissions in Patients Undergoing Posterior Lumbar Fusion
Amir Taree, BS; Varun Arvind, BS; Eric Geng, BS; Kush Mody, BS; Christopher Mikhail, MD; Samuel K. Cho, MD

Paper #136: Patient-reported Outcomes after Complex Adult Spinal Deformity Surgery: 5-year Follow-Up Results of the Scoli-RISK-1 Studyr
Scott Zuckerman, MD; Meghan Cerpa, MPH; Lawrence G. Lenke, MD; Zeeshan M. Sardar, MD; Meghana Vulapalli ; Eric Leung, BS; Michael P. Kelly, MD; Christopher I. Shaffrey, MD; Yong Qiu, MD; Frank J. Schwab, MD; Leah Y. Carreon, MD; Kenneth Cheung, MD, MBBS, FRCS; Oheneba Boachie-Adjei, MD; Ames P. Christopher, MD; Ferran Pellisé, MD, PhD; Justin S. Smith, MD, PhD; Yukihiro Matsuyama, MD, PhD; Khaled M. Kebaish, MD

Paper #137: Do Readmissions and Reoperations Adversely Affect Patient-reported Outcomes Associated with Complex Adult Spinal Deformity Surgery at a Minimum 2 Year Postoperative?
Nathan J. Lee, MD; Jun Kim, MD; Andrew C. Vivas, MD; Joseph M. Lombardi, MD; Jay S. Reidler, MD; Scott Zuckerman, MD; Daniel Hong, MD; Paul J. Park, MD; Meghan Cerpa, MPH; Eric Leung, BS; Zeeshan M. Sardar, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Paper #138: Complication Profile Associated with S1 Pedicle Subtraction Osteotomy Compared to Three Column Osteotomies at Other Thoracolumbar Spinal Levels: Series of 405 Patients with 9 Sacral Osteotomies
Darryl Lau, MD; Alexander Haddad, BS; Rushikesh S. Joshi, BS; Vedat Deviren, MD; Christopher P. Ames, MD

Paper #139: Management of Severe Adult Spinal Deformity (ASD) with Circumferential Minimally Invasive Surgical (CMIS) Strategies: A 13-Year Study
Neel Anand, MD; Edward K. Nomoto, MD; Christopher Kong, MD; Alisa Alayan, MD; Babak Khandehroo, MD; Sheila Kahwaty, PA-C

Paper #140: Residual Coronal Malalignment Results in Less Improvement in Pain and Disability after ASD Surgery
Amit Jain, MD; Emmanuel McNeely, MS; Brian J. Neuman, MD; Jeffrey L. Gum, MD; Shay Bess, MD; Richard Hostin, MD; Virginie Lafage, PhD; Samrat Yeramaneni, PhD; Eric O. Klineberg, MD; Renaud Lafage, MS; Munish C. Gupta, MD; Justin S. Smith, MD, PhD; Douglas C. Burton, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Khaled M. Kebaish, MD

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Paper #141: Examination of Adult Spinal Deformity Patients Undergoing Surgery with and without Implanted Spinal Cord Stimulators and Intrathecal Pumps
Alan H. Daniels, MD; Wesley M. Durand, BS; Alyssa Steinbaum, BS; Renaud Lafage, MS; D. Kojo Hamilton, MD; Peter G. Passias, MD; Han Jo Kim, MD; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Jeffrey L. Gum, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Khaled M. Kebaish, MD; Alex Soroceanu, MPH; Richard Hostin, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; Robert A. Hart, MD

Paper #142: Correlation of Desoxypiridinoline Levels and Frequency of Pseudarthrosis Formation in Patients with Degenerative Spine Deformity
Sergey Kolesov, MD, PhD; Natalia Morozova, MD, PhD

Paper #143: The Rate of Perioperative Neurologic Complications Associated with Transforaminal Lumbar Interbody Fusion in Patients Undergoing Adult Spinal Deformity Surgery
Thomas J. Errico, MD; Tina Raman, MD

Session 11: Basic Science

Moderators: Hamid Hassanzadeh, MD & Ying Li, MD

Paper #144: LncAIS: A Novel and Significant Long Non-coding RNA Identified by Microarray Analysis which is Implicated in the Pathogenesis of AIS and Associated Osteopenia
Qianyu Zhuang, MD; Jianguo Zhang, MD

Paper #145: Collagen X Biomarker (CXM) is Predictive of Growth Cessation in Idiopathic Scoliosis
Michelle C. Welborn, MD; Ryan Coghlan, MS; James O. Sanders, MD; Joseph Stone, MD; Amer F. Samdani, MD; Vishwas R. Talwalkar, MD; Daniel Bouton, MD; William Horton, MD; Susan Sienko, PhD

Paper #146: Fourteen Novel Susceptibility Loci and Genetic Architecture in Adolescent Idiopathic Scoliosis
Nao Otomo, MD; Kazuki Takeda, MD, PhD; Yoji Ogura, MD, PhD; Yohei Takahashi, MD, PhD; Noriaki Kawakami, MD, PhD; Koki Uno, MD, PhD; Manabu Ito, MD, PhD; Shohei Minami, MD, PhD; Hiroshi Taneichi, MD, PhD; Satoshi Inami, MD, PhD; Teppei Suzuki, MD, PhD; Hideki Sudo, MD, PhD; Ikuho Yonezawa, MD, PhD; Takashi Kaito, MD, PhD; Kei Watanabe, MD, PhD; Yuki Taniguchi, MD, PhD; Katsumi Harimaya, MD, PhD; Toshiaki Kotani, MD, PhD; Nobuyuki Fujita, MD, PhD; Mitsuru Yagi, MD, PhD; Kazuhiro Chiba, MD, PhD; Naobumi Hosogane, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Eijiro Okada, MD, PhD; Tatsuya Sato, MD, PhD; Tsutomu Akazawa, MD, PhD; Kotaro Nishida, MD, PhD; Hideki Shigematsu, MD, PhD; Takahiro Iida, MD, PhD; Satoru Demura, MD, PhD; Kenichiro Kakutani, MD, PhD; Ryo Sugawara, MD, PhD; Taichi Tsuji, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Chikashi Terao, MD, PhD; Shiro Ikegawa, MD, PhD; Kota Watanabe, MD, PhD

Paper #147: Investigation of In-vivo Three-dimensional Changes of the Spinal Canal After Corrective Surgeries of the Adolescent Idioopathic Scoliosis
Yong Hai, MD, PhD; Chaofan Han, MD, PhD; Guoan Li, PhD

Paper #148: Tether Tension Declines Over Time: A Biomechanical Study
Vincent Ruggieri, BS; Benjamin Sinder, PhD; Jason B. Anari, MD; Patrick J. Cahill, MD

Paper #149: Are Pre-contoured Spinal Rods Mechanically Superior to Manually Contoured Rods?
Kenneth A. Shaw, DO; Dennis P. Devito, MD; Michael L. Schmitz, MD; Joshua S. Murphy, MD

Paper #150: 3D Cone-beam Tomosynthesis (CBT) Offered Accurate Magnitude of Pedicle Width Measurement and Pedicle Breach Assessment at Lower Radiation Dose than Computed Tomography (CT)
Vidyadhar V. Upasani, MD; Harsha Bandaralage, MS; Christine L. Farnsworth, MS

Paper #151: Does the Bone Mineral Density of the Pedicles Correlate with DEXA T-score? A Cadaver-based Analysis of CT Densitometry
Khalid Odeh, MD; Ashish Mittal, MD; Alexander Rosinski, MS; Joseph Pourtabib, BS; Jeremi Leasure, MS; Dimitriy Kondrashov, MD

Paper #152: Allograft Reconstructed Iliac Bone-graft Donor Site Remodels to Viable Bone and Its Preliminary Clinical Effectiveness in Revision Fusion
Glenn Robin Buttermann, MD; Andrew Freeman, MS; Byron H. Simmons, MD

Self-Paced Program

September 3-December 31, 2020

Self-paced content will be available to all registered attendees through December 31, 2020. Once all content in the self-paced program is completed, additional CME can be claimed.

Paper #153: Effectiveness of Partial Polyacrylic Acid Silver Salt as a Local Hemostatic Agent in Surgical Treatment of Degenerative Spine Disease
Sergey Kolesov, MD, PhD; Natalia Morozova, MD, PhD

Paper #154: Standing Balance and Postural Compensation Among Common Degenerative Spinal Pathologies
Ram Haddas, PhD; Thomas Kosztowski, MD; Damon Mar, PhD; Isador H. Lieberman, MD

Paper #155: Comparison of the Load Delivered to Scoliosis Patients Using Different Halo Gravity Traction Systems: A Bench Study
Jonathan Poli, MS; Robert Aylor, BS; Christopher Howard, MBA; Walter F. Krengel, III, MD; Klane K. White, MD; Gregory J. Redding, MD; Jennifer M. Bauer, MD

Membership Information Session

Prospective members and new candidate members are invited to visit the SRS membership module to learn more about membership with SRS.

Industry Workshops

September 3-December 31, 2020

Delegates are encouraged to view the industry workshops and take part in the live workshop discussions. Each workshop is programmed by a single-supporting company and will feature presentations on topics and technologies selected by the company.

DEPUY SYNTHES

Perioperative Neurologic Complications in Adult and Pediatric Deformity

Faculty: Randal Betz, MD; Puya Alikhani, MD; Baron Lonner, MD; Amer Samdani, MD

Please join this webinar to hear from our distinguished faculty panel in a case based discussion focusing on perioperative neurologic complications in adult and pediatric deformity.

Faculty cases will cover the following:

- Management of IONM Alerts in the OR
- Prevention of Nerve Root Injury
- Delayed Neurologic Events
- Sub-acute Management of the Patient After Paralysis in the OR

GLOBUS MEDICAL, INC.

Adult and Adolescent Spinal Deformity: Complex Surgical Techniques with ExcelsiusGPS®

Faculty: Hoon Choi, MD, MS, PhD; Sajan Hegde, MBBS, MS

This webinar is an overview of complex surgical techniques using the revolutionary robotic navigation system, ExcelsiusGPS®. The session will feature real life experiences and in depth case discussions with surgeon experts.

The following will be addressed:

- Initial ExcelsiusGPS® Experience and Learning Curve
- Technology Evaluation: Robotics versus Navigation
- Case Review Session: Complex Surgical Techniques with Robotic Navigation
- Cases Featuring: Pediatric and Adult Deformity, Trauma, Posterior Cervical, SI Fusion, Single Position Lateral Screw Placement
- Case Review Discussion and Q&A with Audience **pre-recorded*

MEDICREA

The Importance of Artificial Intelligence to Improve Outcomes and Efficiencies through Standardization

Moderator: Rajiv Sethi, MD

Faculty: Christopher Ames, MD; Evalina Burger, MD; Christopher Kleck, MD; Rajiv Sethi, MD

Spinal deformities are complex conditions leading to variability in care outcome and cost. Maximizing the care value equation, i.e. improving the health outcomes while reducing the cost of care delivery, has become the most important challenge for the industry.

Using artificial intelligence, predictive modeling, and patient specific implants, MEDICREA®'s UNiD® ASI platform is driving the change toward standardization by improving outcomes predictability and reproducibility.

Please join us for this industry workshop that will go over:

1. The importance of standardization for spinal surgery.
2. The current challenges in adult spinal deformity and the opportunity offered by A.I.
3. The presentation of MEDICREA® UNiD® ASI platform through case examples.*Faculty:*

MEDTRONIC

Evolutions in Spine Care: Innovative Solutions for Complex Cases

Moderator: Lawrence Lenke, MD

Faculty: Jeremy Fogelson, MD; Ron Lehman, MD; Andrew Bowey, MD

Dr. Larry Lenke will moderate this informative workshop reviewing complex deformity cases and the use of novel surgical techniques, enabling technologies, and construct designs to address challenging spinal malalignments. Through a series of case reviews, faculty members will discuss patient selection, pre-operative planning, navigated robotic guidance, building sustaining constructs, and innovative ways surgeons are learning new skills.

- Challenging Constructs; When Two Rods are Just Not Enough - Jeremy Fogelson, MD
- Spinal Robotics; Holistic Construct Design with Robotic-guided Execution - Ron Lehman, MD
- A New Era in Pediatric Deformity: From Virtual Reality to Anterior Vertebral Body Tethering - Andrew Bowey, MD

Industry Workshops

September 3-December 31, 2020

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NUVASIVE

Powerful and Efficient Deformity Correction

Moderator: Amer Samdani, MD

Speakers: Jahangir "John" Asghar, MD; Robert H. Cho, MD; Stewart Tucker, MD

In this virtual workshop you will hear Dr. John Asghar, Dr. Bob Cho, and Mr. Stewart Tucker discuss their personal experiences applying the broad applications of Reline 3D across both adult and pediatric deformity cases. The session will be moderated by renowned spinal deformity expert, Dr. Amer Samdani.

STRYKER

Complex Pediatric Deformities: How Have We Evolved in the Past Decade?

Faculty: Benny Dahl, MD; Martin Gehrchen, MD, PhD; Firoz Miyanji, MD, FRCSC; Burt Yaszay, MD

Techniques have evolved, spinal implant technologies have advanced, and lessons have been learned! This interactive workshop will feature discussions around the toughest challenges and greatest lessons of the past decade in the world of pediatric deformity.

Podium Presentations—Adolescent Idiopathic Scoliosis I: From Assessing Skeletal Maturity to Managing Pain

1. Refining the Proximal Humerus Ossification System Using Medial Physeal Closure

Don Li, PhD; Logan Petit, MD; Joseph Kahan, MD; Elsayed Attia, MD; Ashley Startzman, MD; Eric Li ; Siddharth Jadhav, MD; Alana Munger, MD; Ahmed Elabd, MD; Janelle Greene, MD; Jonathan Cui, MD; Ronan Talty, BS; Brett Heldt, BS; Daniel R. Cooperman, MD; *Brian Smith, MD*

Summary
Integrating the closure of the medial physis into the proximal humerus ossification system improved the assessment of maturity. Specifically, Stage 3A patients with an open medial physis have a higher risk of progression to the surgical range compared with Stage 3B patients with a closing or closed medial physis. The divergence between these two groups is particularly striking in intermediate curve sizes (20-35 degrees).

Hypothesis
We hypothesize that integrating closure of the medial physis will allow for further refinement of the proximal humerus ossification system assessment of maturity.

Design
We analyzed data from 121 patients with adolescent idiopathic scoliosis who were followed at least every six months between 2007 and 2017.

Introduction
We have previously demonstrated that proximal humeral ossification patterns are an excellent method of predicting progression to surgery in patients with adolescent idiopathic scoliosis. Furthermore, we found that peak growth corresponded to Stage 3 of our system, which was defined based on the appearance of the lateral epiphysis and physis.

Methods
We analyzed 171 radiographs from 121 patients with adolescent idiopathic scoliosis who were followed at least every six months between 2007 and 2017. All patients had either undergone surgery or had finished monitoring after skeletal maturity. Each patient's age, sex, treatment status, bracing status, and curve size during a visit were recorded. Visits without complete information, postsurgical films, and films taken in brace were excluded. The percentage of patients who progressed to surgery were stratified by assessment of the medial physis using the criteria shown in the figure. Average intraclass correlation coefficients (ICC) were used to determine reliability.

Results
We demonstrate that Stage 3A patients have a significantly greater risk of progression to surgery compared with Stage 3B patients (P=0.0391). We summarize the risk of progression for each curve size by stage in the attached figure. As can be seen, while all stage 3 patients are low risk with curve sizes <20 and high risk with curve sizes >35, stage 3A vs 3B patients show significant differences in progression with intermediate curve sizes. Reliability was found to be excellent with 0.915 inter-rater ICC from 12 observers and 0.894 intra-rater reliability ICC.

Conclusion
The critical Stage 3 of the proximal humerus ossification system can be further refined by evaluating closure of the medial physis. This will allow for better understanding of which patients are likely to progress to the surgical range.

Take Home Message
The proximal humerus ossification system can be refined by assessing medial physis closure status. Stage 3A patients are higher risk than Stage 3B patients in intermediate curve sizes (20-35 degrees).

Stage	Lateral Margin	Medial Physis	Lateral Physis
1	Oblique	Open	Open
2	Curved	Open	Open
3A	Co-Linear	Open	Open
3B	Co-Linear	Closing/Closed	Open
4	Co-Linear	Closed	Closing
5	Co-Linear	Closed	Closed

Curve	All Stage 3	Stage 3A	Stage 3B
< 10°	0% (N=7)	0% (N=2)	0% (N=5)
10°–14°	0% (N=21)	0% (N=8)	0% (N=13)
15°–19°	9% (N=32)	13% (N=15)	6% (N=17)
20°–24°	16% (N=25)	25% (N=12)	8% (N=13)
25°–29°	20% (N=15)	29% (N=7)	13% (N=8)
30°–34°	27% (N=11)	40% (N=5)	17% (N=6)
35°–39°	79% (N=14)	100% (N=4)	70% (N=10)
40°–44°	100% (N=14)	100% (N=8)	100% (N=6)
> 45°	100% (N=33)	100% (N=15)	100% (N=18)

Rating Criteria and Progression Outcomes

2. Multi-site Assessment of Pediatric Bone Age Using Deep Learning

Aly A. Valliani, BS; John T. Schwartz, BS; Eric Geng, BS; Varun Arvind, BS; Christopher Mikhail, MD; *Jun Kim, MD*; Samuel K. Cho, MD

Summary
Classification of pediatric bone age is an important consideration for the management of pediatric spinal deformity. Traditional methods of assessment of pediatric bone age are subject to rater-dependent error. In this study, we show that machine learning can automatically assess pediatric bone age from hand radiographs with low absolute error.

Hypothesis
We hypothesize that machine learning can be used to automatically assess pediatric bone age from hand x-rays with low error.

Design
Retrospective analysis of 14,002 xrays from two hospitals in the United States

Podium Presentations—Adolescent Idiopathic Scoliosis I: From Assessing Skeletal Maturity to Managing Pain

Introduction
Management of pediatric spinal deformity patients requires measurement of bone age to predict future patient growth in order to optimize treatment outcomes. Performing bone age assessment by traditional methods is intensive and subject to rater-dependent error. Deep learning image analysis techniques may be able to automate this task and streamline the clinical workflow.

Methods
14,002 hand radiographs were obtained from three hospitals based in the United States. All x-ray images were accompanied by patient sex information and skeletal bone age estimated made by pediatric radiologists. A machine learning model was trained on 12,611 hand radiographs, incorporating sex to predict bone age which was compared to assessments made by pediatric radiologists. Following training of the machine learning model on this data, the model was tested in a blinded fashion on 1,391 radiographs from the Children's Hospital Los Angeles.

Results
When tested in a blinded fashion on 1,391 radiographs from the Children's Hospital Los Angeles, the machine learning model performed with a mean absolute error or 11.3 months.

Conclusion
Pediatric bone age assessment is an important measure of pediatric growth and therefore an important variable in the management of pediatric spinal deformity. Recent studies have explored automated method for bone age assessment using machine learning, but none have been validated on external hospital sites. We show that machine-learning algorithms for bone age assessment have clinical efficacy and also demonstrate the need for further work in the development of algorithms that generalize across institutions and populations.

Take Home Message
Machine learning can be used to assess pediatric bone age, an important factor in the management of pediatric spinal deformity, and maintains low error when tested across different institutions.

3. Comparison between Low-Dose Slot Scanning and Conventional Radiography for Hand Bone Age: Imaging Quality and Radiation Dose

Jie C. Nguyen, MD, MS; Andressa G. Alves, MD; Anthony Nicholson, BS; Liya Gendler, MD; Victor Ho-Fung, MD; Sze Alyssa, BA; Michael Nguyen, BS; Zhu Winnie, PhD; Divya Talwar, PhD; Kassa Darge, MD, PhD; John (Jack) M. Flynn, MD; Patrick J. Cahill, MD

Summary
Accurate estimation of skeletal maturity is extremely important for treatment decision-making in children with scoliosis. We investigated the differences in image quality and radiation dose between hand bone age radiographs obtained using slot scanning radiograph (SSR) (aka, stereoradiography) and conventional radiography. Although image quality is lower, inter-reader agreement was excellent and radiation dose was lower with SSR.

Hypothesis
SSR can produce lower dose diagnostic hand images when compared to conventional radiography.

Design
Case Control

Introduction
In children with scoliosis, the Sanders staging system based on a hand radiograph is the most accurate method for determining skeletal maturity and directly impacts treatment decision-making. Although SSR can generate hand radiographs, its diagnostic quality and radiation dose have not been systematically investigated. Therefore, our aim was to determine image quality, inter-reader agreement, and radiation dose between age-, gender-, and BMI-matched children imaged using either SSR or conventional radiography.

Methods
This IRB-approved and HIPPA-compliant retrospective study included 100 consecutive bone age SSR, performed between October and December 2019 and 100 matched control radiographs. Blinded to clinical information and imaging modality, 5 readers (3 physicians and 2 trainees) independently reviewed all images and estimated bone age using the Greulich & Pyle method and rated image quality (poor, acceptable, excellent). Radiation doses were recorded. Intraclass correlation (ICC) was used to assess inter-reader agreement. Mann-Whitney and t-tests were used to compare radiation dose between SSR and radiographs.

Results
Image quality was rated as either acceptable or excellent in 99% with SSR and 100% with radiography. ICC was excellent to slightly better for SSR (0.986; 95% CI = 0.982-0.990) than for radiography (0.979; 95% CI = 0.971-0.985). Within a matched subgroup of 130 children (65 with SSR, 65 with radiography) with radiation doses, SSR was significantly lower than radiography (p=0.015).

Conclusion
Bone age determination using SSR has excellent inter-reader agreement and radiation exposure is lower than radiography. Further prospective investigation is needed to compare diagnostic accuracy against radiography.

Take Home Message
SSR is a low-dose method for estimating skeletal maturity that can be obtained in conjunction with the spine, reducing the need to switch modalities and may positively impact clinical workflow.

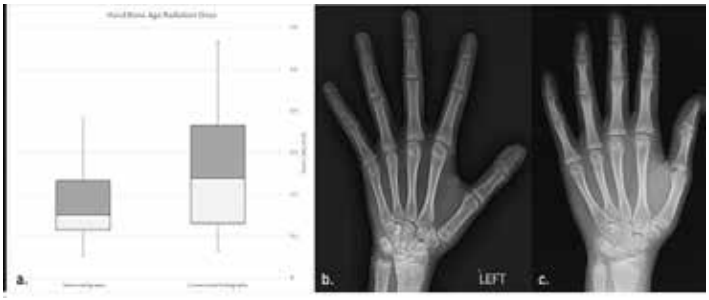


Figure 1. Box-whisker graph (a) shows mean and range for radiation dose between SSR and conventional radiography. Examples of hand images from a 13 year-old girl (b) using SSR (dose, 0.182 dGy cm2) and from a matched control (c) using radiography (dose, 0.245 dGy cm2).

4. MOBI (My Orthopedic Brace Inventory): A New Reliable and Valid Questionnaire to Identify Factors Associated with Poor Adherence to Brace Treatment in AIS

Omar Elsemin, BSN; Marie Beausejour, PhD; Samuel Sassine, BS; Julie Joncas, RN; Soraya Barchi, BSc; Sylvie Le May, PhD; Nikita Cobetto, PhD; Carole Fortin, PhD; Carl-Eric Aubin, PhD; Stefan Parent, MD, PhD; *Hubert Labelle, MD*

Summary
Poor adherence to brace treatment is a serious threat to effective management of AIS. We present a self-administrated questionnaire designed to identify factors associated with poor adherence to brace treatment. Extensive validation has confirmed its proper content and discriminant validity, as well as very good to excellent reliability for use in the adolescent population.

Hypothesis
A questionnaire focussing on brace adherence with a very good reliability and validity can be designed and should help to identify causes of poor bracing wear in AIS.

Design
Psychometric validation protocol.

Introduction
The BrAIST study reported a correlation between the number of hours of brace wear and the effectiveness of brace treatment in AIS. Unfortunately, poor adherence to brace wear was also documented, for causes which remain to be identified.

Methods
Based on the conceptual framework of the World Health Organization, a 34-items questionnaire was developed, covering 7 domains: physical, emotional, functional and social well-being, and barriers to enrollment related to the patient, treatment and health system. The content validity was established through triangulation of a thorough literature review, results from a patient focus group and a Delphi process with health professionals. Usability was confirmed in a pre-test. The questionnaire was then administered to 128 AIS patients undergoing brace treatment with a compliance monitor. MOBI scale distribution, test-retest reliability, internal consistency and discriminant capacity were tested.

Results
53% of patients were considered as adherent to treatment by wearing their brace as prescribed (≥16 hours/day). MOBI's global score was successful to discriminate between adherent and non-adherent patients (p=0.001). Patients with a curve >40o had a significantly higher MOBI score (p=0.04). The mean global score was 44.2±17.4 [11.0-94.0] (over a maximum of 132; lower scale indicating a better outcome). The score distribution showed no significant floor/ceiling effect on the conceptual domains, but 3 items showed a ceiling effect. Internal consistency was excellent (Cronbach alpha 0.89). Test-retest reliability (40 patients) was adequate (33 items with good/moderate interclass coefficients; >0.5).

Conclusion
The MOBI self-administered questionnaire documents reliably and validly for the first-time factors associated to poor brace adherence in AIS.

Take Home Message
After cross-cultural adaptation in various languages, MOBI will be distributed freely to the spine community to help assess factors associated to poor adherence and design strategies to improve brace wear.

5. AIS Patients with Pain Catastrophizing Have Worse SRS Scores 1 Year Postoperatively

Kiley F. Poppino, BS; Shelby P. Cerza, MA; Teresa L. Collins-Jones, PhD; *Brandon A. Ramo, MD*

Summary
Pain catastrophizing is a psychological trait quantified by the Pain Catastrophizing Scale. Patients scoring ≥30 on this scale are at risk for development of chronic pain. 11.33% of surgical AIS patients demonstrated clinically significant pain catastrophizing preoperatively and continued to have worse SRS scores in all domains than their peers 1-year postoperatively. ROC analysis showed a preoperative SRS pain domain score ≤3.5 could be used as a simple screening cut-off to identify those patients appropriate for preoperative psychological evaluation.

Hypothesis
Some preoperative AIS patients have pain catastrophizing characteristics that influence postop pain.

Design
Prospective cohort

Introduction
AIS patients often report chronic back pain, but limited research exists on psychological factors associated with this pain. Pain catastrophizing is a pattern of negative thoughts/feelings about pain. Greater levels of pain catastrophizing are associated with pain intensity and poorer response to pain intervention. Our purpose was to report preoperative pain catastrophizing scale (PCS) scores in the AIS population and assess its relationship to 1-year postop quality of life and pain levels using SRS scores.

Methods
From 2015-2018, PCS and SRS scales were prospectively collected preoperatively on surgical AIS patients. Patients with clinically significant pain catastrophizing levels, (PCS total score ≥ 30), were compared to patients within normal PCS limits regarding their SRS outcomes at 1 year postoperatively.

Results
Of 203 AIS patients (168F, 35M), 23 patients (11.33%; 20F, 3M)

had clinically elevated PCS scores. There was no significant difference in age, BMI, or major Cobb (62.5° v 62.9°). Elevated PCS patients had significantly lower preoperative SRS scores in the domains of Pain (2.96 v 3.98; p<0.001); Appearance (3.18 v 3.46; p=0.019); Activity (3.55 v 3.99; p<0.001); Mental health (3.33 v 4.05; p<0.001); and Total (3.26 v 3.83; p<0.001). 1-year postoperatively, elevated PCS patients continued to have significantly worse SRS scores in Pain (4.01 v 4.36; p=0.038); Appearance (3.76 v 4.14; p=0.005); Activity (3.64 v 3.97; p=0.006); Mental health (3.44 v 4.3; p<0.001); and Total (3.76 v 4.21; p<0.001) than their peers. Receiver operative characteristic (ROC) curve analysis showed a predictive cutoff value of 3.50 for the SRS preoperative pain domain (AUC=0.864, 95% CI 0.777-0.870) to identify pain catastrophizers.

Conclusion
AIS Patients who pain catastrophize are at risk for chronic pain and mental health concerns, and they continue to have worse SRS scores 1-year postop compared to peers. A preoperative SRS pain domain score ≤ 3.50 may be useful to identify patients appropriate for psychological pain assessment prior to AIS surgery.

Take Home Message
11.33% of AIS patients exhibited psychological risk factors for chronic pain. SRS pain domain and PCS scores can be used as effective preoperative screening protocols to identify these patients preoperatively.

6. The Effects of Obesity and Poverty on Perioperative Complications in Adolescent Idiopathic Scoliosis: A Multi-Center Analysis

Tyler C. McDonald, MD; Michael J. Heffernan, MD; Bryant Song, BS; Hamdi Sukkarieh, MD; Lawrence L. L. Haber, MD; Michael Joseph Conklin, MD; Shawn R. Gilbert, MD; Benjamin W. Sheffer, MD; William H. Stafford, BS; Jeffrey E. Martus, MD; Charles H. Crawford III, MD; Leah Y. Carreon, MD; John P. P. Lubicky, MD; David S. Tager, MD; David B. Bumpass, MD; Killian Coyne, BS; Brandon A. Ramo, MD; Patrick B. Wright, MD; Jaysson T. Brooks, MD

Summary
Ten southern U.S. institutions, in states classified as endemic for childhood obesity by the Centers for Disease Control, performed a retrospective analysis of 379 AIS patients undergoing PSF. Overweight and obese patients were found to have a significantly higher rate of surgical site infections (SSIs) as compared to normal weight patients. In addition, obese patients had a lower socioeconomic status (SES) than normal weight patients did. When controlling for a patient's SES, their BMI no longer affected their SSI rate.

Hypothesis
In patients with adolescent idiopathic scoliosis (AIS), undergoing posterior spinal fusion (PSF), overweight (OW) and obese (OB) patients have increased perioperative complications and a lower socioeconomic status (SES) as compared to normal weight (NW) patients.

Design
Multicenter retrospective analysis

Introduction
A multi-center research consortium composed of institutions in the southern U.S., located in states classified as endemic for childhood obesity by the Centers for Disease Control (CDC) was formed to evaluate the effect of obesity on pediatric musculoskeletal disorders. This study aims to evaluate how childhood obesity and poverty affects perioperative outcomes after PSF for AIS.

Methods
The records of AIS patients who underwent PSF between Jan 1, 2011 to Dec 31, 2017 were reviewed from multiple centers. Patients were classified by CDC BMI for age categories: NW (5th to <85th %ile), OW (85th to <95th %ile), and OB (>/=95th %ile). SES was determined by the area deprivation index (ADI), where a higher number indicates economic disadvantage. Perioperative complications were the main outcome measure therefore 2 years of follow-up was not required.

Results
379 patients were randomly selected within each BMI category: 36% (134) NW, 28% (107) OW and 36% (138) OB. OB patients had significantly lower SES vs NW patients (ADI 73 ± 18 vs 64 ± 24, p=0.005). OB and OW patients had a significantly higher surgical site infection (SSI) rate vs NW patients (4% vs 0%, p=0.02). The mean BMI %ile was 95 ± 6 and 77 ± 26 in patients with and without SSIs, respectively (p=0.04). When controlling for ADI, SSI rate was no longer significantly different between groups (p=0.09). No other perioperative complications were significant amongst BMI groups (Table).

Conclusion
OB and OW patients with AIS have an increased risk of SSIs compared to NW patients, however this risk is abated when controlling for socioeconomic status.

Take Home Message
In patients with AIS undergoing PSF, their socioeconomic status is a significant confounder of perioperative surgical site infections.

Podium Presentations—Adolescent Idiopathic Scoliosis I: From Assessing Skeletal Maturity to Managing Pain

	Normal Weight (NW) (134 patients)	Overweight (OW) (107 patients)	Obese (OB) (138 patients)	
	n (%)	n (%)	n (%)	p value
Superficial Infection	0 (0%)	4 (3.9%)	6 (4.5%)	0.018†
Deep Infection	1 (0.8%)	3 (2.9%)	2 (1.5%)	0.440
Wound Dehiscence	1 (0.8%)	3 (2.9%)	7 (5.3%)	0.104
Readmission	3 (2.3%)	4 (3.9%)	8 (6.2%)	0.319
Hardware Failure	1 (0.8%)	2 (1.9%)	3 (2.2%)	0.516
Return to OR	10 (8.1%)	7 (7.0%)	9 (7.0%)	0.943
Transient Loss of SSEPs	0 (0%)	3 (3.4%)	0 (0%)	0.098
Permanent Loss of SSEPs	0 (0%)	1 (1.1%)	0 (0%)	0.599
Transient Loss of TcMEPs	2 (1.9%)	2 (2.3%)	2 (1.6%)	0.952
Permanent Loss of TcMEPs	0 (0%)	1 (1.1%)	0 (0%)	0.583
Transient Paralysis	1 (0.9%)	2 (2.2%)	1 (0.9%)	0.546
Permanent Paralysis	0 (0%)	0 (0%)	0 (0%)	n/a
Coma	0 (0%)	0 (0%)	0 (0%)	n/a
Pneumonia	0 (0%)	0 (0%)	0 (0%)	n/a
Reintubation	0 (0%)	0 (0%)	0 (0%)	n/a
Stroke	0 (0%)	0 (0%)	0 (0%)	n/a
Pulmonary Embolism	0 (0%)	0 (0%)	0 (0%)	n/a
Cardiac Arrest	1 (0.8%)	0 (0%)	0 (0%)	0.400
Renal Failure	0 (0%)	0 (0%)	0 (0%)	n/a
Sepsis	0 (0%)	0 (0%)	0 (0%)	n/a
Septic Shock	0 (0%)	0 (0%)	0 (0%)	n/a
DVT	0 (0%)	0 (0%)	0 (0%)	n/a
	mean (SD)	mean (SD)	mean (SD)	
Area Deprivation Index (ADI)	64.14 (23.86)	67.58 (21.16)	72.78 (18.55)	0.005‡
Pre-op major Cobb angle	57 (36)	56 (28)	56 (36)	0.499
Post-op major Cobb angle	19.13 (8.99)	17.15 (9.36)	18.67 (10.93)	0.289
Post-op T1-T12 Kyphosis	31.88 (10.88)	29.57 (10.68)	32.43 (9.81)	0.161
Post-op T5-12 Kyphosis	21.21 (8.84)	19.24 (9.27)	21.06 (9.72)	0.081
Post-op Lumbar Lordosis	44.57 (17.61)	45.13 (13.71)	44.38 (11.53)	0.924
Length of Stay (days)	4.28 (1.74)	4.17 (1.44)	4.6 (7.23)	0.518
Implant Density	1.37 (0.44)	1.48 (0.39)	1.37 (0.41)	0.069
Anesthesia Time (min)	375.68 (105.79)	369 (89.12)	410.65 (127.76)	< 0.005§
OR Time (min)	359.21 (111.62)	349.97 (95.59)	388.66 (137.65)	< 0.005§
EBL (mL)	658.91 (439.49)	685.67 (490.42)	675 (406.05)	0.964

†OW & OB patients combined and compared to NW group. ‡post hoc testing: p-value for pairwise comparison between NW & OB groups. §post hoc testing: p-value for pairwise comparison of NW vs OB & OW vs OB

7. Comparison of Four Different Methods of Correction for Adolescent Idiopathic Scoliosis: Results from A National Cohort Study

Sebastien Pesenti, MD, PhD; Federico Solla, MD; Yann Philippe Charles, MD, PhD; Brice Ilharreborde, MD, PhD; Christian Morin, MD; Jean-Luc Clement, MD

Summary
Through a national database, we aimed to compare the radiographic results of the four most used techniques for correction of AIS. Cobb angle correction rates were different between the 4 techniques. However, multivariate analysis revealed that correction technique did not influence correction rate, whereas implant density, concave distraction and use of derotation connectors did. TK increased was significantly higher in the PMT group. Therefore, PMT should particularly be used in hypokyphotic patients.

Hypothesis
Posteromedial translation allows for a better correction than the other techniques in 562 adolescents diagnosed with idiopathic scoliosis.

Design
Retrospective, multicenter

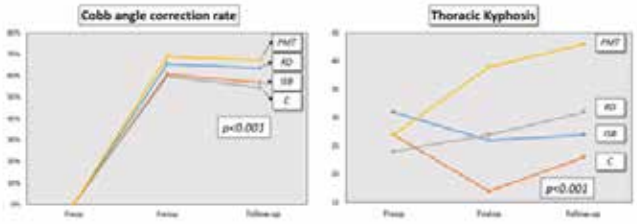
Introduction
Posterior fusion has become the gold standard for surgical correction of adolescent idiopathic scoliosis (AIS). Besides from implants type, several correction maneuvers have been described but it remains unclear whether a technique provides better correction than the others do. Through a national database, we aimed to compare the radiographic results of the four most used techniques for correction of AIS.

Methods
Over our national database, we identified 562 adolescents (mean 15yo) diagnosed with Lenke 1, 2, 3, 4, or 6 idiopathic scoliosis with at least 2 years follow-up (mean 46 mths). Patients were divided according to the correction maneuvers that were used for their surgical correction: in situ bending (ISB), cantilever (C), rod derotation (RD) and posteromedial translation (PMT). Radiographic analysis was performed from AP and lateral x-rays preoperatively, at first erect and at last follow-up. Main outcomes were Cobb angle correction and thoracic kyphosis restoration (TK).

Results
Over the study population, 62 patients underwent surgical correction following the ISB technique, 39 the C technique, 113 the RD technique and 348 the PMT technique. Cobb angle correction rates were different between the 4 techniques (ISB 64% vs C 57% vs RD 55% vs PMT 67%, p<0.01). However, multivariate analysis revealed that correction technique did not influence correction rate, whereas implant density, concave distraction and use of derotation connectors did. TK increased was significantly higher in the PMT group (ISB -4° vs C -5° vs RD +7 vs PMT +16°, p<0.01).

Conclusion
None of the 4 techniques we assessed showed superior results for coronal plane correction. However, it appears that PMT offers a better potential for TK restoration. Therefore, this technique should be preferred when treating hypokyphotic patients.

Take Home Message
The 4 techniques offer the same coronal correction but PMT allows for a better correction of the sagittal plane



Comparison of in situ bending (ISB), cantilever (C), red derotation (RD) and posteromedial translation (PMT) for the correction of AIS patients

8. What Factors are Associated with Greater Apical Derotation? Is Single or Dual Rod Derotation Better?

Steven W. Hwang, MD; Joshua M. Pahys, MD; Tracey P. Bastrom, MA; Peter O. Newton, MD; Suken A. Shah, MD; Stefan Parent, MD, PhD; Harms Study Group; Amer F. Samdani, MD

Summary
3D imaging has improved our understanding of rotation in AIS

surgery and allows us to better measure surgical derotation achieved. Comparing 452 patients with Lenke 1-4 curves, 73.1% of patients achieved > 50% improvement in apical rotation or thoracic rib prominence. Greater pre-op rotation and institution-specific factors were most predictive of improvement in apical rotation. Single vs dual rod derotation, metal type, implant density, osteotomies, and other radiographic variables were not associated with greater correction.

Hypothesis
Peri-op and operative variables can predict apical derotation

Design
Retrospective multicenter study

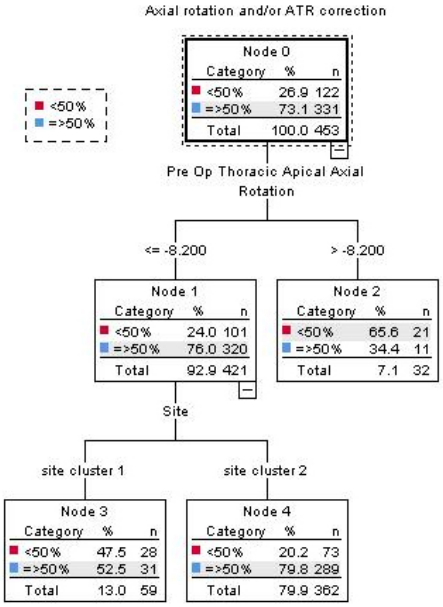
Introduction
Significant variation still exists in surgeon techniques to optimize axial rotation. We sought to investigate factors associated with better correction of apical axial rotation, specifically whether single or dual rod derotation had a greater impact.

Methods
A multicenter prospectively collected registry was retrospectively queried identifying all AIS patients with Lenke 1-4 curves having undergone a posterior spinal fusion with 2 years of follow-up and 3D imaging and reconstructions. Patients having undergone concurrent thoracoplasty or anterior procedures were excluded. Success was defined as having ≥ 50% improvement in the apical rotation (3D reconstruction) or ≥ 50% improvement in the rib prominence.

Results
453 patients were included; 73.1% achieved > 50% improvement in apical rotation whereas 26.9% did not. Patients with more rotation pre-op (17.1 ± 8.5° vs 12.6 ± 11.1°, p<0.05) and larger rib prominences pre-op (15.9 ± 4.4° vs 14.0 ± 4.7°, p<0.05) more often had > 50% improvement. Female gender was also associated with greater apical rotational success (75% vs 63%, p<0.05) but not curve flexibility (p=0.88). Success of apical derotation also varied by institutional site, ranging from 40-100% (p<0.05). Derotation using one rod achieved success in 70% vs 75% using 2 rods but was not significant (p=0.21). Pre-op curve magnitude (p=0.69), pre-op apical translation (p=0.08), post-op correction (p=0.10), thoracic apex level (p=0.88), use of osteotomies (p=0.88), number of levels fused (p=0.27), implant density (p=0.23), and metal type (p=0.70) were not significant. In a CART analysis, > 8° of pre-op rotation and site were predictive of success.

Conclusion
Single vs dual rod derotation, metal type, and implant density were not associated with greater correction of apical rotation, but greater pre-op rotation and site-specific variations did lead to greater improvement in rotation. Site specific variations (that may encompass differing techniques) might account for greater improvement in axial rotation.

Take Home Message
Site specific variations (that may reflect a combination of surgical techniques) and greater pre-op rotation were associated with greater correction of apical rotation.



9. Perioperative Steroid Use in Patients Undergoing PSF for AIS

Tracy Ruska, NP; Thomas Austin, MD, MS; Ndeye F. Guisse, MS; Robert W. Bruce Jr., MD; Joshua S. Murphy, MD; *Nicholas D. Fletcher, MD*

Summary
A review of 123 patients undergoing PSF for AIS who were treated with without post operative steroids was performed. Patients with steroids showed a 40% decrease in opioid usage, a higher likelihood to ambulate during PT, and a shorter LOS than those who did not receive steroids when accounting for all other pain medications. No patient treated with steroids developed a postoperative infection and there was an no difference in the number of patients who developed a wound dehiscence.

Hypothesis
Use of postoperative steroids following PSF for AIS would result in lower opioid usage without increasing wound complications.

Design
Review of a prospectively collected series of patients undergoing PSF for AIS

Introduction
Surgeons have avoided steroids after PSF in AIS. Literature has supported the use of postoperative steroids in other areas of orthopaedics, touting rapid recovery and improved postoperative pain.

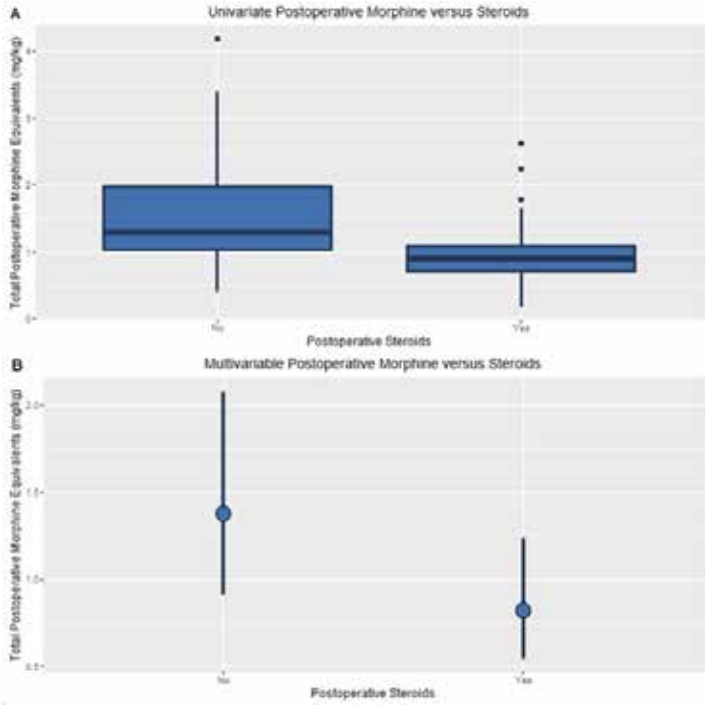
Methods
Patients undergoing PSF for AIS from 2015-2018 at a single hospital were reviewed. Opioid usage was determined by con-

verting all postoperative opioids given into morphine equivalents (MsEq).

Results
65 patients underwent PSF for AIS without postoperative steroids (NS) from and 58 patients treated with steroids (WS) for three doses (average 8.9 mg/dose). There was no difference in curve size, levels fused, or EBL between groups. There was a 40% decrease in total morphine equivalents used in the group with steroids when controlling for weight (1.374 mg/kg vs 0.841 mg/kg; p-<0.001; Figure). This difference persisted after accounting for gabapentin, ketorolac and diazepam usage, surgical time, curve size, and levels fused (decrease of 40.4 MsEq, p= 0.001). WS patients were more likely to ambulate at first PT session (60.4% vs 35.4%, p=0.013). LOS was shorter (46.5 hrs WS vs 49.2 hrs NS, p<0.001) in the WS group. One NS patient developed a deep infection. There was no difference in pain at discharge or days missed from school between groups.

Conclusion
In spite of long-standing concerns over their use, a short course of postoperative steroids after PSF resulted in a 40% decrease in use of opioids and a shorter length of stay with no increase in wound complications.

Take Home Message
Perioperative steroid use following PSF for AIS resulted in a large (40%) decrease in opioid usage and shorter length of stay without any increase in wound healing complications.



Morphine Equivalents Used

10. Parents Anxiety Predicts Child's Narcotic Use

Natalya Sarkisova, BS; *Lindsay M. Andras, MD*; Joshua Yang, BA; Vernon T. Tolo, MD; David L. Skaggs, MD

Summary
Female patients with parents who have high general anxiety are more likely to be using narcotics at their first post-op visit after a spinal fusion.

Hypothesis
Parents with high general anxiety are more likely to have children continue their narcotic use at first post-op visit following spinal fusion.

Design
Prospective, single center

Introduction
Parental mental status and behavior may influence postoperative recovery and use of pain medication. The purpose of this study is to assess if parent's anxiety levels are associated with their children's post-operative narcotic use in adolescent idiopathic scoliosis (AIS) patients undergoing posterior spinal fusion (PSF).

Methods
AIS females age 11-20 years undergoing PSF and a parent were prospectively enrolled. At the pre-operative appointment, patients completed the Spence Children's Anxiety Scale (SCAS) and parents completed the State-Trait Anxiety Inventory (STAI). High parental anxiety was defined as 1 standard deviation above the normative mean. At the first post-operative visit, patients were asked about medication use.

Results
50 patients were enrolled. 32% (16/50) of parents had high general anxiety trait on the STAI and 68% (34/50) had normal general anxiety. 30% (15/50) of patients were taking narcotics at the time of their first post-operative visit (mean: 15 days post-op). At the first post-operative visit 50% (8/16) of female patients with high anxiety trait parents were on narcotics compared to 21% (7/34) of female patients with normal anxiety parents (p=0.03). There was no correlation between pre-operative parental anxiety scales and child anxiety scores (p=0.12). Patient anxiety scores was not associated with post-operative narcotic use (p=0.35).

Conclusion
Patients with high anxiety parents were more than twice as likely to be on narcotics at their first postoperative visit.

Take Home Message
As parent anxiety is associated with prolonged narcotic use in patient's following PSF for AIS, there may be an opportunity to lessen patient narcotic use by addressing parents' concerns.

Podium Presentations—Adolescent Idiopathic Scoliosis I: From Assessing Skeletal Maturity to Managing Pain

11. Zero PCA is an Achievable Target for Postoperative Rapid Recovery Management of AIS Patients

Vishal Sarwahi, MD, MBBS; Sayyida Hasan, BS; Michelle Kars, MD; Benita Liao, MD; Jesse Galina, BS; Yungtai Lo, PhD; Terry D. Amaral, MD

Summary
Use of intraoperative micro-dose Duramorph has significantly better postoperative recovery outcomes and pain control and can replace the need for postoperative PCA in an RRP after scoliosis surgery.

Hypothesis
The use of intrathecal single micro-dose Duramorph can replace the need for patient-controlled analgesia (PCA) in a rapid recovery pathway (RRP) protocol after scoliosis surgery.

Design
Retrospective Review

Introduction
The objective of this study was to report on one institution's use of single bolus micro-dose intrathecal morphine (ITM) during PSF for AIS and its comparison to patients whose pain was controlled with PCA.

Methods
In 2018, we instituted an RRP for scoliosis patients undergoing PSF utilizing intrathecal micro dose ITM. Previously, PCA was the mainstay for postop pain management. In the ITM protocol, patients receive 1.5 mcg/kg ITM diluted in 1 cc saline administered preoperatively by anesthesiologists or intraoperatively by the surgeon. Postoperatively, patients received IV ketorolac at 0.5mg/kg Q6h, PO Tylenol (15 mg/kg q6h), PO Oxycodone (0.1 mg/kg q4), and IV Hydromorphone (15 mcg/kg) for breakthrough pain. At discharge, PCA patients received 14-day prescriptions for 5mg Oxycodone q6 compared to just 7-day prescriptions in the ITM group. Charts from 2011 – 2019 were reviewed. PCA patients were included in Group 1 and ITM in Group 2. Periop data and patient requests for prescription refills were analyzed and compared using Kruskal-Wallis and Chi-squared tests.

Results
340 patients (PCA: 215; ITM: 125). Levels fused ($p = 0.325$) and BMI ($p = 0.746$) were similar. Patients in group 1 had a significantly higher median length of stay($p<0.001$). Group 2 patients began ambulating significantly earlier with 93.5% patients out of bed by POD 2 compared to 82.1% in group 1($p < 0.001$). In addition, group 2 patients had significantly lower maximum pain scores with activity compared to group 1($p < 0.001$). Foley catheters removal was earlier in group 2($p<0.001$) and 69.6% of patients had their first fluid intake on POD 0 in group 2, significantly higher than 35.4% in group 1($p < 0.001$). Time to first stool ($p = 0.776$) and postoperative emesis ($p = 0.547$) were similar.

Conclusion
This is the first study showing that use of micro-dose ITM with oral analgesics have significantly better postoperative pain control and perioperative outcomes to PCA in the AIS population following PSF

Take Home Message
Single micro-dose ITM has significantly better perioperative outcomes and pain control than traditional postoperative PCA in AIS patients undergoing PSF.

12. Can Opioid Free Anesthesia (OFA) Reduce Postoperative Pain after Adolescent Idiopathic Scoliosis Surgery?

Florence Julien-Marsollier, MD; Rita Assaker, MD; Souhayl Dahmani, MD, PhD; Brice Ilharreborde, MD, PhD

Summary
Common anaesthesia in adolescent idiopathic scoliosis (AIS) surgery usually associates hypnotics and morphinomimetics while postoperative pain management combines opioids and non-opioid analgesics. High doses of morphine have been reported to trigger chronic pain and Opioid Free Anaesthesia (OFA) has recently gained popularity in colorectal surgery.

Hypothesis
We therefore hypothesized that avoiding intraoperative opioids during AIS surgery using a new OFA protocol could decrease postoperative morphine consumption during hospitalization stay, but also the occurrence of chronic neuropathic pain.

Design
Retrospective

Introduction
Posterior fusion for AIS is one of the most painful surgeries. Anaesthesia usually associates hypnotics and morphinomimetics, while postoperative pain management combines opioids and non-opioid analgesics. High doses of morphine have been reported to trigger chronic pain, responsible for poorer functional outcomes, and Opioid Free Anaesthesia (OFA) has recently gained popularity in colorectal surgery. We therefore hypothesized that avoiding intraoperative opioids during AIS surgery using a new OFA protocol could decrease postoperative morphine consumption during hospitalization stay, but also the occurrence of chronic neuropathic pain.

Methods
After IRB approval, a consecutive series of patients operated for AIS were prospectively included. A control group (patients operated between January and June 2017) using a standard opioid-based anaesthesia, was compared to the OFA group (surgeries between June 2018 and November 2018) using dexmedetomidine and ketamine. The primary measured outcome was morphine consumption at day 1 and day 3 postoperative. The second outcome was the occurrence of self-reported chronic pain at 1-year follow-up.

Results
A total of 33 patients included in the OFA protocol were compared to 36 controls. All patients were discharged at day 4 postoperative, without difference between groups. Morphine

consumption was significantly decreased in the OFA group at both day 1 (0.78 mg/Kg [0.16-1.5] vs 1.07 mg/Kg [0.60-1.54], p=0.023) and day 3 (0.9 mg/Kg [0.07-1.73] vs 1.39 mg/Kg [0.46-2.32], p=0.048). No difference was reported between groups for pain intensity at day 1 and day 3, but the occurrence of chronic pain was significantly reduced in the OFA group at 1-year postoperative (48% vs 12%, p=0.036) without any side effect or complication reported.

Conclusion

OFA is efficient to reduce both postoperative morphine consumption and chronic neuropathic pain after AIS surgery.

Take Home Message

OFA should be considered to enhance fast-track rehabilitation.

Podium Presentations—Quality/Safety/Value/Complications

13. Use of Predictive Machine Learning Models at the Population Level Has the Potential to Save Cost by Directing Economic Resources to Those Likely to Improve Most: A Simulation Analysis Stratified by Risk in Largest Combined US/European ASD Registry

Rushikesh S. Joshi, BS; Miquel Serra-Burriel, PhD; Ferran Pellisé, MD, PhD; Darryl Lau, MD; Justin S. Smith, MD, PhD; Michael P. Kelly, MD; Ahmet Alanay, MD; Emre R. Acaroglu, MD; Francisco Javier S. Perez-Grueso, MD; Frank S. Kleinstueck, MD; Ibrahim Obeid, MD; Douglas C. Burton, MD; Virginie Lafage, PhD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; Christopher P. Ames, MD; European Spine Study Group; International Spine Study Group

Summary
Healthcare costs continue to accelerate at an unsustainable rate. Machine learning models can preoperatively predict patient benefit before incurring their expense of care, and were utilized to predict outcomes for ASD patients in the largest combined ASD database of US and Europe. Criteria of >50% MCID and <20% complication rates yielded only 33% of existing patients as surgical candidates. Using US data from 2013, this would have resulted in total cost savings of $541 million in direct cost alone.

Hypothesis
Predictive models can be used to simulate optimal surgical candidates for resource allocation.

Design
A prospective database of ASD surgical patients with 2-year follow-up was used to simulate surgical candidate reduction meeting different outcomes profiles.

Introduction
Increasing healthcare costs present significant economic burden, especially for management of complex disease. By using robust machine learning models to preoperatively predict optimal surgical candidates, resources can be directed towards patients most likely to benefit from surgical correction before incurring costs.

Methods
A prospective cohort of patients treated at 17 ASD specialty centers in US and Europe from 2008-2016 was queried. Clinical outcomes including minimum clinically important difference (MCID), complication, and reoperation rates were predicted using gradient boosting classification. Thresholds were applied to simulate patients who met specific outcomes criteria for surgical utilization. Resulting percentages were then applied to public health data from both the United States (US) and Spain.

Results
Our cohort of 1,245 patients with 195 variables was used to train a predictive model (complications AUC = 0.68, MCID AUC = 0.70). Criteria of >50% MCID and <20% complication rates corresponded to 33% of patients qualifying for surgery. Using $120,000 as average hospital cost for ASD correction and applying simulated surgical utilization rate, this translated to total hospital savings of $541 million in the US (2013) in direct cost. In Spain (2015) only 244 patients out of 740 would have received surgery, reducing surgery rate per 100,000 adults from 1.64 to 0.54.

Conclusion
Accurate models predicting outcomes for ASD patients can be used to guide clinical decision making by preoperatively identifying patients who would benefit most from surgery, prior to incurring their expense of care. Given the large number of surgeries conducted around the world, better candidate selection can result in significant cost savings and maximize outcomes.

Take Home Message
Predictive models can simulate sub-populations of ASD patients that would benefit most from surgery. This may reduce societal costs from surgeries yielding little clinical benefit with high complication rates.

MCID Rate Threshold	# of Patients Selected (% total)	Total Cost Reduction ($ millions)	Cost Reduction / 100 patients ($ millions)	Complication Rate Threshold	# of Patients Selected (% total)	Total Cost Reduction ($ millions)	Cost Reduction / 100 patients ($ millions)
>10%	1197 (96)	5.76	0.06	<10%	177 (14)	128.16	1.28
>20%	1137 (91)	12.96	0.13	<20%	573 (46)	80.64	0.81
>30%	1098 (88)	17.64	0.18	<30%	817 (66)	51.36	0.51
>40%	1055 (85)	22.8	0.23	<40%	961 (77)	34.08	0.34
>50%	997 (80)	29.76	0.30	<50%	1081 (86)	19.68	0.20
>60%	909 (73)	40.32	0.40	<60%	1153 (93)	11.04	0.11
>70%	780 (63)	55.8	0.56	<70%	1197 (96)	5.76	0.06
>80%	593 (48)	78.24	0.78	<80%	1223 (98)	2.64	0.03
>90%	238 (19)	120.84	1.21	<90%	1238 (99)	0.84	0.01
MCID + Complication Rate Thresholds	**# of Patients Selected (% total)**	**Total Cost Reduction ($ millions)**	**Cost Reduction / 100 patients ($ millions)**	**Reoperation Rate Threshold**	**# of Patients Selected (% total)**	**Total Cost Reduction ($ millions)**	**Cost Reduction / 100 patients ($ millions)**
MCID >50%, Comps <10%	90 (7)	138.6	1.39	<10%	352 (28)	107.16	1.07
MCID >50%, Comps <20%	407 (33)	100.56	1.01	<20%	714 (57)	63.72	0.64
MCID >50%, Comps <30%	620 (50)	75	0.75	<30%	880 (71)	43.8	0.44
MCID >50%, Comps <40%	751 (60)	59.28	0.59	<40%	986 (79)	31.08	0.31
MCID >50%, Comps <50%	857 (69)	46.56	0.47	<50%	1075 (86)	20.4	0.20
MCID >50%, Comps <60%	924 (74)	38.52	0.39	<60%	1139 (91)	12.72	0.13
MCID >50%, Comps <70%	960 (77)	34.2	0.34	<70%	1191 (96)	6.48	0.06
MCID >50%, Comps <80%	981 (79)	31.68	0.32	<80%	1225 (98)	2.4	0.02
MCID >50%, Comps <90%	995 (80)	30	0.30	<90%	1237 (99)	0.96	0.01

Table 1: Simulating surgical candidates using incremental thresholds for MCID, complication rate, and reoperation rate to demonstrate the resulting cost savings attributed to decreased surgical utilization.

14. Clinical Review of Spine Surgery Patient Safety Indicators Avoids CMS Payment Reductions

John A. Buza III, MD; Ryan Nazar, MD; Portia A. Steele, RN; Leah Y. Carreon, MD; Joseph L. Laratta, MD; Steven D. Glassman, MD; Jeffrey L. Gum, MD

Summary
The Centers for Medicare and Medicaid (CMS) provides a financial incentive to hospitals to prevent harm to patients by reducing the number of reported Patient Safety Indicators (PSI), largely determined through International Classification of Diseases (ICD) coding. Given the inaccuracy of ICD coding, implementation of a clinical reviewer resulted in a reduction in reportable PSI related to spine surgery, leading to a substantial cost savings.

Hypothesis
Addition of a clinician to the review process results in the reduction of incorrectly generated PSI.

Podium Presentations—Quality/Safety/Value/Complications

Design
Retrospective chart review

Introduction
The Hospital Acquired Conditions Reduction Program provides a financial incentive to reduce Patient Safety Indicators (PSI), defined as potentially preventable hospital-related events associated with harmful outcomes for patients. PSI are identified by ICD coding. However, ICD coding does not always reflect the true medical course of the patient.

Methods
All PSI generated at our institution were collected over a 57-month period. The number and type of spine-related PSI were compared before and after the implementation a clinical reviewer to identify incorrectly generated PSI. The financial impact of this intervention was also calculated.

Results
From 2015 to 2019, a total of 1290 PSI were reported with 140 (11%) attributable to spine surgery. Prior to implementation of a clinical reviewer, 112 PSI were reported over 40 months (2.8 PSI/month). Following implementation, 28 PSI were reported over 17 months, a statistically significant decrease by 1.2 PSI/month ($p<0.000$). In addition, 10 different PSI types were reported prior to, compared to 6 after implementation. This resulted in our organization avoiding a 1% CMS cost reduction, ranging from $3 to 4 million.

Conclusion
Implementation of a review process with clinician collaboration to ensure ICD-10 coding accurately reflects the medical course for a patient may lead to more precise PSI reporting, with substantial cost-savings for hospitals.

Take Home Message
Spine surgeons should be aware of the PSI reporting process at their hospital, as clinician involvement may improve the accuracy of reporting and lead to significant cost savings.

15. The Impact of Early Physical Therapy on Resource Utilization and Spending in First Time Presenters of Low Back Pain

Majd Marrache, MD; Niyathi Prasad, BS; Suresh Nayar, MD; Matt Best, MD; Richard L. Skolasky, PhD

Summary
We looked at 30 day and 1-year resource utilization and spending in 979,223 patients that were first time presenters for low back pain. Initiation of physical therapy within 14 days is associated with decreased advanced imaging, specialty visits, ER visits and steroid injections both 30-days and 1 year after presentation, and thus a decrease in overall care seeking behavior. Furthermore, early physical therapy is associated with less overall spending during the acute episode of pain.

Hypothesis
We hypothesize that those who had received early physical therapy would have decreased resource utilization and overall 30-day expenses.

Design
Retrospective review

Introduction
Current recommendations for acute low back pain include conservative care like physical therapy as initial intervention. However, the majority of patients presenting for acute low back pain receive a late referral to physical therapy. Little is know regarding the effect of early physical therapy on health care utilization among first time presenters for low back pain.

Methods
We identified 979,223 patients, aged 18 to 64 years old with no history of non-musculoskeletal causes of LBP, that presented to an outpatient clinic for LBP. Early physical therapy was defined as at least 1 session received within 14 days of initial visit. We assessed 30-day and 1-year resource utilization and spending between patients receiving early physical therapy (EPT) and without early physical therapy (WPT). Multivariate regression analysis, adjusting for confounders, was performed to estimate the association between physical therapy and 30 day and 1-year resource utilization and spending.

Results
110,834 (11%) patients received early physical therapy, 554,089 (57%) were female and mean age was 47 ± 11 years. Early physical therapy was significantly associated with less utilization of advanced imaging (OR: 0.57), orthopedic visit (OR: 0.67), pain specialist visit (OR:0.49), chiropractor (OR:0.41), ED visits (OR:0.51) and epidural steroid injections (OR:0.68) at 30 days. At 1 year following initial presentation, EPT was still associated with less utilization of advanced imaging (OR: 0.77), orthopaedic visit (OR 0.89), pain specialist visit (OR:0.80), chiropractor visit (OR: 0.67), ED visits (OR: 0.72), and ESI (OR:0.84). Patients with early physical therapy spent significantly less on resources at 30 days ($1,183 ± 1,504) compared to those that didn't receive early physical therapy ($1,248 ± 2,558), $p<0.001$.

Conclusion
Early physical therapy for patients presenting to an outpatient clinic for low back pain can significantly decrease 30-day and 1-year resource utilization, and 30-day spending.

Take Home Message
First time presenters for low back pain receiving early physical therapy had significantly less 30 day and 1 year resource utilization and spending.

30 day resource utilization among patients with early physical therapy and those without.

30 Day	Resources	Early Physical Therapy *N (%)*	Without Early Physical Therapy *N (%)*	P-value	OR (95% CI) *
	Advanced imaging	14,572 (13%)	182,971 (21%)	<0.001	0.57 (0.56 – 0.58)
	Epidural Steroid Injection	3,994 (3.6%)	45,546 (5.2%)		0.68 (0.65 – 0.70)
	Chiropractor visit	8,469 (7.6%)	146,073 (17%)		0.41 (0.40 – 0.42)
	Orthopaedic visit	12,479 (11%)	137,893 (16%)		0.67 (0.66– 0.690
	Pain specialist visit	3,959 (3.6%)	61,399 (7.1%)		0.49 (0.47 – 0.51)
	Emergency Department visit	1,775 (1.6%)	26,772 (3.1%)		0.51 (0.49 – 0.54)
	Total Spending†	$747 ± 940	$799 ± 1510	<0.001	

Podium Presentations—Quality/Safety/Value/Complications

16. Critical Analysis of Anterior/Posterior Staged vs. Same Day Surgery in Patients Undergoing Identical Corrective Surgery for Adult Spinal Deformity

Waleed Ahmad, BS; *Peter G. Passias, MD*; Renaud Lafage, MS; Virginie Lafage, PhD; Breton G. Line, BS; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Pierce D. Nunley, MD; D. Kojo Hamilton, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Christopher P. Ames, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; Eric O. Klineberg, MD; International Spine Study Group

Summary
Adult spinal deformity (ASD) is a collection of malalignments that often requires complex surgical intervention. Due to the challenging nature of corrective surgery, providers may choose to perform the anterior/posterior procedure in a staged manner. Our results demonstrated staging can show benefits in patient reported outcomes as well as spinal proportionality when the optimal interval between staged procedures is given consideration.

Hypothesis
An optimal interval of time between staged surgeries exists

Design
Retrospective

Introduction
This study aimed to determine the effect of staging and interval of days in-between on outcomes and alignment

Methods
ASD patients undergoing anterior/posterior (A/P) fusion to the ilium with radiographic and HRQL data at baseline (BL) and 2Y were included. Propensity score match (PSM) for levels fused, # interbodies, interbody approach, # osteotomies, frailty, ODI, CCI, revisions, SVA, PI-LL, and UIV isolated a matched cohort of Same Day and Staged surgical patients. All patients underwent A/P procedures during same admission. Posterior-only procedures were excluded. Staged patients were stratified into percentiles of days between staging: 1) 25th (2days); 2) 50th (3days); 3) 75th (5days)

Results
176 PSM patients (63.0yrs, 80% F) were isolated. Median interval between A/P staged procedures was 3 days. Staged patients had greater OR time and lower ICU stays postop($p<0.05$). At 2Y, staged patients compared to same day showed a greater improvement in PI, TS-CL, C2SS, and SRS-Schwab SVA ($p<0.05$). Staged patients had higher rates of gain in MCID for SRS appearance at 1Y and PCS at 2Y. Assessing different intervals of staging, patients reaching 75th percentile interval showed greater improvement in SRS Pain and Total postop as well as SRS Activity, Pain, Satisfaction, and Total at 1Y (all $p<0.05$). Compared to the 25th percentile interval, patients reaching the 50th percentile interval were associated with increased odds of improvement in GAP proportionality (9.3[1.6-53.2], $p=0.01$). Adjusting for institution and surgeon, patients at the 50th percentile interval continued to show higher rate of improvement in GAP proportionality at 2Y($p<0.05$)

Conclusion
In the closest matched cohort known to date of A/P staged and same day surgery patients, staged procedures resulted in significant improvement radiographically, reduced ICU stays, and superior patient reported outcomes. An interval of 3 days between A/P staged procedures was associated with increased improvement in GAP proportionality even after adjusting for institution and surgeon

Take Home Message
In the closest matched cohort of ASD patients known to date, A/P staged procedures were found to result in significant radiographic improvement and GAP proportionality at 2Y.

17. Does a Dedicated "Scoliosis Team" and Surgical Standardization Improve Outcomes in AIS Surgery and is it Reproducible?

Vishal Sarwahi, MD, MBBS; Sayyida Hasan, BS; Jesse Galina, BS; Aaron M. Atlas, BS; Michelle Kars, MD; Benita Liao, MD; Yungtai Lo, PhD; Terry D. Amaral, MD

Summary
Standardization of the perioperative approach for AIS correction with a dedicated team resulted in significantly decreased blood loss, surgical time and length of stay. These results occurred as the team continued to refine the protocol over the course of the study duration.

Hypothesis
A standardized protocol with a dedicated team will improve outcomes in AIS Surgery

Design
Retrospective Chart Review

Introduction
Surgical correction of AIS is a high-risk procedure with potential complications including blood loss and neurological complications. Expedited recovery after surgery protocols and the perioperative surgical home are two initiatives that address the need for increased efficiency in patient care. In 2011, we implemented a standardized approach including a "scoliosis team" of dedicated anesthesiologists, operating room nurses, surgical technicians, and neurophysiologists. We also implemented a standardized pre-operative work-up, specific intraoperative protocols and a multi-disciplinary postoperative care model. The purpose of this study is to determine if standardization improves AIS surgery outcomes and whether it is transferrable between institutions.

Methods
A review was conducted of a prospective AIS database from 2009-2018 at 2 institutions (IA and IB). In each institution, a non-standardized group (NST) and a standardized group (ST), were compared. Demographics and perioperative outcomes were recorded. In 2015, the surgeons changed institutions (to IB). Reproducibility was determined between institutions (IA

vs. IB). Median (IQR), Kruskal-Wallis, and Fisher's exact test were used.

Results
325 AIS patients were included. The NST group included 44 patients, while the ST group included 281 patients. Age (p=0.21), BMI (p=0.48), preoperative Cobb angle (p=0.48) and levels fused (p=0.42) were similar. ST patients had lower estimated blood loss (EBL)(p<0.001), shorter anesthesia time (p=0.004), shorter surgical time(p<0.001) and shorter length of stay (LOS)(p<0.001). IA (n=101) and IB (n=105) were compared. Age (p=0.21), BMI (p=0.48) and preoperative Cobb angle (p=0.48) were similar. EBL (p<0.001), anesthesia time (p<0.001), surgical time (p<0.001), and LOS (p<0.001) were significantly lower in IB.

Conclusion
A standardized AIS approach including a dedicated operative team, pre-operative work up, postoperative multi-disciplinary management, and streamlined surgical steps improves outcomes and efficiency.

Take Home Message
A standardized protocol with a dedicated team improve AIS surgery outcomes.

18. Ultrasonic Bone Scalpel Does Not Reduce Blood Loss in Adolescent Idiopathic Scoliosis: Randomized Clinical Trial

Sumeet Garg, MD; James Joseph Thomas, MD; Hannah Quick, BA; Patrick Carry, MS; Eun Kim, BA; Mark A. Erickson, MD

Summary
The effects of the ultrasonic bone scalpel (USBS) on blood loss during posterior spinal fusion (PSF) have not been rigorously evaluated in the adolescent idiopathic scoliosis (AIS) population. The purpose of this randomized clinical trial was to compare the difference in blood loss and perioperative complications between the USBS and osteotome in patients with AIS undergoing PSF with instrumentation. No clinically significant difference in blood loss or complication rate was identified between the two groups.

Hypothesis
We hypothesized that there would be a 33% reduction in EBL in the USBS group than the osteotome group, and there would be no significant difference in perioperative complications between groups.

Design
This randomized clinical trial used a two-stage group sequential design to assign patients to the treatment or standard of care group. Patients were blinded to their study assignment until after the procedure.

Introduction
Inferior facetectomies during posterior spinal fusion (PSF) are often performed with an osteotome. The USBS can cut bone while preserving soft tissue. Its effects on blood loss have not been rigorously evaluated. This study compares blood loss between the USBS and osteotome in patients with AIS undergoing PSF.

Methods
Based on a published retrospective study, an a priori power analysis determined that 62 subjects were needed to power the study to 90% for a 33% reduction in EBL using the USBS. Patients scheduled for PSF were consecutively approached for informed consent. Subjects were assigned in a 1:1 ratio using a stratified randomization scheme to the USBS or osteotome group. Perioperative cell salvage reports were used to collect estimated blood loss values.

Results
65/85 (77%) of patients approached for participation consented. 1 patient withdrew consent and 2 were withdrawn. Of the final 62 patients, 10 (16%) were male and 52 (84%) were female. 1 year follow up was obtained for 57/62 patients (92%). Total EBL averaged 419 and 497 mL in the USBS and osteotome groups respectively. Blood loss per level fused averaged 39 and 47 mL in the USBS and osteotome groups, respectively [mean difference: USBS – osteotome: -8mL/level, 95% CI: -16.4 to 0.3 mL/level, p = 0.0575]). 9 complications in 8 patients were reported. 3 were in 2 patients assigned to the USBS group, and 6 were in patients assigned to the osteotome group. There were 5 reoperations to treat 2 superficial infections (1 osteotome, 1 USBS), 1 pseudarthrosis (USBS), 1 seroma (osteotome) and 1 distal junctional kyphosis (osteotome).

Conclusion
There was no clinically significant difference in total blood loss, blood loss per level fused, or complications between the two groups.

Take Home Message
The USBS did not result in significantly reduced blood loss at a high-volume spine surgery center.

19. The Necessity and Risk Factors of Subsequent Fusion after Decompression Alone for Lumbar Spinal Stenosis with Lumbar Spondylolisthesis: 5-years Follow-up in 2 Large Populations

Hikari Urakawa, MD; Andre M. Samuel, MD; Avani S. Vaishnav, MBBS; Yoshihiro Katsuura, MD; Sravisht Iyer, MD; Steven J. Mcanany, MD; Todd J. Albert, MD; (Catherine) Himo Gang, MPH; Sheeraz Qureshi, MD

Summary
The necessity and risk factors of subsequent fusion after decompression alone for lumbar spinal stenosis with spondylolisthesis was examined in 2 large populations with more than 5 years follow-up. In both populations, the revision rate was under 15%, while age under 70 years, presence of claudication, and RA were common risk factors for revision at 5 years. For patients with degenerative spondylolisthesis, RA was also a risk factor for subsequent fusion at 2 years.

Podium Presentations—Quality/Safety/Value/Complications

Hypothesis
This large study will contribute to find the correct rate and timing and novel risk factors of subsequent fusion after decompression alone for LSS with spondylolisthesis.

Design
Retrospective cohort study

Introduction
Decompression without fusion is one of common surgical treatments for patients with lumbar spinal stenosis (LSS) with spondylolisthesis, but no studies have examined the rate, timing and risk factors of decompression alone for spondylolisthesis in large population with long term follow-up.

Methods
LSS patients with spondylolisthesis followed more than 5 years after decompression alone at 1 or 2 levels for primary lumbar surgery were extracted from both public and private insurance resources in a nationwide insurer database. The rate and timing of subsequent fusion was examined for each population. Risk factors for subsequent fusion were also evaluated by multivariate logistic regression.

Results
5875 patients in the public insurance population (P1) and 1456 patients in the private insurance population (P2) were included. The rates of subsequent fusion were 1.9% and 4.3% at 1 year, 3.5% and 8.9% at 2 years and 6.7% and 14.6% at 5 years in P1 and P2, respectively. The time to subsequent fusion was 730 (365-1234) days and 588 (300-998) days in P1 and P2, respectively. Age under 70 years, presence of claudication and rheumatoid arthritis (RA) / collagen vascular diseases (CVD) were common risk factors for subsequent fusion at 5 years in both populations. For patients with degenerative spondylolisthesis, RA/CVD was also a risk factor for subsequent fusion at 2 years.

Conclusion
Decompression alone demonstrated good outcomes with a low rate of subsequent fusion for LSS with spondylolisthesis. Age under 70 years, presence of claudication and RA/CVD were associated with a higher rate of subsequent fusion at 5 years, and for degenerative spondylolisthesis the presence of RA/CVD had an impact on the rate of subsequent fusion at 2 years.

Take Home Message
The necessity of subsequent fusion after decompression for LSS with spondylolisthesis was under 15% at 5 years. Age under 70 years, presence of claudication, and RA were risk factors.

	Population 1 (n=5875)		Population 2 (n=1456)	
	Odds ratio (95% CI)	p value	Odds ratio (95% CI)	p value
All subjects				
at 5 years				
under 70 years old	1.40 (1.12-1.76)	0.003	2.23 (1.64-3.05)	<0.001
with claudication	1.64 (1.16-2.27)	0.004	1.67 (1.19-2.34)	0.003
RA / CVD	1.64 (1.31-2.06)	<0.001	1.55 (1.13-2.13)	0.006
Patients with degenerative spondylolisthesis				
at 2 years				
RA / CVD	1.44 (1.04-1.97)	0.025	1.54 (1.04-2.27)	0.031
at 5 years				
under 70 years old	1.43 (1.12-1.81)	0.004	2.21 (1.60-3.07)	<0.001
with claudication	1.82 (1.27-2.54)	<0.001	1.70 (1.18-2.41)	0.003
RA / CVD	1.62 (1.27-2.05)	<0.001	1.51 (1.08-2.10)	0.014

Risk factors for subsequent fusion

20. Predicting mechanical complications after Adult Spinal Deformity Surgery: Modified Global Alignment and Proportion Scoring with Body Mass Index and Bone Mineral Density (GAPB) vs Global Alignment and Proportion (GAP) Score in Each Categorical Comparative Analysis

Sung Hyun Noh, MD; Kyunghyun Kim, MD

Summary
The GAPB system, which includes BMI and BMD, showed improved predictability for mechanical complications after ASD surgery in each group of GAP score. In particular, the GAPB system was more meaningful in the moderately disproportioned and severely disproportioned groups.

Hypothesis
GAPB system was more meaningful in the moderately disproportioned and severely disproportioned groups.

Design
Retrospective analysis

Introduction
Compared to Global Alignment and Proportion (GAP) score, the modified Global Alignment and Proportion scoring with BMI an BMD (GAPB) system improved the predictive value of mechanical complications after surgery for adult spinal deformity. However, the prediction rates of GAPB in the three categories of GAP score have not been analyzed. Therefore, this study aims to analyze the prediction rate of GAPB in each GAP of the three categories.

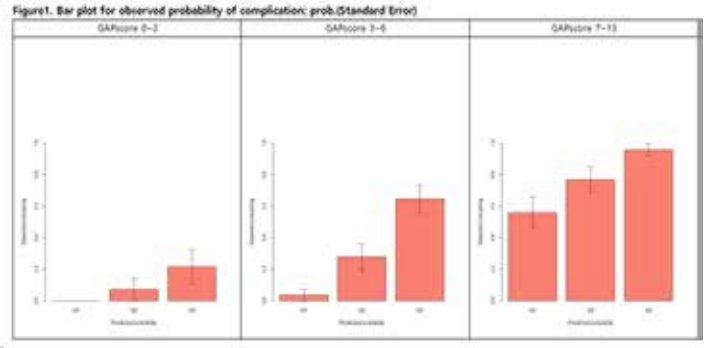
Methods
Retrospective analysis of adult spinal deformity (ASD) patients' data was performed. Between January 2009 and December 2016, 203 consecutive patients with ASD underwent corrective fusion of more than 4 levels and were followed up for more than 2 years. Each patient's GAP score and GAPB system complication rate were examined. In each category of GAP, GAPB scores were converted and the correlation between this score and actual mechanical complications was analyzed.

Results
Patients' average age was 66.8±12.28 years, and they were

followed for an average of 30.54±10.25 months. Of the 203, 89 patients (44%) developed mechanical complications after ASD surgery. A GAP score analysis of the patients found that 42 patients were proportioned, 85 patients were moderately disproportioned, and 76 patients were severely disproportioned. Mechanical complications occurred with increasing GAPB in the proportioned group, but were not statistically significant (P = 0.0534). However, mechanical complications occurred statistically significant in the moderately disproportioned and severely disproportioned groups as GAPB increased (P < 0.001).

Conclusion
The GAPB system, which includes BMI and BMD, showed improved predictability for mechanical complications after ASD surgery in each group of GAP score. In particular, the GAPB system was more meaningful in the moderately disproportioned and severely disproportioned groups.

Take Home Message
GAPB was more meaningful in the moderately disproportioned and severely disproportioned groups.



GAP vs GAPB

21. Lower Extremity Motor Scores (LEMS) after Complex Adult Spinal Deformity Surgery: 5-year Follow-up of the Scoli-Risk-1 Study

Lawrence G. Lenke, MD; Meghan Cerpa, MPH; Scott Zuckerman, MD; Zeeshan M. Sardar, MD; Yong Qiu, MD; Christopher I. Shaffrey, MD; Leah Y. Carreon, MD; Kenneth Cheung, MD, MBBS, FRCS; Michael P. Kelly, MD; Ames P. Christopher, MD; Frank J. Schwab, MD; Oheneba Boachie-Adjei, MD; Yukihiro Matsuyama, MD, PhD; Khaled M. Kebaish, MD

Summary
At 5-years postoperative from complex ASD surgery there was no significant changes in LEMS compared to baseline. Mean LEMS remained stable following the 6-month visit at both 2- and 5-years f/u for all patients reviewed. However, 8/75 (10.7%) patients did experience a worsening in LEMS in the 2-5-year period. These results highlight the importance of long-term follow-up to 5-years postoperative to truly evaluate neurologic motor function following complex ASD surgery.

Hypothesis
To prospectively evaluate lower extremity motor function (LEMS) before and at 5-years following surgical correction of complex ASD

Design
Prospective, multicenter, international observational study (Scoli-Risk-1)

Introduction
Neurologic complications after surgery for complex adult spinal deformity (ASD) are important, yet outcomes are heterogeneously reported and long-term follow-up is sparse.

Methods
The Scoli-RISK-1 study enrolled 272 ASD pts. undergoing surgery from 15 international centers. Inclusion criteria was Cobb angle of >80 deg, corrective osteotomy for congenital or revision deformity, and/or 3-column osteotomy (76% of all pts). Change in LEMS over a 5-year follow-up was analyzed.

Results
Of the 272 patients, follow-up rates were: 271 (99.6%) discharge, 260 (95.6%) 6-weeks, 255 (93.8%) 6-months, 217 (79.8%) 2-year, and 77 (28.3%) 5-years postoperatively. Comparing all patients who returned for follow-up, rates of postoperative LEMS decline compared to preoperative function were 23.0% at discharge, 17.1% at 6 weeks, 9.9% at 6-months, 10.0% at 2-years and 9.3% at 5-years. At 5-years there was no significant changes in LEMS compared to baseline (49.0 vs. 48.4 p=0.163). Mean LEMS remained quite stable following the 6-month visit at both 2- and 5-years f/u (49.0 vs. 48.7 vs. 49.0). However, 8/75 (10.7%) patients did experience a worsening in LEMS in the 2-5-year f/u period.

Conclusion
After complex ASD surgery, mean LEMS function stabilized after 6 months postoperative until the 5 yr. f/u with 10.0% of returning pts. still having lower LEMS than preop. In addition, subtle LEMS decline occurred in 10.7% of returning patients during the 2-year to 5-year follow-up period. These results document long-term 5 yr. f/u of LEMS following complex ASD surgery and the importance of assessing both individual and group average LEMS.

Take Home Message
No significant changes in LEMS were seen at 5-years-postop as mean LEMS stabilized at 6-months, 2-and 5-year f/u. However, 10.7% of individual patients experienced worsening in LEMS in the 2-5-year-period.

22. The Additional Economic Burden of Frailty in Adult Spinal Deformity Patients Undergoing Surgical Intervention

Peter G. Passias, MD; Waleed Ahmad, BS; Renaud Lafage, MS; Virginie Lafage, PhD; Khaled M. Kebaish, MD; Alan H. Daniels, MD; Eric O. Klineberg, MD; Alex Soroceanu, MPH; Jeffrey L. Gum, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Richard Hostin, MD; Shay Bess, MD; International Spine Study Group

Summary
While previous literature focused on direct costs, our study evaluated direct and indirect costs of ASD surgery with the additional burden of frailty. Results demonstrated that despite initial higher costs associated with surgical intervention in frail patients, the cost per QALY become comparable if utility gained is sustained to life expectancy. A limitation of the analysis is frailty also incorporates HRQLs, which may be a confounding variable in the association.

Hypothesis
Surgical intervention in frail patients becomes cost effective as patients improve in quality of life

Design
Retrospective

Introduction
This study aims to identify direct and indirect costs of ASD with the additional burden of frailty

Methods
ASD patients with available BL and 2Y radiographic data were included. Patients were stratified according to Frailty states of: Severely Frail (SF), Frail(F), and Not Frail (NF). Utility data was calculated by converting ODI to SF-6D using published conversion methods. Direct costs were calculated using the PearlDiver database. Indirect cost associated with loss of work was calculated based on response to SRS-22rQ9 and estimating loss of average weekly earnings based on the average weekly income from the US Bureau of Labor Statistics. After accounting for complications, LOS, revisions, and death, cost per QALY at 2Y and life expectancy were calculated.

Results
592 ASD patients were included (59.8yrs, 80%F, ASD-FI: 3.3±1.6). Overall, 4.7% of patients were categorized as severely frail (SF), 22.3% as frail (F), and 73.0% as not frail (NF). At baseline, 104 ASD were classified as unemployed experiencing an average weekly earnings loss of $971.38. After 1Y postoperatively, 62 patients remained unemployed experiencing an overall average loss of $50,508.64 yearly income. After propensity score matching for BL SVA, the average cost of ASD surgery at 2Y follow up for F/SF patients was greater compared to NF ($81,347 vs. $69,722). Furthermore, the cost per QALY was higher for F/SF patient at 2Y compared to NF ($436,473 vs. $430,437). If utility gained is sustained to life expectancy, the cost per QALY differences between F/SF and NF become comparable ($58,965 vs. $58,149).

Conclusion
Despite an initial greater cost of intervention, frail and severely frail patients are likely to show greater improvement postoperatively. Overall, the cost difference between not frail and frail patients offset as cost per QALY at life expectancy become similar.

Take Home Message
Frail patients experience an added economic burden of frailty. Surgical intervention may help offset cost burden in the long-term as patients have greater room for improvement.

23. Rates of Loosening, Failure, and Revision of Iliac Fixation in Adult Deformity Surgery

Robert K. Eastlack, MD; Alex Soroceanu, MPH; Gregory M. Mundis, MD; Alan H. Daniels, MD; Justin S. Smith, MD, PhD; Breton G. Line, BS; Peter G. Passias, MD; Pierce D. Nunley, MD; David O. Okonkwo, MD; Khoi D. Than, MD; Juan S. S. Uribe, MD; Praveen V. Mummaneni, MD; Dean Chou, MD; Khaled M. Kebaish, MD; Christopher I. Shaffrey, MD; Shay Bess, MD; International Spine Study Group

Summary
The variability in failure of lumbopelvic fixation was analyzed in patients undergoing ASD correction that included traditional iliac or S2 alar iliac screws. Our results demonstrate a substantial rate (29.4%) of pelvic fixation failure following ASD correction with IS/S2AI screws, which led to reduction in HRQL improvements. S2AI screws were more likely to demonstrate loosening, but less commonly associated with rod fractures, than were iliac screws.

Hypothesis
The type of iliac fixation utilized for ASD correction will result in lumbopelvic fixation failure variation.

Design
Retrospective review of prospective, multicenter ASD database

Introduction
Traditional iliac (IS) and S2-alar-iliac (S2AI) pelvic fixation methods have unique technical characteristics for their application, and result in varied biomechanical and anatomic impact. These differences may lead to variance in lumbopelvic fixation failure types and rates.

Methods
Inclusion criteria included ASD (coronal Cobb≥20°, SVA≥5cm, pelvic tilt ≥25° and/or thoracic kyphosis >60°) ≥ 18 years old, 2yr f/u, and >5 level fusion with pelvic fixation. Cohort subdivided by IS vs S2AI. Loosening defined by lucency around the screw on radiographs. Univariate testing was performed with chi2 and t-tests. Multivariate logistic regression, accounting for significant confounders, was used to examine differences between the two groups for screw loosening/fracture, rod fracture (below L4), and revision surgery. Level of significance = $p<0.05$.

Results
Groups (IS=287,S2AI=131;total=410) had similar age, BMI, baseline co-morbidities, # fused levels ($p>0.05$), baseline HRQL (SF-36, ODI, SRS-22, NRS leg and back, $p>0.05$) and deformity (PT, PI-LL, SVA, $p>0.05$). IS had a higher rate of unilateral fixation vs. S2AI (12.9% vs 5.6%;$p=0.001$). Overall pelvic fixation failure rate (screw loosening/screw fracture/rod fracture) was 29.4%. Pelvic fixation loosening occurred in 13.4%, and was higher in S2AI (OR 2.74, $p=0.001$). S1 screw lucency (2.9%) was greater in the S2AI group (OR 4.17, $p=0.045$). IS/S2AI fracture rate (2.3%) was similar between groups ($p=0.37$). Rod fracture (14.1%; OR 0.47, $p=0.06$) and revision surgery rates (22.7%) were similar between groups($p=0.449$). Pelvic fixation failure led to less HRQL improve-

ment at 2yr (PCS 7.69/10.46,p=0.028; SRS 0.83/1.03,p=0.019; ODI 12.91/19.77,p=0.0016).

Conclusion
Our results demonstrate a substantial rate (29.4%) of pelvic fixation failure following ASD correction with IS/S2AI screws, which led to reduction in HRQL improvements. S2AI screws were more likely to demonstrate loosening, but less commonly associated with rod fractures than IS.

Take Home Message
Lumbopelvic fixation failure occurred at a rate of 29.4% following surgical correction of ASD that involved iliac fixation, and was associated with less favorable clinical outcomes.

24. Prolonged Post-Operative Intubation Following Spinal Fusion in Cerebral Palsy: Are there Modifiable Risk Factors and Associated Consequences?

Scott M. LaValva, BA; *Keith Baldwin, MD*; Ishaan Swarup, MD; John (Jack) M. Flynn, MD; Joshua M. Pahys, MD; Burt Yaszay, MD; Mark Abel, MD; Keith Bachmann, MD; Suken A. Shah, MD; Paul D. Sponseller, MD; Harms Study Group; Patrick J. Cahill, MD

Summary
In an analysis of prospectively collected data, we describe three risk factors (pre-operative BMI, history of pneumonia, and intra-operative estimated blood loss) for prolonged intubation (PI) following spinal fusion for patients with cerebral palsy. We also demonstrate that PI is associated with numerous additional peri-operative medical complications.

Hypothesis
We hypothesized that (1) there are identifiable pre- and intra-operative risk factors for PI and (2) PI is associated with additional peri-operative complications.

Design
A retrospective case-control analysis of prospectively collected multicenter data.

Introduction
PI is a common peri-operative adverse event following spinal fusion for patients with cerebral palsy, though little is known about the risk factors and consequences. The purpose of this study was to determine 1) pre- and intra-operative risk factors associated with PI and 2) peri- and post-operative complications associated with PI.

Methods
Patients extubated on post-operative-day (POD) 0 were the early extubation group (EE) and those extubated on POD 3 or later were the prolonged intubation group (PI). Comparisons were made between PI and EE groups with respect to several pre- and intra-operative variables to identify risk factors for PI. Multivariate logistic regression was performed to identify independent predictors of this outcome. The post-operative hospital stay and rate of complications at two years were also compared.

Results
253 patients (52% males; mean age 14.1+2.8 years) underwent spinal fusion for cerebral palsy. In this cohort, 65 patients (26%) had EE and 63 patients (25%) had PI. There were several independent predictors of PI including pre-operative BMI < 15(OR 10.1 [95% CI 1.5–66.1]; p=0.016), history of pneumonia(OR 8.3 [95% CI 1.4–48.8]; p=0.020), and intra-operative estimated blood loss (EBL) of > 3000 cc(OR 14 [95% CI 1.2–159]; p=0.033). Additionally, PI was associated with a higher rate of peri- and post-operative respiratory(p<0.001), cardiovascular (p=0.006), gastrointestinal(p<0.001), systemic(p=0.027), and surgical site(p=0.019) complications, as well as prolonged hospitalization(p<0.001) and ICU stay(p<0.001).

Conclusion
Surgeons should optimize nutritional status and pulmonary function, and minimize blood loss in patients with CP to decrease the risk of PI. Efforts should be made to extubate patients on POD 0 to decrease the risk of complications associated with PI.

Take Home Message
Prolonged intubation following fusion for CP is associated with increased complication rates. We have identified factors associated with the risk of PI, some of which may be modifiable.

Figure 1. Multivariate analysis demonstrating (A) independent predictors of prolonged intubation with (B) the receiver operator characteristic (ROC) curve for the model.

A.

Variable	P-value	Odds Ratio	95% CI
History of Pneumonia	0.020	8.28	1.41 – 48.82
EBL > 3000 cc	0.033	14.00	1.23 – 158.99
BMI < 15	0.016	10.11	1.55 – 66.08
Constant	0.004	0.084	

B.

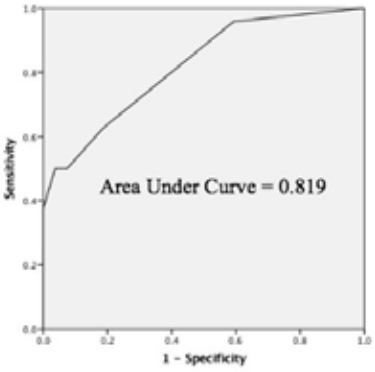


Figure 1

26. Patient Centered Interdisciplinary Medical Optimization Clinic Decreases Surgical Site Infection (SSI) Risk in Pediatric Neuromuscular and Syndromic Scoliosis Patients

Amy L. McIntosh, MD; Kerry Wilder, PhD

Summary
Surgical site infections (SSI) that occur within 90 days of spinal fusion surgery in pediatric patients with underlying neuromuscular and syndromic (NMS) conditions are considered hospital acquired infections (HAI) and lead to high morbidity and cost.

Interdisciplinary pre-operative medical optimization modified the SSI risk in this group of NMS scoliosis patients. This cohort had a 20% predicted risk of developing a HAI SSI, and actual rate was 0%.

Hypothesis
Interdisciplinary pre-operative medical optimization will modify the risk of HAI SSI in NMS spine fusion patients.

Design
prospective cohort

Introduction
Spinal surgery in NMS patients is complicated and associated with numerous perioperative adverse events and suboptimal outcomes. This quality initiative focused on the development and implementation of a standardized clinical pathway for NMS spinal fusion patients. The purpose was to reduce HAI SSI over a 2-year period.

Methods
A multidisciplinary committee created a patient centered medical optimization clinic (Neuromuscular and Syndromic Spine Pathway (NSP)). All NSP patients had standardized pre-surgical assessment that included: baseline nutritional labs, pulmonary function tests and 6 minute walk test, sleep studies, swallow studies, P/A and lateral spine x-rays, manipulative films to determine curve flexibility, as well as, evaluation by pulmonology, anesthesiology, dietary/nutrition, child psychology, developmental pediatricians, neurology, physical and occupational therapy, and child life. Interventions were performed to reduce complications pre-operatively (ex: initiation of CPAP/BIPAP to treat apnea, G/J tube placement for nutritional optimization). The patient's SSI risk was calculated using the Risk Severity Scale (RSS) pre-operatively. This was compared to the actual HAI SSI rate to determine if the SSI risk could be modified through pre-operative medical optimization.

Results
From 1/2018 -12/2019, 160 NMS patients underwent spinal fusion. 29 (18%) of those NMS patients were seen and cleared through the NSP clinic. There were 13 M and 16 F patients. The average age was 12.8 years. The average pre-operative SSI RSS was calculated to be 19.69%. 0/29 (0%) NSP patients developed a HAI SSI. (p = 0.015) 10/131 (7.63%) NMS scoliosis fusion patients that were not cleared through the NSP clinic developed a HAI SSI.

Conclusion
Interdisciplinary pre-operative medical optimization modified the SSI risk in this group of NMS scoliosis patients. This cohort had a 20% predicted risk of developing a HAI SSI, and actual rate was 0%.

Take Home Message
Interdisciplinary pre-operative medical optimization modified the SSI risk in NMS scoliosis patients. This cohort had a 20% predicted risk of developing a HAI SSI, and actual rate was 0%.

27. Surgical Site Infection Incidence in Neuromuscular Posterior Spinal Fusion: Comparing Incidence Before and After the Implementation of the 2013 Best Practice Guideline

Stephen Stephan, MD; Kenneth D. Illingworth, MD; Kavish Gupta, BS; David L. Skaggs, MD; Lindsay M. Andras, MD

Summary
Surgical site infections (SSI) in children with neuromuscular scoliosis (NMS) is consistently higher than idiopathic scoliosis. A Best Practice Guideline for prevention of SSI in high-risk pediatric spine surgery patients was published in 2013, which outlined 14 perioperative strategies to decrease incidence. Our study compares the incidence of SSI prior to and after the implementation of these strategies at our institution. We report a significant decrease in incidence of SSI in NMS patients undergoing primary spinal fusion.

Hypothesis
SSI incidence in NMS patients will decrease following the implementation of perioperative strategies mentioned in the 2013 Best Practice Guideline.

Design
Retrospective chart review

Introduction
In 2013, a Best Practice Guideline for SSI prevention in high-risk pediatric spine surgery patients reported 14 perioperative strategies to decrease incidence. The purpose of this study is to investigate the efficacy of these interventions on surgical site infection incidence in NMS patients.

Methods
A single center, retrospective review of SSI in NMS patients was performed before and after the Best Practice Guidelines were instituted. NMS patients undergoing primary posterior spinal fusion from January 2008-December 2012 (Group 1) and January 2014-December 2017 (Group 2) were included, with 2013 excluded as a transition year. The primary outcome was incidence of surgical site infection, as defined by the Centers for Disease Control and Prevention's National Healthcare Safety Network definition. Minimum 2-year follow-up was required.

Results
167 patients were analyzed, 62 in Group 1 and 105 in Group 2. There were no differences in age (p=0.478), BMI (p=0.889), sex (p=0.203), fusion to pelvis (p=0.745), Cobb angle (p=0.172), and bowel/bladder incontinence (p=0.921) between groups. SSI occurred in 11 (17.7%) patients in Group 1 and 4 (3.8%) patients in Group 2 (p=0.00234). The most common isolated pathogens were pseudomonas (45% Group 1), E. coli (27% Group 1; 25% Group 2), and methicillin-resistant staphylococcus aureus (18% Group 1).

Conclusion
The incidence of SSI in NMS patients decreased significantly at our institution after the implementation of the perioperative strategies mentioned in the Best Practice Guideline of 2013. Fur-

ther studies are required to continue to decrease the incidence in this high-risk population.

Take Home Message

Adoption of the 14 perioperative strategies mentioned in the 2013 Best Practice Guideline significantly decreased rates of SSI in NMS patients at our institution.

Podium Presentations—Adolescent Idiopathic Scoliosis II

28. Three Dimensional Changes are Predictors of Brace Effectiveness in Patients with Idiopathic Scoliosis

Kenny Kwan, MD; Amy Cheung, BA; Kenneth Cheung, MD, MBBS, FRCS

Summary
The purpose of this study was to determine the influence of axial plane parameters on bracing effectiveness in idiopathic scoliosis. We found significant differences between non-progressive and progressive groups in apical vertebral rotation (AVR) at brace initiation (p=0.028), AVR reduction velocity (VR) (p=0.039) and torsion index (p=0.037) at 1 year. Logistic regression analysis revealed that AVR at brace initiation (OR 1.07, p=0.04) and AVR RV at 1 year (OR 1.15, p=0.049) were predictive for curve progression in braced girls.

Hypothesis
In-brace axial plane correction is related to brace effectiveness in idiopathic scoliosis.

Design
A prospective longitudinal cohort study.

Introduction
It is known that the percentage of in-brace coronal correction is a determinant of brace success but AIS is a three-dimensional (3D) deformity and the role of 3D changes in brace success is unknown. The aim of this study was to determine the influence of in-brace axial plane parameters on bracing effectiveness in idiopathic scoliosis.

Methods
53 consecutive patients with idiopathic scoliosis who fulfilled the SRS criteria for bracing were prospectively recruited. Compliance was recorded by thermal sensors. Radiographic parameters were determined using 3D reconstruction of images obtained from EOS Imaging System at brace initiation, immediate in-brace, 1-year in-brace, and 2-year out-of-brace. Patients were analysed according to whether their curves had progressed (Cobb ≥6°) or not progressed (Cobb <6°) at minimum 2-year follow-up.

Results
53 patients (49F, 4M; mean age=11.9±1.8years) were recruited with a mean follow-up of 37.4±5.8 months. The mean Cobb angle at brace initiation was 29.7°±7.0°, which was corrected to 15.0°±9.4° after bracing. At final follow-up, 17 patients progressed (Cobb=41.3°±11.5°) and 36 did not progress (Cobb=25.3°±8.8°). There was no statistical difference in baseline demographics, curve characteristics and brace compliance between the two groups. Significant differences between non-progressive and progressive groups were found in apical vertebral rotation (AVR) at brace initiation (-2.99°±9.29° vs 3.88°±10.76°, p=0.028), AVR reduction velocity (VR) (-1.25°±4.72° vs 1.73°±4.66°, p=0.039) and torsion index (0.19°±1.19° vs -0.54°±1.14°, p=0.037) at 1 year. Logistic regression analysis revealed that AVR at brace initiation (OR 1.07, p=0.04) and AVR RV at 1 year (OR 1.15, p=0.049) were predictive for curve progression in braced girls.

Conclusion
3D axial plane parameters (AVR and AVR RV) are predictive of curve progression in braced idiopathic scoliosis patients. Attention is needed to focus on braces that can control axial plane parameters to improve brace effectiveness.

Take Home Message
Brace effectiveness is related 3D changes and axial plane parameters correction in patients with idiopathic scoliosis.

29. The Association between Axial Rotation and Curve Progression in Patients with Adolescent Idiopathic Scoliosis Undergoing Bracing Intervention

Michael Fields, BS; Matthew E. Simhon, BS; Hiroko Matsumoto, PhD; Gerard F. Marciano, MD; Afrain Boby, MS, BS; *Benjamin D. Roye, MD*; Michael G. Vitale, MD

Summary
This study investigated the association between axial rotation (AR), measured using 3D reconstructions, and curve progression in skeletally immature patients with AIS. A 1° increase in in-brace absolute AR resulted in an increased risk for treatment failure (26.5% for male, p=0.037; 4.5% for female, p=0.128). In addition, improvement in AR with bracing was associated with a reduced risk of treatment failure compared to those without improvement after adjusting for pre-brace major coronal curve (p=0.066).

Hypothesis
AIS patients with large in-brace axial rotation (AR) and/or poor improvement in AR with bracing will have increased risk of treatment failure at 2 years follow-up.

Design
Retrospective cohort study.

Introduction
AIS literature suggests magnitude of preop AR and postop residual AR are predictors of curve progression after surgical intervention. This study is the first to investigate the effects of AR on curve progression in AIS patients undergoing bracing treatment.

Methods
AIS patients undergoing Rigo bracing at a single institution with pre- and/or in-brace radiographs were included. Exclusion criteria were skeletal maturity (Sanders 6/7) and supernumerary vertebra which prevent 3D reconstruction using SterEOS® software (EOS imaging, Paris, France). A subset analysis was performed for patients with both pre- and in-brace EOS imaging to determine the association of improvement in AR and treatment failure (curve progression of >5° or surgery).

Results
75 AIS patients (81.3% female) were identified (Table). Gender was determined to be an effect modifier and was controlled for in the uni/bivariate analysis. 25 patients (33.3%; 6 male, 19 female) failed treatment. The failure group had greater in-brace

absolute axial rotation than the success group in both male (8.6° vs. 4.1°, p=0.026) and female (11.5° vs. 6.5°, p=0.006) patients. In addition, in male patients, a 1° increase in absolute in-brace axial rotation increased the risk of treatment failure by 26.5% (p=0.037). Similarly, in female patients, an increase in in-brace absolute axial rotation by 1° increased the risk of treatment failure by 4.5% (p=0.128). Of 31 patients with both pre- and in-brace EOS imaging, 26 (83.9%) patients had correction of AR from pre-brace to in-brace. Patients with AR improvement had an 85% risk reduction in treatment failure compared to those without improvement after adjusting for pre-brace major coronal curve (p=0.066).

Conclusion

These results establish associations between AR and clinical outcomes in braced AIS patients. The association of in-brace AR magnitude/correction with treatment failure supports clinician use as a metric in assessing bracing quality.

Take Home Message

AIS patients with large in-brace axial rotation (AR) and/or poor improvement in AR with bracing have increased risk of treatment failure at 2 years follow-up.

		Treatment Failure?		
		No (N=50)	Yes (N=25)	P-value
Age an Initiation of Bracing (mean ± SD)		12.9 ± 1.3	12.5 ± 1.4	0.171
Gender (N (%))	Female	42 (84%)	19 (76%)	0.402
	Male	8 (16%)	6 (24%)	
Sanders Stage	2	4 (8%)	6 (24%)	0.097
	3	30 (60%)	11 (44%)	
	4	9 (18%)	7 (28%)	
	5	7 (14%)	1 (4%)	
Pre-Brace Major Curve		28.4 ± 5.16	36.3 ± 5.9	<0.001
In-Brace Major Curve		16.2 ± 5.8	25.3 ± 7.4	<0.001
Pre to In-Brace Major Curve Correction		12.2 ± 6.5	11.0 ± 6.2	0.434
|Pre-brace Major Curve Axial Rotation|, n=31		9.5 ± 5.1	12.0 ± 5.6	0.213
|In-brace Major Curve Axial Rotation|		5.8 ± 4.1	9.9 ± 7.6	0.003
Major Curve Axial Rotation Correction, n=31		4.1 ± 5.2	3.2 ± 7.8	0.700
Major Curve Axial Rotation Improvement, n=31	No	3 (14.3%)	2 (20%)	0.686
	Yes	18 (85.7%)	8 (80%)	
Years In-Brace		1.9 ± 0.7	1.5 ± 0.9	0.023

Demographics.

30. Realities of a Multi-Site Randomized Schroth-Based Trial for AIS <25°

Karina Zapata, DPT; Rebecca J. Dieckmann, BS; Steven D. Glassman, MD; Michael T. Hresko, MD; Brian Smith, MD; Paul D. Sponseller, MD; Michael G. Vitale, MD; *Daniel J. Sucato, MD, MS*

Summary

41 months after starting a 2-year grant-funded multi-site RCT assessing the Schroth-based method in small AIS skeletally immature curves, 88/90 patients have enrolled. 2/6 sites enrolled their expected patient quota. 33 out of the needed 72 patients have achieved 1-year follow-up with 20% attrition so far, contributing to uncertainty regarding feasibility according to enrollment rate.

Hypothesis

A 2-year SRS grant-funded multi-site randomized control trial (RCT) assessing the efficacy of the Schroth-based method is feasible.

Design

Grant-Funded, IRB-Approved Prospective Multi-Site, Dual-Arm RCT

Introduction

The Schroth-based method is a growing physiotherapeutic scoliosis-specific exercise (PSSE) treatment option for managing AIS. However, little is known about PSSE outcomes. The purpose of this update is to report on the feasibility of PSSE as part of a multi-site RCT.

Methods

6 sites enrolled Risser 0 patients with a single AIS curve between 12-24° from 08/2016-12/2019. Patients were randomized to exercise or control/observation arms in a 2:1 ratio of exercise:control. A pre-study power analysis determined 90 patients needed to detect a 5° Cobb difference between arms, 72 patients after attrition.

Results

Original study design allocated 1 year for enrollment, expecting enrollment of 15 patients per site with 18 patients/month total, and 1 year for follow up. 41 months after starting, 2/6 sites enrolled their expected 15 patients. 88/164 (54%) approached patients enrolled, averaging two patients/month study-wide. One year after starting, sites addressed enrollment barriers by widening inclusion criteria from Cobb range 15-20° to 12-24°, developing recruitment tools, and increasing study calls. Site enrollment varies from 2%-60% of 88. Attrition averages 20% (18/88: 15 exercise), with 33 patients who have returned for 1-year follow-up. Research Coordinator time, accessibility to clinics, follow-up orders for these patients, off-site PT, and unwillingness to randomize impact enrollment. Initial average age was 11.9±1.3 years (N=33). Cobb angle was 16.3±2.5° for exercise patients (N=23) and 16.9±2.7° controls (N=10). At 1 year, exercise patients averaged 16.2±6.0° (N=23) and controls 18.4±5.3° (N=10). Between group differences were not significant at 1 year (p=0.54).

Conclusion

A multi-site RCT on PSSE is not as feasible as predicted due to the resources required and a patient population consisting of young adolescents with small curves who may be expected to perform an intensive exercise program.

Take Home Message

Undertaking a multi-site RCT assessing PSSE is challenging but may be doable in young patients with small AIS curves. The lead site should expect to do the “heavy lifting.”

Podium Presentations—Adolescent Idiopathic Scoliosis II

Enrollment Overview

31. Variability in Anesthetic Practices in Surgical Treatment of Adolescent Idiopathic Scoliosis

Niyathi Prasad, BS; Majd Marrache, MD; Dolores Njoku, MD; Paul D. Sponseller, MD; *Amit Jain, MD*

Summary
There was significant variability in the choice of anesthetic and analgesic agents used during pediatric spinal fusion surgery for Adolescent Idiopathic Scoliosis. There was a mean hand-off of 2.6 providers (min 2, max 6) during a case. Understanding these practice differences and the impact they have on outcomes may be targets for future investigation.

Hypothesis
The goal of this study is to characterize the variability in the anesthetic practices and type of anesthetic agents used in the surgical treatment of Adolescent Idiopathic Scoliosis (AIS). A secondary goal was to assess the impact of the variability on outcomes.

Design
Single-center, Retrospective

Introduction
Perioperative literature in AIS has historically focused on standardizing surgeon-driven practices. There is a paucity of literature on variability in anesthetic practices in AIS surgery.

Methods
We reviewed anesthesia records for 209 patients with AIS who underwent posterior spinal fusion at a single institution from 2016 through 2019. Details regarding patient factors, anesthetic agents, handoffs and outcomes were collected.

Results
At our institution, the anesthetic cocktail preference was anesthesia provider driven, and inhalational gases were the predominant choice for anesthetic agent in 97% cases (202 gas, 7 TIVA). Agents that may potentially impact neuromonitoring, such as nitrous oxide and muscle relaxants, were used in 38% and 53% cases, respectively. All cases had high narcotic use, and there was significant variability in the choice of narcotics ($p<0.001$). Ketamine was used in 15% of cases. There was a mean hand-off of 2.6 providers (min 2, max 6) during a case. Ten percent of cases had at least 1 neuromonitoring alert. There were no neurological deficits.

Conclusion
There was a significant variability in the choice of anesthetic and analgesic agents used during pediatric spinal fusion surgery for AIS. Future efforts focused on reducing variability in anesthetic practices may be fruitful.

Take Home Message
There was significant variability in the choice of anesthetic and analgesic agents used during PSF for AIS. Future efforts focused on reducing variability in anesthetic practices may be fruitful.

32. Bone Graft Substitutes and Extenders are Associated with a Higher Rate of Wound Complications

Dhananjay Bansal, BS; Majd Marrache, MD; Paul D. Sponseller, MD; Suken A. Shah, MD; Amer F. Samdani, MD; Patrick J. Cahill, MD; Baron Lonner, MD; Michelle Claire Marks, PT; Peter O. Newton, MD; Thomas J. Errico, MD; *Amit Jain, MD*; Harms Study Group

Summary
There is substantial variability in the use of bone grafts and substitutes within a large cohort of AIS patients who underwent spinal fusion. The use of bone graft substitutes or extenders (BS) did not reduce the rate of reoperation or pseudarthrosis. However, it was associated with higher incidence of wound related complications.

Hypothesis
Use of bone substitutes and extenders (BS) does not reduce rates of pseudarthrosis or reoperation, while it may potentially contribute to wound complications in surgical treatment of adolescent idiopathic scoliosis (AIS).

Design
Retrospective review

Introduction
Osteobiologics are often used in pediatric spinal deformity surgery as bone substitutes or extenders for enhancing spinal fusion. There is a paucity of literature regarding differences in fusion rates and complications in BS versus auto and traditional bone grafts used in AIS patients

Methods
We included patients that had a posterior spinal fusion (PSF), no prior spine surgeries, >80% pedicle screw constructs, and minimum of 2-year follow-up. Patients were divided into 2 groups based on type of graft used: 1) Real Bone (RB) group: autograft and/or cancellous allograft, versus 2) addition of bone graft substitutes or extenders, (BS) group. BS included: tricalcium phosphate, demineralized bone matrix, hydroxyapatite, cellular bone matrix, and stem cell-based products. Multivariate logistic regression analysis was performed to determine the association between complications and type of graft used.

Results
2,222 patients were included in this analysis of which 81% were female; mean major curve Cobb was 56° + 12°. Of all patients, 84% were in the RB group and 16% were in the BS group. On univariate analysis, there was no significant difference among the groups in levels fused (P=0.057), mean age (P=0.266), BMI (P=0.308), rate of reoperation (P=0.965), pseudarthrosis (P=0.278), or in the rate of deep (P=0.119) and superficial (P=0.594) infections. However, patients in the BS group had significantly more wound related complications such as wound dehiscence and drainage (5% in the BS group vs. 1.9% in the RB group, P<0.001). Patients in the BS group had 2.4 times higher odds of wound complications compared to the RB group [OR: 2.4, 95%CI: 1.3 – 4.4]. Center was an independent predictor of choice of graft (P<0.001) and not of wound related issues (p=0.129).

Conclusion
In AIS patients the addition of BS was associated with higher wound related complications. BS may be a potentially avoidable expense in AIS surgery.

Take Home Message
The addition of BS did not reduce reoperation or pseudarthrosis rates, however it was associated with higher wound related complications in AIS patients.

33. Sinister! The High Preop Left Shoulder is Less Likely to be Balanced at 2 Years Postop

Joshua T. Bram, BS; Nishank Mehta, BA; Jason B. Anari, MD; Burt Yaszay, MD; Joshua M. Pahys, MD; Harms Study Group; Patrick J. Cahill, MD

Summary
Shoulder balance is an important component of symmetry and is a vital contributor to cosmetic outcomes after surgery for adolescent idiopathic scoliosis (AIS). Patients with left shoulder elevation (LSE) are less likely to achieve level shoulders 2 years postoperatively. Upper instrumented vertebra (UIV) selection does not affect the incidence of shoulder imbalance.

Hypothesis
AIS cases with LSE at baseline are less likely to result in level shoulders at 2 years postop when compared to patients with right shoulder elevation (RSE).

Design
Cohort study

Introduction
AIS patients consider shoulder balance to be an important cosmetic outcome after surgery, and many studies cite level shoulders as vital to proximal trunk symmetry. We aimed to determine the impact of preop LSE and choice of UIV on postop shoulder balance.

Methods
This was a retrospective review of a prospective AIS database. Patients had Lenke class 1-4 curves and preop shoulder imbalance ≥1.0cm. Patients with preop LSE and RSE were compared. Radiographic shoulder height was measured on PA spine films. Post-op shoulder imbalance <1.5cm was considered 'balanced', while ≥1.5cm was 'unbalanced'.

Results
467 patients had ≥1.0cm imbalance preop (1.8±0.8cm), with 112 (24%) LSE (Table 1). There were no differences in gender (p=0.658) or age (p=0.886). Patients with LSE more frequently underwent anterior fusion (15% vs 7%, p=0.020) and had Lenke class 2 curves (38% vs 17%, p<0.001). LSE were also more often unbalanced at 2 years postop (41% vs 16%, p<0.001). Preop RSE averaged 1.9±0.9cm vs 1.6±0.6cm for LSE (p=0.002), and postop balance was more significantly improved in the RSE cohort (0.8±0.7cm at 2 years) vs only mild improvement for LSE patients (1.4±1.0cm at 2 years, p<0.001). Among those with balanced preop LSE, 33% worsened to >1.5cm postop, and only 53% with unbalanced preop LSE corrected to balanced post-op. In contrast, most patients with RSE were balanced postop regardless of the degree of shoulder imbalance, with 84% of preop RSE >1.5cm corrected to balanced. When examining only LSE patients, those instrumented to T2 had increased preop imbalance (1.7±0.6cm, p=0.040) compared to T3 and T4 (1.4±0.4cm and 1.4±0.5cm, respectively), but the UIV level did not impact the proportion of unbalanced patients postop (50%, 50%, and 38% for T2-T4, p=0.661).

Conclusion
AIS patients with preop LSE are less likely to achieve level shoulders 2 years postop. Further, preop LSE should not influence surgeon choice of a higher UIV.

Take Home Message
Patients with preoperative LSE are harder to bring into balance operatively vs RSE. Additionally, choice of higher UIV did not affect achievement of shoulder balance in patients with preoperative LSE.

Table 1. Comparison of Patients with RSE vs LSE

	Right Shoulder Elevation	Left Shoulder Elevation	P-value
N	355 (76.0)	112 (24.0)	-
Age (years)	14.3 ± 2.0	14.2 ± 2.1	0.886
Female gender	292 (82.3)	89 (79.5)	0.658
Anterior instrumentation	24 (6.8)	17 (15.2)	**0.020**
Pre-op shoulder elevation	1.9 ± 0.9	1.6 ± 0.6	**0.002**
Post-op shoulder elevation	0.8 ± 0.7	1.4 ± 1.0	**<0.001**
Pre-op upper thoracic curve	27.3 ± 8.0	32.9 ± 12.9	**<0.001**
Post-op upper thoracic curve	15.3 ± 6.3	17.7 ± 8.9	**0.001**
Upper thoracic correction	43 ± 20%	46 ± 16%	0.161
Upper thoracic flexibility	31 ± 24%	29 ± 23%	0.464
Pre-op thoracic curve	56.8 ± 12.1	55.7 ± 15.2	0.438
Post-op thoracic curve	21.2 ± 7.6	20.2 ± 8.1	0.252
Thoracic correction	62 ± 13%	63 ± 13%	0.423
Thoracic flexibility	36 ± 20%	38 ± 19%	0.273
Pre-op lumbar curve	39.5 ± 13.1	33.7 ± 11.8	**<0.001**
Post-op lumbar curve	16.9 ± 8.4	12.5 ± 8.0	**<0.001**
Lumbar correction	57 ± 21%	63 ± 22%	**0.003**
Lumbar flexibility	62 ± 22%	70 ± 23%	**0.003**

Values reported as mean ± SD or number (%)

Table 1. Comparison of Patients with RSE vs LSE

34. Selective vs. Non-Selective Thoracic Fusion for Lenke Type 1-4C Curves: Which has More Complications at 5-year Follow-up?

Jay S. Reidler, MD; Scott Zuckerman, MD; Joseph M. Lombardi, MD; Jun Kim, MD; Andrew C. Vivas, MD; Meghan Cerpa, MPH; Peter O. Newton, MD; Lawrence G. Lenke, MD; Harms Study Group

Summary
In this multi-center study with minimum 5-year follow-up, we compared rates of complications following selective vs. non-selective thoracic fusion in Lenke Type 1-4C curves. We found that selective thoracic fusion is associated with less blood loss, shorter surgery, and a lower complication rate. It did not lead to any cases of residual deformity requiring reoperation.

Hypothesis
Selective thoracic fusion is associated with lower rates of complications compared to non-selective fusion.

Design
Retrospective analysis of prospectively-collected, multi-center data.

Introduction
Selective thoracic fusion (STF) is a less invasive option compared to non-selective fusion (NSF) for adolescent idiopathic scoliosis Lenke Type 1-4C curves with significant lumbar deformity. Differences in perioperative and long-term complications between STF vs. NSF remain unknown.

Methods
A multicenter, prospective database was queried for Lenke 1-4C curves with minimum 5-year follow-up. Patients were grouped as STF (fusion to L1 or above) vs. NSF (fusion below L1). Perioperative events and complications were compared.

Results
In 219 patients (102 STF vs. 117 NSF), NSF had longer surgery (332.3min vs. 231.8min, p<0.001), more blood loss (β=639.9cc, p<0.001), and more levels fused (12.1 vs. 8.5; p<0.001), though no differences were seen in POD1 pain score, days to oral pain meds, or length of stay. NSF had higher complication rates (24.1% vs. 12.7%, p=0.032) and a non-significantly higher reoperation rate (8.5% vs. 3.9%, p=0.164). The most common non-reoperative complications in the NSF group were transient paresthesias (5/18, 27.8%) and pulmonary issues (5/18, 27.8%) within 0-90 days, indicating morbidity associated with longer surgeries. Implant-related reoperations in the STF group included one repositioned thoracic pedicle screw causing radiculopathy, and in the NSF group included three prominent implants requiring removal/shortening and one broken screw requiring replacement. There were 3 cases of residual deformity (1 STF vs. 2 NSF), treated with a heel lift (STF), bracing (NSF), and thoracoplasty (NSF). Infections requiring reoperations occurred in 2 STF cases vs. 5 NSF cases.

Conclusion
Selective thoracic fusion for Lenke 1-4C curves is associated with less blood loss, shorter surgery, and a lower overall complication rate at minimum 5-year follow-up than non-selective fusion. There were no cases of reoperation for residual deformity in the selective thoracic fusion group.

Take Home Message
Selective thoracic fusion is associated with lower short- and long-term complications compared to non-selective fusion. It did not increase the rate of reoperation rate for residual lumbar deformity.

Variables (mean±SD or n (%))	**STF N=102**	**NSF N=117**	**p-value**
Perioperative events			
Length of surgery (min)	231.8±95.2	332.3±111.5	<0.001*
Estimated blood loss (EBL, cc)	637.4±461.8	1277.3±921.3	<0.001*
Fusion Length	8.5±1.3	12.1±1.1	<0.001*
VAS Pain POD1	6.4±0.2	6.4±0.2	0.938
Days to oral pain meds	3.1±0.9	3.1±1.0	0.703
Length of stay (days)	5.0±1.7	5.5±3.2	0.190
Complications			
Total complications	13 (12.7)	28 (23.9)	0.034*
Medical without reoperation	9 (8.8)	18 (15.4)	
Reoperation	4 (3.9)	10 (8.5)	0.164
Time period (% of all complications)			
0-90d	8 (61.5)	15 (53.6)	
90d-2y	1 (7.7)	3 (10.7)	
2-5y	4 (30.8)	10 (35.7)	
Complication type			
Infection	3 (23.1)	6 (21.4)	
Implant	3 (23.1)	7 (25.0)	
Medical	4 (28.6)	8 (28.6)	
Neuro	2 (15.4)	5 (17.9)	
Residual Deformity	1 (7.7)	2 (7.1)	

Perioperative Events and Complications for STF vs. NSF

Podium Presentations—Adolescent Idiopathic Scoliosis II

35. Preoperative LIV Translation and LIV Tilt are Risk Factors for Adding-On in Lenke 1/2AR Curves

Brendon Mitchell, MD; David L. Skaggs, MD; Lawrence G. Lenke, MD; Tracey P. Bastrom, MA; Carrie E. Bartley, MA; *Peter O. Newton, MD*

Summary
Two years after PSF to treat Lenke 1/2AR curves, adding-on occurs at a significantly higher rate when there is evidence of preoperative LIV translation from the CSVL and initial postoperative LIV tilt. This study highlights variables worth considering when determining length of fixation and counseling patients.

Hypothesis
The frequency of adding-on in 1/2AR curves is related to translation of the preoperative lowest instrumented vertebra (LIV) from the central sacral vertical line (CSVL) and the initial postoperative LIV tilt.

Design
Review of prospectively collected multi-center study data.

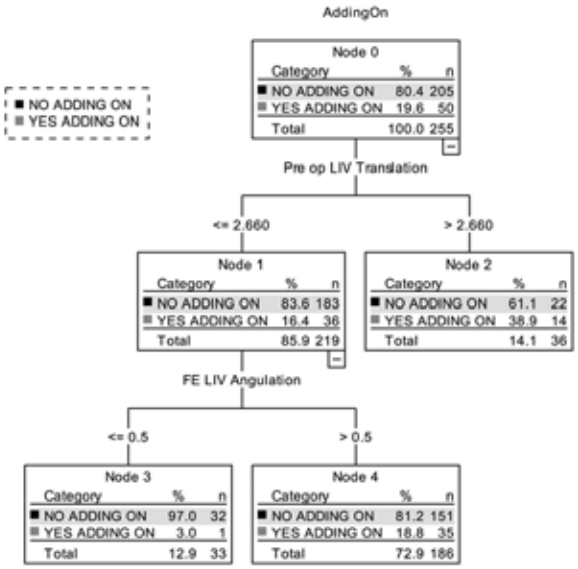
Introduction
Prior work has demonstrated the 1AR curve pattern is at an increased risk of adding-on postoperatively. We sought to identify curve/correction characteristics associated with adding-on at 2 years after posterior spinal fusion (PSF) in 1and 2AR curves.

Methods
A prospective multicenter registry was queried to identify patients with AIS, Lenke type 1 and 2 right thoracic curves with AR lumbar modifiers, who underwent PSF with a >2 year follow-up. Adding-on was first defined radiographically and confirmed via review of the images. Patient demographic as well as pre- and postoperative radiographic variables were evaluated using Classification and Regression Tree (CART) analysis to determine what factors contribute to adding-on in these high-risk curve types.

Results
255 patients (1AR or 2AR) treated with PSF were assessed for adding-on, of which 50 patients (19.6%) met criteria. Multivariate CART analysis identified pre-operative LIV translation >2.7cm as an independent predictor of adding-on; and, in the <2.7cm group, FE LIV angulation >0.5° was a predictor of adding-on.

Conclusion
Adding-on was more than 2x greater (39% vs 17%) with an LIV that was more than 2.7cm from the CSVL. When the LIV was <2.7cm off midline, the postoperative risk of adding-on was further reduced to 3% when the LIV was leveled on the FE film. These cut-offs are not absolute, but indicate greater preoperative translation of the LIV and greater postoperative LIV tilt are risk factors for adding on in overhanging lumbar modifier AR curves.

Take Home Message
An LIV <2.7cm from the CSVL results in a 2x decrease in risk of adding-on, and drops to 3% if you perfectly level the LIV on the FE film.



36. Fusions Ending above the Sagittal Stable Vertebrae in Adolescent Idiopathic Scoliosis: Does it Matter?

Dale Segal, MD; Keith Orland, MD; Eric Yoon, BS; Tracey P. Bastrom, MA; Harms Study Group; *Nicholas D. Fletcher, MD*

Summary
Patients treated with a selective fusion where LIV was proximal to the stable sagittal vertebrae resulted in a 15% incidence of DJK at five years follow up compared to 2.2% of patients fused distal to the SSV. Surgeons should take the SSV into account when planning selective thoracic fusion to avoid DJK and the possibility of revision surgery.

Hypothesis
Fusions stopped proximal to the stable sagittal vertebrae (SSV) will result in a higher rate of distal junctional kyphosis (DJK) compared to those fused distal to SSV

Design
Retrospective review of a prospectively collected multi center database.

Introduction
Selective thoracic fusions have the advantage of preserving mobile segments. If the LIV is not selected correctly there is an increased risk of adding on and distal junctional kyphosis. The purpose of this study is to determine whether fusions that end proximal to the SSV are at risk for developing DJK in patients with AIS at five year follow up.

Methods
A multi-center database of prospectively enrolled subjects was queried for patients with AIS that had Lenke type 1, 2 or 3 curves treated with posterior pedicle screw instrumentation. Radiographs and clinical data were obtained on each patient at a minimum of five year follow up. DJK was defined as a greater

than 10° increase in segmental kyphosis between the LIV and the LIV+1 vertebra.

Results
335 patients were included with a mean age was 14.2 +/- 2.08 years. At five years postoperatively, there was a difference in rate of DJK dependent on the LIV relative to SSV. DJK occurred at a rate of 2.2% in fusions ending distal to the SSV, 6.5% for fusions ending at the SSV and 15% for fusion ending proximal to the SSV($p<0.001$). DJK angle ranged from 3.6° when LIV was proximal to the SSV to -11.8° when LIV was distal to SSV ($p<0.001$). 13 patients (3.7%) underwent revision surgery with 6 patients (6.4%) with LIV above, 4 patients at (5.1%) and 3 patients (1.6%) distal to the SSV ($p=0.10$).

Conclusion
There is an increased risk for development of DJK in patients with AIS treated with PSF where the LIV was chosen proximal to the SSV. Revision rates trended higher in patients treated with an LIV proximal to SSV.

Take Home Message
Stopping a selective thoracic fusion proximal to the SSV may result in DJK in 15% of patients at 5 year follow up.

37. Sagittal Considerations and Implications in Lenke 5 Curves

Majd Marrache, MD; Patrick J. Cahill, MD; Baron Lonner, MD; Peter O. Newton, MD; *Paul D. Sponseller, MD*; Harms Study Group

Summary
There is great variability in levels fused among Lenke 5 patients. Preoperative thoracic kyphosis and a short fusion are the greatest predictors of postoperative thoracic kyphosis. A long fusion provides better clinical and surgical outcomes in patients with preoperative kyphosis >38 degrees.

Hypothesis
We hypothesized that that among Lenke 5 patients with preoperative kyphosis, those that underwent long fusion would have significantly better surgical and clinical outcomes.

Design
Retrospective review

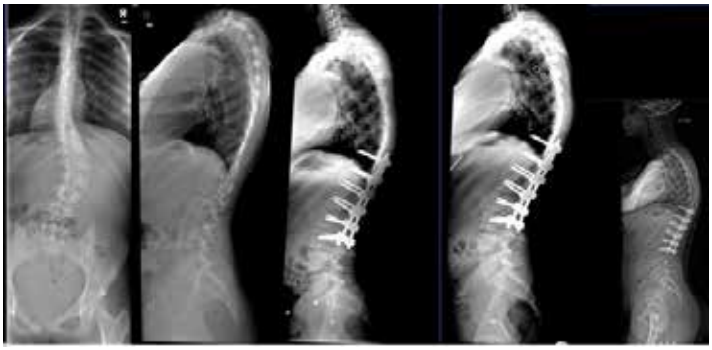
Introduction
The correction of Lenke 5 curves creates a rigid segment at the mid-portion of the spine. The incidence of and risk factors for developing PJK after surgery in Lenke 5 patients remains understudied

Methods
We studied a prospective registry of patients with adolescent idiopathic scoliosis that underwent posterior spinal fusion. We assessed difference in demographics, clinical outcomes and radiographic outcomes between patients with Lenke 5 curves who underwent fusion of the TL/L curve vs. those with longer fusion into the upper thoracic spine. Thoracic hyperkyphosis (THK) was defined as a T2 – T12 Cobb angle > 50°. Long fusion was defined as a spinal fusion of greater than 7 levels.

Results
299 Lenke 5 AIS patients were studied. 48% of patients with Lenke 5 curves underwent spinal fusion greater than 7 levels. The Lenke 5 patients that underwent a short fusion were significantly more likely to have THK at 2 years (32% vs 11%, $p<0.001$) and 5 years (31% vs 11%, $p=0.02$), respectively. Using the Youden index, 38 degrees of preoperative thoracic kyphosis was determined as the cutoff before placing the patient at an increased risk for postoperative THK. Pelvic incidence, pelvic tilt, lumbar lordosis and UIV were not predictors of developing postoperative THK. Lenke 5 patients with preoperative THK revealed significantly more patients reaching MCID for improvement in pain at 2 years among those that underwent long fusion compared to those that underwent a short fusion.

Conclusion
There is significant variability in levels fused and preoperative kyphosis among Lenke 5 curves. A short fusion in Lenke 5 patients and preoperative kyphosis over 38 degrees resulted in an increased risk of THK and results in a decreased ability to reach MCID for pain at 2 years. The sagittal profile should be assessed prior to spinal fusion in Lenke 5 patients, with a long fusion preferred in patients with >38 degree preoperative kyphosis for better clinical and surgical outcomes.

Take Home Message
Among Lenke 5 patients, preoperative thoracic kyphosis greater than 38 degrees and a short fusion are significant predictors of postoperative thoracic kyphosis.



38. Surgical Treatment of Lenke Type 5 Curves using Vertebral Body Tethering with Double Screw-Double Cord Fixation: Radiological and Clinical Outcomes

Azmi Hamzaoglu, MD; Mustafa Eltayep, MD; Huseyin Ozturk, MD; Seray G. Gur, MD; Ayhan Mutlu, MD; Sinan Kahraman, MD; Tunay Sanli, MA; Selhan Karadereler, MD; *Meric Enercan, MD*

Summary
16 AIS patients with Lenke type 5 curves were treated using Vertebral Body Tethering (VBT) technique with Double Screw-Double Cord (DS-DC) fixation. VBT with DS-DC fixation provided satisfactory corrections on both planes. The lumbar flexibility and motion was preserved with DS-DC fixation. There were no cord ruptures at the end of 2 years f/up. SRS22r scores improved significantly at final f/up.

Podium Presentations—Adolescent Idiopathic Scoliosis II

Hypothesis
VBT with single cord fixation has high risk of cord rupture at the mobile TL/L spine.DS-DC fixation will eliminate or minimize cord rupture problem & will preserve spinal flexibility & motion of the mobile TL/L spine.

Design
Retrospective

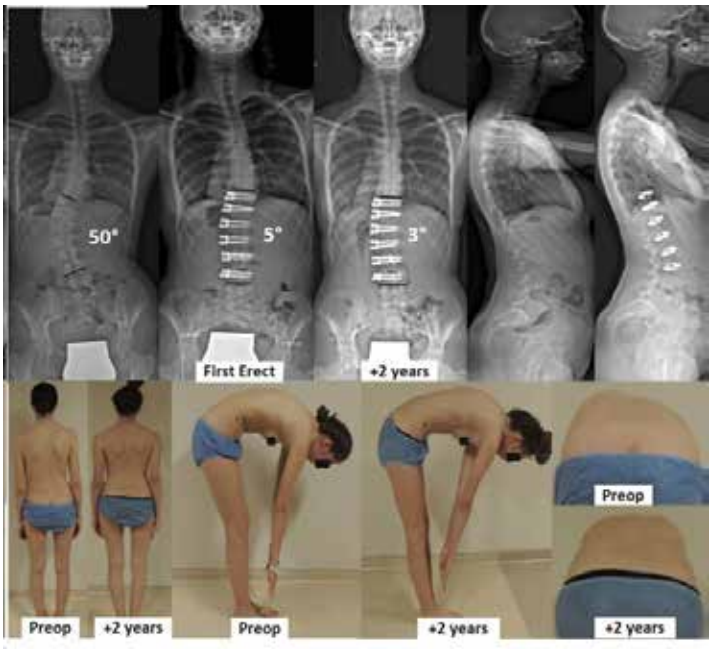
Introduction
There is a high risk of cord rupture when single cord was used for fixation especially for mobile TL/L spine. We are performing VBT with DS-DC fixation in order to preserve spinal flexibility & motion and prevent cord rupture. The aim of this study to evaluate the outcomes of VBT with DS-DC fixation in the surgical treatment of Lenke type 5 curves.

Methods
16(13F,3M) pts, mean age 14(11-17) years were included. DS-DC fixation was performed via mini open TL approach between Cobb levels. Anterior cord was tightened first in pts with hyperlordotic TL alignment and posterior cord was tightened first in pts with hypolordotic TL alignment during correction maneuver. Preop, first erect and f/up coronal and sagittal parameters were compared. Preop, f/up lumbar ROM were compared. SRS-22r was used for clinical assessment.

Results
Mean f/up was 28,8(26-32) months. LIV was L3 in 14 pts & L4 in 2 pts. Mean TL curve 45° was corrected to 9.3° & 8° at f/up (82% correction). Mean MT curve of 16° was corrected spontaneously to 12° & 11° at f/up. Preop TK of 30° improved to 37°, preop LL of 65° restored to 56° at f/up. Lumbar AVT improved from 29 mm to 11 mm & 9 mm at f/up. 15 pts with TL hyperlordosis of 11.6° improved to 1.8°. None of the parameters did not detoriate during f/up. There was no cord rupture, neurological deficit or implant failure. Preop lumbar ROM was preserved at f/up.SRS-22r improved from 4,2 to 4,6.

Conclusion
VBT with DS-DC fixation provided satisfactory curve corrections. In addition to coronal plane correction, sagittal alignment between Cobb levels were restored with DS-DC fixation. In pts with TL hyperlordosis anterior cord was tightened first and in pts with TL hypolordosis posterior cord was tightened first in order to restore ideal TL sagittal alignment. DS-DC fixation eliminated cord rupture & preserved lumbar flexibility in all pts at the end of 2 years f/up.

Take Home Message
VBT with Double Screw-Double Cord fixation eliminated cord rupture problem, provided satisfactory corrections in both planes, preserved lumbar spine flexibility & motion in the surgical treatment of Lenke type 5 curves.



DS-DC

39. Coronal and Sagittal Parameters That Affect Disc and Facet Joint Degeneration in Lenke 5 Curves after Selective Posterior Lumbar Fusion: An MRI Study with 10-year Follow-up

Seray G. Gur, MD; Mustafa Eltayep, MD; Huseyin Ozturk, MD; Tunay Sanli, MA; Ayhan Mutlu, MD; Selhan Karadereler, MD; Tom Reinsel, MD; *Sinan Kahraman, MD*; Meric Enercan, MD; Azmi Hamzaoglu, MD

Summary
Disc and facet joint degeneration (DD) was assessed at 10 years following surgery for Lenke type 5 adolescent idiopathic scoliosis curves. Coronal and sagittal radiographic parameters were compared between patients with (D) and without (ND) adjacent level degenerative changes. A LIV tilt greater than 5°, residual curve greater than 7° and PI-LL mismatch greater than 16° were seen more frequently in patients with degenerative changes (p<0,05). The SRS22 scores were however similar in the D and ND groups.

Hypothesis
We hypothesized that there is coronal and sagittal radiologic parameters that could predict FJD-DD changes and may be measured in the SRS22.

Design
Retrospective

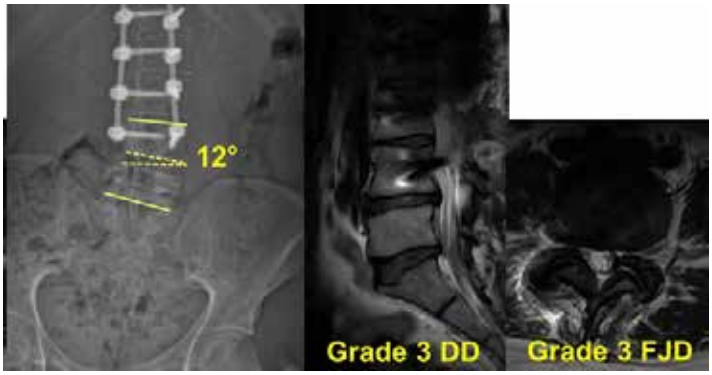
Introduction
To evaluate coronal and sagittal parameters which effect disc and facet joint degenerations (DD-FJD) of unfused segments in patients in Lenke5 AIS pts whom were treated with posterior selective fusion and to compare degenerative (D) and non-degenerative (ND) pts in terms of SRS22 scores after min. 10 yrs f/up

Methods
39 Lenke 5 AIS patients treated with selective posterior fusion were followed for a min of 10 yrs. All sagittal and coronal measurements along with DD and FJD were independently measured by 2 radiologists. X-ray and MRI before and after surgery were compared between Group D included 18 female pts with a mean age of 27 (25-31)yrs at latest visit and Group ND which included 21 pts (18F,3M) with mean age 27(23-31)yrs

Results
Both groups had similar ages, gender and BMI with an av f/u of 12 yrs(10-15) in Group D and 11 yrs in Group ND(10-14).No significant loss of correction was observed;83% group D and 85% group ND.A LIV tilt > 5°,residual curve>7° and PI-LL miss-match>16° were all significantly higher in group D($p<0.05$).PI and PT were lower in group D ($p<0.05$).Other coronal and sagittal parameters were not statistically different. Significantly lower degeneration was seen with a LIV of L3 compared to L4.SRS22r subtotal scores were similar in both groups (D=4.4 ND=4.5, $p>0.05$)

Conclusion
After a min of 10 yrs of f/up following posterior spinal fusion for Lenke5 curves, DD-FJD changes were seen more frequently in pts with higher LIV tilt, higher residual coronal curves and higher PI-LL miss-match. Selecting L3 as the LIV may be beneficial in preserving motion and preventing disc and facet joint degeneration distally. The radiographic and MRI changes seen in the 2 groups were not manifested by any change in the SRS22 scores after 10 yrs, although the pts are still quite young

Take Home Message
LIV tilt<5°, residual curve<7° and PI-LL mismatch<16° may prevent DD-FJD in unfused lumbar segments in long term f/up



Follow up x-ray and MRI images shows that LIV tilt and residual curve is12° with grade 3 disc and facet joint degeneration

40. Junctional Segment Degeneration 20 Years following Posterior Instrumented Fusion for Adolescent Idiopathic Scoliosis (AIS): Comparative Analysis of Lumbar Vertebral Tilt, Sagittal Balance and Patient Outcome

Isobella Henzell, MBBS; Kenan Burrows, MBBS; Bruce F. Hodgson, MBBS, FRCS; Ginny Martin, RN

Summary
The incidence of junctional degeneration in AIS patients followed for 20 years was evaluated. This was correlated with lumbar vertebral tilt, sagittal balance, coronal cobb angle and patient reported outcomes. 37 of 48 patients (77%) participated at an average of 21 years post surgery. 66% were found to have degenerative disc disease at the adjacent lumbar level. A significantly high incidence of adjacent level segment degeneration was found despite adequate correction of deformity.

Hypothesis
Is the incidence of degenerative disc disease increased at long term follow up post instrumented fusion for AIS?

Design
Longitudinal cohort study

Introduction
Instrumented spinal fusion for AIS has good medium-term outcomes for progressive AIS. However, there are few published reports in the very long term, comparing spinal alignment and degeneration in junctional segments with patient outcome. The incidence of junctional degeneration (DDD) in AIS patients followed for 20 years was evaluated. This was correlated with lumbar vertebral tilt (LVT), sagittal balance, coronal cobb angle (CCA) and patient reported outcomes.

Methods
A single surgeon cohort study was undertaken using a prospectively collated dataset in consecutive AIS patients treated surgically from 1992 – 1999. 48 patients met the inclusion criteria. Institutional ethical approval was obtained. Standing 36-inch PA and lateral radiographs, patient reported outcome measures (PROMs) including SRS 30 questionnaire and revised Oswestry Disability Index (ODI) were completed. Mimura classification system was used to grade DDD.

Results
37 of 48 patients (77%) participated at an average of 21 years post surgery. 23 (66%) were found to have DDD at the adjacent lumbar level. Age at follow-up did not correlate with severity of DDD. In addition, the presence of DDD was not associated with PROMs or residual CCA. CCA averages corrected from 56° pre-operatively to 19°, deteriorating to 22° at 20 years (60.3% curve correction). Average pre and post operative sagittal balance was improved (10.5mm vs 8.8mm). The average adjacent LVT was 8.5° (SD 4.7°). Average ODI of 12.1%, SRS 30 score 3.74/5. Increased LVT correlated with poorer ODI and SRS 30 scores.

Conclusion
A high incidence of adjacent level segment degeneration was found despite adequate correction of deformity. This raises concern for the longer term. Neutral sagittal balance and lower vertebral tilt were associated with better PROMs.

Take Home Message
A high incidence of adjacent level segment degeneration was found in instrumented spinal fusion for AIS at 20 year follow up.

41. Repeat Surgical Interventions Following "Definitive" Instrumentation and Fusion for Idiopathic Scoliosis: A 30 Year Update

William Z. Morris, MD; Kiley F. Poppino, BS; Dong-Phuong Tran, MS; Brandon A. Ramo, MD; B. Stephens Richards, MD

Summary
The purpose of this study was to characterize reoperation following posterior spinal fusion (PSF) for juvenile/adolescent idiopathic scoliosis (JIS/AIS) from 2013-2017 and compare against 25 years of historical controls. 682 patients underwent PSF with 34 complications requiring reoperation (5.0%), a 50% decrease from 2008-2012 (5.0% vs 10.9%, respectively; p<0.001), and an overall downward trend was observed since 1988. The decrease stemmed mainly from improved rates of infection (p<0.001), screw malposition (p=0.004), and symptomatic implants (p=0.01).

Hypothesis
Complication rates for juvenile/adolescent idiopathic scoliosis over the past five years have declined when compared to 25 years of historical controls.

Design
Retrospective review of prospectively enrolled patients

Introduction
Although posterior spinal fusion (PSF) is considered "definitive" treatment in juvenile/adolescent idiopathic scoliosis (JIS/AIS), complications requiring reoperation continue to occur. The purpose of this study is to characterize the evolving rates and reasons for reoperation following PSF in idiopathic scoliosis.

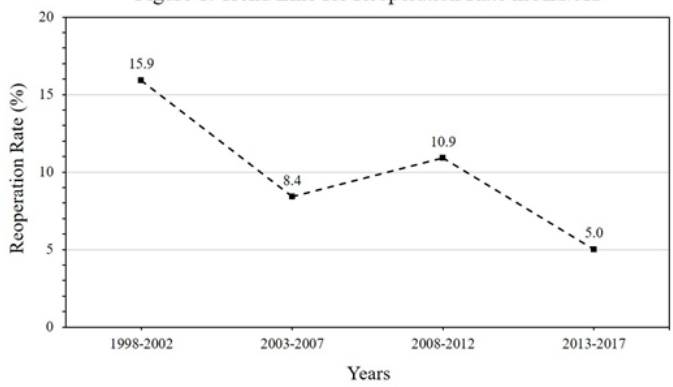
Methods
Single center retrospective review of a consecutively-enrolled prospectively-collected database. We identified all patients who underwent PSF for JIS/AIS as their index surgical treatment between 2013-2017. Demographic and perioperative data were collected to identify complications requiring reoperation and factors associated with reoperation. Complication rates from 2013-2017 were compared to historical controls from 1988-2012.

Results
682 patients (82.7% female) underwent PSF at mean age 14.5±2.0 years. There were 34 complications requiring reoperation in 28 patients (5.0%), a 50% decrease from the 2008-2012 population (5.0% vs 10.9%, respectively; p<0.001) and an overall downward trend since 1988 (Figure 1). The decrease stemmed mainly from decreases in rates of infection (4.5% vs 0.9%, p<0.001), screw malposition (1.7% vs 0.1%, p=0.004), and symptomatic implants (2.1% vs 0.4%, p=0.01). Univariate analysis revealed that complications were associated with increased age at index surgery (15.2±1.9 vs 14.5±2.0 years, p=0.046), increased levels fused (11.7±2.1 vs 10.4±2.1, p=0.002), and increased surgical time (276.3±82.8 vs 248.8±70.9 minutes, p=0.05). BMI percentile, major Cobb angle, implant density, EBL, and total anesthesia time were not found to be significant predictors of reoperation (p>0.05).

Conclusion
Complication rates following definitive fusion for JIS/AIS continue to improve as evolving quality initiatives and lower-profile implants decrease rates of infection and symptomatic implants.

Take Home Message
A 5-year update of a 30-year cohort shows that reoperation rates following PSF for AIS/JIS continue to improve as rates of infection, screw malposition, and symptomatic implants decline.

Figure 1. Trend Line for Reoperation Rate in AIS/JIS



42. Ultralong Follow-up of Spinal Fusion for Adolescent Idiopathic Scoliosis: Harrington Instrumentation versus Un-Instrumented Fusion: Minimum 53-years Follow-up

Noorullah Maqsoodi, MS; Aron Sulovari, BS; Adan Omar, MD; Jarren Section, MD; Emmanuel N. Menga, MD; James O. Sanders, MD; Paul T. Rubery, MD; *Addisu Mesfin, MD*

Summary
Ultralong follow up of patients undergoing posterior spinal fusion with Harrington instrumentation and patients with uninstrumented fusion was performed. There were no differences in the long-term related patient reported outcomes in Neck Disability Index (NDI), Oswestry Disability Index (ODI) and Scoliosis Research Society-7 (SRS-7). Additionally, there were no differences in radiographic measurements of Pelvic incidence (PI), Sagittal vertical axis (SVA), Pelvic tilt (PT) and Lumbar lordosis (LL).

Hypothesis
Patients undergoing uninstrumented spinal fusion will have less sagittal deformity and better patient reported outcomes compared to patients with Harrington instrumentation

Podium Presentations—Adolescent Idiopathic Scoliosis II

Design
Case control series

Introduction
Harrington instrumentation for AIS was revolutionary and allowed patients to mobilize faster as compared to patients treated with uninstrumented fusion. However, Harrington instrumentation provided correction of the deformity in one plane resulting in loss of thoracic kyphosis as well as the crank-shaft phenomenon. To date ultralong follow up of patients undergoing these two surgeries has not been reported.

Methods
Fourteen adult patients with AIS who were previously instrumented (n=7), or uninstrumented (n=7) were identified. Recent x-ray measurements were used to analyze deformities. SRS-7, NDI and ODI were used to evaluate patient reported outcomes. The rate of revision surgery was also evaluated

Results
Mean age for instrumented was 67.1±5 years and 64.1±9 years in uninstrumented group. There were no significant differences between instrumented vs. uninstrumented in SRS-7 (23.4 vs. 23.6, p=0.93), NDI (8.3 vs.10.6 p=0.09) and ODI (9.4 vs. 9.7 p=0.99). Radiographic measurements of instrumented vs uninstrumented resulted in SVA (38.1 vs. 52.3 p=0.37), PT (24.0 vs. 30.5 p=0.09), PI (61.3 vs. 67.2 p=0.47), and LL (34.9 vs. 42.8 p=0.29). There were 2 patients in the instrumented group who developed adjacent segment disease requiring operative intervention as compared to none in the uninstrumented group (p=0.46).

Conclusion
In long term follow up of instrumented and uninstrumented fusion, patients have similar patient reported outcomes, although the instrumented cohort had higher rates of adjacent segment disease.

Take Home Message
Our case-controlled study showed that in long term follow up, there were no statistically significant difference in patient reported outcomes and radiological imaging between the two fusion types.

Podium Presentations— Adult Spinal Deformity I

43. Dubousset Functional Test (DFT): The First Application on Spine Patients and Asymptomatic Volunteers

Bassel G. Diebo, MD; David Kim, BS; Michael G. Dubner, BS; Neil Patel, BS; Sanjeev Agarwal, MD; Harleen Kaur, BS; George A. Beyer, MS; Neil V. Shah, MD, MS; Renaud Lafage, MS; Carl B. Paulino, MD; Peter G. Passias, MD; Vincent Challier, MD; Frank J. Schwab, MD; Virginie Lafage, PhD

Summary
In this prospective, 2-arm study on a novel test proposed by Dr. Jean Dubousset, patients with spinal pathologies spent longer time performing DFT domains than asymptomatic volunteers. DFT performance correlated with ODI, SF12 and EQ5D, while coefficients ranged from 0.356-0.655.

Hypothesis
DFT correlates with PROMs

Design
Prospective, 2-arm

Introduction
PROMs and radiographic parameters have advanced our ability to assess patients, but radiographs are static, and PROMs are limited by quantifying the pts perception of disability. This study investigates performance of the novel 4-component functional test proposed by Dr. Dubousset (Fig) between patients with spinal pathologies and asymptomatic subjects.

Methods
This is a prospective, single center, 2-arm study that included asymptomatic volunteers (Norm) and primary pt (Pts) who presented to the spine service for evaluation of lumbar degenerative disease and spinal deformity. DFT is a test which assesses 4 components. Each test was timed and performance was scored by time (in seconds) required to finish the test. Pts completed PROMs (EQ5D, ODI, SF12), and Montreal Cognitive Assessment (MoCA). DFT was compared between populations, and was correlated to PROMs

Results
117 subjects were included (51 pts: 52y, 66%F, BMI 25.6; 66 Norm: 41y, 67%, 28.8). Pts spent significantly more time performing DFT than Norm: UWT (26.8 vs. 14.4 seconds), DTT (21.2 vs. 12.3), DST (10.6 vs. 5.7) and ST (12.1 vs. 6.3), respectively, $p<0.05$. This held true when controlling for age. In Pts: Mean PROMs were ODI 33.1±17.2, SF12PCS: 34.7±5.5, EQ5D: 0.6±0.2, and MoCa 22.9±3.8. Correlations were observed between UWT, DTT, DST, ST and ODI (R=0.655, 0.429, 0.556, 0.521), SF12PCS (-0.540, -0.-356, -0.462, -0.437) and EQ5D (-0.534, -0.328, -0.383, -0.378), respectively, $p<0.05$. DTT correlated with MoCa scores of cognitive ability (-0.365, $p<0.05$). Lumbar radiculopathy was associated with increased time to perform the Steps domain: 18.5 vs. 8.5 second, $p<0.05$

Conclusion
DFT is an objective assessment of functionality and can distinguish between healthy subjects and pts with spinal pathologies. Time spent performing DFT domains correlated with established PROMs. Studies are underway to investigate changes in DFT after surgical management of spine pts and the ability of DFT to predict complications

Take Home Message
Dubousset Functional Test is a four-component, novel functional assessment. DFT is simple and can be utilized in a clinic setting with correlations between times spent performing DFT and PROMs.

The **Dubousset Functional Test** consists of the following four components: (1) **UWT (Up-and-Walking Test)**: unassisted sit-to-stand, walk forward/backward 5m (no turn), unassisted sit; (2) **ST (Steps Test)**: ascend 3 steps, turn, descend 3 steps; **(3) DST (Down-and-Sitting Test)**: stand-to-ground, sit-to-stand, assistance as needed; **(4) DTT (Dual-Tasking Test)**: walk 5m forth and back while counting down from 50 by 2.

44. Relationships between Radiographic Parameters and Spinopelvic Muscles in Adult Spinal Deformity Patients

Emmanuelle Ferrero, MD, PhD; Pierre Guigui, MD; Wafa Skalli, PhD; Virginie Lafage, PhD

Summary
First study to explore relationships between muscle degeneration and ASD in 3D. Using a dedicated validated software, volumetric 3D reconstructions and fat infiltration (FI) of 30 spinopelvic muscles was performed: sagittal malalignment is associated with increased fat infiltration for all muscle groups (more severely for erector spinae, hip flexor and extensor), and decreased muscle volumes were associated with worst outcomes. Surgeons should take care of that in surgical planning to avoid some complications.

Hypothesis
3D deformity is associated with muscles degeneration in adult spinal deformity (ASD) patients

Design
Prospective cohort study

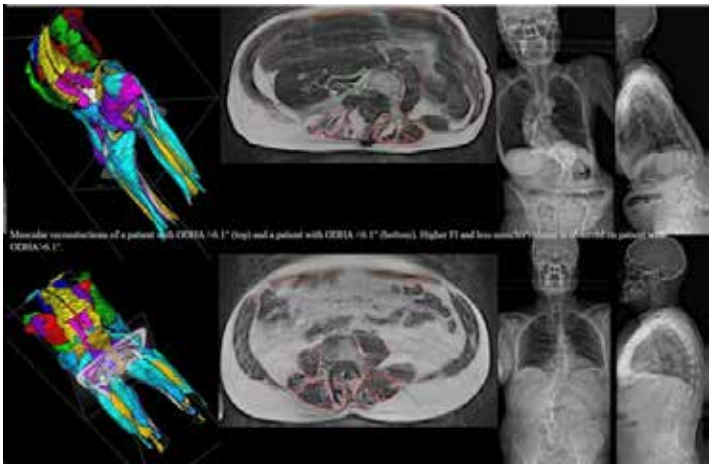
Introduction
While the clinical impact of coronal and sagittal alignment in ASD patients is established, there is a paucity of data in terms of muscle degeneration analysis in ASD. Indeed, all the ASD surgical complication cannot be explained by sagittal malalignment only. The purpose of this study was to analyze spinopelvic muscles characteristics in association with the 3D deformity of ASD patients.

Methods
Primary lumbar scoliosis patients (Cobb angle>20°) were enrolled and sustained a low dose biplanar X-Rays with 3D spinal reconstructions and a fat/water separation MRI (Dixon method, from C7 to the knee). Using a validated software, volumetric 3D reconstructions and fat infiltration (FI) of 6 muscles groups were performed (spinal erector and flexor, hip extensors and flexors, pectorals and scapulo-thoracic). Relationships between muscular data, radiographic parameters and HRQoL were investigated. Patients were stratified and compared based on the SRS classification (PI-LL> or <10°, PT > or <20°), the odontoid-hip axis (ODHA) angle (> or <6.1°), and the occurrence of rotatory subluxation (lateral listhesis >3mm).

Results
28 patients were enrolled with a mean age of 60±16yo, 71% females, without differences between groups. There was a moderate sagittal malalignment, and a Cobb angle of 45+/-11°. Muscular volume was smaller in pts with more severe deformity (p>0.05). Pts with ODHA>6.1° or PI-LL>10° had significantly higher FI for the 6 muscular groups (figure), pts with PT>20° had significantly higher FI for erector spinae, hip flexors and extensors. Pts with RS had higher FI (not significantly). SF36-PCS significantly correlated with the muscular volume (erector spinae, psoas, and gluteus medius, r>0.66, p<0.05). SRS and ODI correlated with the erectors spinae volume (r>0.64, p<0.05).

Conclusion
This study analyzed for the 1st time muscular characteristics in ASD. Whereas coronal malalignment was not involved, sagittal malalignment is associated with increased FI, and decreased muscle volumes with poor outcomes.

Take Home Message
Great variability exists between muscles volume and fat infiltration. Sagittal malalignment is associated with significant increased fat infiltration of spinopelvic muscles and tendency to smaller muscular volume, with worst outcomes.



45. Risk Factors for Rapid Curve Progression in De Novo Degenerative Lumbar Scoliosis

Dmitrii Ptashnikov, MD, PhD; Sergei Masevnin, MD, PhD; Dmitrii Mikhailov, MD, PhD; Nikita Zaborovskii, MD, PhD; Anton Denisov, MD

Summary
We studied risk factors for the rapid deformity progression in patients with degenerative scoliosis.

Hypothesis
We hypothesize that patients with a coronal malalignment will have greater odds of deformity progression compared with normally balanced patients due to the lack of compensation mechanisms, especially in the rigid thoracic spine in the elderly.

Design
Retrospective cohort study.

Introduction
The mean curve progression in patients with degenerative scoliosis, according to most researchers, is 2-3° per year, but there are cases of faster progression. Risk factors for the rapid progression of deformity in patients with de novo scoliosis are not widely discussed. The aim of this study was to identify risk factors for the rapid progression of lumbar deformity.

Methods
This study included 128 patients with de novo scoliosis which were dynamically observed and treated conservatively for an average of 3.2 years (2-6 years). All patients' age > 40 with lumbar scoliosis and no neurological deficits were included. Indications for surgical treatment were determined with the appearance of a neurological deficit, as well as persistent low back pain recurring with conservative treatment. Long cassette standing radiographs were reviewed annually. We then compared patients with rapidly progressing deformity (>10° per year) with other patients to determine the independent risk factors associated with rapid curve progression based on multivariate regression analysis.

Results
104 patients were kept for final analysis with a mean age of 64.6 years. Rapid curve progression occurred in 27% of cases. Multivariate regression analysis revealed coronal malalignment (T1 plumbline displacement) in patients older than 60 years (hazards ratio=3.136, 95%CI=1.643–6.178, P<0.001) was the combined significant independent risk factor associated with rapid deformity progression. Cox proportional hazard model showed that risks of curve progression more than 10° per year were 2,6 times higher in patients with coronal malalignment more than 3 cm and over 60 years old.

Conclusion
We found rapid deformity progression in 28 (27%) patients with de novo scoliosis. Coronal malalignment more than 3 cm in patients older than 60 was independent risk factor with 2,6 times higher rate of rapid curve progression.

Take Home Message
Patients with a coronal malalignment and rigid thoracic spine are

more likely to have rapid lumbar deformity progression due to the lack of compensation mechanisms.

46. Efficacy of Adult Spinal Deformity Surgical Decision Making (ASD-SDM) Score in Patients Over 40 Years as an Indication for Surgical Management

Sreenath R. Jakinapally, MD; Louis Boissiere, MD; Ferran Pellisé, MD, PhD; Francisco Javier S. Perez-Grueso, MD; Frank S. Kleinstueck, MD; Emre R. Acaroglu, MD; Ahmet Alanay, MD; Ibrahim Obeid, MD

Summary
ASD-SDM score and its implication when used as surgical indication were investigated retrospectively in a multi-center prospective database. Operated patients in high surgical indication group have significant improvement in HRQOL, radiological parameters at the last visit, with three times improvement in patients with minor complications compared to non-operated patients whereas in the low surgical indication group the data is similar at the last visit between operated and non-operated cases. These findings support the effectiveness of ASD-SDM score as surgical indication.

Hypothesis
If the ASD-SDM score used as an Indication for Surgical management in patients over 40 years is correlated to patient improvement after surgery.

Design
A multi-center retrospective study in a prospective database.

Introduction
The recently developed Adult spinal deformity surgical decision making (ASD-SDM) score is the only scheme that is specific to the decision-making process for ASD. The ASD-SDM score was developed separately for Adult spinal deformity (ASD) populations aged above and below 40 years, and it consists of baseline symptomatology, Health related quality of life (HRQoL) measures, and radiographic parameters. The purpose of this study is to investigate whether ASD-SDM score is a proper surgical indication.

Methods
A multi-center prospective database was retrospectively reviewed in patients > 40 years. Analyzed variables were baseline symptomatology, HRQOL measures, major clinical and radiographic values in addition to demographic data of ASD patients, complications and follow up (min 2 yrs). Operated and non-operated patients were compared in low surgical indication (LSI) and high surgical indication (HSI) groups.

Results
A total of 913 patients was enrolled in this cohort, and 750 (82.1%) met the inclusion criteria. Included were 118 males and 632 females, with a mean age of 63.5 yrs. A total of 410 cases (54.7%) selected surgical management. In LSI group (score 0-4) at the baseline visit, non-operated patients have better HRQoL values, but at the last visit, operated patients have better cobb angle and improved HRQoL values to the level of non operated patients. ($p<0.01$, OR 1.91). In the HSI group (score 8-12) the baseline values are similar but at the last visit operated patients have significant improvement of NRS back and leg pain, HRQoL with $p< 0.001$, $p<0.001$ and OR 1.96 respectively compared to no improvement in non-operative patients. The patients with minor complications have three times improvement compared to patients with major complications.

Conclusion
ASD-SDM score, when used as a surgical indication in patients over 40 years is correlated to long term clinical result and HRQoL improvement.

Take Home Message
The Adult Spinal Deformity Surgical Decision-Making score is highly effective when used as an indication for surgical management with high correlation to patient improvement and satisfaction after surgery.

47. Identifying Subsets of Adult Spinal Deformity Patients that Maintained a Positive Response to Non-operative Management

Peter G. Passias, MD; Waleed Ahmad, BS; Frank A. Segreto, BS; Renaud Lafage, MS; Virginie Lafage, PhD; Alex Soroceanu, MPH; Alan H. Daniels, MD; Jeffrey L. Gum, MD; Breton G. Line, BS; Robert A. Hart, MD; Douglas C. Burton, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Richard Hostin, MD; Shay Bess, MD; International Spine Study Group

Summary
As adult spinal deformity (ASD) stands as a major cause of disability in the elderly population, surgical intervention has been shown to reduce disability and pain in properly indicated patients. However, there is a small subset of patients in whom non-operative (N-Op) treatment is able to maintain or improve symptoms for a sustained period, without the need for an invasive intervention. Our results demonstrate N-Op success is achievable in patients starting off with less deformity, disability, and frailty.

Hypothesis
There is a subset of patients in which N-Op treatment will maintain or improve symptoms.

Design
Retrospective

Introduction
This study aims to examine the likelihood of success of N-Op treatment

Methods
N-Op patients who met ASD database criteria with radiographic and HRQL data at baseline (BL) and 2Y were included. Patients were stratified into three groups based on outcome of treatment: (1) Success, (2) No Change, (3) Failure. Success was defined as a gain in MCID in both ODI and SRS-Pain and failure as a loss in MCID or conversion to operative treatment. Patients with

BL ODI ≤20 and continued ODI at 2Y ≤ 20 were considered N-Op success. No change was not achieving either outcome. Conditional inference decision trees established cut-offs for success based on ASD Frailty Index (ASD-FI) and SVA.

Results

207 N-Op patients were included. At 2Y, 44.9% of patients had successful N-Op treatment, 22.7% exhibited no change, and 32.4% failed. Among failed Non-Op patients, 62/67 patients were initially N-Op and crossed over to operative treatment. Successful Non-Op patients had significantly higher rates of grade 0 deformity for all Schwab modifiers (all p<0.05). Stratifying patients by BL disability, patients with an ODI <40 had significantly higher rates of successful Non-Op treatment compared to patients with ODI>40(p<0.001). Comparing patients that maintained and had successful Non-Op treatment vs. failed Non-op treatment, a logistic regression controlling for age, SVA, and CCI determined increased frailty to be the strongest predictor of failed Non-Op treatment (OR: 2.2 [1.6-3.0],p<0.001). Adjusting for BL SVA, patients with a baseline GAP Proportioned (2.7[1.1-6.3], p<0.05) were associated with significantly increased odds of Non-Op success. Conditional inference decision tree analysis determined patients with a baseline ASD-FI ≤ 1.579(8.3[4.0-17.5]) and SVA ≤ 4.1(2.1[1.0-4.4]) were significantly more likely achieve success with N-Op treatment(both p<0.05).

Conclusion

Success of non-operative treatment was predicated on a combination baseline risk factors with the most imperative being minimal sagittal deformity, disability, and frailty.

Take Home Message

Success of non-operative treatment was far less common among patients starting with more severe baseline deformity and worse disability. Controlling for these major disparities, frailty was the major determinant.

Age	52.6yrs±15.8
Gender	86% Female
BMI (kg/m²)	25.4
Frailty	1.9±1.5
CCI	1.0 ±1.2

N-Op BL Characteristics and rates	Success	No Change	Failure	p-value
Age	47.2 yrs	56.0 yrs	57.8yrs	p<0.001
BMI	23.4	26.9	27.2	p<0.001
CCI	0.548	1.32	1.3	p<0.001
Frailty	0.93	2.5	3.0	p<0.001
Obesity	8.0%	23.4%	26.2%	p=0.007
Depression	5.4%	17.0%	17.9%	p=0.028
Hypertension	8.6%	21.3%	37.3%	p<0.001

Table 1. Baseline patient demographics and differences in characteristics, rates, and baseline among successful, maintenance, and failed non-operative treatment.

48. When Not to Operate in Spinal Deformity: Identifying Subsets of Patients with Simultaneous Clinical Deterioration, Major Complications, and Reoperation

Peter G. Passias, MD; Katherine E. Pierce, BS; Renaud Lafage, MS; Virginie Lafage, PhD; D. Kojo Hamilton, MD; Gregory M. Mundis, MD; Han Jo Kim, MD; Richard Hostin, MD; Alan H. Daniels, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Christopher P. Ames, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; Eric O. Klineberg, MD; International Spine Study Group

Summary

Due to the complexity and invasiveness of adult spinal deformity correction, poor outcomes are often associated. This study sought to determine what factors produce a poor triplicate outcome: clinical deterioration, major complications, and reoperation. The predictors identified can help guide deformity surgeon decision making.

Hypothesis

Certain patient factors justify determining a patient ineligible for a deformity correction.

Design

Retrospective cohort study

Introduction

Currently, it is unknown what factors predict an unacceptable patient for surgery

Methods

Patients>18yrs undergoing surgery for ASD (scoliosis≥20°, SVA≥5cm, PT≥25°, or TK≥60°). An unsatisfactory outcome was defined by the following categories met at 2Y: (1) clinical: deteriorating in ODI at 2Y f/u (2) complications/reop: having a reoperation and major complication were deemed unacceptable for surgery (NoOp). Baseline demographic, clinical and radiographic information were utilized through univariate/multivariate analyses to assess predictive factors of NoOp patients in adult spinal deformity patients. Multivariate regression with backward model selection was employed to create a model for when not to operate.

Results

633 ASD patients (59.9 years, 79%F, 27.7 kg/m2, CCI: 1.74) were included. By approach, 0.6% were anterior, 69.7% posterior and 29.5% combined approaches (Levels fused: 7.5±2.1). 15.5% of patients deteriorated in ODI by 2 years, while 7.6% underwent a reoperation and had a major complication. This categorized 11 (1.7%) of patients in the total cohort as NoOp. Surgically, NoOp patients an overall greater EBL (4431ccs) underwent more osteotomies (91%), specifically Ponte (36%) and Three Column Osteotomies (55%), which occurred more at L2 (91%). NoOp patients underwent more PLIFs (45%) and had more blood transfusion units (2641ccs), all p<0.050. For ASD patients, a multivariate regression model to predict NoOp group is listed in Table 1.

Conclusion
When addressing adult spine deformities, a negative outcome of clinical deterioration, major complications, and reoperations is exceedingly rare, but does occur. This tends to occur in severely comorbid patients with major baseline psychological distress scores, poor neurologic function and concomitant cervical malalignment.

Take Home Message
Deformity surgeons should be wary of certain preoperative factors that could result in poor triplicate of outcomes.

Model Predicting NoOp Patients (R^2=0.535, p<0.001)
DRAM score in the 75th percentile
Arthritis
Kidney Disease
Right Lower Extremity Motor Score ≤3
cSVA >65mm
C2 slope >30.2°
CTPA >5.5°

49. The Effect of Intraoperative Prone Cross-Table Lateral X-Ray on Surgical Treatment of Adult Spinal Deformity

Ayhan Mutlu, MD; Mustafa Eltayep, MD; Seray G. Gur, MD; Huseyin Ozturk, MD; Sinan Kahraman, MD; Tunay Sanli, MA; Selhan Karadereler, MD; *Meric Enercan, MD*; Azmi Hamzaoglu, MD

Summary
Sagittal parameters measured on standing full spine lateral x-ray and intraoperative prone cross-table (IPCT) lateral x-ray taken under general anesthesia were different (p<0.05). IPCT lateral x-ray eliminated planned 3 column osteotomy (3-CO) in 23% pts and ideal sagittal alignment was achieved in 86.9% pts when IPCT x-ray and standing x-ray were used together for surgical decision making.

Hypothesis
Intraoperative prone cross-table (IPCT) full spine lateral x-ray shows more accurate LL & TK values due to full muscle relaxation and pain elimination provided by general anesthesia. LL & TK values can be different in standing & prone position. This difference may change the preoperative surgical plan.

Design
Retrospective

Introduction
The surgical strategy for the restoration of the sagittal balance is generally planned according to the sagittal parameters (TK,LL,-PI) measured on standing x-rays. General anesthesia provides full muscle relaxation & eliminates the pain therefore; sagittal parameters measured on IPCT lateral x-ray taken under general anesthesia can be different. The preoperative surgical plan may change according this difference. The aim of this study is to analyze the effect of IPCT lateral x-ray on the surgical plan in adult deformity surgery.

Methods
124(45M,79F) pts were reviewed. All pts were positioned prone on the same spinal surgery frame with hips and knees in extension position to achieve maximum LL. IPCT lateral x-rays were taken at the beginning of surgery before the incision. Sagittal parameters & local kyphosis angle (LCA) were measured on standing, IPCT & f/up lateral x-rays. Preoperative surgical plans were compared with the surgical procedure performed & changes in preoperative plan after IPCT lateral x-ray were noted.

Results
Mean age 69(36-88).Mean LL was -28.7° on standing and -39.3° on IPCT x-ray. The difference was significant (p<0.05,Z=-4.53). Mean TK was 35.9°on standing & 43° on IPCT x-ray (p>0.05). LCA was 19.3°on standing & 3.4° on IPCT x-ray (p<0.05, t=8.795). IPCT x-ray changed surgical plan in 41pts (33.7%) & osteotomy type (3-CO converted to posterior column osteotomy or interbody fusion) in 28 pts (23%). Ideal LL was achieved in 86.9% pts according to PI-LL mismatch.

Conclusion
IPCT lateral x-ray taken under general anesthesia provides muscle relaxation & eliminates pain therefore shows more accurate TK & LL. IPCT lateral x-ray eliminated planned 3-CO in 23% of the pts & ideal sagittal alignment was achieved in 86.9% pts. IPCT & standing x-ray should be used together inplanning to achieve ideal sagittal alignment.

Take Home Message
Intraoperative prone cross-table lateral x-ray and standing x-ray should be used together for surgical planning to achieve ideal sagittal alignment.

50. Opioid Use Prior to Adult Spine Deformity (ASD) Surgery is Associated with Decreased Cost Effectiveness; A Matched Cohort Analysis

Breton G. Line, BS; Shay Bess, MD; Samrat Yeramaneni, PhD; Richard Hostin, MD; Christopher P. Ames, MD; Virginie Lafage, PhD; Renaud Lafage, MS; Douglas C. Burton, MD; Eric O. Klineberg, MD; Munish C. Gupta, MD; Robert K. Eastlack, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Robert A. Hart, MD; Khaled M. Kebaish, MD; Han Jo Kim, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; International Spine Study Group

Summary
Opioid use prior to ASD surgery is associated with worse patient health state and greater costs. After controlling for patient demographics, deformity magnitude, and type of surgery, OPIOID had greater cost of care, despite similar perioperative complications. At two years postop OPIOID and NON demonstrated cost effectiveness of index surgery, however the residual cost to society was $21,300 greater for OPIOID vs NON. Over 52% of OPIOD had continued opioid usage at two years postop compared to 8.7% of NON.

Hypothesis
Opioid use prior to ASD surgery is associated with worse post-

operative quality adjusted life years (QALY) and worse cost/QALY than nonusers.

Design
Cost/QALY analysis of propensity score matched (PSM) operatively treated ASD patients from a prospective, multi-center study.

Introduction
Opioid use prior to surgery is associated with worse postop outcomes. Little is known regarding the impact that preop opioid use has upon QALYs and cost/QALY for ASD surgery.

Methods
ASD patients were divided into preop opioid (OPIOID) vs non (NON) users. PSM used to control for demographic, radiographic, and surgical variables. Preop, one year, and minimum two year postop SF6D values and QALYs calculated, index surgery costs calculated using CMS DRG reimbursements, cost/QALY evaluated at one and two years postop, perioperative complications, and two year postop opioid use was evaluated.

Results
DRG data was available for 182/262 patients meeting inclusion criteria. OPIOID (n=68) and NON (n=114) had similar preop demographics, deformity, surgical treatment, and mean follow up (3.4 vs. 3.3 years), respectively (p>0.05). SF6D was worse for OPIOID at preop (0.521 vs 0.598), one year (0.613 vs. 0.749), and two years postop (0.626 vs. 0.749) than NON, respectively (p<0.05). QALYs were worse for OPIOID one (0.567 vs. 0.674) and two years postop (0.674 vs. 0.825) vs. NON, respectively (p<0.05). Index surgery cost was greater for OPIOID ($83,363.02) vs. NON ($70,281.17). Cost/QALY was higher for OPIOID at one year ($150,294.51vs. $107,947.19) and 2 years postop ($69,615.78 vs. $48,761.14) than NON (p<0.05). Perioperative complications were similar for OPIOID vs. NON (p>0.05). Opioid use at two years postop was greater for OPIOID (52.4%) vs. NON (8.7%; p>0.05).

Conclusion
Opioid use prior to ASD surgery is associated with worse health state and greater costs. At 2 years postop OPIOID and NON demonstrated cost effectiveness of index surgery, however cost was $21,300 greater for OPIOID vs NON. Over 52% of OPIOD had continued opioid usage at two years postop compared to 8.7% of NON.

Take Home Message
Matched analysis for confounding variables demonstrated preoperative opioid use in ASD is associated with worse health state, greater costs, and worse cost/QALY at two years postop compared to opioid nonusers.

51. Recovery Kinetics of Post-Operative Opiate Usage in Adult Spinal Deformity Corrective Surgery: Is There an Optimal Time Frame for Cessation?

Waleed Ahmad, BS; *Peter G. Passias, MD*; Renaud Lafage, MS; Virginie Lafage, PhD; Eric O. Klineberg, MD; Michael P. Kelly, MD; Jeffrey L. Gum, MD; Breton G. Line, BS; Mitsuru Yagi, MD, PhD; Robert A. Hart, MD; Douglas C. Burton, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Richard Hostin, MD; Shay Bess, MD; International Spine Study Group

Summary
Prior to undergoing corrective surgery for adult spinal deformity, patients present with differing preoperative use of opioid and non-opioid medication. There is paucity in the literature on the effect of preoperative opioid usage and timing of conversion to non-opioid use postoperatively on the recovery of patients.

Hypothesis
Postoperative opioid use will yield comparative recovery as opioid naïve patients

Design
Retrospective

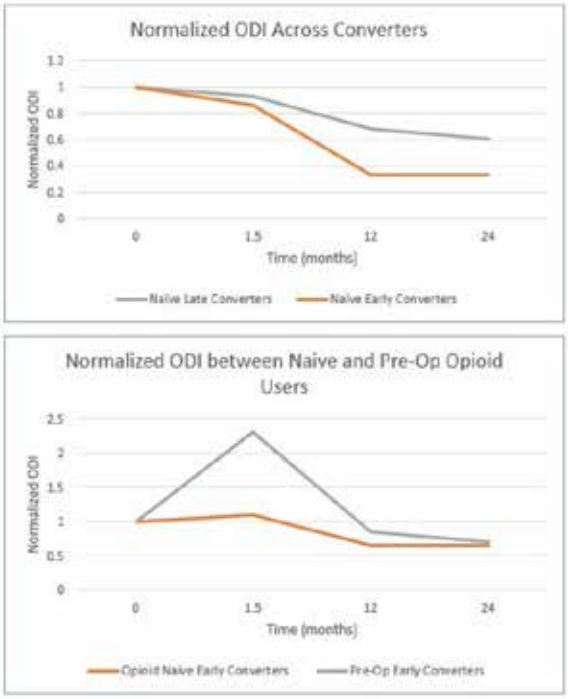
Introduction
Cessation of preoperative opioid use has not been identified in relation to recovery kinetics

Methods
ASD patients (>18yrs, scoliosis≥20°, SVA≥5cm, PT≥25° and/or TK>60°) were stratified into 2 groups based on BL use of pain medication: 1) Preoperative Opioid 2) Opioid Naïve. Means comparison tests assessed differences in BL demographics and clinical data between cohorts. Patients were further stratified into early (6W to 3M post-op) or late (1Y post-op) conversion groups based on stoppage of opioid use postoperatively.

Results
479 ASD patients were included (59.6yrs, 80%F, 27.6 kg/m2). Preoperatively, 28.2% of patients reported narcotic use (13.2% daily use and 15.0% weekly), 28.3% non-narcotic only, and 43.4% no pain medication. Opioid naïve patients at BL had significantly higher rates of severe (++) sagittal deformity according to SRS-Schwab classifications (p<0.05). At BL, opioid naïve patients had greater rates of anemia, arthritis, depression, hypertension, and neurological dysfunction (all p<0.05). Compared to opioid naïve cohort, patients reporting preoperative opioid use were significantly younger, had a lower BMI, lower CCI, less frail, lower baseline ODI, and greater SRS total scores(p<0.05). At 2Y, Opioid Naïve patients showed greater radiographic improvement in PI-LL, lumbar lordosis, thoracic kyphosis, and SVA(p<0.05). Among Opioid naïve patients, 45 stopped opioid use early and 27 stopped late. Controlling for BL SVA, IHS-adjusted HRQL outcomes from BL to 2Y showed differences between opioid naïve early and late converters in ODI(Early: 0.48 vs. Late: 0.74, p<0.05). For pre-op opioid users, there were no significant differences found in IHS-adjust outcomes between early and late converters (all p>0.05). However, there was a difference between opioid naïve and preop opioid among early converters (Naïve:0.76 vs. Pre-Op Opioid: 1.2, p<0.05).

Conclusion
Preoperative opioid users failed to show the same trajectory of improvement in IHS-adjusted ODI compared to opioid naïve patients.

Take Home Message
The trajectory of recovery for preoperative opioid users continued to remain diminished despite early cessation. During risk assessment, providers may consider suggesting preoperative stoppage of opioids to enhance recovery.



52. Decompression Alone, Limited Fusion, or Full Correction of Adult Scoliosis: Outcomes and Morbidity with Minimum 2-year Follow-up

Minghao Wang, MD, PhD; Gregory Hawryluk, MD; Praveen V. Mummaneni, MD; Darryl Lau, MD; Ratnesh N. Mehra, MD; Rory R. Mayer, MD; Dean Chou, MD; *Bo Li, MD*

Summary
Although complete adult spinal deformity correction is associated with the greatest morbidity, there was also the greatest back pain improvement. However, limited decompression and fusion in highly selected patients primarily with leg pain may give comparable reduction in ODI and VAS leg pain scores compared to full correction.

Hypothesis
We compared patients who had full deformity correction, limited decompression and fusion (≤3 levels), and decompression alone in adult scoliosis patients.

Design
Retrospective review

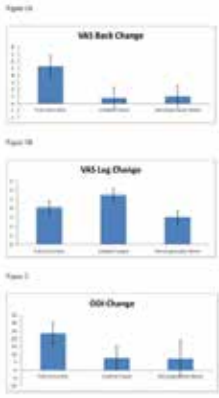
Introduction
Full surgical correction of adult spinal deformity carries associated risks and morbidity. Decompression and limited fusion or decompression alone may, however, ultimately worsen the deformity and require revision surgery. We compared patients who had full deformity correction, limited decompression and fusion (≤3 levels), and decompression alone in adult scoliosis patients.

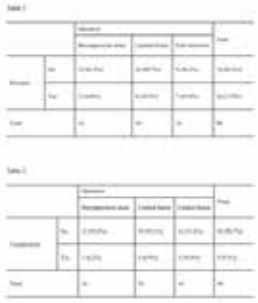
Methods
A retrospective review of adult spinal deformity patients was performed. Inclusion criteria were: first-time surgery, pre-op LL-PI mismatch<30°, thoracic kyphosis<60°, thoracolumbar kyphosis<10°, coronal Cobb angle<80°, and minimum 2-year f/u. We assessed peri-op metrics such as operative time, intra-op blood loss and length of stay. We also recorded complications as well as re-operation rates. Patients reported quality of life outcomes including VAS for back and leg as well as ODI.

Results
A total of 90 patients met inclusion criteria. 16 patients underwent full deformity correction, 58 underwent limited decompression and fusion, and 16 underwent decompression alone. Full deformity correction was associated with greater length of stay (p=0.461), greater blood loss (p=0.032) and greater operative time (p<0.0001). Full deformity correction was associated with an increased rate of complications (p<0.05) and re-operation (p<0.05). There was no significant difference between VAS for leg pain and ODI among the 3 groups in terms of improvement: however, full scoliosis correction significantly alleviated back pain more than the other groups, indicated by VAS change (full: 5.3±1.8, limited: 0.75±3.6, decompression: 1.0±5.4, p<0.05).

Conclusion
Although complete adult spinal deformity correction is associated with the greatest morbidity, there was also the greatest back pain improvement. However, limited decompression and fusion in highly selected patients primarily with leg pain may give comparable reduction in ODI and VAS leg pain scores compared to full correction.

Take Home Message
Limited decompression and fusion in highly selected patients primarily with leg pain may give comparable reduction in ODI and VAS leg pain scores compared to full correction.





Podium Presentations— Adult Spinal Deformity I

53. Cost Effectiveness of Adult Lumbar Scoliosis Surgery: An As-treated Analysis from the Adult Symptomatic Scoliosis Surgery Trial with Five Year Follow-up

Steven D. Glassman, MD; Leah Y. Carreon, MD; Christopher I. Shaffrey, MD; Michael P. Kelly, MD; Charles H. Crawford III, MD; Elizabeth L. Yanik, PhD; Jon D. Lurie, MD, MS; Shay Bess, MD; Christine Baldus, RN; Keith H. Bridwell, MD

Summary
This as-treated analysis demonstrates that surgery for adult symptomatic scoliosis becomes favorable compared to non-operative treatment at year-three post-op, one year earlier than suggested by a previous intent-to-treat analysis.

Hypothesis
Operative treatment for Adult Symptomatic Lumbar Scoliosis (ASLS) is more cost-effective than non-operative treatment.

Design
Secondary analysis of data from the NIH sponsored study on ASLS that included randomized and observational arms.

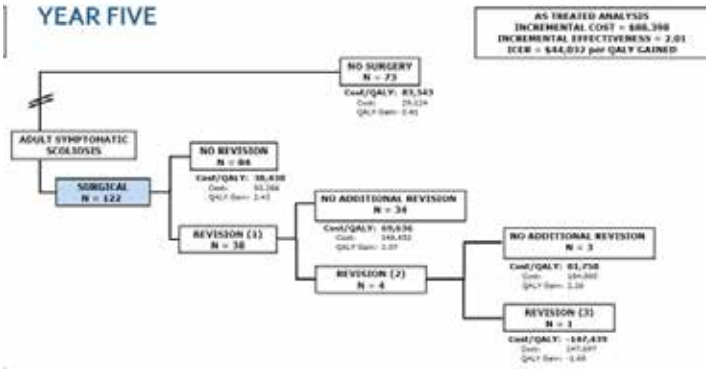
Introduction
The purpose of this study is to report on the cost-effectiveness of surgical versus nonsurgical treatment for Adult Symptomatic Lumbar Scoliosis (ASLS) using the as-treated data and provide a comparison to previously reported intent-to-treat (ITT) analysis.

Methods
Patients with at least five-year follow-up data within the same treatment arm were included. Data collected every three months included use of nonoperative modalities, medications and employment status. Costs for surgeries and non-operative modalities were determined using Medicare Allowable rates. Medication costs were determined using the RedBook and indirect costs were calculated based on reported employment status and income. Quality Adjusted Life Years (QALY) was determined using the SF-6D.

Results
Of 286 patients enrolled, 195 patients (73 Non-op, 122 Op) met inclusion criteria. At five years, 29 (24%) patients in the Op group had a revision surgery of whom two had two revisions and one had three revisions. The cumulative cost for the Op group was $111,451 with a cumulative QALY gain of 2.29. The cumulative cost for the Non-Op group was $29,124 with a cumulative QALY gain of 0.41. This results in an ICER of $44,033 in favor of Op treatment.

Conclusion
This as-treated cost effectiveness analysis demonstrates that surgical treatment for adult lumbar scoliosis becomes favorable at year-three, one year earlier than suggested by a previous intent-to-treat analysis.

Take Home Message
In well-selected patients, surgical treatment for symptomatic adult scoliosis can be cost-effective. Cost-effectiveness depends upon durability of clinical benefit and avoidance of revision surgery.



54. Adverse Events Occurring up to 5-years After Complex Adult Spinal Deformity Surgery: A Scoli-Risk-1 Analysis

Meghan Cerpa, MPH; Scott Zuckerman, MD; Lawrence G. Lenke, MD; Zeeshan M. Sardar, MD; Eric Leung, BS; Meghana Vulapalli ; Joseph M. Lombardi, MD; Ferran Pellisé, MD, PhD; Khaled M. Kebaish, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Yukihiro Matsuyama, MD, PhD; Leah Y. Carreon, MD; Yong Qiu, MD; Kenneth Cheung, MD, MBBS, FRCS; Michael P. Kelly, MD; Ames P. Christopher, MD; Frank J. Schwab, MD; Oheneba Boachie-Adjei, MD

Summary
Following complex ASD surgery at 5-years postoperative, 77.9% of patients experienced an adverse event (AE). Of patients with an AE, 20.2% had a severe complication, while 59% of patients that experienced an AE required surgical treatment. 75.9% of neurologic deficits were transient and improved over time. Common etiologies for neurologic AEs were nerve root retraction, compression, direct injury, and distraction. Most common spine complication in years 2-5 was implant failure, followed by sensory and motor deficit.

Hypothesis
Prospectively evaluate neurologic and non-neurologic adverse events (AEs) occurring up to 5-yrs postop following surgical correction of complex ASD

Design
Prospective/multicenter/international/observational, Scoli-Risk-1

Introduction
Surgical treatment for complex adult spinal deformity (ASD) is associated with a variety of postop complications. Rates of periop complications following complex ASD surgery are well established, while reports of long-term postop complications remain unclear

Methods
272 ASD pts undergoing surgery from 15 centers were enrolled. Inclusion criteria: Cobb>80, corrective osteotomy for congenital or revision deformity, and/or 3-column osteotomy (76% of all

pts.). At each f/u visit any neurologic or non-neurologic AE was documented & categorized

Results

Of the 272 pts., f/u rates were: 271 (99.6%) discharge, 260 (95.6%) 6-weeks, 255 (93.8%) 6-months, 217 (79.8%) 2yr, and 77 (28.3%) 5yrs. By 5yrs postop, 212/272 pts. (77.9%) experienced an AE. Of those that experienced an AE, 20% had a severe AE, 24% mild, and 33% moderate. A total 190/272 (69.9%) experienced a non-neurologic AE & 101(37%) experienced a neurologic AE. Of all pts with complications, conservative management or no action was taken in 87 pts. (41%), whereas 125 (59%) of the pts. that experienced AEs required some form of surgical treatment (either revision spine or other surgery). 3 deaths occurred, none of which were directly related to surgery: ileus 3.2 months postop, cardiac arrest 9.8 months postop, &suicide 1.2 yrs postop. Specifically in the 2-to 5yr period, a total of 58 complications occurred that were related or possibly related to surgery, including: 27(47%) implant failure, 6(10%) sensory deficits, 3(5%) loss of correction, 3(5%) cord/motor deficits, and 2(3%) deep infections

Conclusion

At 5yrs postop following complex ASD surgery with prospective assessment, 77.9% of pts. experienced an AE, with 20% having a severe complication and 59% requiring surgical treatment either spine or non-spine. 75.9% of neurologic deficits were transient and improved over time. The most common spine complication in yrs 2-5 was implant failure, followed by motor and sensory deficit

Take Home Message

5-years postoperative ASD surgery, 77.9% patients experienced an AE. The majority of neurologic deficits were transient and improved. Most common complications between 2-5years being implant failure and sensory/motor deficit.

Podium Presentations—Hibbs Basic Research Award Nominees

55. Genetic Prediction of Onset and Progression of Adolescent Idiopathic Scoliosis

Nao Otomo, MD; Kazuki Takeda, MD, PhD; Yoji Ogura, MD, PhD; Yohei Takahashi, MD, PhD; Shohei Minami, MD, PhD; Koki Uno, MD, PhD; Noriaki Kawakami, MD, PhD; Manabu Ito, MD, PhD; Kei Watanabe, MD, PhD; Takashi Kaito, MD, PhD; Hiroshi Taneichi, MD, PhD; Katsumi Harimaya, MD, PhD; Yuki Taniguchi, MD, PhD; Hideki Shigematsu, MD, PhD; Takahiro Iida, MD, PhD; Satoru Demura, MD, PhD; Ryo Sugawara, MD, PhD; Nobuyuki Fujita, MD, PhD; Mitsuru Yagi, MD, PhD; Eijiro Okada, MD, PhD; Naobumi Hosogane, MD, PhD; Kazuhiro Chiba, MD, PhD; Toshiaki Kotani, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Tsutomu Akazawa, MD, PhD; Teppei Suzuki, MD, PhD; Kotaro Nishida, MD, PhD; Kenichiro Kakutani, MD, PhD; Taichi Tsuji, MD, PhD; Tatsuya Sato, MD, PhD; Satoshi Inami, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Shiro Ikegawa, MD, PhD; Chikashi Terao, MD, PhD; Kota Watanabe, MD, PhD

Summary
We constructed polygenic risk score (PRS) based on genome-wide association study (GWAS) results and tried to predict onset and progression of adolescent idiopathic scoliosis (AIS). The PRS was beneficial for predicting the onset and severity of AIS.

Hypothesis
Considering high heritability of AIS, genetic prediction of onset and progression in AIS would be reasonable.

Design
Prospective multi center cohort study

Introduction
The previous attempt in US to predict AIS progression based on ~50 SNPs failed to be replicated. Recent studies have revealed that polygenic architecture confers a major part of heritability in most common diseases including AIS, suggesting usefulness of PRS in AIS.

Methods
We constructed, validated and tested the PRS in the following steps using three GWAS data sets. First, a total of 20 PRSs based on different thresholds of GWAS p-values were derived from the training set (Case: 3028, Control: 26064). We determined the best threshold (PT) in the validation set (Case: 722, Control: 3409). Lastly, reproducibility of PRS prediction ability was confirmed in test set (Case: 1254, Control: 1286). Next, we meta-analyzed these three datasets and generated another PRS to fit Cobb angle in the similar manner to AIS susceptibility. We compared the PRS between The difference between progression group (defined by Cobb angle more than 40 degree) and non-progression group (defined by Cobb angle less than 20 degree).

Results
The PRS (with p-value of 0.5 as a threshold) was significantly associated (p = 3.10 x 10-37) with AIS susceptibility with the AUC of 0.646 (95% CI, 0.624-0.667) in the test set. OR in the top decile of PRS were up to 9.41 (p=2.67 × 10-27) compared to lowest decile. When we include male subject and added gender information as covariate, the AUC improved to 0.8. We observed moderate to strong genetic correlation between AIS susceptibility and Cobb angle (rg=0.6, p=3×10-4). The PRS (with p-value of 0.01 as a threshold) demonstrated a good performance to distinguish the progression group from non-progression group with the AUC of 0.627 (95% CI 0.551-0.704) in the test set.

Conclusion
We successfully constructed PRS of susceptibility and progression of AIS. To improve our PRS, identification of further genetic factors and environmental factors are needed.

Take Home Message
The onset and progression of AIS can be genetically predicted by common variants.

56. Correlation of Collagen X Biomarker (CXM) with Peak Height Velocity and Radiographic Measures of Growth in Idiopathic Scoliosis

Michelle C. Welborn, MD; Ryan Coghlan, MS; James O. Sanders, MD; Vishwas R. Talwalkar, MD; Amer F. Samdani, MD; Joseph Stone, MD; Daniel Bouton, MD; William Horton, MD; Susan Sienko, PhD

Summary
Current techniques assessing pediatric growth status have minimum >6month standard error (SE). Mid-term results indicate CXM is a patient-specific real time measure of growth velocity that is highly reproducible with low SE

Hypothesis
Our hypothesis is that higher levels of CXM would correlate with rapid longitudinal bone growth while lower CXM levels will indicate growth cessation

Design
IRB approved Prospective Comparative Study

Introduction
Assessment of growth in pediatric patients with spinal deformity is critical. Current techniques poorly predict growth and have a large SE. Type X collagen is produced in the growing physis during enchondral ossification. CXM is a breakdown product from type X collagen that can be measured in serum. CXM is thus a direct measure of enchondral ossification

Methods
Q6mo anthropometrics and spine PA biplanar slot scanner images including the hand were assessed for major curve magnitude, Risser score (RS) and Sanders Stage (SS). Longitudinal serial Dried Blood Spots (DBS) were collected on 3 consecutive days Q1-2months based on SS to obtain CXM levels

Results
68 patients (25 M, 43 F) with idiopathic scoliosis, Cobb ≥20 were enrolled. Mean age at enrollment was 12.18 years (range 7.02-16.54 years). CXM levels were assayed in quadruplicate for a total of 5137 samples. CXM results were highly reproducible

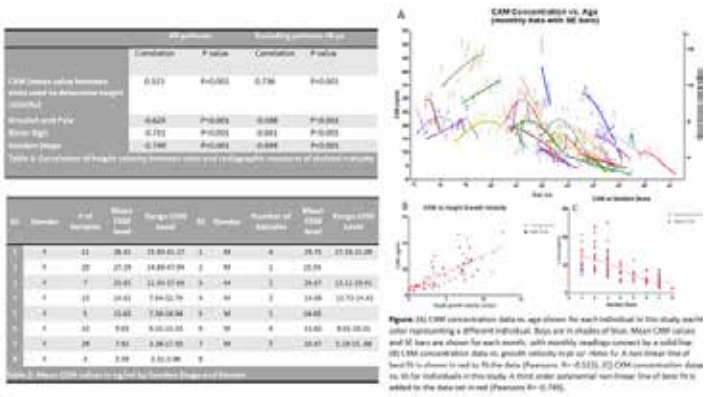
with an intraassay coefficient of variation of 3%, and interassay of 12%. CXM 3-day average Pearson correlation coefficients was significantly correlated with RS R= -0.711, p<0.001, SS R= -0.749, p<0.001, Greulich and Pyle R=-0.629, p<0.001 and with height R= -0.523, p<0.001. No patient with a CXM level <5ng/ml had remaining growth

Conclusion

CXM is the first biomarker specific to longitudinal bone growth. Early results indicate it is a patient-specific, real time measure of growth velocity with highly correlated to the established anthropometric and radiographic measures of growth. Furthermore, it appears to be predictive of cessation of growth. It is highly reproducible with a low SE. Longer term follow-up is required to determine the ability of CXM to help guide clinical decision-making

Take Home Message

CXM is a direct measure of enchondral ossification. Mid-term results indicate it is a patient-specific real time measure of growth velocity



57. Does Implant Density Matter in the Surgical Outcomes of Severe Kyphoscoliosis Exceeding 100 Degrees or Treated by 3CO?

Oheneba Boachie-Adjei, MD; Henry Ofori Duah, MPH; Arthur Sackeyfio, MD; Kwadwo Poku Yankey, MD; Lawrence G. Lenke, MD; Paul D. Sponseller, MD; Amer F. Samdani, MD; Daniel J. Sucato, MD, MS; Brenda A. Sides, MA; Peter O. Newton, MD; Suken A. Shah, MD; Harry Akoto, MD; Munish C. Gupta, MD; Fox Pediatric Spinal Deformity Study

Summary

A review of complex pediatric spine deformity patients with curves > 100deg or treated with 3CO showed that regardless of curve type and etiologies, implant density >1.5 provides better coronal curve correction and has lower implant related complications and revision rates. Improvement in SRS scores was achieved in all patients regardless of implant density

Hypothesis

Implant density has no effect on implant related complications in complex pediatric spine reconstruction

Design

Prospective observational multi center cohort

Introduction

Implant density in spine deformity surgery has been a subject of much debate with some authors advocating higher density for better correction. Few studies have looked at the effect of implant density on severe curves > 100 deg or treated with 3CO.

Methods

250/311 pts with 2-year f/u enrolled in the FOX pediatric database from 17 international sites were queried for the impact of implant density and surgical outcomes. Patients were grouped into three implant density categories for comparative analysis (Group 1 (density ≤ 1) vrs. Group 2(1<density<1.5) and Group 3(density; 1.5-2)

Results

250 pts: 47 (Grp1) / 99 (Grp2) /104 (Grp3); Pre-op age and etiology and curve types were similar in all groups, but BMI was sig. higher in Grp3. Preop HGT was used in 55.32% / 44.44 % / 31.73%, p=0.017; Grp1/ Grp2/Grp3,respectively. Average duration of surgery (min) was sig. higher in Grp3 relative to Grp1 only: 352.45 / 456.46 / 514.96, p= 0.0029. EBL was similar in all Grps. Rate of VCR, PSO and SPO was similar in all Grps. Mean pre-op Cor. Cobb avg 96.08 / 83.59 / 88.56, p= 0.2342, attained similar Cor. correction after HGT (24.59% / 27.21% / 23.24%, p=0.4864. Cor. cobb correction at 2y FU were (37.08% / 40.32% / 53.52%, p=0.0004. Pre-op sag cobb was (105.38 / 101.94 / 75.85, p< 0.01.), achieved similar %correction in HGT (19.09 % / 22.31% / 22.54%, p=0.6851) and at 2yr FU (39.56% / 41.37% / 29.84%, p=0.1916). Implant related complication rates were 25.53% / 11.11% / 2.88% with associated revision rates of 23.40% /9.09%/1.92% ,respectively (p<0.05).There was significant improvement in SRS scores within all Grps at 2yr FU

Conclusion

The use of higher implant density is beneficial in obtaining better post op coronal curve correction in severe pediatric spine reconstruction and has lower implant related complications and revision rate. Implant density had no effect on sagittal Cobb as well as the post op SRS scores

Take Home Message

Regardless of curve type and etiologies in severe spinal deformities, implant density >1.5 provides better coronal curve correction and has lower implant related complications and revision rates

Cumulative Incidence of implant related complications and reoperation rates comparing patient groups of different implant densities

	Group 1: n=47 Implant density ≤ 1	Group 2: n=99 1<density<1.5	Group 3: n=104 Implant Density 1.5-2	P-value
Implant Related Complications	12(25.53%)	11 (11.11%)	3(2.88%)	P<0.001
Reoperations rate	11(23.40%)	9 (9.09%)	2(1.92%)	

Implant complication [Failure,PJK,DJK,broken Rod, Deformity progression etc.]

Implant related complications and reoperation rates by implant density

Podium Presentations—Hibbs Basic Research Award Nominees

58. A Novel Imaging Study to Quantify Respiratory Function in Early Onset Scoliosis - Introducing Quantitative Dynamic Magnetic Resonance Imaging (QdMRI)

Yubing Tong, PhD; Jayaram K. Udupa, PhD; Joseph M. McDonough, MS; Caiyun Wu, MS; Catherine Qiu, MS; Carina Lott, MS; Nirupa Galagedera, BA; Jason B. Anari, MD; Drew A. Torigian, MA; *Patrick J. Cahill, MD*

Summary
Currently, there is no passive imaging modality to measure pulmonary function. Furthermore, spirometry, the current gold standard for pulmonary function measurements, does not provide information about the relative input contribution from regional components of ventilation such as left and right chest wall and diaphragm. QdMRI technique explores this in early onset scoliosis patients. Fifteen volumetric parameters from QdMRI technique are derived for 30 patients. We demonstrate a response to treatment with surgery and a correlation with spirometry.

Hypothesis
QdMRI is an imaging study that can measure pulmonary function and can also provide more granular information about the regional contributions to lung function.

Design
Retrospective cohort study

Introduction
Current gold standards for pulmonary function include spirometry testing which requires patients to have maturity and mental capacity to participate. Ideally, an imaging study would be able to provide quantitative information about pulmonary function independent of patient participation. Pulmonary function testing (PFT) can infer global thoracic function, but cannot provide regional data for individual lung, chest wall, and hemidiaphragm function. In this study, we attempt to correlate QdMRI with spirometry and to demonstrate the responsive of QdMRI to surgical intervention in early onset scoliosis patients (EOS).

Methods
Images from free-breathing dynamic MRI in 30 EOS patients were retrospectively evaluated before and after surgery. Lung volumes and excursion (or tidal) volumes of the left/right chest walls and hemidiaphragms are calculated based on segmentation from 4D constructed images via QdMRI. 15 volumetric parameters in total were derived for statistical comparison via paired Student t-test. Pearson correlation between lung volumes and functional residual capacity (FRC) from PFT is also estimated.

Results
Left and right lung volumes at end inspiration and end expiration increased substantially after surgery, especially right lung volume with 30.74% and 32.68% volume increase at end expiration (p< .001) and end inspiration (p< .001), respectively. Average lung tidal volumes increased after surgery, with 47.74% and 70.47% increase for left lung tidal volume (p=.001) and right lung tidal volume (p< .001), respectively. FRC was highly correlated with lung volumes from QdMRI, with correlation coefficient 0.80 between FRC and end expiratory lung volume (p< .001).

Conclusion
Rib-based distraction surgery was associated with post-surgical increases in all components of tidal volume measured via thoracic QdMRI. FRC was highly correlated with lung volume measures from QdMRI.

Take Home Message
QdMRI is a valid assessment tool for pulmonary function that quantifies overall lung function and elucidates the regional contributions to the respiratory cycle. It is highly correlated with spirometry.

Table 1. Descriptive statistics related to thoracic quantitative dynamic MRI parameters. All volumes are in ml.

	Pre-surgery	Post-surgery	Average increase in volume (%)	p Value
Age (y)	4.9 ± 4.2	8.6 ± 4.5	n.a.	.12
Left lung volume at end inspiration	256.24 ± 240.54	307.02 ± 213.80	19.82	.008
Right lung volume at end inspiration	277.68 ± 242.66	368.43 ± 235.77	32.68	< .001
Bilateral lung volume at end inspiration	533.92 ± 482.40	675.46 ± 447.74	26.51	.001
Left lung volume at end expiration	178.07 ± 148.94	214.33 ± 139.50	20.36	.008
Right lung volume at end expiration	192.28 ± 157.89	251.38 ± 156.81	30.74	< .001
Bilateral lung volume at end expiration	370.35 ± 305.61	465.71 ± 294.65	25.75	< .001
Left lung tidal volume	20.87 ± 15.47	30.83 ± 19.42	47.74	.001
Right lung tidal volume	32.75 ± 22.02	55.82 ± 28.54	70.47	< .001
Bilateral lung tidal volume	53.61 ± 32.81	86.65 ± 43.06	61.63	< .001
Left hemidiaphragm tidal volume	8.71 ± 7.14	14.76 ± 11.92	69.44	.006
Right hemidiaphragm tidal volume	16.91 ± 12.90	34.48 ± 21.01	103.88	< .001
Bilateral hemidiaphragm tidal volume	25.63 ± 17.30	49.25 ± 29.48	92.18	< .001
Left chest wall tidal volume	12.15 ± 9.81	16.07 ± 9.96	32.19	.02
Right chest wall tidal volume	15.83 ± 10.39	21.32 ± 11.11	34.78	.01
Bilateral chest wall tidal volume	27.99 ± 17.66	37.40 ± 18.03	33.65	.001

59. Prospective Study of Intraoperative MEP Monitoring to Identify Lumbosacral Nerve Root Motor Deficits

Kelley McGowan, BS; Hyunmi Choi, MD; Anil Mendiratta, MD; Earl D. Thuet, BS; Paul Kent, MD; Meghan Cerpa, MPH; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Summary
In a prospective cohort study of 328 thoracolumbar spinal surgeries, EP (MEP+/-SEP) responses reached warning criteria indicative of nerve root dysfunction in 44 patients (13%). Postop exam within the first 24 hours demonstrated 25 patients (7.6%) had new onset of weakness attributable to nerve root dysfunction. Adjusted logistic regression analyses showed that EP status at closure was an independent predictor, with unimproved EP change significantly more likely to be associated with neurological deficit.

Hypothesis
Intraoperative MEP changes can predict post-op deficits

Design
Prospective

Introduction
The reliability of nerve root monitoring has not been demonstrated

Methods
This was a prospective cohort study of 328 patients over a 12-month period. The primary outcome was a binary variable

of new deficit detected post-op within the first 24 hours. Six independent variables (Table 1) were considered as potential predictors of outcome. Bivariate logistic regression was used to estimate the unadjusted association between potential predictive factors and neurological outcome (Table 1). Stepwise multivariate logistic regression was then used to determine which factors were independent predictors for postop neuro deficit.

Results

Of 328 patients, EP changes occurred in 44 patients (13%). Twenty-five patients (7.6%) had new onset of weakness detected during the first 24 postop period. As seen in Table 1, notification of EP change, type of data change, and data at closure were associated with postop weakness. Of 44 patients with EP data change, 32 did not improve by closure with 23 developing new weakness. On the other hand, of 44 patients with EP data change, 12 improved by closure with 2 developing new weakness. Compared to those with EP improvement at closure, patients without improvement in EP were significantly more likely to have postop weakness (adjusted OR 12.8, 95% CI 2.22 - 70.12).

Conclusion

During thoracolumbar spine surgeries, EP nerve root warnings occurred in 13% of patients. EP change that did not improve by closure was an independent predictor of postop neurological weakness.

Take Home Message

In a prospective cohort study of thoracolumbar spine surgery, EP change that did not improve by closure of surgery was an independent predictor of lumbosacral nerve root motor deficits.

Table 1. Unadjusted logistic regression examining relationship between new neuro deficit and potential predictors

Covariate		N	P-value
Age		Mean 59.3 (SD 16.0)	0.58
Sex			
	M	138	0.138
	F	190	
Surgery Type			0.76
	Lumbar decompression	4/67 (6%)	
	Lumbar instrumentation	9/129 (7%)	
	Thoracolumbar instrumentation	12/132 (9%)	
Notification of change			<0.0001
	No	6/290 (2%)	
	Yes	19/38 (50%)	
Type of data change			<0.0001
	No change	0/284	
	MEP and SEP	9/12 (75%)	
	Only MEP	15/31 (49%)	
	Only SEP	1/1 (100%)	
Data at closure			<0.0001
	No change throughout case	0/284	
	Improved by closure	2/12 (17%)	
	Not improved by closure	23/32 (72%)	

Table 1. Unadjusted logistic regression examining relationship between new neuro deficit and potential predictors

Podium Presentations—Hibbs Clinical Research Award Nominees

60. Moderate Scoliosis Continues to Progress at 30 Year Follow-up: A Call for Concern?

Christopher Alcala, MD; Amir A. Mehbod, MD; Francis Denis, MD; Timothy A. Garvey, MD; Joseph H. Perra, MD; Ensor E. Transfeldt, MD

Summary
Adolescent idiopathic scoliosis (AIS) curves between 30 and 50° at skeletal maturity tend to progress. Thoracic curves progress faster during the first 20 years; progression then slows down. The opposite happens with lumbar curves. Progression rate decreases with thoracic and increases with lumbar curves. Patients are not functionally limited as indicated by Oswestry Disability Index, SF-36, and Roland-Morris.

Hypothesis
AIS curves between 30 and 50° at skeletal maturity tend to progress

Design
Natural History; Level 3

Introduction
Describe the natural history of moderate AIS curves at skeletal maturity

Methods
We studied AIS patients with moderate curves (30 to 50°). X-rays and charts at 20 and 30 years' follow-up were compared to status at skeletal maturity.

Results
We followed 31 patients. Average age was 17±2y at skeletal maturity. Mean follow-ups were 22±6y and 34±6y. Average ages at these time points were 39±7y and 51±7y. At skeletal maturity, thoracic cobb=35±5°, thoracic kyphosis=20±11°, lumbar cobb=33±7°, and lumbar lordosis=42±8°. At first follow up, thoracic cobb=43±10, thoracic kyphosis=32±13, lumbar cobb=42±15, and lumbar lordosis=51±17. At second follow up, thoracic cobb=47±12, thoracic kyphosis=33±13, lumbar cobb=40±17, and lumbar lordosis=46±8. Thoracic curves changed more rapidly the first 20y and slower over the next 10y. The opposite was true for lumbar curves. From 0-20y, thoracic kyphosis and thoracic cobb progressed 0.5 and 0.4°/y; from 20-30y, these angles changed 0.2 and 0.1°/y. From 0-20y, lumbar lordosis and lumbar cobb progressed 0.1 and 0.3°/y; from 20-30y, these angles changed -0.7 and 0.5°/y. The average change was less than 1°/y in all patients. Functional outcomes were good at 20 and 30y follow-up. ODI scores were 7 at 20y and 8 at 30y. SF-36 domains improved 1% on average between 20 and 30y. The average Roland-Morris scores were 2.6 at 20y and 2.7 at 30y. Pain scores did not change: VAS-B and VAS-L scores were 2 and 0 at 20y and 2 and 1 at 30y.

Conclusion
Moderate AIS curves at skeletal maturity tend to progress. Thoracic curves progress more than lumbar curves during the first 20 years and then slow down. The opposite happens with lumbar curves, in addition to loss of lordosis. ODI, SF-36, and Roland-Morris scores suggest patients are functionally good at 20 and 30y follow-up despite curve changes. More follow up is needed to define the true outcome of moderate curves at maturity.

Take Home Message
AIS curves progress between 20 and 30 years' follow-up without important clinical sequelae. Some patients may need to be observed for a longer time for potential issues.

61. Complications Following Posterior Surgical Treatment of Adolescent Idiopathic Scoliosis: Prospective 10-year Follow-up Study

Arun R. Hariharan, MD; *Suken A. Shah, MD*; Margaret Baldwin, MD; Joseph Petfield, MD; Burt Yaszay, MD; Peter O. Newton, MD; Baron Lonner, MD; Firoz Miyanji, MD; Paul D. Sponseller, MD; Amer F. Samdani, MD; Harms Study Group

Summary
The goal of this study was to report on complication prevalence, re-operation rates and causes in this patient cohort undergoing posterior surgery for AIS, followed for at least 10 years. Results show there is a 12% complication rate and 8.6% re-operation rate over long term follow up after posterior surgery for AIS; this data is important for patient counseling. Complications such as infection and adding-on present even after the 5-year visit; therefore, long-term follow up of these patients is critical.

Hypothesis
In patients with AIS who undergo posterior spinal fusion (PSF), at 10-year follow up, the most common complications are surgical site infection (SSI) and adding-on.

Design
Retrospective review of prospectively collected data from a multicenter database registry

Introduction
Accurate reporting of long-term complications of surgical treatment of AIS is important, but lacking. The purpose of this study is to report on the rate of complications following surgical treatment of AIS among patients with at least 10 years of follow-up.

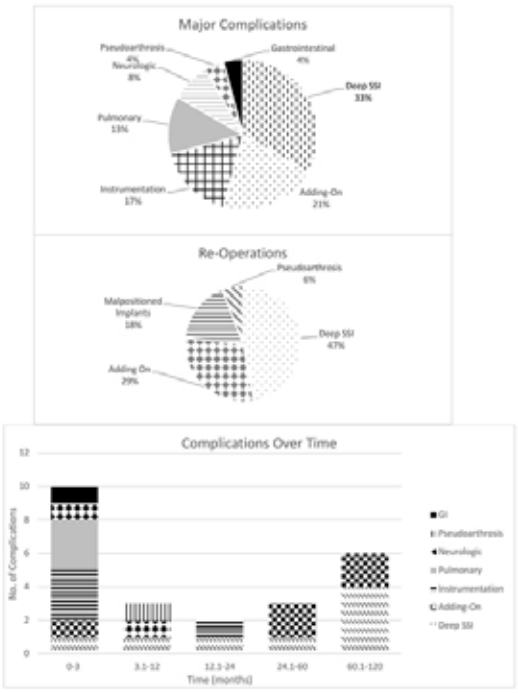
Methods
Retrospective review of prospectively collected data from a multicenter registry of patients who underwent PSF for AIS with minimum 10-year follow-up. From a previous publication, a complication was defined as major if it resulted in reoperation, prolonged hospital stay, SCI/nerve root injury, or was considered life-threatening. Rates and causes of re-operations were also reviewed.

Results
197 patients were identified and had a mean age at surgery of 14.7 +/- 2.2 years. Mean follow up period was 10.5 years (9.5-13.5 years). The majority of patients (88%) had constructs consisting of more than 80% screws. The overall major complication rate was 12.2% (n= 24) in 19 patients. When analyzed by system, 33% (n=8) were SSI, 21% (n=5) were adding-on, 17% (n=4) were

malpositioned implants, 13% (n=3) were pulmonary, 8% (n=2) were neurologic, 4% (n=1) pseudarthrosis, and 4% (n=1) gastrointestinal (see Figure). The re-operation rate was 8.6% (n=17) in 16 patients; 47% (n=8) for SSI, 29% (n=4) for adding on, 17% (n=3) for malpositioned implants, and 6% (n=1) for pseudoarthrosis (see Figure). Complications presented throughout the post-operative period; SSI and adding on were seen even late into the 10-year period (see Figure).

Conclusion
This is the largest study of complications and re-operations following PSF for AIS with at least 10-year follow up. There was an overall complication rate of 12.2% and re-operation rate of 8.6%. Complications presented throughout the 10-year period making long-term follow up critical.

Take Home Message
Surgery for AIS has a 12% rate of complications and 8.6% rate of re-operations over 10 years; and, many complications can present even late into the 10-year period.



Complications, Reoperations, and Complications in Relation to Time

62. Comparison of Clinical and Functional Outcomes of Vertebral Body Tethering to Posterior Spinal Fusion in Patients with Adolescent Idiopathic Scoliosis and Evaluation of Quality of Life

Tuna Pehlivanoglu, MD; Ismail Oltulu, MD; Emre Korkmaz, MD; Yigit Erdag, MD; Ender Sarioglu, MD; Ender Ofluoglu, MD; Mehmet Aydogan, MD

Summary
In skeletally immature patients with AIS, VBT as a result of the utilization of growth modulation was able to yield significantly superior lumbar range of motion, lumbar anterior and lateral flexibility, trunk flexor-extensor endurance and trunk motor strength as compared to patients who underwent fusion. It was also detected, that by yielding significantly superior SRS-22 and SF-36 scores, VBT was able to provide better life quality and satisfaction than fusion. These data were reported for the first time in the literature.

Hypothesis
Vertebral body tethering (VBT) might yield better clinical and functional outcomes, in addition to better quality of life in skeletally immature patients with AIS.

Design
Retrospective, comparative.

Introduction
Fusion is still proposed as the gold standard treatment modality in AIS, while VBT by utilizing growth modulation, preserving spinal motion and avoiding complications of fusion was shown to have promising results in skeletally immature patients. This study was aimed to present the results of the comparison of clinical and functional outcomes of these two techniques for the first time in the literature.

Methods
21 patients (average age/average pre-op major curve flexibility/pre-op-at the latest follow-up major curve magnitude:11.1/41.2%/48.2-9.1), who underwent thoracolumbar (T4-L4) VBT; and 22 patients (average age/average pre-op curve flexibility/pre-op-at the latest follow-up major curve magnitude:10.9/31.2%/48.8-9.7), who underwent thoracolumbar posterior (T3-L3) fusion were enrolled (p=0.27/0.3/0.31-0.24). VBT Group was chosen from our recent VBT study with at least 3 years of FU, while group 2 was chosen from our posterior fusion series as age-gender-fusion level and minimum FU duration matched. Average FU duration of group 1 and 2 were 37.1/37.8 months (p=0.33).

Results
VBT Group was detected to have superior lumbar range of motion; superior anterior–lateral lumbar bending flexibility; superior flexor and extensor endurances of trunk, superior average motor strength of trunk muscles, superior average total SRS-22 and average SF-36 MCS/PCS scores than fusion with high statistical significance (Table 1/Fig1).

Conclusion
This study for the first time in the literature reported, that in skeletally immature patients with AIS, VBT as a result of the utilization of growth modulation was able to yield significantly superior lumbar range of motion, lumbar anterior and lateral flexibility, trunk flexor-extensor endurance and trunk motor strength in addition to significantly superior SRS-22 and SF-36 scores, indicating better life quality and satisfaction.

Take Home Message
In skeletally immature patients with adolescent idiopathic scoliosis, vertebral body tethering was detected to yield better clinical and functional outcomes, in addition to better quality of life.

Podium Presentations—Hibbs Clinical Research Award Nominees

Table 1

	Average Lumbar ROM (°)				Average Lumbar Bending Flexibility (cm)		Average Trunk Endurance (sec)		Average Motor Strength of Trunk Muscles	Average Total SRS-22	Average SF-36	
	Flex.	Ext.	Lat. Bend.	Rot.	Ant.	Lat.	Flex.	Ext.	Extensor-Ant/Lat/ Obl Flexor		MCS	PCS
VBT Group	78.2	34.6	34.4	45.4	3.7	22.4	65.1	60.8	4.7	4.9	56.9	57.2
Fusion Group	58.1	19.4	18.3	24.1	23.4	11.3	19.2	28.7	3.2	3.3	52.3	53.1
p - value	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	0.003	<0.001	<0.001	<0.001

Table 1/Fig 1

63. Anterior Vertebral Body Tethering in Idiopathic Scoliosis: a Prospective, Multicenter Analysis

Firoz Miyanji, MD; Paul R. Rushton, FRCS; Isabelle Turgeon, BSc; Luigi A. Nasto, MD; Jeff Pawelek, BS; Stefan Parent, MD, PhD

Summary
Anterior growth modulation for the treatment of idiopathic scoliosis (IS) has been gaining global interest from both surgeons and patients. Minimal data however exists evaluating its clinical and radiographic outcomes. We present minimum 2-yr results in a prospective cohort of 124 patients treated with anterior vertebral body tethering (AVBT) at 2 independent centers and found the technique effective in preventing curve progression and 88% of patients maintained curve correction ≤ 35° at final f/u.

Hypothesis
AVBT prevents curve progression and maintains curve correction to ≤ 35° at minimum 2 yr f/u

Design
Prospective observational cohort

Introduction
AVBT is being increasingly explored, however majority of studies to date are small, single center series with limited f/u limiting our understanding on its efficacy, and complication rate. Our aim was to evaluate the clinical and radiographic outcomes as well as the complication rates in a large multicenter cohort to determine the efficacy and safety profile of AVBT in the treatment of IS.

Methods
A prospective, multicenter database was used to identify consecutive patients with IS treated with AVBT at 2 centers with ≥2 yr f/u. Clinical success was defined a priori as major coronal Cobb ≤35° and no fusion performed at most recent f/u(MRF).

Results
124 patients with 130 tethers had mean age of 12.7yrs and mean f/u of 35months(24-64).115 females and 9 males had mean preop Risser 0.5(0-3) and mean Sanders score 3.3±1.2.Risser at MRF was 3.9(0-5).There were 114 thoracic tethers,4 lumber and 6 double tethers. Mean OR time was 248min(110-760) and mean EBL was 5.2(0.5-18)ml/kg with no allogeneic blood transfusions. Mean preop thoracic major curve of 50.1°(31-81) corrected to 22.7°(3-57°) on first erect(FE) x-ray with significant further correction of the instrumented curve to 15.7°(-12-55°,p<0.01) at 1 yr f/u. At MRF loss of correction to mean 18.2° (-18-57) was noted. Lumbar tethers corrected from mean preop of 51.2°(45-65°) to mean 10.9°(3-20°) on FE with significant improvement at 1 yr(8.4°(-6-32°)) and MRF(5.2°(-29-32°)p<0.01).There were 32 complications (24.6%) in 17 patients requiring 21 reops(16.1%):6 conversion to fusion and 1 revision;5 for overcorrection;4 for adding-on;2 tether replacements;2 screw malposition with CSF leak; and 1 hemothorax.29 tether failures were suspected (22%) with associated loss of correction on average of 14.9±9.5 all of which occurred greater than 1 yr postop.

Conclusion
AVBT appears effective in maintaining major coronal cobb ≤35° in 88% of skeletally immature patients with IS. There is an associated 24.6% complication rate and 16.1% reop rate highlighting the importance of patient selection and long term f/u.

Take Home Message
AVBT appears to modulate spinal growth with 88% success rate of maintaining major coronal Cobb ≤35° at final f/u. Complications and tether failures are not infrequent and may compromise outcome.

Patient Demographics (N=124; 130 Tethers)				
Mean Age at Surgery (yrs)	12.7 ± 1.4			
Gender	M=7.3%; F= 92.7%			
Mean Sanders	3.3 ±1.2			
Risser Grade	0.5(0-3)			
Outcome Variables				
Mean Follow-up (mnths)	35(24-64)			
Mean OR Time (min)	248 ±(110-760)			
Mean Blood Loss (mL/kg)	5.2 (0.5-18)			
Length of Stay (days)	4.9(3-16)			
Clinical Success (Major Cobb curve ≤35°) (%)	88			
Radiographic Measures	**Pre-op**	**First Erect**	**MRF**	**p-value**
Mean Major Thoracic Cobb (°)	50.1(31-81)	22.7(3-57)	18.2(-18-57)	<0.001*
Mean Major Lumbar Cobb (°)	51.2(45-65)	10.9(3-20)	5.2(-29-32)	<0.001*
T2-T12 Kyphosis (°)	18.6± 11.5	15.3±11.5	21.4± 12.3	0.709
Tether Failure	29	Avg 14.9°±9.5° deformity progression		
Complications Requiring Reoperations (N=21)				
Conversion to Fusion	7			
Over-correction	5			
Adding-on	4			
Hardware Malposition	2			
Recurrent Hemothorax	1			
Tether Replacement	2			

* - indicates point at which a significant difference (p<0.05) found

64. Spring Distraction System to Correct Early Onset Scoliosis: 2 Year Follow-up Results From 22 Patients

Justin V. Lemans, MD; Sebastiaan P. Wijdicks, MD; René M. Castelein, MD, PhD; Moyo C. Kruyt, MD, PhD

Summary
This study investigated the Spring Distraction System (SDS), a novel growth-friendly instrumentation system that treats early onset scoliosis (EOS) by continuous distraction from a titanium spring. In primary patients, we showed a 50% curve correction that is maintained at latest follow-up. In these patients, spinal lengthening was maintained during treatment (15mm/year) without the need for intermittent distractions. Unplanned re-op-

erations were performed in 6/22 patients. Patients with a primary implantation performed slightly better than revision patients.

Hypothesis
The SDS provides adequate curve correction and spinal growth.

Design
Prospective case series.

Introduction
Current surgical treatment of EOS is performed with either Traditional- or Magnetically Controlled Growing Rods, which are distracted periodically and have a high complication rate. We developed the SDS, which uses a compressed spring to continuously correct the curve while stimulating spinal growth. It does not have to be periodically lengthened. This study aimed to establish efficacy and safety of SDS.

Methods
All primary (P) and revision (R) patients (conversion from other systems) who were implanted with SDS and with ≥2 years follow-up were included. Data on demographics, surgical parameters and complications were prospectively collected. Main coronal curve angle, L1-S1 lordosis, T5-T12 kyphosis, T1-T12-, T1-S1 spinal length (measured curve through the midpoint of each endplate) and spring length increase were measured. Length increases (from post-op to latest follow-up) were expressed in mm/year. Results were compared between primary- and revision patients.

Results
We included 22 patients (10 boys; 12 girls, 16 P; 6 R) with a mean of 2.3±0.3 year follow-up. There were 4 idiopathic, 7 congenital, 2 syndromic and 9 neuromuscular curves. Mean age at implantation was 8.2±2.0 and 11.2±1.8 years for primary and revision patients respectively. In primary patients, main coronal curve was reduced from 66° to 34°, and was maintained at latest follow-up. For revision cases, main curve decreased from 46° to 42° but increased during follow-up. T5-T12 kyphosis increased in both groups (P:+8°, R:+8°). Mean spring length increase during follow-up was 11mm/year. Both groups had similar increases in T1-S1 length (P:15mm/yr, R:15mm/yr), instrumented length increase (P: 12mm/yr, R: 8mm/yr) was slightly higher in primary patients. In 6/22 patients, one or more re-operations were necessary due to complications. In 4/22 (18%) patients, spinal growth exceeded expected growth velocity; their springs were retensioned.

Conclusion
In primary patients, SDS provided 50% curve correction and high T1-S1 growth (15mm/year). Revision patients performed slightly worse.

Take Home Message
SDS may be an effective treatment for early onset scoliosis to control the curve and guide spinal growth without the need for repetitive distractions.

	Primary cases (N=16)			Revision cases (N=6)		
	Pre-operative	Post-operative	Latest follow-up	Pre-operative	Post-operative	Latest follow-up
Main curve (°)	66 (±16)	34 (±12)	36 (±17)	46 (±20)	42 (±25)	50 (±25)
Secondary curve (°)	35 (±15)	22 (±15)	23 (±13)	24 (±7)	25 (±9)	24 (±7)
T5T12 length (mm)	168 (±25)	195 (±24)	214 (±35)	209 (±26)	214 (±28)	232 (±30)
T1S1 length (mm)	315 (±40)	326 (±37)	360 (±46)	348 (±31)	356 (±32)	389 (±38)
Instrumented length (mm)	NA	255 (±45)	282 (±56)	NA	270 (±36)	270 (±36)
Spring length increase (mm)	NA	NA	25 (±15)	NA	NA	20 (±10)
L1-S1 lordosis (°)	48 (±14)	42 (±11)	48 (±20)	53 (±14)	51 (±13)	57 (±13)
T5-T12 kyphosis (°)	19 (±23)	18 (±13)	26 (±12)	33 (±14)	34 (±24)	44 (±25)
Complications requiring re-operations		6			2	
Hyperkyphosis		1			1	
Connector failure		1			1	
Anchor failure		2			0	
Rod fracture		1			0	
Deep Surgical Site Infection		1			0	
Retensioning of the spring		1			1	

Table 1: Results

65. Operative versus Nonoperative Treatment for Adult Symptomatic Lumbar Scoliosis at 5-6 Year Follow-up: Outcomes and Impact of Related Serious Adverse Events

Justin S. Smith, MD, PhD; Michael P. Kelly, MD; Elizabeth L. Yanik, PhD; Christine Baldus, RN; Thomas J. Buell, MD; Jon D. Lurie, MD, MS; Charles C. Edwards, MD; Steven D. Glassman, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; Jacob M. Buchowski, MD; Leah Y. Carreon, MD; Charles H. Crawford III, MD; Stephen J. Lewis, MD, FRCS(C); Tyler Koski, MD; Stefan Parent, MD, PhD; Virginie Lafage, PhD; Munish C. Gupta, MD; Han Jo Kim, MD; Christopher P. Ames, MD; Shay Bess, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Keith H. Bridwell, MD

Summary
This study demonstrates that the significantly greater improvement in patient-reported outcomes measures (PROMs) associated with operative (op) versus nonoperative (nonop) treatment for adult symptomatic lumbar scoliosis (ASLS) observed at 2-yr follow-up is durably maintained at 5-6 yr follow-up. Overall, op patients with a related serious adverse event (SAE) still had greater improvement than nonop patients, but for operative patients with 2+ SAEs the treatment effects (TEs) were markedly reduced. These findings have important implications for patient counseling and cost-effectiveness assessments.

Hypothesis
Op treatment for ASLS provides greater improvement of PROMs than nonop at 5-6 yr follow-up.

Design
Prospective multicenter study

Introduction
Long-term studies for op and nonop ASLS treatment are critical for assessment of treatment durability.

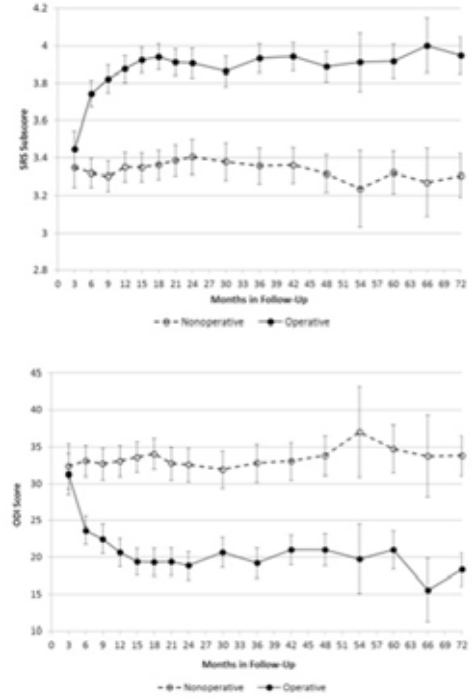
Methods
The ASLS study is an NIH-sponsored multicenter prospective study to assess op vs nonop treatment for ASLS, with randomized and observational treatment arms. Patients were 40-80 yrs with ASLS (Cobb >30o and ODI >20 or SRS-22 subscore (SRS-22)

<4.0 in pain, function and/or self-image). Op and nonop patients were compared using as-treated analysis, and related SAEs were assessed for op patients.

Results
The 286 ASLS patients (108 nonop, 178 op) had follow-up rates at 2 yrs and 5-6 yrs of 90% (256) and 74% (212), respectively. At 5 yrs, compared with nonop, op patients had greater improvement in SRS-22 (mean difference=0.6) and ODI (mean difference=-14) (p<0.001 for both, Figure), with treatment effects (TEs) exceeding minimal detectable measurement difference (MDMD) for SRS-22 (0.4) and ODI (7). TEs at 5 yrs remained as favorable as TEs at 2 yrs (SRS-22=0.7; ODI=-16). The incidence rates of SAEs for op patients during the first 2 yrs and 2-6 yrs post-op were 35 and 23 SAEs per 100 person-yrs, respectively, and the majority of SAEs were revision surgeries. During the first 2 yrs and first 6 yrs post-op, there were 34 and 73 revisions in 24 and 55 op patients, respectively. At 5 yr, op patients with 1 SAE still had significant improvement, with TEs that exceeded MDMD (SRS-22=0.55, ODI=-12.9, p<0.001 for both). The 12 op patients with 2+ SAEs had improvement based on SRS-22 (TE=0.3, p=0.027) that did not exceed MDMD, and lacked significant improvement based on ODI (TE=-7.7, p=0.06).

Conclusion
The significantly greater clinical improvement of op versus nonop treatment for ASLS at 2 yr is maintained at 5-6 yr follow-up. Overall, op patients with an SAE still had greater improvement than nonop patients, but for op patients with 2+ SAEs the TEs were markedly reduced. These findings have important implications for patient counseling and cost-effectiveness assessments.

Take Home Message
The significantly greater improvement of operative over nonoperative treatment for ASLS at 2 yr follow-up is durably maintained at 5-6 yr follow-up, showing no sign of deterioration.



66. Realistic Radiographic Lordosis Achieved in Pedicle Subtraction Osteotomies (PSO) and 3-level Posterior Column Osteotomies (PCO) in Adult Spinal Deformity (ASD) Patients with 2-year Follow-up

Joshua Rivera; Praveen V. Mummaneni, MD; Jeremy Guinn, BS; Hao-Hua Wu, MD; Minghao Wang, MD, PhD; Pingguo Duan, MD; Zhuo Xi, MD; Bo Li, MD; Rory R. Mayer, MD; Shane Burch, MD; Sigurd H. Berven, MD; *Dean Chou, MD*

Summary
Although multi-level PCOs are purported to obtain 10° of lordosis per level, and PSOs obtain 30°, it is unclear if realistically such numbers are achievable in clinical practice.

Hypothesis
PCOs and PSOs obtain less lordosis than 10° and 30°, respectively, in clinical practice.

Design
Retrospective study

Introduction
PCOs, also known as Smith-Petersen or Ponte osteotomies, reportedly can achieve 10° of lordosis/level, and PSO supposedly can achieve 30°. However, in clinical practice, such angular correction may not always be achieved.

Methods
Patients undergoing ASD correction ≥6 levels from the lower thoracic (LT) spine to S1 with a minimum 2-year follow-up were reviewed. Only patients undergoing lumbar PSOs and 3-level PCOs were included. Demographic data and radiographic spinopelvic parameters included: pelvic incidence (PI), pelvic tilt (PT), lumbar lordosis (LL), PI–LL, sacral slope (SS), T1 pelvic angle

(TPA), T5-T12 thoracic kyphosis (TK), and sagittal vertical axis (SVA). Lumbar lordosis was measured from L1 to S1.

Results
Eighty-one patients (27 males, mean age = 65.6) met inclusion criteria with mean follow-up of 3.84 yrs. Forty patients had a single-level PSO and forty-one patients had a 3-level PCO. There were no significant differences in preoperative LL (PSO group: 23.55 ± 13.24° versus PCO group: 29.63 ± 16.63°, p = 0.07), PI-LL (PSO group: 29.93 ± 21.26° versus PCO group: 27.59 ± 17.49°, p = 0.58), and SVA (PSO group: 103.23 ± 55.45° versus PCO group: 81.32 ± 52.77°, p = 0.07) or postoperative LL (PSO group: 42.83 ± 15.17° versus PCO group: 44.18 ± 14.95°, p = 0.69), PI-LL (PSO group: 10.80 ± 16.79° versus PCO group: 14.93 ± 16.53°, p = 0.58), and SVA (PSO group: 64.89 ± 65.80° versus PCO group: 54.23 ± 43.12°, p = 0.07). The PSO cohort obtained an average of 19.28 ± 14.97° lordosis, and the 3-level PCO group obtained 12.39 ± 16.06° of lordosis, or 4.13° per PCO level. The change in lumbar lordosis was higher in the PSO group compared to the 3-level PCO group (p = 0.04).

Conclusion
PSO and 3-level PCOs achieved mean lordosis of 19.28° and 12.39° (4.13° per level), lower than theoretical maximal angular correction. Realistic numbers of lordosis may be considered in surgical planning for ASD correction.

Take Home Message
PCO and PSO angular lordosis induction may be less than that of previously reported numbers, and realistic numbers may be considered when planning ASD correction surgeries.

67. Quality Metrics in Adult Spinal Deformity (ASD) Surgery Over the Last Decade. A Combined Analysis of The Largest Prospective Multicentric Datasets

Ferran Pellisé, MD, PhD; Miquel Serra-Burriel, PhD; Alba Vila-Casademunt, MS; Justin S. Smith, MD, PhD; Ibrahim Obeid, MD; Douglas C. Burton, MD; Frank S. Kleinstueck, MD; Shay Bess, MD; Javier Pizones, MD, PhD; Virginie Lafage, PhD; Francisco Javier S. Perez-Grueso, MD; Frank J. Schwab, MD; Jeffrey L. Gum, MD; Eric O. Klineberg, MD; Christopher I. Shaffrey, MD; Ahmet Alanay, MD; Christopher P. Ames, MD; International Spine Study Group ; European Spine Study Group

Summary
This international (5 countries) longitudinal conjoined effort, based on >2y-fup prospective multicentric (17 sites, 57 surgeons) high quality (follow-up >75%) data, shows a progressive and robust improvement in quality of care indicators associated with ASD surgery. Over the last decade postoperative complications and reinterventions have been progressively reduced by 50%, patient enrollment has increased, postoperative improvement in disability has augmented, while baseline patient characteristics remained the same. Quality-metrics trends show we are facing the ASD epidemic more efficiently.

Hypothesis
ASD surgery quality metrics remained stable over the last decade.

Design
Observational prospective longitudinal cohort study.

Introduction
The reported rate of complications and cost of ASD surgery, associated with an exponential increase in the number of surgeries, cause alarm among healthcare payers and providers worldwide. We analyzed conjointly, the largest prospective available ASD datasets to define trends in quality of care indicators (Complications, Reinterventions, HRQL) since 2010.

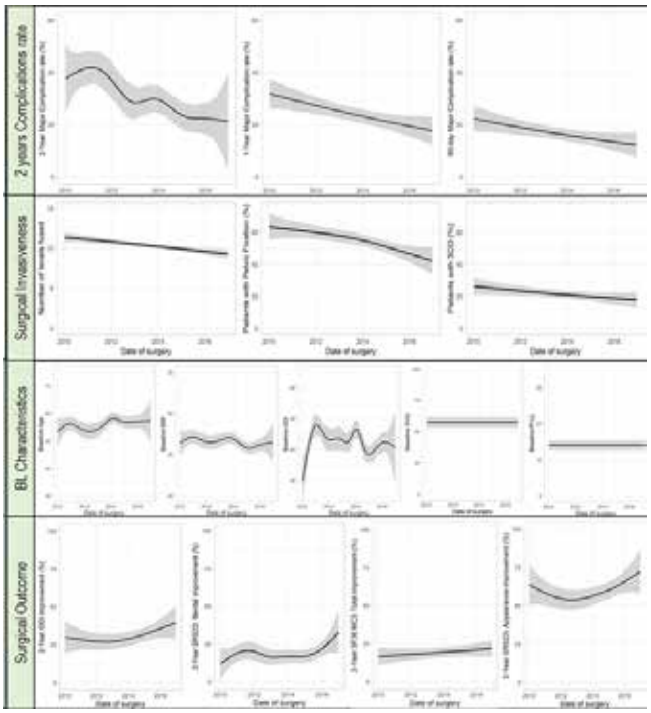
Methods
Patients operated between Jan2010 and Dec2016, with >2 year follow-up data. Demographic, surgical, radiological and HRQL (ODI, SF36, SRS22) data obtained preoperatively, at 3, 6, 12 and 24 months after surgery were evaluated. Trends and changes in indicators were analyzed using local regression (LOESS) and adjusted Odds Ratio (OR).

Results
2286 patients included in the 2 registries, 1520 underwent surgery between 2010-2016. 1151 (75.7%), operated in 17 sites (5 countries, 54 surgeons), met inclusion criteria. Patient recruitment increased (2010-11 vs 2015-16: OR 1.64 p <0.01), while baseline clinical characteristics (age, ASA, HRQL scores, sagittal deformity) did not change. Since 2010 there is a sustained reduction in major (M) and minor (m) complications, observed at 90 days (OR M0.54; m0.48; p <0.01), 1 year (OR M0.59; m0.59 p <0.01) and 2 years of follow-up (OR M0.55 ; m0.66 p <0.01) as well as the 2-year reintervention rate (OR 0.51 p <0.01). Simultaneously, there is a slight improvement in the correction of sagittal deformity (PI-LL) (OR 1.11, p = 0.19) and greater gain in quality of life (ODI 26% vs 40%, p = 0.02 / SRS22 SI OR 1.16 p = 0.13), associated with a progressive reduction of surgical aggressiveness (N fused segments OR 0.81 p <0.01, % pelvic fixation OR 0.66 p <0.01, % 3CO OR 0.63 p <0.01).

Conclusion
Best available data shows a robust global improvement in ASD surgery quality metrics over the last decade. Surgical complications and reoperations have been reduced by half, while improvement in disability increased and correction rates were maintained, in patients with similar baseline characteristics.

Take Home Message
Available prospective international ASD registries show a progressive improvement of surgical outcomes over the last decade. Complications and reinterventions have been reduced by half, while quality of life gain improved.

Podium Presentations—Hibbs Clinical Research Award Nominees



68. Automated Measurement of Spinopelvic Parameters on Lateral Lumbar Radiographs Using Deep Learning

John T. Schwartz, BS; Varun Arvind, BS; Brian H. Cho, BS; Aly A. Valliani, BS; Eric Geng, BS; Peter Tang, MD; *Jun Kim, MD*; Samuel K. Cho, MD

Summary
Sagittal alignment measurements are increasingly recognized as an important quantitative metric for the evaluation of spinal disorders. Manual methods used to derive these measurements are time consuming and subject to rater-dependent error. Thus, a need exists to develop fast and precise automated methods for obtaining sagittal measurements. This study aims to develop an algorithm for the automated measurement of spinopelvic parameters on lateral lumbar radiographs with comparable accuracy to surgeons.

Hypothesis
We hypothesize that we could develop an algorithm for automated measurement of spinopelvic parameters (SPPs) on lumbar radiographs with accuracy comparable to surgeons.

Design
Retrospective analysis of lumbar radiographs

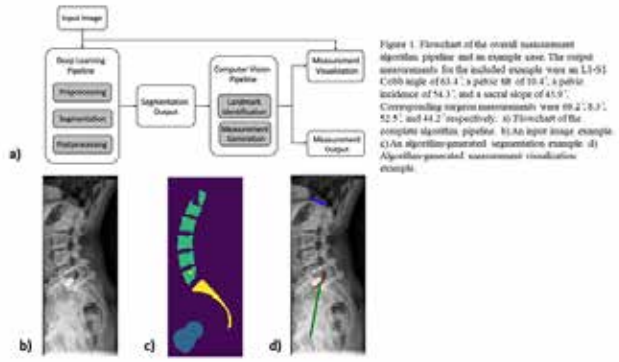
Introduction
Sagittal alignment measurements are increasingly recognized as an important quantitative metric for the evaluation of spinal disorders. This study aims to develop an algorithm for the automated measurement of SPPs on lumbar radiographs with comparable accuracy to surgeons.

Methods
816 patients with lumbar radiographs were collected and used to develop a convolutional neural network (CNN) segmentation algorithm. 80% (n = 653) of these radiographs were used to train and validate the CNN. A CNN and a computer vision algorithm was used to create a complete pipeline for the fully-automated measurement of SPPs from lateral lumbar radiographs. 20% (n = 163) of radiographs were used to test. After exclusion of radiographs which did not contain two femoral heads, 40 radiographs were randomly selected from the test set and manually measured by three surgeons for comparison.

Results
Following training of the algorithm, a final validation accuracy of 0.978 was achieved. The area under the receiver operating curve (AUROC) was 0.942, 0.960, and 0.962 for segmentation of the sacrum, vertebrae, and femoral head classes, respectively. Wilcoxon rank-sum tests revealed algorithm measurements of L1-S1 cobb angle, pelvic incidence, and pelvic tilt were not significantly different from surgeon measurement ($p > 0.05$). In comparison to a gold standard surgeon measurement, the algorithm performed with a similar mean absolute difference to spine surgeons for L1-S1 Cobb angle (4.30 ± 4.14˚ vs 6.00 ± 4.96˚), pelvic tilt (2.14 ± 6.29˚ vs 1.82 ± 5.88˚), pelvic incidence (4.56 ± 5.40˚ vs 4.39 ± 3.48˚), and sacral slope (4.76 ± 6.93˚ vs 5.43 ± 5.54˚).

Conclusion
The results of this study indicate that this algorithm is comparable to surgeons in the evaluation of spinopelvic parameters on lateral lumbar radiographs. The algorithm may find use in clinical workflow through integration into existing spine measurement tools to provide default measurement suggestions.

Take Home Message
This algorithm is comparable to surgeons in the evaluation of SPPs on radiographs. The algorithm may find use in clinical workflow to provide default measurement suggestions.



Podium Presentations—Hibbs Clinical Research Award Nominees

69. Outcomes of Neurologic Deficit and use of Intraoperative Neuromonitoring for Lower Cervical and Upper Thoracic Three Column Osteotomies for Deformity Correction

Darryl Lau, MD; Alexander Haddad, BS; Vedat Deviren, MD; Christopher P. Ames, MD

Summary
49 patients underwent posterior three column osteotomy (3CO) in the lower cervical and upper thoracic spine for severe cervical deformity. Complication rate was 44.4% and neurological deficit rate was 20.4%. New deficits are seen more commonly when osteotomies are performed at C7 and T1. Neuromonitoring including TcMEP and EMG have high false negative rates and poor sensitivity for detecting cervical nerve root deficits. In patient with new weakness, less than half (42.9%) recover to baseline at 2-year follow-up.

Hypothesis
Neurological deficit rates are high following three column osteotomies (3CO) for cervical deformity. Current neuromonitoring modalities may be modest in detecting postoperative weakness.

Design
Single surgeon, retrospective study.

Introduction
Neurologic morbidity associated with correction of fixed deformities with posterior based 3CO is not clearly defined. The performance measures of modern intraoperative neuromonitoring (NM) during cervicothoracic 3CO have yet to be studied well.

Methods
We performed a retrospective review of a single surgeon experience from 2011 to 2018 of all patients who underwent posterior based 3CO for cervical deformity. Medical and neuromonitoring records were reviewed. Neurological status was reviewed at 2 years follow-up.

Results
49 patients were included: 31 PSO and 18 VCR. Mean age was 61.1 years and 44.9% were male. 65.3% were myelopathic and 30.6% had preop weakness. Preoperative and postoperative measures were cSVA (6.8 and 3.7 cm, $p<0.001$), lordosis (0.0 and 9.1 degrees, $p=0.030$), and T1-slope (49.8 and 36.7 degrees, $p<0.001$). Mean blood loss was 1674.5 ml and surgery length was 314.6 minutes. Complication rate was 44.9% and neurological deficit rate was 20.4%. When stratified by osteotomy level, there was significantly higher rates of neurological deficits at C7 and T1: C7 (37.5%), T1 (37.5%), T2 (20.0%), T3 (15.4%), T4 (0.0%) ($p=0.023$). C7 and T1 level deficits were most consistent with nerve root weakness rather than spinal cord injury; C8-hand intrinsic most common followed by C7 triceps. There were 8 NM signal changes with 3 true positives and 7 false negatives. Performance measures were: accuracy 75.5%, PPV 37.5%, NPV 82.9%, sensitivity 30.0%, and specificity 87.2%. In patients with new neurological deficits 42.9% recovered, 14.3% improved, and 28.6% were unchanged at 2-year follow-up.

Conclusion
Complication rates are high following posterior 3CO for cervicothoracic deformity. 3CO at C7 and T1 have the highest rates of neurological deficit. IONM have modest performance in predicting postoperative deficits. Less than half recover to baseline at 2-year follow-up.

Take Home Message
Neurologic complications occur in 20.4% of cervicothoracic deformity correction via posterior 3CO; highest with C7 and T1 3CO. Neuromonitoring is a critical modality but modest in predicting new weakness.

Podium Presentations—Cervical Deformity

70. Postoperative Axial Neck Pain (ANP) and its Associated Radiographic Parameters in the Surgically Treated AIS Patients

Akira Matsumura, MD, PhD; Takashi Namikawa, MD, PhD; Yusuke Hori, MD

Summary
We evaluated postoperative ANP and its associated radiographic parameters in the 111 AIS patients. The prevalence of postoperative ANP is relatively higher (35.1%), and it impacts the postoperative HRQOL. Sagittal alignment in cervicothoracic area may be a significantly important factor for postoperative ANP.

Hypothesis
Prevalence of the postoperative ANP of the AIS patients may be higher than those of the normal population, and it may impact the postoperative HRQOL. Sagittal spinal alignment may be an associated factor for the postoperative ANP.

Design
Retrospective cohort study.

Introduction
The prevalence of ANP has been reported at 15% according to a Japanese national survey. The purpose of this study is to investigate the postoperative ANP and its associated factor after AIS surgery.

Methods
114 consecutive surgically treated AIS patients who had main thoracic curve at our institute from 2010 to 2015. 3 patients who could not be followed for more than 2 years were excluded in this study. We identified 111 AIS patients (mean age at surgery: 15.8 years, and average F/U period: 62.8 months) and evaluated postoperative ANP using VAS at FFU. We also analyzed its associated radiographic parameters and its correlation with the postoperative HRQOL using SRS-22.

Results
The prevalence of postoperative ANP which was more than 20mm of VAS was 35.1 %. Each domain of SRS-22 was following; activity:4.5, pain:4.6, self-image:4.0, mental:4.4, and satisfaction:4.2. Radiographic parameters (Pre/FFU) were PT:33.2/16.4°, MT:62.2/15.7, TL/L:38.9/10.4°,C2-7 lordosis:-7.0/-2.1°, C7 slope:9.7/11.4°, TK:11.4/17.7°, C2-SVA:13.0/-0.8mm, and C7-SVA:3.1/-13.0mm. Statistical analysis indicated postoperative ANP significantly correlated with C7 slope (r=-0.33, P=0.04), MT (r=-0.43, P=0.02), TK (r=-0.34, P=0.04), activity (r=-0.39, P=0.02), and mental (r=-0.34, P=0.04).

Conclusion
Postoperative ANP was seen relatively higher, and impacted the postoperative HRQOL. Sagittal alignment in cervicothoracic area is thought to be a significantly important parameter for postoperative ANP.

Take Home Message
The prevalence of postoperative ANP is relatively higher in the surgically treated AIS patients, and sagittal alignment in cervicothoracic area may be a significantly important parameter for postoperative ANP.

71. Restoration of Thoracic Kyphosis and Higher T1 Slope Angle Impacts Cervical Alignment After Posterior Spinal Fusion in Hypokypotic Adolescent Idiopathic Scoliosis: A Retrospective Study with Minimum Five-years Follow-up

Ayhan Mutlu, MD; Mustafa Eltayep, MD; Seray G. Gur, MD; Huseyin Ozturk, MD; Tunay Sanli, MA; Selhan Karadereler, MD; Tom Reinsel, MD; Meric Enercan, MD; *Sinan Kahraman, MD*; Azmi Hamzaoglu, MD

Summary
Cervical and global sagittal radiographic measurements were used to assess which parameters influence the cervical alignment in adolescent idiopathic scoliosis patients with thoracic hypokyphosis who were treated with posterior spinal fusion and had a minimum of 5 years f/up. Cervical lordosis restoration was found to be highly correlated with increased thoracic kyphosis and a higher T1 slope angle. Achieving a minimum 29.5° thoracic kyphosis was found as a cut-off value for changing the kyphotic cervical alignment to lordotic.

Hypothesis
Restoration of thoracic kyphosis and improvement global sagittal parameters may influence cervical alignment

Design
Retrospective

Introduction
The aim of this study was to investigate the impact of thoracic kyphosis restoration on cervical alignment measurements and to find out which global sagittal parameters influence the cervical alignment in hypokyphotic (AIS) pts who had treated with posterior spinal fusion and had a minimum of 5 years f/up

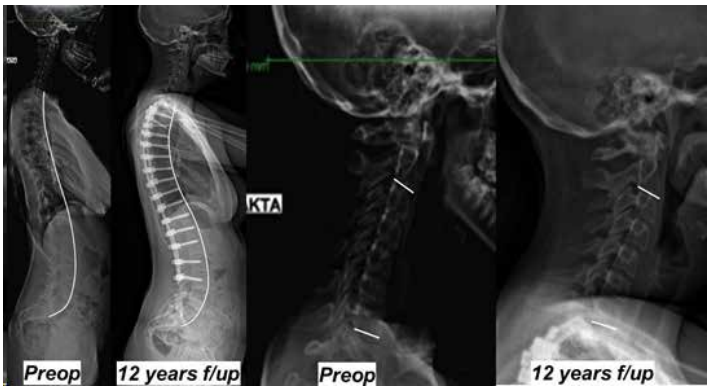
Methods
54 AIS pts (50f,4m) with thoracic hypokyphosis(<20°) with posterior spinal fusion with mean f/up was 10.3(5-21)yrs. Preop and last f/up x-rays measures were:C2 slope,C0–C2,C2–7(CK),C2–T3,T1 slope angles, C2-C7SVA,TK,LL,SS,PI and PT. Two groups were compared with respect to their cervical and global alignment parameters—group A with CK≤ 0 and group B with CK > 0. Patients with and without Ponte osteotomies were compared based on TK and CK improvements. HRQoL score was assessed by SRS-22r. Mann-Whitney U test was used for statistical analyses

Results
Group A had 22 pts with preop TK of 15° which improved to 34° at last f/u; the mean preop CK was 16.9°before surgery and -3° at f/u. Group B included 32 pts that had improved TK from 13.2° preop to 24.8° at f/up and CK 10.8° preop to 9.2° at f/up. The TK and T1 slope were higher in group A($p<0.05$),but 2 groups had similar global and pelvic parameters($p>0.05$).ROC analyses showed that a min.TK of 29.5° and T1 slope of 10,5° at last f/u

was highly correlated with cervical lordosis restoration.12 pts who had Ponte osteotomies had more restoration of TK than those without osteotomies (36° vs 31°),but there was no statistical difference in terms of TK and CK restoration.SRS22 scores were similar in both groups

Conclusion
T1 slope >11° and TK > 30° provides kyphotic cervical alignment to lordotic. A low T1 slope is significantly associated with a higher risk of cervical kyphosis ($p<0.05$).Upper cervical spine parameters, global sagittal and pelvic parameters did not contribute for compensation of cervical alignment as T1 slope and TK restoration in 5 yrs f/up

Take Home Message
Correcting the hypokyphotic AIS to > 30° TK and obtaining higher T1 slope is associated with a more normal cervical lordosis at a min 5 yrs f/up



72. Cervical Radiographic Parameters and Patient Reported Outcomes following Harrington Instrumentation: A Minimum 35-years Follow-up

Noorullah Maqsoodi, MS; Aron Sulovari, BS; Adan Omar, MD; Jarren Section, MD; Emmanuel N. Menga, MD; Paul T. Rubery, MD; *Addisu Mesfin, MD*

Summary
Radiographic parameters and patient reported outcomes were evaluated in patients undergoing Harrington Instrumentation for AIS. The average follow up was 48 years and Higher C2-C7 SVA and C7 SVA angles are correlated with worse patient reported outcomes.

Hypothesis
Cervical radiographic parameters demonstrating more cervical kyphosis are associated with worse patient reported outcomes.

Design
Observational

Introduction
As patients who underwent Harrington instrumentation for AIS approach middle age, identifying the cervical spine deformity in the setting of pre-existing Harrington instrumentation is important. There are few studies that have evaluated this topic.

Methods
AIS patients undergoing Harrington instrumentation from 1962 to 1984 were identified. Inclusion criteria were completion of the patient reported outcomes and recent cervical/scoliosis radiograph. Recent cervical and scoliosis radiographs were used to measure cervical deformity parameters (C2-C7 SVA, T1 slope, C2 SVA, C7 SCA). Neck Disability Index (NDI), was used to assess patient reported outcome. Using multivariate analysis, radiographic measurements and NDI scores were assessed.

Results
32 patients met our inclusion criteria. The mean follow up was 48 years (35-57). The mean age was 63.5± (51-82) years, there were 29 females and 3 males in this cohort. The average age at which surgeries were performed was 15.4 (11-47) years with the average number of levels fused 9.7±1.7. Radiographic measurements resulted in C2-C7 SVA (mean, 24.7°±11.1°), T1 slope (mean, 26.1°±10.7°), C2 SVA (mean, 60.0°±38.1°) and C7 SVA (40.7°±30.6°). The mean NDI was 11.5 (0-48). Higher radiographic measurements of C2-C7 SVA ($p=0.004$) and C7 SVA ($p=0.003$) were strongly correlated with worse NDI scores, indicating decreased patient satisfaction with increased level of angulation. The T1 slope did not yield a statistically significant correlation ($p=0.90$).

Conclusion
Higher C2-C7 SVA and C7 SVA angles are correlated with worse patient reported outcomes in patients with minimum of 35 years follow up after Harrington instrumentation for AIS.

Take Home Message
Radiographic parameters and patient reported outcomes were evaluated in patients undergoing Harrington Instrumentation for AIS. Higher C2-C7 SVA and C7 SVA angles are correlated with worse patient reported outcomes.

73. More than 10-year Clinical Outcome after Pedicle Screw Fixation for Cervical Kyphosis in Athetoid Cerebral Palsy Patients

Satoru Demura, MD, PhD; Satoshi Kato, PhD; Kazuya Shinmura, PhD; Noritaka Yonezawa, MD; Takaki Shimizu, MD; Norihiro Oku, MD; Ryo Kitagawa, MD; Makoto Handa, MD; Ryohei Annen, MD; Hiroyuki Tsuchiya, PhD

Summary
Cervical pedicle screw instrumentation showed favorable initial stability and maintained clinical outcomes in patients with CP. However, more than 90% of the patients showed disc degeneration on either side at 10-year follow-up.

Hypothesis
Pedicle screw instrumentation in patients with cerebral palsy could maintain stable fixation for a long-term.

Design
Retrospective case series

Introduction
Surgery for cervical myelopathy associated with atetoid cerebral

palsy remains a challenge because of perioperative instrumentation failure and adjacent segment problem due to their repetitive involuntary neck movements and deformity of the cervical spine. We investigated the clinical outcome following pedicle screw fixation more than 10 years.

Methods
14 patients were retrospectively reviewed. There were 7 female and 7 male with a mean age at the time of surgery of 52 years. The mean follow-up period and rate were 137 months and 78%. Radiographic evaluation included a change of C2-C7 angle of sagittal plane, adjacent segment problem, instrument failure and accuracy of pedicle screws. Barthel index and the Japanese Orthopaedic Association (JOA) score were also assessed.

Results
Preoperative Cobb angle of sagittal plane from C2-C7 measured 12.0 degrees of kyphosis which improved to 0.3 degrees of lordosis. Solid posterior bony fusion was achieved in all cases without rigid orthosis. Without anterior procedure, autofusion inside the disc was observed in 60 out of 69 discs (86%). There were two cases of proximal adjacent segmental instability, which required additional surgery. Four (3.3%) out of the 119 inserted screws showed more than 2mm deviation with postoperative computed tomography. However, there were no neurovascular complications during or after the surgery in any cases. 10-year JOA score and Barthel index significantly improved in 30.0%, and 47.2% respectively.

Conclusion
The procedure could be a favorable option in patients with cervical deformity associated with atetoid cerebral palsy. However, selection of fusion level and optimal cervical alignment for the patients should be investigated to prevent adjacent segmental problems.

Take Home Message
Cervical pedicle screw instrumentation showed favorable initial stability and maintained clinical outcomes in patients with CP.

figure

74. The Surgical Treatment of Severe Cervical Kyphosis in Diastrophic Dysplasia

John Heydemann, MD; William G. Mackenzie, MD; Colleen Ditro, RN, DNP, CPNP; Kenneth J. Rogers, PhD; Jeffrey Campbell, MD; Suken A. Shah, MD; *William G. Mackenzie, MD*

Summary
Cervical kyphosis in diastrophic dysplasia can be progressive, resulting in severe deformity and neurologic injury. In up to 75% of patients, cervical kyphosis will spontaneously resolve, but close clinical surveillance is required to identify those children at risk. We describe the patient characteristics and surgical indications for those who required correction, along with their medium-term outcomes. Posterior fusion, with or without anterior corpectomy, can result in excellent deformity correction, without recurrence and 100% fusion rate at two years follow-up.

Hypothesis
Progressive cervical kyphosis in diastrophic dysplasia can safely be treated via posterior fusion, with or without anterior corpectomy.

Design
Retrospective case series

Introduction
Cervical kyphosis can be progressive in 25% of children with diastrophic dysplasia, resulting in severe deformity and neurologic injury. We describe the characteristics, indications and outcomes of those who required surgical correction.

Methods
This is a retrospective study of patients with diastrophic dysplasia who had cervical spine surgery at one institution. These patients underwent posterior fusion with or without anterior corpectomy. Surgical indications included severe kyphosis, spinal cord compression, and cervical instability. Patients were evaluated using the C2-C7 Cobb technique and T1 slope on lateral radiographs prior to surgery and at a minimum of two-year follow-up. Pre and postop neurologic examinations, MRI, and complications were reviewed.

Results
Between 1984-2017, 19 patients with diastrophic dysplasia and cervical kyphosis were followed, 8 of whom required surgery. Four patients underwent anterior corpectomy and posterior fusion, and 4 patients underwent posterior fusion only. There was one dural tear and one superficial halo pin site infection, otherwise no complications. Rate of bony fusion was 100%. Patients treated with anterior-posterior surgery had a mean preop C2-C7 Cobb measurement of 90 degrees of kyphosis, improved to 20 degrees of kyphosis. Patients treated with posterior-only surgery had a mean preop Cobb measurement of 70 degrees of kyphosis, improved to 23 degrees of lordosis. All patients were sagittally balanced with kyphotic T1 slopes.

Conclusion
While progressive cervical kyphosis is uncommon in diastrophic dysplasia, this subset of children can develop severe spinal cord compression. Posterior fusion effectively addresses spinal deformity, and we recommend anterior decompression and fusion to address cord compression. Both techniques produce excellent correction without pseudoarthosis or deformity recurrence at 2 years of follow-up.

Take Home Message
In children with diastrophic dysplasia, surgical correction of severe cervical kyphosis can be achieved safely and reliably.

Podium Presentations—Cervical Deformity

A) Patient with cervical kyphosis and B) spinal cord compression. C) Three-year postop radiograph following anterior-posterior arthrodesis.

75. Radiological and Clinical Outcome of Surgery for Basilar Invagination: What Holds the Key to Success in this Difficult Terrain

Shardul Soman, MBBS, MS

Summary
Basilar Invagination is difficult to manage with every case requiring meticulous pre-operative planning. Most patients present after a history of trivial trauma which aggravates the cephalomedullary compression. For irreducible instability anterior release is helpful. Posterior occipito-cervical fusion with rod-plate is a successful procedure for treatment. Space available for cord of more than 15mm and a normal cephalomedullary angle (> 140) correlated with a successful clinical outcome. Complete or partial reduction had no correlation with clinical success until fusion is achieved.

Hypothesis
SAC and CM has prognostic significance in treatment of basilar invagination

Design
Prospective study of consecutive patients with basilar invagination operated by occipitocervical fusion. Patients previously operated for same pathology and patients with neuromuscular disorders were excluded.

Introduction
The subject of craniovertebral junction anomalies is under discussion and evaluation for over a century. A number of classical reviews have attempted to clarify a variety of complex associated issues. Despite the volumes of publications on the subject, it appears that the last word has not yet been said.

Methods
25 consecutive patients with Basilar Invagination (Goel type A) with minimum follow up of 12 months. All patients underwent dynamic films, CT, MRI and angiography pre operative and at final follow up. Clinical assessment of the patients was done using Ranawat neurological scale, Nurick grade, modified JOA score, modified Odoms criteria. Radiological assessment was done using Space Available for the Cord on MRI and Cephalomedullary Angle on CT scan on pre operative and final follow-up. Fusion status was confirmed based on CT scan. Clarks station was used to assess reduction.

Results
16 patients were completely reduced while 9 were partial, the SAC increased from mean 7.95mm to 15.1mm while the CM increased from 120 to 150 at final follow up. on clinical outcomes mJOA increased from 13.4 to 16, modified Odoms showed 12 excellent outcomes.19 patients at final follow up had nurick grade1. There were 6 wound complications and 3 patients required revision surgery.

Conclusion
Space available for cord of more than 15mm and a normal cephalomedullary angle (> 140) correlated with a successful clinical outcome. Complete or partial reduction had no correlation with clinical success until fusion is achieved. Occipito cervical fusion for basilar invagination has a satisfactory clinical outcome. However partial reduction carries theoretical risk of sub-axial cervical degeneration which needs to be studied

Take Home Message
SAC and CM have prognostic significance

Pre operative and final follow up (3 yrs) MRI shows cephalo-medullary angle of 128° to 171°

❖Pre operative and final follow up CT scan showing increase in SAC from 5mm to 15 mm at cephalomedullary junction.
❖Fusion is evident here.
❖ Note there is partial reduction from Clark station 3 to 2.
❖Patient made recovery from Ranawat grade 3A to 1.

76. When Can we Expect Global Sagittal Alignment to Reach a Stable Value following Cervical Deformity Surgery?

Renaud Lafage, MS; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Peter G. Passias, MD; Christopher I. Shaffrey, MD; Gregory M. Mundis, MD; Themistocles S. Protopsaltis, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Jonathan Elysee, MS; Han Jo Kim, MD; Shay Bess, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; International Spine Study Group

Summary
Previous study demonstrated a significant association between TL correction and Cervical improvement but is the opposite also valid? This study investigated the change in global alignment between pre-op, 3-month and 1-year follow-up. Results demonstrated that peak relaxation of compensatory mechanisms is achieved by 3-month follow-up, and remains stable at 1year. Sub-analysis with 2year data supports these findings. These

results can help to identify when outcomes of cervical surgery on global alignment can be evaluated.

Hypothesis
Global sagittal alignment changes significantly following Cervical deformity surgery and stabilizes by 1-year follow-up

Design
Retrospective review of prospective multicenter database of CD patients with a minimum of 1Y follow-up

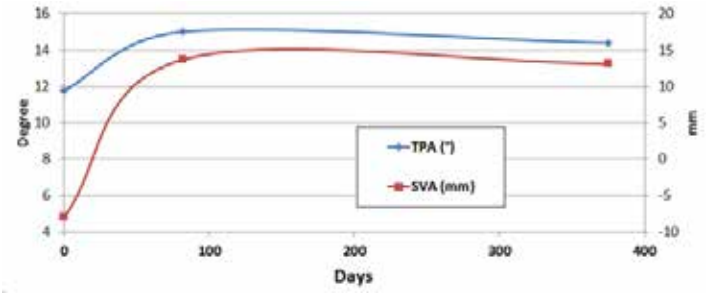
Introduction
Cervical deformity (CD) is a complex condition with a clear impact on patient quality of life, which can be improved with surgical treatment. Previous study following thoracolumbar surgery demonstrated a spontaneous and maintained improvement in cervical alignment following lumbar PSO. This study aims to investigate the complementary aspect: does change in cervical alignment induce a change in global alignment, and does this change stabilize over time?

Methods
In order to analyze spontaneous changes, only patients with at least 5 levels unfused post-op were retained. After describing the entire cohort, repeated measures analysis were conducted between pre, 3M and 1Y follow-up with a post-hoc analysis and Bonferroni correction. A sub-analysis of patients with 2Y follow-up was performed.

Results
121 pts out of 168 (72%) had 1Y follow-up available, and 89 had at least 5 levels unfused post-op (60.8yo±10.2 65.2%F). Pre-operative there was a moderate anterior cervical alignment (C2-C7: -7.7° (kypo); TS-CL: 37.1°; cSVA: 37) combined with a posterior global alignment (SVA:-8mm) with lumbar hyperextension (PI-LL: -0.6°). Patients underwent a significant correction of the cervical alignment (median ΔC2-C7: 13.6°). Simultaneously, PI-LL, TPA and SVA increased significantly (all $p<0.05$) between pre, 3M and 1Y but not PT ($p=0.052$). Post-hoc analysis demonstrated that all the changes occurred between pre-op and 3M. Sub analysis of patients with a complete 2Y follow-up demonstrated similar results with a stable post-operative TL alignment reached at 3M.

Conclusion
Correction of the cervical malalignment can impact significantly the thoracolumbar regional and global alignment. Peak relaxation of compensatory mechanisms is achieved by 3-month follow-up, and remains stable. Sub-analysis with 2year data supports this finding. This result can help to identify when the results of the cervical surgery on global alignment can be evaluated.

Take Home Message
Following CD surgery, peak relaxation of compensatory mechanisms is achieved by 3-month follow-up, and remains stable at 1-year follow-up. Sub-analysis with 2year data supports this finding.



77. Failure Mechanisms and Revision Strategies for DJK Following Cervical Deformity Correction

Themistocles S. Protopsaltis, MD; Eaman Balouch, MD, PhD; William Schreiber-Stainthorp, BS; Robert K. Eastlack, MD; Justin S. Smith, MD, PhD; D. Kojo Hamilton, MD; Alan H. Daniels, MD; Eric O. Klineberg, MD; Brian J. Neuman, MD; Robert A. Hart, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Christopher P. Ames, MD; International Spine Study Group

Summary
Distal junctional kyphosis (DJK) is a common complication of cervical deformity (CD) surgery. We define severe DJK (sDJK) as a postoperative change >20° from lower instrument vertebrae (LIV) to LIV-2. sDJK can erode corrections and postoperative cervical malalignment has been correlated with poor health outcomes (HRQL). The most common sDJK failure mechanism is vertebral fracture, usually of the lower instrumented vertebra. Revision strategies frequently involve longer fusions with mean of 8.3 additional levels, but optimal alignment is not often attained.

Hypothesis
Revisions for severe DJK can restore satisfactory alignment and clinical outcomes.

Design
Retrospective review of a prospective CD database

Introduction
CD surgery can markedly improve a patient's life quality. However, high rates of complications are reported, including DJK. Although studies have identified risk factors for DJK, the mechanisms and revision strategies for sDJK are not well understood

Methods
A database of operative CD patients was analyzed. Fusions below L4 were excluded. Severe DJK was defined as a postoperative change >20° (LIV to LIV-2). Those with LIV to LIV-2 <20° were defined as noDJK. sDJK patients were compared to those without in terms of demographic factors, surgical factors, revisions and HRQL at baseline and 1 year, using t-tests and X2 tests for continuous and categorical variables, respectively. Mechanisms of sDJK and sDJK revision strategies were described

Results
163 patients included (mean age 61.32, 61.11% F). sDJK occurred in 16 (9.8%) with mean max DJK of -31.96˚±9.6˚. Osteoporosis

(p=0.02) and Neuromuscular disease (p=0.001) were more likely in sDJK. There were no significant differences in % smokers, BMI and CCI (all p>.05). sDJK had more posterior levels fused and more caudal posterior and anterior LIV (all p<.05). sDJK patients had a higher rate of Smith-Petersen osteotomy (56.30% vs. 20.40%, p=0.001). There was no significant difference in HRQL change at 3, 6 and 12 months between cohorts. The revision rate was 37.5% for sDJK and 11.6% for noDJK (p=0.005). 64% of sDJK had a bony failure (78% LIV; 22% LIV-1), 21% had screw pull-out of LIV, 14% had ligamentous failure. For noDJK, 31% were revised for neurological deficits, 25% for infection, and 19% for prominent hardware. The mean additional levels fused in sDJK revisions were 8.3±5.5. One sDJK patient required a 2nd revision. Post revision, mean C2 slope was 39.3°±10.3° and cSVA was 45.2±13.2.

Conclusion

Post CD surgery, sDJK occured at 9.8%. Bony failure was the most common DJK mechanism, often occurring at the LIV. Strategies for revision include longer fusions with mean of 8.3 additional levels, however, revisions for sDJK frequently do not result in optimal cervical alignment

Take Home Message

Severe DJK is a common and serious complication, usually occurring by LIV bone failure. Revision strategies often involve longer fusions, but ultimately, optimal alignment is not frequently attained.

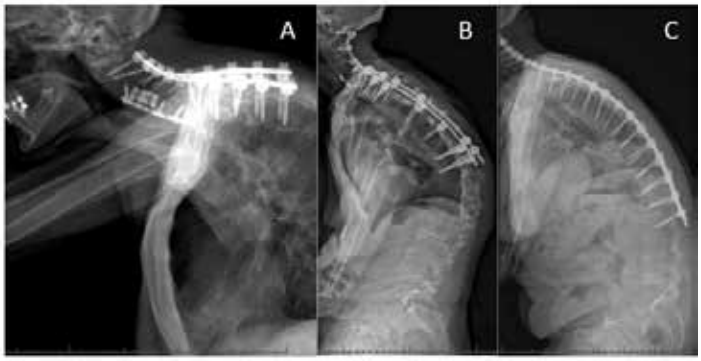


Figure: Failure mechanisms observed for DJK: A) Fracture proximate to LIV, B) Ligamentous failure, C) screw pull-out.

78. Optimizing Cervicothoracic Junction Biomechanics after C7 Pedicle Subtraction Osteotomy: A Cadaveric Study of Stability and Rod Strain

Jakub Godzik, MD; Jennifer N. Lehrman, MS; Bernardo de Andrada, MD; Christopher P. Ames, MD; Heiko Koller, MD; Anna S. Newcomb, MS; Jay D. Turner, MD; Brian P. Kelly, PhD

Summary

In the current study we investigated the choice of construct design in stabilizing posterior cervical construct in a deformity model including a pedicle subtraction osteotomy at C7. We identified that use of tapered rod (TR) is beneficial compared to uniform rod (UR), however as in prior studies, the optimal stabilizing choice is use of accessory rods (AR) across a 3 column osteotomy.

Hypothesis

AR fixation across a cervical osteotomy will provide greater stability and reduced rod strain compared to other forms of fixation

Design

Human biomechanical cadaveric model (n=14)

Introduction

Cervical PSO is a powerful corrective technique for severe cervical deformity that requires a sound biomechanical construct to avoid instrumentation failure and rod fracture. However, little evidence exists regarding optimal construct design in regards to maximizing stability and minimizing posterior rod strain. The current biomechanical study aimed to compare range of motion stability (ROM) and rod strain in uniform, tapered, and accessory rod constructs in a human cadaveric C7 PSO model.

Methods

Specimens (C2-T4) were tested and divided into two statistically equivalent groups; instrumentation was placed C2-T3, with a 25° PSO at C7. The first specimen group was instrumented with 3.5-5.5mm titanium tapered rods (TR). The second group received uniform titanium 4.0mm rods (UR). The UR group was additionally tested with lateral accessory rods (C5-T2) (UR+AR). All conditions were tested with pure moments of 2.0Nm in flexion (F), extension (E), left-right lateral bending (LLB, RLB), left-right axial rotation (LAR, RAR), and compressive load (C, 70N). Intervertebral ROM, posterior (pRS), and lateral (lRS) rod strains were measured at C2-C3, T2-T3, and PSO level. Statistical comparisons were performed using one-way ANOVA and post-hoc tests.

Results

TR demonstrated reduced ROM compared to UR in RAR (p=0.041) and LAR (p=0.023) at the PSO and T2-T3 levels. No differences were found in global or segmental ROM (p>0.08). pRS was highest across the construct at C2-3, without differences between constructs (p>0.12). At the PSO level, pRS was significantly greater using TR compared to UR+AR in F, E, and RAR (p<0.018). LRS was highest at the PSO level with significant differences between TR and UR+AR, in LAR and RAR (p<0.027).

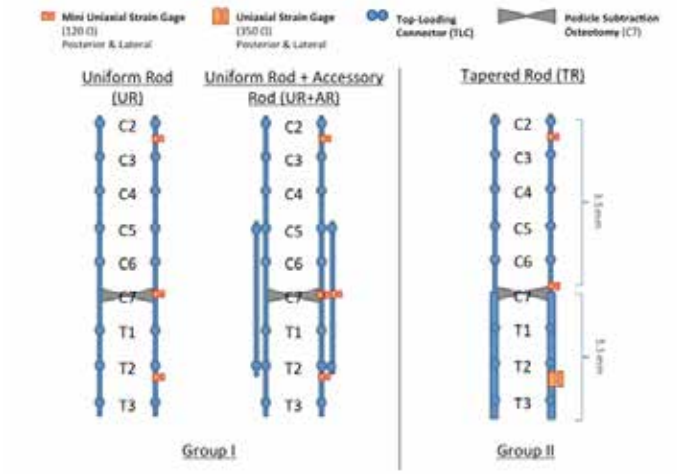
Conclusion

The C7 PSO is highly destabilizing, and maximal rod strain concentrates across the PSO and the cranial fixation site. TR provides higher stability than UR, however UR+AR provides the greatest reduction of pRS and LRS.

Take Home Message

PSO in the cervical spine is highly unstable, biomechanically TR and AR provide greatest stability and strain reduction.

Podium Presentations—Cervical Deformity



Podium Presentations—Early Onset Scoliosis/Syndromic

79. Urgent Field Safety Notice Concerning Locking Pin Fracture from Manufacturer of Magnetically Controlled Growing Rods: How does Data from an Independent Explant Centre Compare?

Thomas J. Joyce, PhD; Simon L. Smith, PhD; Göksu Kandemir, MSc; *Paul R. Rushton, FRCS*; David Fender, FRCS; Andrew J. Bowey, FRCS; Michael J. Gibson, FRCS

Summary
The manufacturer of MCGR released an Urgent Field Safety Notice stating that rods manufactured before 26 March 2015 had a locking pin fracture rate of 5%, and in rods made on/after that date no pin breakages had occurred. We independently examined 134 explanted rods from 11 centres, identifying locking pin fractures in 59% and 21% of rods manufactured before and on/after this date respectively. This data suggests locking pin fracture is common and remains an issue for this implant.

Hypothesis
The rate of locking pin fracture of MCGRs may be higher than stated by the manufacturer.

Design
Analysis of explanted MCGR.

Introduction
On 25 June 2019 the manufacturer of MCGR released an Urgent Field Safety Notice stating that rods manufactured before 26 March 2015 had a higher than expected locking pin breakage rate of 5%. For rods made on or after that date, no pin breakages had occurred.

Methods
From our independent explant database 134 explanted MCGR supplied from 10 UK spinal centres and 1 Danish centre were divided into rods manufactured before 26 March 2015, and those manufactured on/after that date. MCGR were cut open to fully assess internal components including locking pins. From each of the two cohorts, 10 locking pins were selected at random and their diameters were measured using a micrometer.

Results
Of 105 explanted MCGR made before 26 March 2015 62 (59%) had fractured locking pins. Six of the 29 (21%) MCGR manufactured on/after 26 March 2015 had fractured locking pins. For 10 locking pins taken from rods made before 26 March 2015, their mean diameter was 0.78 (0.01) mm. For 10 locking pins taken from rods made on/after 26 March 2015, their mean diameter was 0.92 (0.01) mm. The manufacturer has indicated previously that the earlier material was grade 440 stainless steel, which had been changed to 465 stainless steel in the later pins. Patients treated with each cohort of rods were comparable in terms of age, sex, aetiology of scoliosis and construct types but rods manufactured after March 26th 2015 were more likely to have been used in a revision case and were implanted significantly less time than those manufactured before this date.

Conclusion
59% of the locking pins in MCGR manufactured before 26 March 2015 had fractured, far greater than the 5% stated in the Urgent Field Safety Notice. Despite increasing the diameter and changing material locking pin fracture still occurred in 21% of MCGR manufactured on/after 26 March 2015. This contrasted with the 0% reported by the manufacturer. Surgeons should consider locking pin fracture an ongoing issue for this implant.

Take Home Message
Explanted MCGR manufactured before/after 26 March 2015 were internally examined. 59% or rods made before this date and 21% of rods made after this date had fractured locking pins.

		Date of manufacture		
		Pre 26 March 2015	On/after 26 March 2015	P
Total number of rods		105	29	
Number of patients		59	18	
Age at insertion [range]		8.2 [3.5-13.8]	8.2 [4.4-13.0]	0.94
Rods implanted in females		54	12	0.18
Aetiology of scoliosis	Idiopathic	56	17	0.94
	Syndromic	24	8	
	Congenital	5	2	
Duration of implantation (months) [range]		40.3 [5-75]	28.7 [1-61]	<0.001
Rods in primary vs revision cases		73:13	11:16	<0.001
Construct; single:dual:hybrid		8:96:1	2:27:0	0.86

Drive pin fractures	Rods made before 26 March 2015	Actual numbers	Rods made on/after 26 March 2015	Actual numbers
Manufacturer UFSN	5%	?	0%	?
This study	59%	62/105	21%	6/29

80. Spinal Lengthening with Magnetically Controlled Growing Rods: Data from the Largest Series of Explanted Devices

Paul R. Rushton, FRCS; Simon L. Smith, PhD; Göksu Kandemir, MSc; Liam Forbes ; David Fender, FRCS; Andrew J. Bowey, FRCS; Michael J. Gibson, FRCS; Thomas J. Joyce, PhD

Summary
This study from the largest series of independently analyzed explanted MCGR is the first to measure rod lengthening over implantation directly. Analysis of 99 explanted rods indicates that they are very rarely removed having fully lengthened. The mean instrumented spinal growth over the lifetime of the implant is 22mm. This appears related to a high rate of mechanism failure after around 3 years in vivo. This data questions the effectiveness of MCGR and mandates urgent comparative clinical studies.

Hypothesis
MCGR lengthening in vivo is limited.

Design
Analysis of explanted MCGR.

Introduction
Little data is available regarding the effectiveness of MCGR, not least whether rods reliably lengthen well in vivo.

Methods
Cases were identified from the largest series of independently analyzed explanted MCGR. Rods removed for any indication

were included. The in vivo rod lengthening was determined by the distance between the first 'growth mark' and the actuator. The instrumented spinal lengthening was calculated; in 2 rod constructs where neither rod was telescoping, the mean lengthening of the rods was used. In 2 rod cases where one rod was telescoping, the lengthening of the non-telescoping rod was used. The lengthening of single rod constructs was used if it was not telescoping. Constructs were considered functional if all rods could lengthen on activation with an external remote controller and no rods were telescoping.

Results

55 MCGR constructs (99 rods) from 53 patients treated at 10 centers were included. The mean age at insertion was 8.5 years with rods implanted a mean of 35 months. 60 rods were suitable for lengthening analysis with mean in vivo distraction of 21.7 (10.5) mm, 8.9 (8.0) mm/year. Of these 60 rods, 3 were fully lengthened. Mean instrumented spinal lengthening for 38 suitable cases was 22.1 (10.0) mm, 8.4 (7.2) mm/year. This was positively correlated with the duration of implantation (r=0.34, p=0.04) but negatively with age at insertion (r=-0.35, p=0.03). Of 55 constructs 34 were non-functional at time of removal with 9 functional and 12 indeterminate. Functional constructs had been implanted significantly less time (20.0 vs. 39.7 months, p<0.001) and lengthened less than those non-functional (12.3mm vs. 23.3mm, p=0.04).

Conclusion

This multicenter explant study represents the largest cohort managed with MCGR reported. Rods are very rarely removed having fully lengthened with a mean instrumented spinal growth of 22mm over implantation. This may be explained by a high rate of rod lengthening mechanism failure after around 3 years in vivo. Our findings question the effectiveness of MCGR and mandate urgent comparative studies.

Take Home Message

Analysis of explanted MCGR constructs indicates that at removal they are typically non-functional and very rarely fully lengthened with mean lengthening over a constructs lifetime of only 22mm.

Variable		Value (range)
Sex (n=54)	Female	34
	Male	20
Etiology (n=52)	Idiopathic	31
	Syndromic	16
	Congenital	5
Age at insertion (n=55)		8.50 years (3.6-13.8)
Height at insertion (n=31)		1.23m (0.87-1.44)
Mass at insertion (n=36)		25.3kg (12.5-41.0)
Primary vs Revision (n=52)		38:14
Dual rod/ single rod/ hybrid construct (n=55)		46:8:1
Reported frequency of lengthenings (n=44)	6-8 weekly	15
	8.1-12 weekly	27
	>12 weekly	2
Reported number of lengthenings (n=42)		10.2 (0-27)
Lengthening protocol (n=47)	Clunk	25
	Tail-gate/ fixed length	19
	Mixed	3
Time *in vivo* (months) (n=55)		35.0 (1.2-75.0)
Reason for removal (n=50)	Failure to lengthen	17
	Drive pin fracture	3
	Rod fracture	7
	Definitive fusion	10
	Perceived full rod lengthening	6
	Anchor failure	5
	Infection	1
	Progressive deformity	1

Measurement technique

81. Exo Corporal Evaluation of Magnetic Spinal Growth Rods (MSGR) in Patients Treated by the Protocol of Frequent Small Increments Lengthenings

Joseph Ivan Krajbich, MD; Michelle C. Welborn, MD; Daniel Bouton, MD

Summary

: Direct examination of removed MSGR rod reveals consistent lengthening at the preset small increments. Average lengthening of the concave side rod was 2.00 mm and of the convex rod 1.89 mm. No statistical difference was found between the early lengthening and late lengthening

Hypothesis

Small increment lengthening would cause less soft tissue injury and less stress on the metal bone interface. This would translate into more dependable function of MSGR and fewer complications.

Design

Explanted MSGR were carefully examined and measured under direct magnified vision to assess their performance during their life time in patients during the lengthening process

Introduction

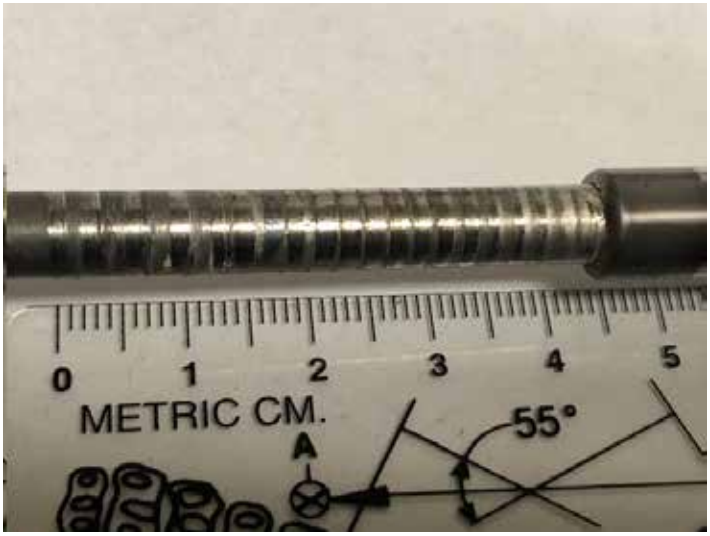
Direct visual examination of MSGRs removed from patients who underwent lengthening allows accurate assessment of the rods function under the lengthening protocol. Each lengthening leaves an obvious mark on the surface of the rod being lengthen. The number of marks and the distances between them can be accurately measured. Process similar to counting annual growth rings on a tree stump. Results of the measurements can then be compared to the lengthening protocol to assess the efficacy of the rods

Methods
MSGR rods were retrieved from patients who underwent their removal for one of the three reasons 1) rods replaced as they reached their maximum length, 2) revised to final instrumentation and fusion due to skeletal maturity, 3) rods failing to lengthen after three unsuccessful attempts. Rods were then carefully measured for overall length achieved, number of lengthening marks (rings) on the rod and the length of first three and last three rings lengthenings. Number of lengthening attempts were noted from the medical records. All patient were lengthened per protocol of 2mm Q 6 weeks.

Results
24 rods were retrieved from 12 patients. Lengthening achieved ranged from 5.5 mm to 49.0 mm. Average 24 mm. The average per lengthening was 2.00mm for the concave rods and 1.89mm for the convex rods. Only minimal difference (6.2 v. 5.8 mm) not statistically significant was found between the first three and the last three lengthenings.

Conclusion
The MSGRs perform well according to lengthening protocol with no significant decay in performance until the end point as confirmed by direct measurements. This can be potentially explained by less trauma to the paraspinal soft tissues and metal bone interface

Take Home Message
Small more frequent lengthening of MSGR may facilitate their more predictable and dependable function



Lengthening markings on the rod surface

82. How to Select the Lower Instrumented Vertebra (LIV) in Traditional Growing Rods (TGR) Index Surgery

Federico Fusini, MD; *Javier Pizones, MD, PhD*; Lucía Moreno-Manzanaro, BS; Jose Miguel Sánchez-Márquez, MD, PhD; Gloria Talavera, MD; Nicomedes Fernández-Baíllo, MD; Francisco Javier S. Perez-Grueso, MD

Summary
Retrospective analysis of prospectively collected data of 25 consecutive patients with EOS treated with TGR. The LIV was analyzed from index surgery to 2 years after graduation. The higher the selection of the LIV above the stable vertebra, the higher the risk of adding-on and distal extension during follow-up. Choosing the substantially touched vertebra as LIV could be justified, because the need for distal extension is not high (15%), and if needed, it can be performed during future scheduled procedures.

Hypothesis
Saving distal segments is worthy in TGR index surgery

Design
Retrospective analysis of prospectively collected data

Introduction
Despite a wide experience with TGRs, there are still no counseled criteria on how to select the LIV at index surgery. The aim was to evaluate whether the criteria used for AIS adapt to EOS, based on the stable vertebra (SV), the substantially touched -by the central sacral vertical line- vertebra (STV), and the not substantially touched vertebra (NSTV).

Methods
Retrospective analysis of prospectively collected data of a consecutive cohort of patients with EOS treated with TGR, expanding from index surgery to 2 years after graduation. The LIV was analyzed regarding its relation to the SV, STV, and NSTV. Failure in LIV selection was considered when distal extension was needed due to adding-on (ΔLIV tilt>10º).

Results
25 patients met inclusion criteria. Mean age x=8.6±3 (at index surgery); x=15.1±1.8 (at graduation); 17.8±1.6 (at final follow-up). 11 patients had single thoracic curves, 6 thoracolumbar and 8 had double curves. The most frequent LIV at index surgery was L3 (13/25), followed by L2 (6/25), L4 (3/25), L1 (2/25) and L5 (1/25). In 13 cases STV was selected as LIV, in 7 it was NSTV, and in 5 SV in the standard AP X-ray. The number of distal anchors used was 2.04±0.2. During follow-up, a significant increase in the mean LIV tilt (p=0.049) and DJA (p=0.017) was found (Table). 9/25 patients (36%) developed adding-on: 20% (1/5) of the SV; 38.5% (5/13) of the STV; 42.8% (3/7) of the NSTV. 44% (4/9) of these suffering adding-on (16% of the total cohort) needed distal extension: 2 STV patients (15.4%), and 2 NSTV patients (28.6%). None of the patients with SV chosen as LIV need distal extension for adding-on.

Conclusion
The higher the selection of the LIV above the SV, the higher

the risk of adding-on and of distal extension during follow-up. Saving motion segments could be justified by choosing STV as LIV, because the need for distal extension is not high, and it can be scheduled during lengthening procedures or at graduation surgery.

Take Home Message
Setting the LIV at the STV calculated in preoperative x-rays is worthy in TGR index surgery

Table. Comparison of the quantitative measures from TGR index surgery until final follow-up

	A. Preop	B. Postop	C. Graduation	Student -t B vs C	D. Final follow-up	Student -t B vs D	Student -t C vs D
Age (years)	8.6±2.9		15.1±1.8		17.8±1.6		
Main Cobb (°)	78.8±15.4	47.6±8.5	52.9±13.2	0.359	49.8±14.9	0.753	0.334
Coronal balance (mm)	19.7±19.8	17.6±15.5	19.3±19.4	0.736	24±20.4	0.257	0.455
LIV-Tilt (°)		10.4±6.71	12.2±7.8	0.049*	11.4±8.8	0.164	0.644
LIV disc wedge (°)		3.1±2.6	3.4±2.5	0.978	3.7±2.7	0.968	0.942
DJA (°)		-3.7±8.9	-16.4±10.2	0.017*	-10.2±14.6	0.009*	0.561

TGR: traditional growing rods; LIV: Lower instrumented vertebra; DJA: distal junctional angle; * statistical

Table LIV

83. The Effect of Magnetically Controlled Growing Rod Lengthening on Kyphosis

Michelle C. Welborn, MD; Nikolas Baksh, MD; Joseph Ivan Krajbich, MD; Daniel Bouton, MD

Summary
Magnetically-controlled growing rod (MCGR) did not result in a change in T1-T12 kyphosis postoperatively nor with repeated lengthenings, but the distribution of kyphosis did change with increased kyphosis from T1-T5 and decreased kyphosis from T5-12 postoperatively in the non halo gravity traction group (HGT)

Hypothesis
Our study tested the hypothesis that due to the straight telescoping portion of the rod that the MCGR treatment would not induce kyphosis but that kyphosis would redistribute to the portion of the rod proximal to the straight actuator

Design
IRB approved retrospective single site cohort study

Introduction
Traditional growing rod (TGR) and vertical expandable prosthetic titanium rib (VEPTR) treatments for EOS can be inherently kyphogenic due to their radius of curvature. Unlike TGR and VEPTR the MCGR elongates through a straight telescoping rod. While initial postoperative kyphosis has been studied, neither the change in kyphosis nor the distribution of kyphosis has studied in MCGR

Methods
Retrospective review of 19 EOS patients treated with primary MCGR with or without HGT from a single site database w >2yr follow-up. Pre-op, post-traction, post-op, one year and final follow up coronal and sagittal Cobb angles, T1-12 and T5-12 kyphosis and proximal junctional angle (PJA) were measured on digital images. Repeated measures ANOVA was used to measure the difference between pre-op, post op, and final kyphosis

Results
There was no significant difference in preop or follow-up kyphosis between T1-12 and T5-12 in the HGT or non-HGT group. There was a redistribution of kyphosis. Kyphosis was predominately located between T5-T12 pre-op and between T1-T5 at latest follow-up. There was no change in PJA nor was there a difference in PJA between the groups. Three pts had proximal anchor failure requiring revision, one of which was associated with mild proximal junctional kyphosis (PJK). None were associated with increased pre-op kyphosis

Conclusion
MCGR did not induce global kyphosis with repeat lengthening in the HGT and non-HGT cohorts, but kyphosis was redistributed postoperatively. It is unclear how this change in kyphosis will affect outcomes in the long term. Furthermore, there was no change in the PJA overtime

Take Home Message
Unlike TGR and VEPTR, MCGR was not found to be kyphogenic overtime, but the distribution of kyphosis did change.

Data Summary

	Preop T1-T12 kyphosis	Preop T5-T12 kyphosis	Post HGT T1-T12 kyphosis	Post HGT T5-T12 Kyphosis	Postop T1-T12 kyphosis	Postop T5-T12 kyphosis	Postop PJA	Most recent f/u T1-T12 kyphosis	Most recent F/u T5-T12 Kyphosis	Most recent PJA	Average Duration of F/u
HGT n=8	38.7 (-7.96-74.5)	28.1 (-6.3-62.9)	16.8 (-7.0-30.8)	14.6 (-7.23-25.6)	28.5 (5.04-61.8)	17.6 (-9.9-39.3)	4.7 (0.2-10)	33.0 (10.0-68.6)	18.3 (-9.9-39.3)	4.5 (0.8-10)	853 days
Non HGT n =11	28.7 (-24.6-52.9)	25.0 (-24.2-73.2)	n/a	n/a	27.7 (7.45-48.1)	12.6 (-7.7-33.5)	3.2 (-3.5-9.3)	32.0 (6.2-67.9)	13.0 (-2.9-29.4)	4.4 (-3.5-11.0)	812 days

Change in distribution of kyphosis over time

	Preop T5-12 percent total kyphosis	Postop T5-T12 percent total kyphosis	P-value preop to postop % kyphosis	Most Recent F/u T5-12 percent total kyphosis	P-value preop vs most recent % total kyphosis
HGT n=8	81.6%	81.8%	0.997	42.8%	0.372
Non HGT n =11	88.9%	25.6%	0.026	48.2%	0.061

84. Does the Law of Diminishing Returns Exist in Early Onset Scoliosis with Connective Tissue Disorders?

Majd Marrache, MD; Klane K. White, MD; A. Noelle Larson, MD; Tricia St. Hilaire, MPH; Majella Vaughan, MPH; Regina Woon, MPH; *Paul D. Sponseller, MD*

Summary
Our study compares the height gain between early onset scoliosis idiopathic patients and patients with connective tissue disorders after repeated lengthening of their growth friendly rods. Contrary to what is seen in idiopathic EOS patients undergoing repeated lengthening of GF rods, our results demonstrate that the law of diminishing returns is not present among patients with early onset scoliosis in the setting of a connective tissue disorder.

Hypothesis
Patients with connective tissue disorders (CTD) undergoing Growth Friendly (GF) surgery will continue to have a steady increase in height gain without evidence of diminishing returns.

Design
Retrospective multicenter study

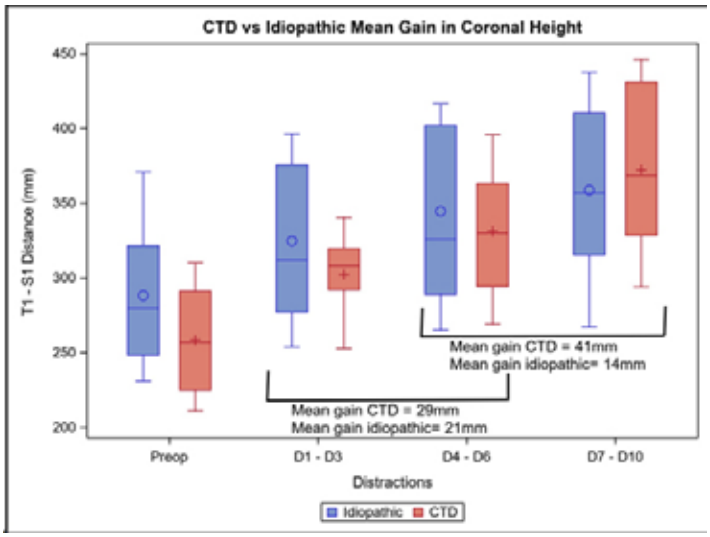
Introduction
Recent studies have demonstrated the law of diminishing returns (LODR) on patients with early onset scoliosis (EOS) undergoing repeated lengthening of growing rods. Little is known about whether this same phenomenon occurs in patients with lax CTDs.

Methods
Patients with CTD, <10 years old, who underwent GF spine surgery were matched with idiopathic EOS patients. All had at least 1 proximal spine anchor and had minimum 5 years follow up. After application of one to one propensity score matching, 42 patients were analyzed (21 CTD patients and 21 idiopathic). T1 – S1 height at pre-index surgery, post index and every available lengthening was assessed. We compared mean height change (MHC) during early set distractions (distractions D1 to D3 and D4 to D6) and late set distractions (D4 to D6 and D7-D10) between patients with CTD and those with idiopathic scoliosis. In order to account for varying distraction intervals, we normalized the distractions by the time interval. The outcome parameter was T1-S1 height gain, mm/year.

Results
42 patients were included in this study. 21 (50%) CTD (17 Marfan syndrome, 1 EDS, 2 LDS and 1 uncharacterized) and 21 (50%) idiopathic scoliosis. Mean age at initial implantation was 6 + 3 years and 22 (52%) were female. There was significantly greater total mean improvement in coronal height at final follow up, including implantation, among the CTD group (102 + 48mm) compared to the idiopathic group (86 + 33m), p=0.02. Compared to the idiopathic group, patients in the CTD group had greater height gain during early distraction (29 vs 21mm, p=0.09) and late distraction (41 vs 14mm, p-= 0.001). When normalized for time, there was no significant difference in net gain per year at different lengthening time points for the CTD group, p=0.59.

Conclusion
There was a continuous significant increase in height gain among patients with CTD, without evidence of the LODR that was present among idiopathic patients.

Take Home Message
Contrary to what is seen in idiopathic EOS patients, our results demonstrate that the law of diminishing returns is not present among patients with connective tissue disorder.



85. Comparison Of Results and Complications: Hybrid Technique of Posterior Osteotomy with Short Segmental Fusion and Dual Growing Rod Technique VS Traditional Dual Growing Rod (TGR) Technique

Jianguo Zhang, MD; Shengru Wang, MD

Summary
Hybrid technique of posterior osteotomy with short segmental fusion has been introduced for the treatment of severe and rigid early-onset congenial scoliosis. However, differences between this hybrid technique and traditional dual growing rod technique for the treatment of early-onset congenial scoliosis have not been well studied.

Hypothesis
There may be differences in outcomes of the hybrid technique VS traditional dual growing rod technique for severe rigid congenital scoliosis.

Design
Retrospective study

Introduction
This study was conducted to evaluate differences in outcomes of the hybrid technique VS traditional dual growing rod technique for severe rigid congenital scoliosis.

Methods
64 patients with early-onset congenital scoliosis who were treated in our hospital from 2004 to 2016 were included in this study.49 patients were treated with traditional growing rod and 15 patients were treated with hybrid technique. The patients' charts were reviewed. The Analysis included age at initial surgery and the latest follow-up, number and frequency of lengthening, and complications. Radiographic evaluation included measured changes in scoliosis Cobb angle, thoracic kyphosis, lumbar lordosis, trunk shift, length of T1–S1 and instrumentation.

Results
All patients were followed at least for 2 years. There were no

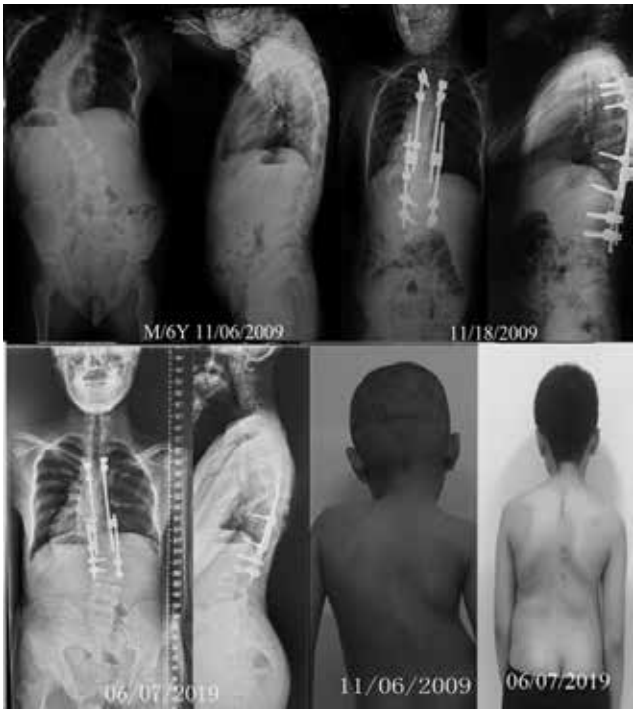
differences in age of initial surgery and number of lengthening procedures. The average preoperative cobb angle of hybrid group was bigger than the TGR group□76.2°VS 63.7°, P□0.05 □. And the correction of hybrid was better than that of TGR group□66.1% VS 55.6%, P□0.05□.The average number complications in hybrid technique group was smaller than that of TGR group(1.17 VS 2.07□P□0.05).No differences were found in the growth of T1-S1 length (1.15cm/y VS 1.34cm/y).

Conclusion

Compared to the TGR, the hybrid technique of osteotomy with short fusion and dual growing rod could help to improve the correction, decrease the risk of complications with little influence on the growth of the spine. This hybrid technique may be an option for young patients who present sharp deformities with large asymmetric growth potential in a long congenital spinal deformity.

Take Home Message

Hybrid technique of osteotomy with short fusion and dual growing rod could help to improve correction, decrease the risks of complications with little influence on the growth of the spine.



6- year-old boy with severe rigid congenital scoliosis. He was treated with osteotomy, short segmental fusion and dual growing rod technique. 10 years follow-up showed correction of the deformity was satisfied.Length of spine and space for lung improved significantly.

86. Surgical Treatment for Congenital Scoliosis Patients Aged from 9 to 11 Years Old: Is Growth-friendly Treatment Superior to One-stage Fusion?

Liang Xu, MD; *Xu Sun, MD*; Zhen Liu, MD; Zezhang Zhu, MD; Bangping Qian, MD; Yong Qiu, MD

Summary

Pediatric surgeons would take a risk of higher complications and choose GF treatment for young children aged less than 8 years old, when rapid development of chest wall and pulmonary alveoli is taking place. Whereas for patients aged from 9 to 11 years old when treatment transitions from growth-friendly to a spinal fusion, there may be a hesitation among surgeons with regards to choice between GF and posterior spinal fusion (PSF)

Hypothesis

GF treatment does not bring benefits for patients aged from 9 to 11 years old

Design

Retrospective and case-matched study.

Introduction

Distraction-based growth friendly (GF) technique has become the mainstay of treatment for congenital early-onset scoliosis. Whereas for patients aged from 9 to 11 years old when treatment transitions from growth-friendly to a spinal fusion, there may be a hesitation among surgeons with regards to choice between GF and posterior spinal fusion (PSF).

Methods

Nine CS patients (mean age 9.5 ± 0.7 years) who underwent GF distraction and definitive spinal fusion were matched with 18 CS patients (mean age 9.7 ± 0.8 years) who underwent one-stage PSF treatment for age, triradiate cartilage, major curve magnitude, and location of major curve apex. All patients had been followed till skeletal maturity.

Results

The major curve in both groups notably improved postoperatively (P<0.01), whereas the correction rate after the initial surgery as well as at the latest follow-up in the PSF group was significantly higher than in the GF group (P<0.05). The overall complication rate in the GF group was notably higher than in the GF group (66.6% vs. 22.2%, P=0.024). There was no significant difference between two groups with regards to T1-T12 gain, T1-S1 gain and PFT before surgery as well as at the latest follow-up (P > 0.05). However, the GF group had better outcomes of EOSQ-parental impact, financial burden scores, and SRS-22 self-image scores when compared with the GF group

Conclusion

For CS patients aged from 9 to 11 years old, one-stage PSF resulted in similar PFT outcomes and spinal height gain but less complication with higher spinal deformity correction rate as compared with GF treatment. Therefore, GF treatment does not bring benefits for patients of this age range.

Podium Presentations—Early Onset Scoliosis/Syndromic

Take Home Message
The current study demonstrated that GF treatment does not bring benefits for patients aged from 9 to 11 years old

87. Revision Rates of 5-year Minimum Graduates of Growth Friendly Surgery for Early Onset Scoliosis

Robert F. Murphy, MD; John B. Emans, MD; Paul D. Sponseller, MD; David S. Marks, FRCSOrth; David L. Skaggs, MD; George H. Thompson, MD; John (Jack) M. Flynn, MD; Behrooz A. Akbarnia, MD; John T. Smith, MD; Jeffrey R. Sawyer, MD; Pediatric Spine Study Group

Summary
In this series of growth friendly graduates with minimum 5-year follow up, revision rate was 22%. The most common reason for revision was implant revision (either growth friendly or spinal fusion).

Hypothesis
Rates of revision of 5-year graduates of growing spine surgery are low.

Design
Retrospective multi-center review

Introduction
After graduation from growth friendly (GF) surgery for early onset scoliosis, treatment includes observation with GF implant maintenance or removal, or spinal fusion. The rates of secondary intervention in a mid-term follow up cohort are unknown.

Methods
An international pediatric spine database was queried for growth friendly graduates. Treatment plan, occurrence of revision, and timing of revision were queried, number and reasons for revision were queried.

Results
171 patients were identified as graduates of a GF program (spine- or rib-based) for early onset scoliosis with a minimum 5-year follow up. Scoliosis etiology was congenital in 41 (23%), idiopathic 36 (21%), neuromuscular 49 (27%), syndromic 42 (25%), other 3 (2%). 115 (68%) of patients underwent spinal fusion as their graduation strategy, 46 (27%) had maintenance of their growing construct, 9 (5%) had implants removed, and 1 did not have data. Thirty-seven (22%) underwent at least one (average 1.7, range 1-7) secondary surgery following graduation, with 40% of the cohort undergoing 2 or more revision surgeries. Reason for revision was implant revision (either growth friendly or spinal fusion) in 34 patients, and implant removal in 3. On average, the first revision was 2.5 years after the definitive treatment plan (Range 0.02 – 7.4 years). Fifteen (41%) revisions occurred over 2 years following the final decision for treatment plan, and 7 (10%) occurred five years after the definitive treatment.

Conclusion
In this mid-term follow up series of GF graduates, overall rate of revision was 22%. Average time to revision surgery was 2.5 years. Fifteen (41%) patients were revised after 3 years, and 7 (10%) after 5 years. Knowledge of late revision rates will allow clinicians to adequately counsel families of graduate patients.

Take Home Message
At minimum 5-year follow up, 22% of GF graduates underwent at least one revision surgery.

88. Spinal Mobility and Muscle Function in Middle-aged Patients Treated for Early Onset Idiopathic Scoliosis: Compared with Untreated and Treated Adolescent Onset Patients

Karin Romberg, PhD; Aina J. Danielsson, MD, PhD; Monika Fagevik Olsen, PhD; Gunilla Kjellby-Wendt, PhD

Summary
Middle-aged patients with idiopathic scoliosis diagnosed before age ten but treated with brace or surgery during adolescence were evaluated for spinal mobility and muscle strength. The results of braced individuals were similar to an untreated AIS group. Despite a longer bracing time they were better than individuals braced for AIS. Operated individuals were both weaker and stiffer, but groups with adolescent or earlier onset showed similar results, despite longer fusion length in those with earlier onset.

Hypothesis
Objectives To evaluate the spinal mobility and trunk muscle strength in these adult patient groups.

Design
Adult patients with idiopathic scoliosis, diagnosed before the age of ten and treated during adolescence but before maturity with either brace or surgery underwent a clinical follow up. Three groups with adolescent idiopathic scoliosis (AIS) with similar curve sizes were used for comparison, previously braced or operated of similar age and previously untreated but 10 years younger.

Introduction
Long-term studies of spinal range of motion (ROM) and muscle strength in patients treated for early onset scoliosis (EOS) have not been published.

Methods
Patients underwent examination of spinal ROM and strength was evaluated by trunk muscle endurance (TME) of flexors and extensors. Back function was evaluated by Oswestry Low Back Pain Disability Questionnaire (ODI).

Results
116 patients attended the follow-up at a mean of 26.5 years after maturity (63 braced, mean length bracing period 4.8 years, 41% Milwaukee, 59% Boston) or surgery (53 operated at mean age 13.2 years, fusion length mean 10.6 levels). Braced EOS patients had similar (n.s.) ROM (thoracic 40˚, lumbar 78˚) and TME (flexor 140 s, extensor 255 s) as untreated AIS patients (ROM: thoracic 34˚, lumbar 88˚; TME: flexor 158 s, extensor 234 s), but significantly better than braced AIS patients (ROM: thoracic 28˚ ($p<0.001$), lumbar 54˚ ($p<0.001$), TME: flexor 106 s ($p=0.002$),

extensor 170 s (p<0.001)). Operated EOS patients were neither weaker nor stiffer than operated AIS patients, despite somewhat longer fusions in the EOS group (10.6 vs. 9.5 levels, p<0.001). The degree of lumbar ROM affected the back function (ODI) in operated EOS patients only (rs=0.49, p<0.001).

Conclusion

Braced EOS patients had similar spinal ROM and TME as untreated AIS patients, but significantly better than their AIS peers, despite a longer bracing period. Operated patients had similar muscle strength and range of motion regardless of onset of the scoliosis.

Take Home Message

Previously treated patients with idiopathic scoliosis diagnosed before age ten have similar or better spinal strength and mobility compared to those with later onset, and similar to untreated patients.

89. Mental Health Consequences of Serial Mehta Casting: Negative Correlation with Behavioral Development

Nishank Mehta, BA; Lacey Magee, BA; Heidi R. Nocka, BA; Peter F. Sturm, MD; Joshua M. Pahys, MD; Sumeet Garg, MD; Robert F. Murphy, MD; Pediatric Spine Study Group ; Patrick J. Cahill, MD

Summary

Mehta casting has gained popularity in infantile idiopathic scoliosis (IIS) treatment due to technique success and result reproducibility. However, we know little regarding the effects of bracing or casting on these pediatric patients' behavior and development. Understanding how a child's brain development is affected by casting or repeat episodes of general anesthesia will help direct practitioners when counseling families on treatment strategies.

Hypothesis

Mehta casting negatively influences a child's behavioral and cognitive development.

Design

Prospective Multi-center Study

Introduction

Annually hundreds of children are diagnosed with IIS. Mehta casting has been shown to resolve scoliosis in a large number of patients when treated early, but potentially at the expense of quality of life, cognitive development, and behavioral development. The aim of this study was to understand the effect of this type of casting on a child's psychological, behavioral and cognitive development.

Methods

Patients diagnosed with IIS whose treatment plan involved Mehta casting were prospectively enrolled and given the validated outcome instrument, Behavior Assessment System for Children (BASC-2), pre-casting and during follow up visits. A greater BASC T-score indicates a greater likelihood of behavioral, emotional, or functional impairment. Preliminary data was analyzed using paired t-tests of pre-casting versus 2 years post-initiation of casting.

Results

Analyzable data was available on 14 patients for the BASC questionnaire pre-cast (mean age 17.4 ± 9.1 months, 85.7% male) and 2 years post-initiation of casting (mean age 42.1 ± 8.4 months). Raw T-score means, standard deviations, and calculated p-values from 2-tailed paired t-tests are listed in Figure 1 for 15 BASC subscales. The subscales that reached statistical significance when comparing pre-casting and 2-year post-initiation scores were patient Anxiety (p=.003), Social Skills (p=.029), Functional Communication (p=.016), Activities of Daily Living (p=.015), Internalizing Problems (p=.012), and Atypicality (p=.034).

Conclusion

To our knowledge this is the first study evaluating the psychological and social impact of casting intervention in IIS. Although the data is limited, a slight increasing trend for the likelihood of problems in the BASC 2-year post-initiation Anxiety, Social Skills, Functional Communication, Activities of Daily Living, Internalizing Problems, and Atypicality sub-scale scores suggests Mehta casting may negatively impact behavior and emotional status in children.

Take Home Message

When deciding how to treat children with IIS, we should consider how Mehta casting procedures, although effective, may negatively impact the behavioral and cognitive maturation of these children.

Figure 1: Infantile Idiopathic Scoliosis BASC Sub-Scores Pre- and 2 Years Post-Initiation of Mehta Casting

	AGGRESSION T-SCORE		ANXIETY T-SCORE		SOCIAL SKILLS T-SCORE		FUNCTIONAL COMMUNICATION T-SCORE		ACTIVITIES OF DAILY LIVING T-SCORE	
	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST
AVERAGE	44.5	47.2	42.3	53.8	36.5	48.5	37.7	47.2	37.9	46.8
ST. DEV.	7.9	8.7	8	10.6	9.1	11.7	4.9	9.6	7.1	12.7
P-VALUES (2-TAILED)	0.21		*0.003		*0.029		*0.016		*0.015	
	ATYPICALITY T-SCORE		INTERNALIZING PROBLEMS T-SCORE		ATTENTION PROBLEMS T-SCORE		HYPERACTIVITY T-SCORE		DEPRESSION T-SCORE	
	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST
AVERAGE	59.1	50	44.5	52.1	54.9	52.3	47.8	50.5	47.4	51.6
ST. DEV.	6.5	10.3	8.1	7.7	10.1	11.6	6.7	11	8.6	11.1
P-VALUES (2-TAILED)	*0.034		*0.012		0.364		0.354		0.143	
	ADAPTABILITY T-SCORE		ADAPTIVE SKILLS T-SCORE		WITHDRAWAL T-SCORE		EXTERNALIZING PROBLEMS T-SCORE		SOMATIZATION T-SCORE	
	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST	PRE-CAST	2 YEAR POST
AVERAGE	52.1	47.4	39.6	47.4	51.4	52.6	44.4	48.3	47	47.3
ST. DEV.	8	9.4	5.9	11.3	11.2	9.3	7	10.9	5.4	6.9
P-VALUES (2-TAILED)	0.083		0.082		0.623		0.184		0.899	

Figure 1: Infantile Idiopathic Scoliosis BASC Sub-Scores Pre- and 2 Year Post- Mehta Casting

Podium Presentations—Early Onset Scoliosis/Syndromic

90. Pulmonary Hypertension (PH) and Thoracic Cage Function in Patients with Early Onset Scoliosis: Assessment with Quantitative Dynamic Magnetic Resonance Imaging (QdMRI)

Yubing Tong, PhD; Jayaram K. Udupa, PhD; Joseph M. McDonough, MS; Caiyun Wu, MS; Catherine Qiu, MS; Carina Lott, MS; Nirupa Galagedera, BA; Catherine M. Avitabile, MD; *Jason B. Anari, MD*; Drew A. Torigian, MA; Patrick J. Cahill, MD

Summary
Little is understood about patients who have pulmonary hypertension (PH) and lung disease due to early onset scoliosis (EOS). No quantitative approaches are available to evaluate the association between PH and thoracic dynamics of EOS patients. EOS patients with PH have lower diaphragm excursion tidal volume as well as lower right lung tidal volume when compared to EOS patients without PH. All QdMRI volume parameters of EOS patients independent of PH status are lower than those of normal children.

Hypothesis
EOS patients with PH will have more severe lung disease than those without PH.

Design
Retrospective cohort study

Introduction
Currently, the association between PH and thoracic dynamics in patients with EOS is unknown. QdMRI is feasible technique to quantify the dynamics of thoracic components (lung, chest walls, and hemi-diaphragms) of EOS patients and normal children. The purpose of this work is to analyze the relationship between PH and components of thoracic dynamics and study how they differ among EOS patients with and without PH as well as normal children. To date no report exists on the correlation of early onset spinal deformity to the development of cardiac dysfunction.

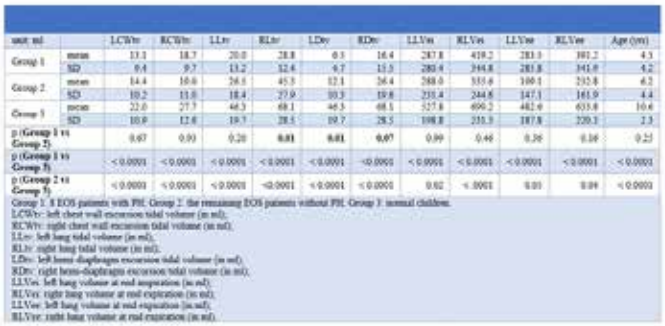
Methods
34 EOS patients (19M, 15F) and 51 normal children (24M, 27F) were evaluated. 8 EOS patients diagnosed with PH composed Group 1, 26 EOS patients without PH composed Group 2, and 51 normal children composed Group 3. PH was defined by at least one echo criteria: right ventricular pressure > ½ systemic blood pressure estimated from tricuspid regurgitant jet or patent ductus arteriosus (PDA) velocity, bidirectional or right to left PDA, flattened or bowing ventricular septum at end-systole, and/or clinical diagnosis of PH. Tidal volumetric parameters for thoracic components were derived for all groups via QdMRI technology. T-tests were performed to compare volumetric parameters among groups.

Results
Right lung tidal volume of EOS patients with PH was significantly lower than EOS patients without PH (p=0.01). Similarly, left and right hemi-diaphragmatic tidal volumes of patients with PH were lower than without PH (p=0.01, p=0.07 for left and right components respectively). No significant difference was found for lung volumes and chest wall tidal volumes (p>0.05). All QdMRI parameters of EOS patients (with/without PH) had significantly lower values than those for normal children (p<0.0001).

Conclusion
Tidal volumes of right lung and left hemi-diaphragm of EOS patients with PH are significantly lower than patients without PH. EOS patients with PH have more severe lung disease than EOS patients without PH.

Take Home Message
Pulmonary hypertension is a potential manifestation of EOS and affected patients have objective and quantifiable impairments in their respiratory cycle.

Table 1. QdMRI parameters for EOS patients with/without pulmonary hypertension (PH) and normal children. Mean and standard deviation (SD) are listed as well as p-values from comparisons among groups.



91. Nusinersin Does Not Mitigate Spine Pathoanatomy in Spinal Muscular Atrophy Patients

Michael J. Troy, BS; Patricia E. Miller, MS; Carina Lott, MS; Catherine Qiu, MS; Jason B. Anari, MD; *Brian D. Snyder, MD, PhD*

Summary
The efficacy of Nusinersen on modifying spinal deformity in SMA patients is unknown. Baseline and long-term radiographs of patients with SMA treated with serial intrathecal injections of Nusinersen were compared to a matched cohort of untreated patients (historical controls) to assess whether Nusinersen ameliorated the incidence or progression of neuromuscular spinal deformity and need for augmentative respiratory support. Nusinersen did not impact the incidence or progression rate of scoliosis, and did not diminish eventual need for respiratory assistance.

Hypothesis
In patients with spinal muscle atrophy (SMA), Nusinersen treatment will lower the incidence, slow the progression and diminish the need for surgical correction of spine deformity compared to untreated patients.

Design
Multicenter Retrospective Cohort Comparison

Introduction
SMA is a genetically-inherited, neuromuscular disorder characterized by degeneration of α-motor neurons due to deletions or mutations in SMN1 gene resulting in nonfunctioning SMN pro-

tein. Phenotype severity depends on the number of SMN2 rescue gene copies: ≤3 copies is associated with progressive muscle atrophy, respiratory dysfunction and spine/thoracic (parasol rib) deformity. Nusinersen is an antisense oligonucleotide, administered intrathecally that improves muscle strength and pulmonary function in SMA patients, depending on SMN2 copy number and age at treatment initiation.

Methods

87 SMA subjects were analyzed: median age @ baseline 3.9 years (range, 0.2-23.9), followed for median 7.1 yrs (2.1-15.3) to median age 11.6 yrs (3.0-36.3) (Table 1). 43 subjects (49%) were treated with Nusinersen for a median of 2.1 yrs (1-6.6). Baseline and follow-up radiographs of the spine and thorax were measured to document presence/progression of deformity. Owing to differences in age and phenotype between treatment groups at baseline (untreated: older, bigger Cobb), statistical analysis included younger subjects with baseline scoliosis <40° to better match the cohorts at baseline: 39/66 (59%) treated with Nusinersen before 2018. The effect of treatment on change in curve magnitude between baseline and follow-up was evaluated using mixed model analysis that controlled for age and duration follow-up.

Results

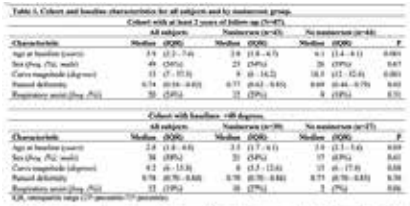
No differences were detected between treatment groups with regard to progression of scoliosis, (Figure 1) parasol rib deformity, need for respiratory assist, or need for spine surgery (Table 2).

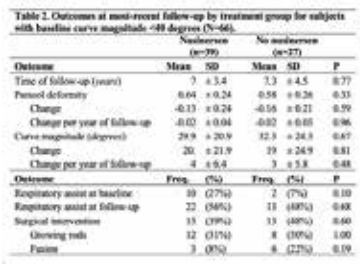
Conclusion

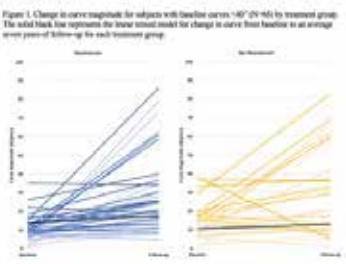
The benefit to SMA patients treated with Nusinersen depends on the number of SMN2 copies and remaining neuro-motor axis growth at the time of treatment initiation. Yet, Nusinersen did not delay or ameliorate the progression of scoliosis, parasol rib deformity, need for respiratory assist or surgical intervention

Take Home Message

Although Nusinersen positively impacts the overall health in patients with SMA, it does not prevent the occurrence or mitigate the progression of spine and parasol deformity associated with SMA.







92. Is the Sagittal Profile of the Spine Modified in Patients with Achondroplasia after the Lower Limb Lengthening Surgery?

Rosa M. Egea-Gámez, MD, PhD; María Galán-Olleros, MD; Cristina Madrid de la Serna, MD; Javier Alonso Hernández, MD; Carlos Miranda-Gorozarri, MD; Carmen Martínez-González, MD; Rafael González-Díaz, MD, PhD

Summary

Achondroplasia is a rhizomelic skeletal dysplasia, the aim of this study is to analyse the changes in the spinopelvic alignment and sagittal balance after lower limb lengthening surgery in achondroplasic patients. Bilateral lower limb lengthening in achondroplasia not only increases their final size, but also decreases pelvic anteversion and therefore LL, increases TK and improves the spinopelvic alignment and sagittal balance.

Hypothesis

Lower limb lengthening surgery improves the sagittal profile of the spine in achondroplasia.

Design

Prospective study

Introduction

Achondroplasia is a rhizomelic skeletal dysplasia, characterised by short stature, lumbar hyperlordosis and thoracolumbar (TL) kyphosis, spinal canal stenosis, genu varus, and trident hand. Limb lengthening surgery based on the concept of distraction osteogenesis has undergone a great development in the recent years with the use of telescopic intramedullary nails.

Methods

Prospective study of patients with achondroplasia treated for bilateral femoral lengthening using an intramedullary telescopic nail. Different sagittal plane parameters were measured on pre and postoperatively standing whole spine radiographs: cervical lordosis, T1 and TL slope and tilt, thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence, pelvic tilt (PT), sacral slope (SS), and sagittal vertebral alignment (SVA). All measurements were performed by two independent researchers. Similarly, information regarding the elongation procedure was recorded.

Results

A total of 10 patients were included (60% male), with a median age of 13.56 ± 1.3 years at first surgery. A 10 cm elongation was performed in all patients, using a femoral subtrochanteric osteotomy, being the median distance from the lesser trochanter to the osteotomy zone 1.33 ± 0.43 cm. The TK T5-T12 changed from 22.25º to 24.95º, the LL from 68.85º to 52.35º, PT from 14.1º to 15.35º, SS from 59.45º to 41.3º and | SVA | from 42.25mm to 15.7mm.

Conclusion

Bilateral lower limb lengthening in patients with achondroplasia not only increases their final size, but also decreases pelvic anteversion and therefore LL, increases TK and improves the spinopelvic alignment and sagittal balance in a statistically significant way.

Take Home Message
Bilateral lower limb lengthening in achondroplasia not only increases their final size, but also decreases pelvic anteversion and therefore LL, increases TK and improves the spinopelvic alignment and sagittal balance.

	Pre- lengthening	Post- lengthening	p value
Thoracic Kyphosis T5-T12	22,25°	24,95°	**p = 0,02**
Lumbar lordosis T12-S1	68,85°	52,35°	**p = 0,01**
PT	14,1°	15,35°	p > 0,05
SS	59,45°	41,3°	**p = 0,036**
|SVA|	42,25mm	15,7mm	**p = 0,012**

Results

93. Prospective Spine at Risk Program for Prevalence of Intracanal Spine Lesions in Pediatric Hereditary Multiple Osteochondromas

Catphuong L. Vu, MD; Antoinette W. Lindberg, MD; Viviana Bompadre, PhD; Klane K. White, MD; Jennifer M. Bauer, MD

Summary
Intracanal exostoses in multiple hereditary exostoses are rarely symptomatic. However, to avoid neurologic injury, MRI surveillance in a prospective spine at risk program determine that optimal timing of MRI is at preoperative evaluation for surgery to prevent unnecessary sedation for younger children.

Hypothesis
The majority of patients with multiple hereditary exostoses with intracanal exostoses are asymptomatic and surveillance can be done at time of preoperative evaluation to minimize risk of sedation.

Design
Retrospective cohort study

Introduction
Unidentified intraspinal exostoses in HMO can lead to neurologic injury in children during sedated procedures but no MRI guidelines exist. We sought to determine the prevalence and age of intraspinal exostoses from MRIs and the utility of MRI surveillance in a prospective Spine at Risk (SAR) program.

Methods
Retrospective review was performed of pediatric HMO patients who underwent total spine MRIs at a single institution after a prospective SAR program was instituted. Charts were reviewed for MRI indication and findings, symptoms, surgery, and location of other exostoses. Fisher's exact test was used to compare categorical variables and T-test to compare continuous variables. Predictive value of pelvic/rib exostoses was calculated for intraspinal lesions.

Results
Forty-three patients with HMO underwent total spine MRIs with average age of 11.5 years. Fifteen (35%) patients had exostoses on vertebral column, eight (19%) had intra-canal spinal exostoses. Higher prevalence of spine lesions occurred in symptomatic patients than asymptomatic (any spinal lesion: 73% prevalence in symptomatic vs 22% in asymptomatic; intra-canal spinal lesion: 46% vs 9%). Only two of the 11 'symptomatic presentations' could be attributable to intra-canal spinal exostoses. Only one intra-canal exostosis found on asymptomatic surveillance was treated surgically. Presence of pelvic or rib exostoses were not strongly predictive of intra-canal lesions (23% PPV, 85% NPV, 63% sensitivity, 51% specificity).

Conclusion
Even with the presence of intra-canal exostoses, true symptomatic lesions are rare. Rib and pelvic lesions were not predictive of intra-canal lesions in our population. We recommend obtaining MRIs at time of preoperative evaluation in asymptomatic children old enough to not need sedation, or in patients with true neurologic symptoms to prevent unnecessary sedation of younger children for surveillance MRI.

Take Home Message
Spine at risk program can be implemented to screen for intracanal exostoses in patients with multiple hereditary exostoses at time of preoperative evaluation to minimize unnecessary sedation in young kids.

Podium Presentations—Sagittal/PJK

94. Age- and Gender-based Normative Values of Whole-body Sagittal Alignment: A Large Cohort Study of 584 Chinese Adults aged from 20 to 89

Zongshan Hu, PhD; Zhen Liu, MD; Tsz Ping Lam, PhD; *Zezhang Zhu, MD*; Yong Qiu, MD; Jack Chun Yiu Cheng, MD, PhD

Summary
This review analyzed 584 asymptomatic Chinese adults aged 20-89 years. Whole-body standing radiographs were acquired for evaluating sagittal alignment from spine to lower limb and compared between gender in different age groups. The current study found that age can influence the recruitment of compensation mechanism that involve more pelvic and lower limb mechanisms for elderly people.

Hypothesis
Age might influence the recruitment of compensation mechanism that might involve more pelvic and lower limb mechanisms for elderly people.

Design
Retrospective chart and radiographic review

Introduction
Previous studies have reported normative data for sagittal spinal alignment in asymptomatic adults. However, there was a lack of comprehensive investigation on age- and gender-related normative values of whole-body sagittal alignment. To establish the age- and sex-based normative values of whole-body sagittal alignment in asymptomatic Chinese adult population, and to investigate the changes and possible associated compensation mechanisms across age groups.

Methods
584 asymptomatic Chinese adults aged 20-89 years were recruited. Subjects were grouped according to age and gender. Whole-body standing radiographs were acquired for evaluating sagittal alignment from spine to lower limb. Comparisons of sagittal parameters between gender in different age groups were performed by independent t test.

Results
Mean values of each sagittal parameter were presented based on age and gender. Thoracic kyphosis showed steady increasing trend while lumbar lordosis gradual decrease in both genders. Pelvic tilt (PT) in male is greater than in female across all age groups with age related gradual increase. There were significant differences between male and female from 20s to 60s in terms of KneeFlex angle (KA) and AnkleFlex angle, but the differences were not significant after 60s. T1 pelvic angle (TPA) was significantly correlated with spinal, pelvic and lower-limb alignment. The older group (aged ≥50 years) had a stronger correlation of TPA with PT and KA, whereas the younger (aged<50 years) had stronger correlation with TK.

Conclusion
This study presented a comprehensive study of whole-body sagittal alignment based on a large asymptomatic population, which could serve as an age- and gender-specific reference value for spine surgeons when planning for correction surgery. Age can influence the recruitment of compensation mechanism that involve more pelvic and lower limb mechanisms for elderly people.

Take Home Message
Age can influence the recruitment of compensation mechanism that involve more pelvic and lower limb mechanisms for elderly people.

95. Increase in Thoracic Kyphosis with Aging is the Main Factor that Leads to Positive Sagittal Balance: Results of the Multi-Ethnic Alignment Normative Study (MEANS) of Asymptomatic Adults

Zeeshan M. Sardar, MD; Meghan Cerpa, MPH; Jean-Charles Le Huec, MD; Stephane Bourret, PhD; Kazuhiro Hasegawa, MD, PhD; Hee-Kit Wong, FRCS; Gabriel KP Liu, MD; Hwee Weng Dennis Hey, MD; Hend Riahi, MD; Michael P. Kelly, MD; Lawrence G. Lenke, MD

Summary
Volunteers from five countries were enrolled in this radiographic study to evaluate spinal alignment. The results showed no significant difference in lumbar lordosis between the different age groups. Thoracic kyphosis was noted to be significantly higher in patients over the age of 50. The increase in TK appeared to be the main driver for increasing SVA. Interestingly, the odontoid remained centered over the knees and not the hips in the sagittal plane in all age groups despite increasing SVA.

Hypothesis
We hypothesize that the spinal alignment in adults changes with age

Design
Retrospective review of prospectively collected data

Introduction
Adult sagittal spinal alignment can have a significant impact on overall quality of life. While significant advances have been made over the last few decades in better defining normal alignment, predicting the ideal alignment of a specific individual is still a difficult task. Normal variations of the spinal alignment parameters are studied in this asymptomatic cohort in hopes to define patient specific alignment goals.

Methods
Radiographic evaluation of Full-body low dose stereoradiography in the largest reported multiethnic cohort of 488 asymptomatic adult volunteers (Mean age: 40.8; Range: 18-79 yrs). Patients from 5 different countries were included; France, Japan, Singapore, Tunisia, and the United States. 3D measurements were performed using a commercially available 2D/3D modeling software.

Results
The lumbar lordosis was similar between the different age groups with means ranging from 56.7±11.9 to 57.8±11.5 (p=0.92). Mean T1-T12 thoracic kyphosis (TK) did increase significantly with age increasing from 43.5±11.9 in patients

younger than 50 to 48.6±12.1 in those older than 50 (p<0.0001). Following the trend of TK, there was an increase in the sagittal vertical axis (SVA) with age (-13.9±23.3 vs. 5.3±32.1; p<0.0001). The mean distance between the odontoid and the middle of the knees in the sagittal plane range from -3.2±30.7 to 4.5±32.1, and did not vary significantly with age in asymptomatic patients (p=0.26). The patients compensated with increased cervical lordosis, increased hip extension, and increased knee flexion as TK and SVA increased with age to maintain the odontoid centered over the knees. Pelvic tilt also increased with age from 10.5±6.8 to 15.9±7.6.

Conclusion
Lumbar lordosis was similar across the different age groups, while thoracic kyphosis increased in patients over the age of 50 and accounted for the increase in SVA.

Take Home Message
Lumbar lordosis may not decrease with age as previously thought. Thoracic kyphosis was the main parameter that increased with age and led to an increase in SVA.

	Group 1 (18-28yrs) (n=131)	Group 2 (29-37yrs) (n=103)	Group 3 (38-50yrs) (n=131)	Group 4 (>51yrs) (n=123)	p-value
C2-C7° Lordosis	-3.3±12.9	-0.7±11.8	0.6±12.0	6.0±12.4*	<0.001
T1-T12° TK	41.3±10.3	42.0±10.6	43.5±12.0	48.6±12.1*	<0.001
L1-S1° LL	57.3±10.8	57.1±11.0	57.8±11.5	56.7±11.9	0.92
PI°	50.0±11.5	50.7±9.2	52.9±11.5	54.0±10.3*	0.01
PT°	10.5±6.8	10.8±6.2	12.7±7.4*	15.9±7.6*	<0.001
SS°	39.6±8.5	40.0±7.7	40.1±8.0	38.0±8.8	0.21
SVA (mm)	-13.9±23.3	-9.6±24.0	-4.9±24.2*	5.3±32.1*	<0.001
OD-Knee Lateral (mm)	1.9±29.0	4.5±32.1	3.0±28.3	-3.2±30.7	0.26
OD-Ankle Lateral (mm)	24.2±28.6	30.0±32.2	31.0±29.5	32.3±33.0*	<0.001
CAM-Knee Lateral (mm)	2.6±29.3	4.1±33.2	2.4±30.0	-5.3±31.7	0.10
CAM-Ankle Lateral (mm)	24.9±29.3	29.8±33.4	31.0±31.0	30.2±34.5	0.61
Left/Right Knee Flexion°	-3.2±5.1/ -3.2±4.9	-2.8±4.8/ -2.4±4.9	-2.8±4.3/- 2.5±4.2	1.3±6.2*/1.4± 6.2*	<0.001/ <0.001
PI-LL°	-7.3±9.8*	-6.4±9.6	-4.9±11.0	-2.8±11.5*	0.005
TPA	6.9±4.9	6.9±5.0	8.3±6.4	11.4±7.4	<0.001
T1 Tilt°	5.4±2.3	5.0±2.4	5.0±2.5	4.7±3.3	0.25
*post-hoc Tukey's HSD significant group					

Age Group Radiographic Characteristics

96. Correlation Between Degenerative Diseases of the Lumbar Spine and Types of Lumbar Lordosis

Nelson Astur, MD; Bruno B. Roberto, MD; Delio E. Martins, MD, PhD; Michel Kanas, MD; Marcelo Wajchenberg, MD, PhD

Summary
Analysis of the sagittal curvature pattern of the lumbar spine, according to Roussouly, and the correlation with the incidence of different degenerative diseases of the lumbar spine contribute to a better understanding of the etiology and natural history of potential degenerative processes of the intervertebral unit, as well as adjacent structures.

Hypothesis
Degenerative diseases of the lumbar spine are correlated to different type of lumbar lordosis

Design
Retrospective Study

Introduction
Sagittal alignment of the spine has been related to specific degenerative diseases of the spine. Roussouly described the variations in sagittal alignment and classified lumbar lordosis into 4 types, but did not statistically correlate it to types of degenerative lumbar spine disease. The objective of this study was to evaluate a relationship between different types of degenerative spine diseases and type of lordosis.

Methods
Patients with a diagnostic of degenerative lumbar spine referred to us during the period of 2015 to 2019 without primary spine surgery were included. We classified patients' lumbar lordosis into four types according to Roussouly. We diagnosed specific degenerative lumbar spine disease after MRI analysis as Stenosis (St), Degenerative Disc Disease (DDD), Spondylolisthesis (SL), and Facet Joint Arthropathy (FJA) and correlated it to type of lumbar lordosis. Statistical tests, such as chi-square, were performed and the types of curvature and diagnostics used were recorded by absolute frequencies and reported for a general sample and by type of treatment

Results
A total of 418 patients were enrolled, 203 females and 215 males. There was 47 (11.2%) patients with type I lordosis, 159 (38%) with type II, 168 (40.2%) with type III, and 44(10.5%) type IV. Main diagnosis found was DDD (52.4%), followed by FJA (22.7%) and St (9.8%). DDD was mostly seen in patients with type III lordosis. Spondylolisthesis was more common in type IV lumbar lordosis. A higher rate of surgical treatment was significantly indicated for Roussoly type I and II patients compared to conservative treatment, representing 64% and 56%, respectively. There was no statistical significance that could correlate diagnose with type of lumbar lordosis.

Conclusion
Most frequent type of lordosis in a sample of patients with degenerative lumbar spine disease are types III and II. Lumbar disc herniation seemed more frequent in patients with type II or III lumbar lordosis. Surgical treatment is more frequent in types I and II.

Take Home Message
Most frequent type of lordosis in patients with degenerative lumbar spine disease are types III and II. Surgical treatment is more frequent in types I and II.

97. A Patient-specific Approach to Alignment Goals and Assessing Proximal Junctional Kyphosis Risk After Adult Spinal Deformity Surgery

Jeffrey M. Hills, MD; Benjamin M. Weisenthal, MD; Jacquelyn S. Pennings, PhD; John Wanner, MD; Byron F. Stephens, MD; Nida Fatima, MD; Frank A. Segreto, BS; Hongqi Zhang, MD; Jiong Li, MD; John L. Valentino, BS; Jacob Neary, BS; Tina Raman, MD

Summary
Risk of proximal junctional kyphosis is multifactorial. Patient-specific alignment goals likely have the greatest potential to minimize PJK. We reviewed 145 adult deformity patients and built an ordinal regression model to assess predictors of PJK severity. Charlson Comorbidity Index, vertebral Hounsfield units, preoperative TPA, and postoperative segmental lumbar lordosis

were significantly associated with PJK severity. By accounting for comorbidities, bone density, and preoperative alignment measures, patient-specific lumbar alignment goals can be selected to potentially minimize PJK risk.

Hypothesis
Patient comorbidities, bone density, preoperative sagittal deformity, and postoperative segmental lumbar lordosis are associated with proximal junctional kyphosis (PJK).

Design
Retrospective Cohort Study

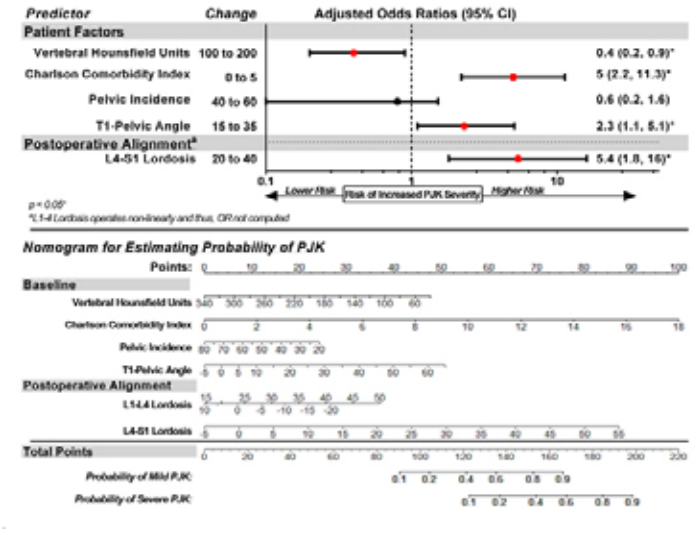
Introduction
Prior alignment goals for preventing PJK are based on age or pelvic incidence (PI), but do not adjust for other established risk factors. The purpose of this study was to develop a model for predicting PJK risk based on patient comorbidities, vertebral bone density, preoperative deformity, and postoperative lumbar alignment.

Methods
Patients undergoing adult spinal deformity surgery between 2009 and 2017 with minimum 2-year follow-up were retrospectively reviewed. The primary outcome was PJK severity, based on the Hart-ISSG PJK Severity Scale (0 = none, 1-5 = mild, >5 = severe PJK). Covariates were chosen a priori and included preoperative factors (Charlson Comorbidity Index [CCI], average vertebral Hounsfield units [HU] nearest the UIV, pelvic incidence [PI], and T1 Pelvic Angle [TPA]), and postoperative segmental lumbar lordosis (L1-L4 and L4-S1). Using a proportional odds regression model, adjusted odds ratios were computed for the odds of an increase in PJK severity associated with a specified change in linear predictors, and a nomogram was constructed for computing probability of PJK. Multiple imputation was used for missing data.

Results
Of 145 patients included, 20 (14%) developed mild PJK and 27 (19%) developed severe PJK. Higher CCI, lower vertebral HU, higher preoperative TPA, higher L4-S1 lordosis, and L1-L4 lordosis (nonlinearly) were significantly associated with an increase in PJK severity ($p < 0.05$). The c-index (AUC) for the probability estimates was 0.76.

Conclusion
Comorbidities, vertebral HU, preoperative TPA, and postoperative segmental lumbar lordosis were significantly associated with PJK. By adjusting for comorbidities, bone density, and preoperative TPA, PJK risk can be assessed for varying postoperative segmental lumbar lordosis values. Larger studies are needed to update and validate a model for generating patient-specific alignment goals that minimize complications and maximize outcomes.

Take Home Message
By adjusting for comorbidities, bone density, and preoperative sagittal alignment, patient-specific lumbar alignment goals can be selected with the potential to minimize risk of PJK.



98. Is Chin-brow Vertical Angle Always the Reliable Parameter for Correction Planning in Ankylosing Spondylitis Patients with Thoracolumbar Kyphosis?

Bangping Qian, MD; Wen-Bin Xuan, MD; Yong Qiu, MD; Jichen Huang, MD

Summary
Chin-brow vertical angle (CBVA) is regarded as a crucial parameter in the correction planning of thoracolumbar kyphosis (TLK) secondary to ankylosing spondylitis (AS). However, there is a paucity of literature regarding its reliability. The study aimed to evaluate whether CBVA was reliable in surgical planning for TLK in AS patients.

Hypothesis
For AS patients with cervical ankylosis, CBVA was reliable in determining kyphosis correction angle, while for patients without fused cervical spine, CBVA was unreliable.

Design
A prospective study.

Introduction
The importance of CBVA for kyphosis correction was noted in previous studies; however, there is scarcity of literature concerning its reliability. The study aimed to investigate the reliability of CBVA in predicting the corrective angle.

Methods
31 AS patients (27 males and 4 females) with TLK who had undergone one-level pedicle subtraction osteotomy in our institution were included in the study. The patients were divided into 2 groups according to cervical range of motion (CROM), group A (CROM< 20°, 13 patients), group B (CROM >20°, 18 patients). Global kyphosis angle (GK), C7-S1 sagittal vertical axis (SVA) and osteotomized vertebral angle (OVA) were measured as radiographical parameters. Numerical Rating Scale and Oswestry Disability Index were collected as clinical parameters.

Results
The average age receiving surgery was 37.0 ± 7.0 years (range, 28-51 years) of group A and 35.6 ± 12.8 years (range, 21-59 years) of group B. The change of CBVA (38.5±12.1°, 14° to 55°) of group A was correlated strongly with that of OVA (38.9±10.4°, 13° to 52°, r=0.773) while the correlation was weak (r=0.102) in group B. C7-S1 SVA, GK and clinical parameters improved significantly in both groups (p<0.05).

Conclusion
CBVA was not reliable in determining correction angle for AS patients with unfused cervical spine. For patients with cervical ankylosis, CBVA was an objective index for planning sagittal plane corrective osteotomy.

Take Home Message
CBVA is reliable in kyphosis correction planning for AS patients with cervical ankylosis. When patients have a larger CROM, other factors should be taken into consideration for corrective planning.

99. C2 SVA: When Angles are Too Complicated and the X-ray is Too Small

Simon Morr, MD; Meghan Cerpa, MPH; Joseph A. Osorio, MD, PhD; James D. Lin, MD; Zeeshan M. Sardar, MD; Richard P. Menger, MD; Eric Leung, BS; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Summary
We propose an alternative sagittal alignment parameter that can substitute for the Cranial SVA or Gravity Line. Obtaining long adequately placed radiographs spanning from head to femurs may be difficult, especially intraoperatively. We correlate new sagittal alignment parameters with established parameters, like T1PA, as well as the SRS-22 and ODI. C2SVA correlates well with the SRS-22, ODI, and T1PA. It is superior to other plumbline parameters, and allows for global alignment assessment even with limited radiographic capability.

Hypothesis
C2 SVA, which requires neither skull nor femoral heads, will provide statistically significant correlation to health related quality of life measures (HRQOL) and to previously established sagittal plumbline and global angular sagittal parameters.

Design
Retrospective observational cohort

Introduction
The cranial sagittal vertical axis (CrSVA) and the cranial gravity line (CrGL), respectively defined as vertical plumblines from the center of the skull to the posterior sacral vertical line and the center of the femoral heads/hip axis, are superior to the C7 SVA and better predict HRQOL. The T1 pelvic angle (T1PA) is an angular parameter that obviates the need to account for compensatory mechanisms distally such as knee flexion. Global Tilt (GT) is another angular parameter &is an important feature of the GAP score. Long cassette films that incorporate the femoral heads and the skull simultaneously are often difficult to obtain, especially in the intraoperative setting. We sought to study other possible substitutes for the CrSVA and CrGL that could be applied in the setting of more limited radiographic resources.

Methods
A cohort of 53 operative patients including adult and adolescent deformity cases were selected and analyzed for preoperative baseline sagittal parameters, including C2SVA, C2GL, C7SVA, CrSVA, CrGL, T1PA, as well as baseline preoperative SRS-22 and ODI. Pearson's r was used to quantify the correlation.

Results
The C2SVA has a statistically significant correlation with the CrGL [r (51) =0.87; p<0.0001] and T1PA [r (51) =0.77; p<0.0001]. The angular measures of T1PA and GT correlated exceptionally with each other[r(51)=0.98; p<0.0001] and demonstrated the highest correlation to ODI and total SRS. Of the plumbline parameters, the C2-SVA demonstrated the highest correlation with the SRS-22 scores and ODI, as well as T1PA and GT.

Conclusion
Validated angular parameters of T1PA and GT have the highest correlation with each other and with SRS-22 and ODI. Among plumbline parameters, the C2 SVA has the highest correlation with the T1PA, GT, ODI and SRS-22 scores.

Take Home Message
C2SVA is a simple, effective, and easily obtained sagittal plumbline technique that correlates highly with established sagittal balance parameters, ODI, and SRS-22 Scores.

100. The Posterior Cranial Vertical Line (PCVL): A Novel Predictor for Proximal Junctional Kyphosis in Spinal Deformity Surgery

Griffin R. Baum, MD; Meghan Cerpa, MPH; Paul J. Park, MD; Joseph A. Osorio, MD, PhD; Nathan J. Lee, MD; Eric Leung, BS; Meghana Vulapalli ; Ronald A. Lehman, MD; K. Daniel Riew, MD; Lawrence G. Lenke, MD

Summary
The Posterior Cranial Vertical Line (PCVL) is a novel radiographic measurement that is easy to assess on a first-erect radiograph to predict the development of PJK. 10 patients out of 139 eligible patients (minimum 2 year follow up) developed PJK and had a median (please use mean) PCVL of 0.5cm ventral to the instrumentation at the UIV. The ease of measuring the PSIL makes it a valuable tool for deformity surgeons for prediction of PJK in at-risk postoperative patients.

Hypothesis
Proximity of a line extending from the posterior skull down toward the feet to the posterior most cephalad aspect of spinal instrumentation will correlate with the development of proximal junctional kyphosis in patients undergoing spinal deformity correction

Design
Observational Cohort

Podium Presentations—Sagittal/PJK

Introduction
Proximal junctional kyphosis (PJK) can be an insidious complication after a spinal deformity reconstruction surgery. Many groups have identified risk factors for the development of PJK, but there are few immediate postoperative radiographic measurements able to prognosticate the development of PJK. We hypothesize that if the posterior skull is at or ventral to the dorsal-most aspect of the instrumentation at the UIV, the biomechanical forces on the skull will predispose the development of PJK. This radiographic relationship, the PCVL, can be used on an immediate and subsequent postoperative radiographs to predict the development of PJK

Methods
All adult patients (≥18) undergoing spinal deformity surgery at a single institution from 2015 to 2017 with a minimum 2 years of follow up were included. The PCVL was drawn perpendicular to the dorsal most extent of the skull on a standing radiograph. The distance from the dorsal most aspect of the instrumentation was measured to the PCVL and values were entered into the database registry

Results
139 patients were identified who had spinal deformity correction surgery with minimum 2 year follow up. 10 of the 139 patients developed proximal junctional kyphosis (7.2%). Average age was 61.7 years (18 – 75) and 60% (n/139) of the cohort were female. The most frequent UIV level was T2 (C3-T10) and 30% (n/139) had previously undergone either anterior or posterior cervical surgery. The mean PSIL distance was 0.17 cm and the median PSIL distance was 0.5cm (-2.78 – 3.05 cm)

Conclusion
The PCVL is a novel predictor for PJK after spinal deformity correction surgery, and a PCVL distance of as little as 0.5cm may be a predictor for PJK. This simple radiographic measurement is easy to visualize and obtain from a lateral radiograph, and should be included in future studies into the prediction and prevention of PJK

Take Home Message
The PCVL is an easy, simple predictor for the development of PJK after spinal deformity correction

101. Is the Distance from the Upper Instrumented Vertebrae (UIV) to the Gravity Line Associated with Proximal Junctional Kyphosis (PJK) after Adult Spinal Deformity (ASD) Correction?

Pingguo Duan, MD; Praveen V. Mummaneni, MD; Jeremy Guinn, BS; Minghao Wang, MD, PhD; Zhuo Xi, MD; Bo Li, MD; Hao-Hua Wu, MD; Rory R. Mayer, MD; Joshua Rivera ; Shane Burch, MD; Sigurd H. Berven, MD; Dean Chou, MD

Summary
After ASD correction, the position of the UIV relative to the sagittal vertical axis (SVA) is associated with PJK, but it is unclear if the UIV relative to the gravity line (GL) is associated with PJK.

Hypothesis
The further away that the post-op UIV is from the GL, the more likely PJK will occur.

Design
Retrospective study

Introduction
Although restoring the spine to within 5cm of the SVA is a well-known goal in ASD surgery, the position of the UIV relative to the GL leading to PJK is less clear. We evaluated ASD patients and their post-op UIV position relative to the GL and the correlation with PJK.

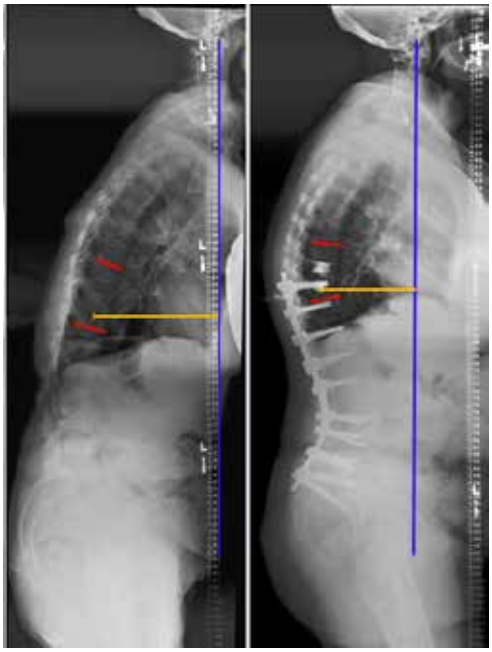
Methods
A retrospective study of patients who undergoing ASD correction from the lower thoracic (LT) spine (T9 to T11) to S1 with minimum of 2-year follow-up was performed. Demographic data and radiographic spinopelvic parameters included: pelvic incidence (PI), pelvic tilt (PT), lumbar lordosis (LL), PI-LL, sacral slope

(SS), T1 pelvic angle (TPA), thoracic kyphosis (TK), SVA, GL, and UIV-GL (cm).

Results
Sixty-five patients (mean age, 64.95 years; 18 males) met inclusion criteria, including 38 patients with PJK and 27 patients without PJK, with minimum 2-year follow up (mean, 2.83 years). There was no difference in age, BMI, sex, and follow-up in the two groups. There was no statistical difference between groups with regard to PI, SS, PT, LL and TPA (P > 0.05). Preoperative UIV-GL and TK were higher in the patients with PJK than in without (P = 0.042 and 0.01, respectively). Post-op, UIV-GL was 8.97 ± 3.50 and 5.12 ± 2.63 in the patients with and without PJK, respectively; and TK was 47.11 ± 10.54 and 34.72 ± 12.55 in the patients with and without PJK, respectively. Their differences were both statistically significant (P = 0.000). A receive operating characteristic (ROC) curve for UIV-GL as a predictor for PJK was established, with an area under the curve (AUC) of 0.824 (95% CI: 0.722-0.926). The optimal UIV-GL cut-off value determined by the Youden index was 5.6 (sensitivity, 0.868; specificity, 0.667).

Conclusion
We found that a postoperative UIV-GL of more than 5.6 was a risk factor for PJK in the patients undergoing ASD correction. These findings suggest that UIV-GL may be associated with the PJK after ASD correction.

Take Home Message
The postoperative position of the UIV relative to the GL may be associated with PJK in patients undergoing ASD correction from the LT spine to S1.



Measure of UIV-GL (orange) and angle of proximal junction (red).

103. Low Pelvic Incidence (PI) Patients are at High Risk of Over Correction Following ASD Surgery

Alex Soroceanu, MPH; Themistocles S. Protopsaltis, MD; Gregory M. Mundis, MD; Justin S. Smith, MD, PhD; Michael P. Kelly, MD; Alan H. Daniels, MD; Eric O. Klineberg, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Shay Bess, MD; Christopher I. Shaffrey, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Munish C. Gupta, MD; International Spine Study Group

Summary
Low pelvic incidence (PI) patients are at higher risk of overcorrection compared non-low PI (73% vs 53%, p=0.0001). The over-corrected low PI patients were less likely to have their lordosis apex below L4. PJK (defined as 1) proximal junctional angle (PJA, UIV – UIV+2) >10o and 2) increase in the PJA > 10o) occurred in 52% of low PI patients. Over-corrected patients were more likely to experience radiographic PJK (OR 2.61, p=0.03).

Hypothesis
Low PI patients are susceptible to overcorrection.

Design
Retrospective

Introduction
Age and PI optimal alignment has been shown to minimize mechanical complications such as PJK. Low PI patients may be more susceptible to overcorrection.

Methods
Prospective ASD patients. Patients undergoing fusions >5 levels and completed 2y follow-up were included. Low PI (<46°) was defined by <1 SD from average. A previously developed formula relating LL, PI, TK and age was used to calculate the optimal LL for each patient. Overcorrection was defined as a postoperative lumbar lordosis >5° greater than the calculated optimal LL. Low PI patients were divided into: overcorrected vs not overcorrected. Groups were compared in terms of demographics, radiographic parameters, surgical invasiveness, and PJK using t-tests, chi-2 tests, and multivariate regression as appropriate.

Results
118 low PI patients met inclusion criteria. Overcorrection occurred in 73.7%. By comparison, overcorrection occurred in only 53.1% of non-low PI patients enrolled in the same registry (p=0.0001). There was no difference between overcorrected low PI patients and non-overcorrected in regards to baseline demographics, radiographic parameters, and HRQL The two groups were different in regards to surgical invasiveness (111.46 vs 95.6, p=0.03). The over-corrected group were less likely to have their apex of lordosis below the level of L4 (2.3% vs 19.35% p=0.001), had a lower proportion of their lumbar lordosis coming from L5-S1 (39% vs 48%, p=0.009), and a higher proportion of their lumbar lordosis coming from L1-L3 (8.23% vs 3.4%, p=0.04). Radiographic PJK occurred in 52% of low PI patients. Over-corrected patients were more likely to experience radiographic PJK (OR 2.61, p=0.03).

Conclusion
Overcorrection occurred 73.7% of low PI patients. Those who were overcorrected were less likely to have their apex of lordosis below L4, and had a lower proportion of their overall lordosis coming from L5-S1. They were also more likely to experience radiographic PJK than those who were not overcorrected. These results highlight the importance of not overcorrecting low PI patients and optimizing the apex of lordosis below L4.

Take Home Message
Low PI patients are susceptible to overcorrection of LL with a resulting higher rate of PJK. Care should be taken to optimize lordosis and the lordosis apex below L4.

104. Understanding Sagittal Compensation in Adult Spinal Deformity Patients: Relationship Between Pelvic Tilt and Lower Extremity Position

Takayoshi Shimizu, MD, PhD; Meghan Cerpa, MPH; Eric Leung, BS; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Summary
This study investigated the relationship between pelvic tilt (PT) and lower extremity (LE) compensation in adult spinal deformity patients with cranio-hip (CrSVA-hip) imbalance. We determined the PT value that significantly correlated with the extent of LE compensation. Patients with CrSVA-Hip imbalance demonstrated a higher prevalence of LE compensation, especially knee flexion. Using the cut-off value of a 28.0° PT, surgeons may preoperatively estimate the extent of LE compensation without obtaining a full-body X-ray (XR).

Hypothesis
Patients with cranio-hip anterior sagittal imbalance show a higher prevalence of lower extremity (LE) compensation. The extent of LE compensation can be estimated by using a cut-off value of pelvic tilt (PT).

Design
Retrospective cross-sectional cohort

Introduction
In adult spinal deformity (ASD) surgery, quantifying preoperative LE compensation is important in formulating an operative plan to achieve optimal global sagittal alignment. Total body radiographs are not always available. This study evaluated the possibility to estimate LE compensation without total body x-rays.

Methods
200 ASD patients with full-body XR assessment were categorized into three groups according to their cranio-hip balance (CrSVA-H - distance between cranial sagittal vertical axis and hip axis): Group 1: Anterior-shift (A-Shift) group (CrSVA-H > 40 mm); Group 2: balanced (Balanced) group (-40 mm < CrSVA-H < 40 mm); Group 3: Posterior-shift (P-Shift) group (CrSVA-H < -40 mm). After analyzing the correlation between CrSVA-H, PT, and LE parameters, the cut-off PT and PT/PI (pelvic incidence) values that correlated with the presence of LE compensation were determined. Previously published data from asymptomatic volunteers were used as a baseline threshold (sacrofemoral angle > 217.0° and KA >11.0°).

Results
Knee flexion angle (KA) showed a significant increase in the A-Shift group compared to the other two groups ($p<0.01$). Based on previously published asymptomatic thresholds, 62.2% of the A-Shift group showed LE compensation (hip, knee or both), which was greater than those in the other two groups ($p<0.01$). The CrSVA-H was moderately correlated with KA ($r=0.502$). The ROC curves determined a 28.0° PT (or PT/PI > 0.52) reliably predicts the presence of LE compensation.

Conclusion
ASD patients with increased cranio-hip anterior sagittal imbalance demonstrated a higher prevalence of LE compensation. Using the cut-off value of PT >28.0°, surgeons may preoperatively estimate the magnitude of LE compensation without obtaining a full-body XR.

Take Home Message
Using the 28.0° pelvic tilt cut-off value determined in this study, surgeons may preoperatively estimate the extent of lower extremity compensation without obtaining a full-body XR.

105. What is Actually Happening inside the "Cone of Economy": Compensatory Mechanisms during a Dynamic Balance Test

Ram Haddas, PhD; Alexander M. Satin, MD; Isador H. Lieberman, MD

Summary
This study aims to define motor-control strategies utilized by adult degenerative scoliosis (ADS) patients to maintain balance. ADS patients have a larger cone of economy dimensions and increased sway while utilizing hip-based compensatory mechanisms and lower extremity RoM in comparison to the non-scoliotic controls in their effort to maintain balance.

Hypothesis
To further develop Cone of Economy (CoE) measurements by identifying compensatory mechanisms at the extremes of the CoE and comparing balance control strategies in a group of adult degenerative scoliosis (ADS) patients with non-scoliotic controls.

Design
A non-randomized, prospective, concurrent control cohort study.

Introduction
The CoE concept was first proposed by Dubousset and is frequently referred to when assessing balance in spinal deformity patients. Recently, a method that quantifies the CoE of individual patients through 3D video kinematic and electromyography data was developed. However, this method lacks measurements that describe the motor control strategies utilized by spinal disorder patients to maintain balance.

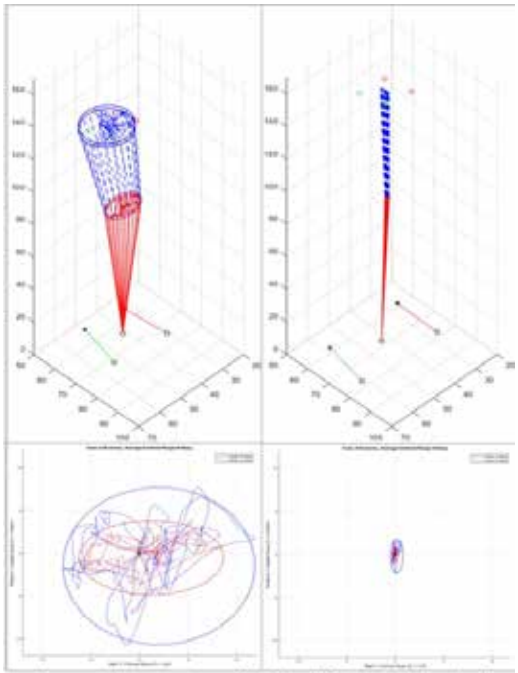
Methods
Twenty ADS patients and 15 non-scoliotic controls were fitted with a full-body marker set. Each subject performed a series of

functional balance tests (Romberg's with eyes opened) while being recorded in a human motion capture system. 3-Dimensional CoE dimensions, range of sway (RoS), overall sway, and lower extremity and trunk range of motion (RoM) were measured and analyzed.

Results
Patients with ADS demonstrated greater overall sway and RoS in the sagittal and coronal planes compared to controls. Moreover, ADS patients presented with more hip flexion and trunk flexion at maximal points of sway and more ankle, knee, hip, and trunk RoM when swaying in comparison to controls.

Conclusion
ADS patients have larger CoE dimensions and increased sway when compared to non-scoliotic controls. ADS patients rely on a hip balance control "strategy" and lower extremity RoM to maintain balance, which differed from control subjects. By expanding on prior CoE measurements, we were able to define a unique dynamic balance control strategy for each patient.

Take Home Message
Unlike prior attempts to define compensatory mechanisms in ADS patients, the described technique utilizes dynamic, 3-dimensional measurements to define what is occurring within the CoE.



Representative comparisons of 3- (Top) and 2- (Bottom) dimensional Cone of Economy and range of sway of Adult Degenerative Scoliosis (Left) and Non-Scoliotic Controls (Right)

107. Achieving Harmonious Sagittal Profile Prevents from PJK in Adolescents with Idiopathic Scoliosis

Sebastien Pesenti, MD, PhD; Federico Solla, MD; Brice Ilharreborde, MD, PhD; Christian Morin, MD; Yann Philippe Charles, MD, PhD; Jean-Luc Clement, MD

Summary
We aimed to assess the effect of restoring ideal TK following the formula iTK=2(PT+LL-PI) on the risk of PJK in 562 AIS patients. The mismatch between iTK and actualTK was higher in PJK patient. Inflexion point between TK and LL was located higher in PJK patients than in no PJK pts. Our results suggest that it is of primary importance to restore a proper TK and harmonious transition between sagittal curvatures in order to prevent PJK.

Hypothesis
Achieving an ideal TK (iTK) following the formula iTK=2(PT+LL-PI) allows for reduction of PJK occurrence in patients operated on for thoracic AIS

Design
Retrospective multicenter

Introduction
Achieving proper sagittal balance correction in AIS patients remains challenging. Recently, Clement et al demonstrated from postoperative data that theoretical ideal TK could be calculated as follows: iTK=2(PT+LL-PI). We aimed to assess the effect of restoring ideal TK on the risk of PJK.

Methods
From a national database, we identified 562 adolescents with posterior fusion for a Lenke type 1, 2, 3, 4 or 6 idiopathic scoliosis. We measured sagittal parameters and calculated the mismatch between iTK and actual TK with minimum 2-year follow-up (average 46). Finally, we stratified our population according to PJK occurrence at final follow-up.

Results
Overall, PJK occurred in 22% of the population. At last follow-up the rate of PJK was significantly higher when actual TK was lower than iTK (36% vs 13%, $p<0.01$). In patients who sustained PJK, TK at follow-up and TK change were lower (27° vs 38° and -6° vs +11°, respectively, all $p<0.01$). The mismatch between iTK and actual TK was higher in PJK patients (-10° vs +6, $p<0.01$). Otherwise, PJK patients had longer fusions (12 vs 11 levels, $p<0.01$). Inflexion point between TK and LL was located higher in PJK patients than in no PJK pts (T11 vs T12, $p<0.01$)

Conclusion
Sagittal profile restoration in AIS patients is challenging. Our results suggest that it is of primary importance to restore a proper TK and harmonious transition between sagittal curvatures in order to prevent PJK. Achieving ideal TK following the formula iTK=2(PT+LL-PI) lead to a decreased risk of PJK occurrence.

Take Home Message
Achieving an ideal TK following the formula iTK=2(PT+LL-PI) leads to a decreased risk of PJK occurrence.

108. Upper Instrumented Vertebral Pelvic Angle and Risk of Proximal Junctional Kyphosis at Two-Year Follow-Up

Hao-Hua Wu, MD; Dean Chou, MD; Jeremy Guinn, BS; Joshua Rivera ; Pingguo Duan, MD; Minghao Wang, MD, PhD; Zhuo Xi, MD; Bo Li, MD; Shane Burch, MD; Praveen V. Mummaneni, MD; Sigurd H. Berven, MD

Podium Presentations—Sagittal/PJK

Summary
Increased upper instrumented vertebral pelvic angle is associated with higher risk of proximal junctional kyphosis in adult patients undergoing six-level fusion.

Hypothesis
We hypothesize that increased upper instrumented vertebral pelvic angle is associated with higher risk of proximal junctional kyphosis in adult patients undergoing six-level fusion.

Design
Retrospective cohort study

Introduction
There remains a need for practical radiographic parameters to help predict risk of proximal junctional kyphosis (PJK) in adult patients undergoing multilevel posterior fusion. The upper instrumented vertebral pelvic angle (UIVPA) is a novel measure of sagittal alignment that is easy to measure and can account for both spinal inclination and pelvic retroversion. We hypothesize that the further the UIV is from the center of gravity, the higher the risk of PJK.

Methods
In this retrospective cohort study, adult patients with two-year follow-up and ≥6 levels of posterior fusion for spinal deformity were included. The UIVPA was measured between a line from the UIV centroid to the center of the femoral head to a line from the center of the sacrum to the center of the femoral head. PJK was defined as a >10 degree kyphotic angle between the UIV and the vertebra 2 levels above. Proximal junctional failure (PJF) was defined as PJK that required surgery. Patients who developed PJK and those who did not were compared with respect to UIVPA, T1 pelvic angle (T1PA), pelvic tilt, sagittal vertical axis and central sacral vertical line.

Results
There were 291 patients with an average 3.0 years follow-up enrolled in the study. 50 (17%) patients were diagnosed with PJK and 29 (10%) qualified for PJF. The average UIVPA was 19.5 degrees preop. Patients with PJK had significantly higher preoperative UIVPA than those without PJK or PJF (25.6 vs. 16.2 $p<0.05$). A similar phenomenon was seen in patients with PJF compared to those who did not (UIVPA 26.2 vs.15.9, $P<0.05$). The UIVPA correlated well with the T1PA ($r=0.81$), the SVA ($r=0.77$) and the pelvic tilt ($r=0.75$).

Conclusion
UIV pelvic angle correlates well with established measures of sagittal spinopelvic alignment, such as T1PA, SVA and pelvic tilt. Patients with PJK and PJF at least two-years from surgery were more likely to have a significantly higher preoperative UIVPA than their counterparts.

Take Home Message
UIV pelvic angle correlates well with T1PA, SVA and pelvic tilt. Patients with PJK and PJF two-years from surgery were more likely to have a significantly higher preoperative UIVPA.

Podium Presentations—Nerves and Big Curves: Advances in Neuromonitoring and Management of Severe Spinal Deformity

109. Review of New Neurological Injuries and Prognosis Associated with Idiopathic Scoliosis Surgeries Utilizing the Scoliosis Research Society Morbidity and Mortality (SRS M&M) Database

Swamy Kurra, MD; Harman Chopra, BS; Jinhui Shi, MD; Stephen A. Albanese, MD; Elizabeth A. Demers Lavelle, MD; *William F. Lavelle, MD*

Summary
Lower complete recovery rate was observed in adult IS patients. Complete cord injuries reduced NNIs complete recovery rate. IONM signal abnormalities have potential effect on intraoperative NNI prognosis and not on postoperative or delayed NNI prognosis.

Hypothesis
Summarize the prognosis of NNIs associated with IS surgeries from the SRS M&M database.

Design
Reviewed IS patients with NNIs associated with surgeries from SRS M&M database between 2009 and 2017.

Introduction
The incidence and risk factors for new neurological injuries (NNIs) associated with idiopathic scoliosis (IS) surgeries has been well reported; however, the prognosis of NNIs has been poorly studied.

Methods
Reviewed and statistically analyzed patients' demographics, surgical parameters, cord injuries (complete vs. incomplete vs. root), NNI occurrence time (intraoperative; postoperative <24 hrs; delayed >24 hrs), spinal cord injury level (cervical, lumbar or thoracic) and types of NNI recovery status (complete, partial and no recovery).

Results
Study sample, n=418; gender distribution: male=93, female=322, 3 unknown; and IS type: EOIS=30, AIS=244 and adult IS=144. Occurrences of NNIs were: intraoperative=168; postoperative=159; delayed=91. Cord injuries were: complete=53; incomplete=178; root=142; and no information for 45 patients. Injuries noticed at: cervical=20; thoracic=181, lumbar=187, sacrum=5, and unknown=25. Recovery status was: complete=269, partial=125; no recovery=24. Average follow-up length was no different among recovery types, p=0.40. Complete NNI recovery rate was significantly lower for adult IS patients (p<0.001). Significant decrease in complete recovery rate noticed for complete cord injuries (p<0.001); IONM abnormalities decreased complete recovery for intraoperative NNIs (p=0.001). There was a trend toward lower complete recovery rates if IONM was not used intraoperatively NNIs (p=0.06). Table 1.

Conclusion
Lower complete recovery rate was observed in adult IS patients. Complete cord injuries reduced NNIs complete recovery rate. IONM signal abnormalities have potential effect on intraoperative NNI prognosis and not on postoperative or delayed NNI prognosis.

Take Home Message
Lower complete recovery rate was observed in adult IS patients. Complete cord injuries reduced NNIs complete recovery rate. IONM signal abnormalities have potential effect on intraoperative NNI prognosis.

Table 1: Summary of Factors of Neurological Recovery Rates

		Complete Recovery	Partial Recovery	No Recovery	p value
n		269	125	24	
IS type					
EOIS		24 (80%)	3 (10%)	3 (10%)	<0.001
AIS		178 (73%)	52 (21.3%)	14 (5.7%)	
Adult IS		67 (46.5%)	70 (48.6%)	7 (4.9%)	
NNI Event Occurrence:					
Intraoperative		120 (71.4%)	42 (25.0%)	6 (3.6%)	
Postoperative < 24hrs.		100 (62.9%)	48 (30.2%)	11 (6.9%)	0.06
Delayed Postoperative >24hrs.		49 (53.8%)	35 (38.5%)	7 (7.7%)	
Type of Spinal Cord Injury					
Complete cord		29 (54.7%)	11 (20.8%)	13 (24.5%)	
Incomplete cord		130 (73%)	44 (24.8%)	4 (2.2%)	<0.001
Root injury		83 (58.5%)	55 (38.7%)	4 (2.8%)	
Length of follow-up (days)		190	174	174	0.35
IONM Signal Changes (Intraoperative NNIs)	Yes	4 (33%)	8 (67%)	0	0.001
	No	109 (76.8%)	27 (19.0%)	6 (4.2%)	

Summary of Factors of Neurological Recovery Rates

110. Intraoperative Neuromonitoring Practice Patterns in Spinal Deformity Surgery

Pinar Yalinay Dikmen, MD; Altug Yucekul, MD; Matthew Halsey, MD; Irem Havlucu; Tais Zulemyan, MD; Caglar Yilgor, MD; *Ahmet Alanay, MD*

Summary
Multimodal IONM has reached a widespread use. Yet, there is a shortage of skilled neurologists and neurophysiologists in this field. In North America, IONM is usually conducted by a technician with remote supervision for single or multiple cases, whereas a single case was usually monitored by a neurologist or a neurophysiologist in Europe and Asia. Surgeons preferences and reactions to signal changes vary. Only 13.7% reported to never use wake up test while others use it for under various conditions.

Hypothesis
There is a wide variability in the management of IONM changes

Design
Web survey approved by SRS Safety & Value Committee

Introduction
In 2009, the SRS approved a new IONM information statement summarizing SRS opinion on the role of IONM during spinal deformity surgeries. A consensus created-checklist was published in Spine Deformity in 2014 (Vitale et al). The utilization of such protocols in clinical practice remains to be seen. The aim was

to determine geographical differences to form a basis for taking actions to improve patient safety globally.

Methods

A survey was distributed to the membership of the SRS, twice by email, two weeks apart. The survey comprised 19 questions that were divided into 3 sections: Participant demographics, hospital setup & IONM modalities and routine practices & reaction to alerts.

Results

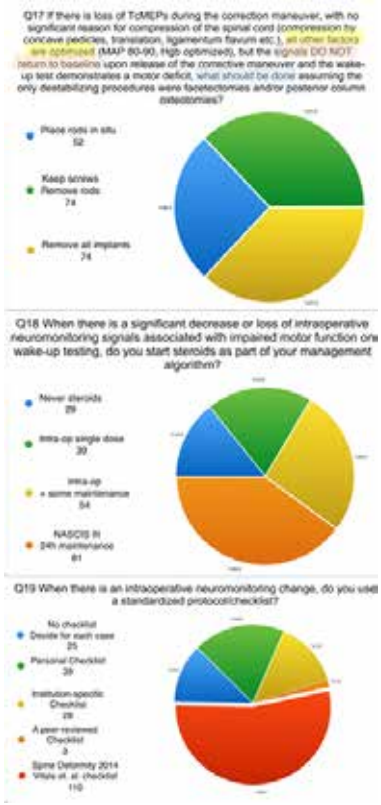
Of the approximated 1300 members, 205 (15%) completed the survey. Participant distribution reflected SRS member distribution (70.7% North America, 12.2% Europe, 11.2% Asia and the rest). 96% were orthopedic surgeons. 43.4% had >20 and 30.7% had >10 years of experience. Only 4.4% reported that a neurophysiology MD/PhD routinely examines every patient preop, while another 19% would see the patient if the surgeon requested. 87.8% declared that they had both TcMEP and SSEP and additional modalities. Discontinuation of IONM varied widely between right after final tightening of the implants to until anesthetic discontinuation. In an uneventful case, 34% reported decreasing sedation and checking motor function if the patient was to be transferred to ICU intubated. Reactions to dropped signals that returned or that did not fully return varied between attempting same correction for a second time, to aborting the surgery with no rods and returning another day, with or without implant removal. 85.7% uses steroids of varied doses after a decrease or loss of signals. Only 53.7% reported to use the consensus created-checklist published in Spine Deformity in 2014.

Conclusion

Although, multimodal IONM has reached a widespread use in spinal deformity surgery, there is no consensus on reactions to alerts and there is a need for additional studies on the best practice regarding checklists.

Take Home Message

Responses of 205 experienced SRS members from different regions of the world showed that surgeons had different approaches in their routine IONM practice and handling changes during spinal deformity surgery.



111. A Wireless Intraoperative Neuromonitoring System is as Reliable and Accurate as the Traditional Wired Systems for AIS Surgery

Shi Wenyuan, PhD; J.C. Chiao, PhD; Steven P. Sparagana, MD; Patricia Rampy, CNIM; Kiley F. Poppino, BS; *Daniel J. Sucato, MD, MS*

Summary

Twenty AIS patients who underwent surgical treatment had intraoperative neuromonitoring performed by both a traditional system and a wireless/digital system to determine feasibility and correlation to the traditional system. The wireless system had excellent correlations with similarities ranging between 0.976-0.997 to the standard IONM for the abductor hallucis muscle. This wireless system has potential to be easier to use, faster to set up with the same reliability as the traditional wired IONM systems.

Hypothesis

A wireless IONM system can provide a reducible, accurate assessment of the status of the spinal cord that is equal to the traditional wired systems.

Design

Prospective enrollment of patients

Introduction

Intraoperative neurophysiological monitoring (IONM) utilizes subdermal needle electrodes connected to an IONM system through multiple cables that crowd the surgical field, take time for placement and are susceptible to electromagnetic inter-

ference affecting signal integrity. We present a new wireless network system to acquire transcranial (TcMEP) signals digitally and wirelessly

Methods

This was an IRB-approved prospective study of consecutive AIS patients undergoing surgery. Four wireless modules were designed with a two-stage amplifier to maximize the TcMEP waveforms. Amplifier gains were tailored to each muscle's specific output. To verify the performance of the new design, TcMEPs were recorded by both systems simultaneously. Wireless recordings were then transformed and evaluated to its equivalent wired IONM waveform. Signals were examined by the goodness of fit, Pearson's correlation, and root mean square errors methods (RMSE).

Results

There were 20 AIS patients. Due to differences in hardware and software configurations between systems, differences in frequency responses and waveform distortion were noted. A transfer function was calibrated to establish a relationship between these systems and used for transform the recorded wireless signals to compare with the wired signals, as shown in Fig. 1 For each patient, calibrated wireless waveforms displayed excellent correlation with the standard wired recording, with similarities ranging from 0.976- 0.997 in the waveforms from the abductor hallucis. The wireless signals, since they are digitalized in real time at the module near the needle, contain more original contents in the signals and much less noises from the environment.

Conclusion

While wired IONM recording has been considered as the gold standard for spinal deformity surgery, a wireless recording application is feasible and advantageous due to small size, low cost, better signal integrity and shorter setup time.

Take Home Message

A new wireless sensor network can be applied to acquire TcMEP signals with high effectiveness and reliability of recordings.

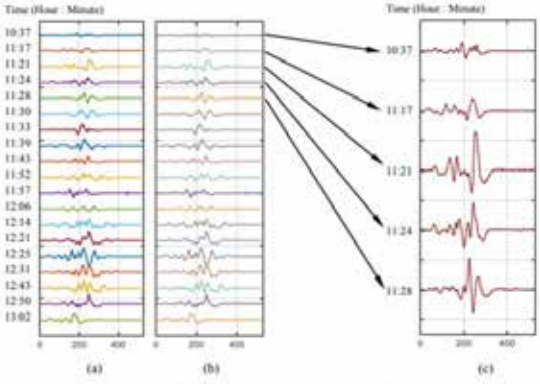


Fig. 1. Waveforms were measured from the abductor hallucis muscle during the 2.5-hour surgery period. (a) The wired IONM waveforms. (b) The transformed wireless waveforms (dotted lines). (c) The details in five waveforms.

112. Prospective Validation of The Spinal Cord Shape Classification System (SCSCS) to Assess the Risk of Intraoperative Neuromonitoring Data Loss with Thoracic Deformity Correction

Meghan Cerpa, MPH; J. Alex Sielatycki, MD; Scott Zuckerman, MD; Earl D. Thuet, BS; Griffin R. Baum, MD; Zeeshan M. Sardar, MD; Paul J. Park, MD; Joseph M. Lombardi, MD; Eric Leung, BS; Meghana Vulapalli ; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Summary

We present a prospective validation of the novel spinal cord shape classification system (SCSCS) that is able to identify patients with Type 3 spinal cords (spinal cord deformed against the concave pedicle in the axial plane), have 4x greater odds of losing monitoring data during thoracic deformity correction versus type 1 or 2 spinal cords.

Hypothesis

Preop morphology of the spinal cord within the spinal canal assessed at the thoracic apical concavity can be used to predict intraop loss of intraop neuromonitoring (IONM) data

Design

Prospective single-center cohort

Introduction

A prior retrospective study of the SCSCS demonstrated increased risk of IONM data loss in type 3 spinal cords, & we now present a prospective study to further validate this novel preop SCSCS to identify spinal cords at risk for data loss w/ correction of thoracic spinal deformity

Methods

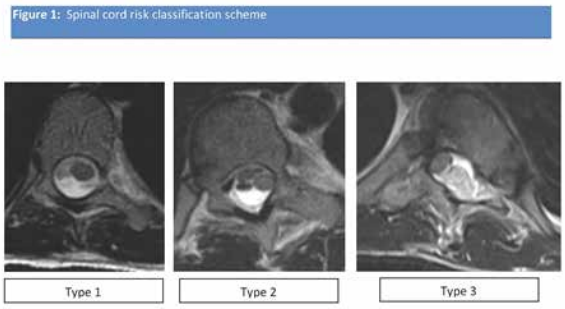
176 consecutive pts. undergoing surgical correction of a thoracic deformity with pedicle screw/rod constructs were prospectively enrolled. Spinal cords were classified into 3 types based on the appearance of the cord on the apical axial T2 MRI: Type 1 a circular/symmetric cord w/ visible CSF between the cord and the apical concave pedicle/vertebral body; Type 2 a circular/oval/symmetric cord with no visible CSF between the concave pedicle & the cord; Type 3 a spinal cord that is flattened/deformed by the apical concave pedicle or vertebral body, w/ no intervening CSF. Logistic regression was used to assess odds ratios and predictor variables of losing IONM data intrap

Results

Of 176 pts, 93(53%) had a Type 1 cord; 46 (26%) had a Type 2 cord, and 37 (21%) had Type 3 spinal cord shapes. IONM data changes in trans-cranial motor-evoked potentials (TcMEPs) and/or somatosensory evoked potentials (SSEPs) in 44 (25%;p<0.001) cases; 19/93(20%) in Type 1, 6/46(13%) in Type 2, & 19/37(51%) in Type 3. On regression analysis, Type 1&2 spinal cords showed a protective effect against IONM data loss (OR=0.24, 95%CI:0.11-55; p<0.001;OR=0.14, 95%CI:0.05-0.42;p<0.001). Type 3 spinal cords had a significantly higher odds of IONM data loss (OR=4.1, 95%CI:1.8-9.3; p<0.001). Vertebral column resection itself was not associated with loss of IONM data (p=0.12)

Conclusion
This prospective validation of the novel SCSCS to identify pts w/ increased odds of losing IONM data w/ thoracic spinal deformity correction, we found that Type 3 spinal cords were 4x more likely to have IONM data changes than types 1 or 2

Take Home Message
We recommend careful review of the axial apical MRI to classify the spinal cord morphology using the SCSCS which demonstrates a markedly increased risk of losing IONM during deformity correction.



113. How a Compressed Spinal Cord is Rejuvenated in Spinal Tuberculosis: A Case Series of Surgical Approaches on 715 Patients

Mohammed Shah Alam, FCPS; Sharif A. Jonayed, FCPS; Sarwar Jahan, FCPS; Abdullah Al Mamun, FCPS; O Z M Dastagir, D Ortho; Shubhendu Chakraborty, MRCS

Summary
Primary TB is better where as the secondary one is worse & complicated. A significant number of Pott's disease can be managed conservatively. Surgery eradicates the disease & protect spinal cord. Instrumentation enhances biological union & prevents further deformity

Hypothesis
Surgery in spinal tuberculosis facilitate a better outcome & helps to maintain a decompressed spinal cord.

Design
Prospective study

Introduction
The diagnosis of spinal tuberculosis is difficult and it commonly presents at an advanced stage. Delays in establishing diagnosis and management result in complications such as spinal cord compression and spinal deformity.

Methods
Total of 715 patients with tuberculosis of the cervical, thoracic and lumbar spine with moderate to severe cord compression were studied. Variable degrees of neurological deficit with deformity were treated from January, 2003 to July, 2019. Thoracotomy along with anterolateral decompression and autogenous strut bone grafting with simultaneous fixation by screws and rods were done in 113 cases. Posterior decompression, posterior interbody and posterolateral fusion by bone graft with stabilization by transpedicular screws and rods were done in 550 cases, whereas 52 cases of cervical tuberculosis were operated by either anterior approach or both anterior and posterior approaches. Appropriate anti TB drugs were given to all patients for 12-18 months. The follow-up period was 3 months to 10 years.

Results
The average age was 47 (9-85) years. All patients survived surgery. There were 9 cases of superficial infections (1.2%) whilst there were 5 cases (0.7%) of deep infections. Revision surgery was performed in 7 patients (1.0%). Implant failure occurred in 5 cases (0.7%) whilst malposition of screws occurred in 15 cases (2.1%). Perioperative bleeding complications were reported for 5 patients (0.7%). Neurological improvement occurred in all patients except for 8 cases (1.1%). Preoperatively, the majority of patients (n=265, 37%) were classified with Class B on the American Spinal Injury Association (ASIA) neurological impairment scale. This was significantly reduced postoperatively to 0.3%.

Conclusion
For patients with spinal tuberculosis anterior debridement, autograft bone fusion, anterior or posterior fixation appears to be effective in arresting disease, correcting kyphotic deformity and maintaining correction until solid spinal fusion.

Take Home Message
Surgery in spinal tuberculosis is always rewarding. However, case selection & timing along with anti Tb drugs of adequate duration mandate a successful outcome.

114. Better Late than Never: Neurological Outcomes of Surgical Decompression in Neglected Tuberculosis Spine with Neurodeficit

Tushar N. Rathod, MS; Ashwin Sathe, MS; Swapnil Keny, MS; Abhinav Jogani, MS

Summary
A retrospective analysis of 60 thoracolumbar spinal Tuberculosis patients with progressive neurodeficits showed that there is significant scope for neurological improvement in spite of a delay between the appearance of deficit and decompression surgery. Preoperative neurological status was found to be the most significant determinant of post-operative neurological outcome.

Hypothesis
Delayed neurological decompression in neglected Tuberculosis of the spine leads to poor neurological outcomes.

Design
Observational

Introduction
Late presentation to Healthcare facilities of spinal tuberculosis with incomplete paraparesis is a common problem in developing countries. The timing of surgical decompression in these patients remains controversial.

Methods
Retrospective analysis of 60 cases with thoracolumbar TB who

underwent posterior decompression and instrumentation was done. Parameters like time interval between the appearance of neurodeficit to decompression surgery, Maximal Spinal cord compression (MSCC), Neurology on admission, presence of drug resistance, Number of Vertebrae Involved were recorded. The patients were divided in 2 groups as per neurological improvement measured with LEMS (Lower Extremity Motor Score) at the end of 1 year follow up and analyzed.

Results
The mean time between appearance of neurodeficit and decompression surgery for the entire cohort of 60 patients was 42.12(range 5- 200 days). On admission the mean LEMS score of the entire cohort of 60 patients was 28.72(SD 12.88). Score improved to 41.80(SD 10.46) at the end of 1 year (p-value <0.001). 32(52%) patients categorized into 'Satisfactory' improvement (>10 LEMS) group and remaining 28 patients into 'non-satisfactory' improvement group. The median time interval between the appearance of neurodeficit and decompression surgery was 23.70 days in satisfactory group and in non-satisfactory group it was 29.60 days (p-value 0.110). MSCC was 0.390 in satisfactory outcome group and 0.377 in non-satisfactory outcome group (p-value 0.754). The mean pre-operative LEMS score was 36.62 in satisfactory outcome group while that in non-satisfactory outcome group was 19.25(p-value <0.001)

Conclusion
Patients who present late to competent healthcare facilities, particularly in developing nations, owing to multitudes of socio-economical and logistic issues and delays, can still expect a fair amount of recovery after decompression surgery. Preoperative neurological status was found to be the most significant determinant of post-operative neurological outcome.

Take Home Message
Significant scope exists for neurological improvement in spite of delayed decompression in tuberculosis of the spine with progressive neurological deficits. Preoperative neurological status was most significant determinant of neurological outcome.

115. The Contribution of Preoperative Halo-pelvic Traction to Correcting Severe Rigid Scoliosis

Kai Cao, MD, PhD; Lu Chen, MD, PhD; Honggui Yu, MD, PhD; Zhenhai Zhou, MD, PhD; Rongping Zhou, MD, PhD; Wenbing Wan, MD, PhD; Zhimin Pan, MD, PhD

Summary
Twenty-six Pts suffered from severe rigid scoliosis who underwent only Ponte osteotomy after pre-operative halo-pelvic traction were included in this study. Radiographic parameters in pre-, post-traction and at last F/U were measured and compared. Traction duration, spine elongation, surgery time, EBL and related complications were also analyzed. Halo-pelvic traction combined Ponte osteotomy produced a satisfied correction without major neurodeficit.

Hypothesis
Preoperative halo-pelvic traction increases the safety and improve the magnitude of curve correction in the treatment of severe rigid scoliosis.

Design
A retrospective study.

Introduction
The management of severe rigid scoliosis is a challenge for spine surgeons. As single stage surgery carries high risk of post-op paralysis, long surgery time and much blood lose, pre-operative traction is one of the ways that proven to be successful in reducing the peri-operative risks and improve the magnitude of curve correction. However, halo-gravity traction is much less effective for this highly rigid and severe adulthood deformity. Here, we present a cohort of severe rigid scoliosis which was managed pre-operatively by using halo-pelvic traction and then underwent correction surgery.

Methods
Twenty-six consecutive severe rigid scoliosis Pts who underwent only Ponte osteotomy after helo-pelvic traction were included. Radiographical measurements included major Cobb angle (MCA), thoracic kyphosis (TK), lumbar lordosis (LL), coronal and sagittal balance in pre-, post-traction and at last F/U after surgery. Traction duration, spine length, surgery time, EBL and related complications were analyzed. F/U was at least 2 years.

Results
MCA, TK, LL, C7-CSVL distance and SVA were 110.9±14.9°, 44.9±43.9°, -47.8±30.2°, 2.29±1.84cm and 2.4±1.9cm preoperatively, changed to 74.8±16.2°(p<0.001), 28.8±25.7°, -42.4±19.1°, 1.9±1.1cm and 4.3±2.5cm post-tractively, as well as finally corrected to 46.6±8.5°(p<0.01), 36.7±17.8°, -47.7±13.3°, 0.9±0.2cm and 2.2±1.2cm(p<0.05). The traction contributed 56% of magnitude to the final correction. The mean traction duration was 31.7 days. C7-S1 length were 33.8±7.1cm, 43.5±6.9cm(p<0.001), 45.1±6.0cm(p<0.05) pre-, post-tractively and at last F/U, respectively. The traction contributed 91% of elongation to the final spinal length. Surgical time was 6.2±1.4h with 1216±312ml EBL, and no major neurodeficit occurred.

Conclusion
Preoperative helo-pelvic traction contributed 56% of magnitude to the final correction and 91% of elongation to the final spinal length in severe rigid scoliosis.

Take Home Message
Preoperative halo-pelvic traction not only increases security for severe rigid scoliosis correction, but also avoid high-grade osteotomy in such deformity. Furthermore, the traction contributes to the magnitude of curve correction.

Podium Presentations—Nerves and Big Curves: Advances in Neuromonitoring and Management of Severe Spinal Deformity

Fig.1, Preoperative X-ray (A,B); X-ray after traction(C,D); X-ray at final F/U (E,F).

117. Intraoperative and Early Postoperative Complications after Surgery for Severe Pediatric Spinal Deformity Have a High Rate of Resolution at 2 Years but Affect Outcome Scores

Munish C. Gupta, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; David B. Bumpass, MD; Mark A. Erickson, MD; Sumeet Garg, MD; Richard E. McCarthy, MD; Peter O. Newton, MD; Joshua M. Pahys, MD; Amer F. Samdani, MD; Suken A. Shah, MD; Harry L. Shufflebarger, MD; Paul D. Sponseller, MD; Daniel J. Sucato, MD, MS; Burt Yaszay, MD; Brenda A. Sides, MA; Michael P. Kelly, MD; Fox Pediatric Spinal Deformity Study

Summary

135/231 (58%) of pts treated surgically for severe pediatric deformity (min.100° or planned VCR) had intraop or early postop (within 90 days) complications. Majority of the complications resolved. The occurrence of a complication did not affect total SRS scores at 2 yr. The 9 pts with unresolved complications at 2 yr had lower SRS function and satisfaction scores. Pts with motor deficits had lower SRS satisfaction scores.

Hypothesis

Patients with intraop and early postop complications have lower SRS scores at 2 yrs postop.

Design

Prospective observational multi center cohort of pediatric patients treated surgically for severe spinal deformity.

Introduction

Surgical treatment of severe pediatric deformity can be challenging. We investigated the rate of intraop and early postop complications in this population and the effect on outcome scores at 2 years.

Methods

Pts with severe spinal def. (min. 100° or planned VCR) were included with 2 yr f/u. We studied preop to 2 yr po change in SRS scores correlated with resolved and unresolved intraop and early po complications.

Results

242/311 (78%) pts had min 2 yr f/u; 231/242 (95%) had both preop and 2 yr po SRS scores. 106/231 pts (46%) had a total of 143 intraop complications (comps.) (N=35 major, 108 minor) (avg. 0.57, range 1-4). 54/231 (23%) had a total of 71 early (90 days) postop comps. (N=32 major, 39 minor);(avg. 0.31, range 1-5). There was no difference in 2 yr total SRS scores between the patients with or without intraop comps or with or without post op comps. At 2 yr po, 5/106 (5%) patients had unresolved intraop comps. (4 major, 1 minor) and 5/54 (9%) (4 major, 1 minor) reported unresolved po comps. SRS function and satisfaction scores at 2yr were significantly different between the patients with unresolved compared to resolved comps. (function avg. 3.62 and 4.31 respectively, p=0.026) (satisfaction avg. 3.94 and 4.50 respectively, p=0.010). The change in SRS total scores from preop to 2 yr postop was not significant but self-image was significant (0.64 and 1.47, p=0.035). All pts with a motor deficit had lower satisfaction at 2yr than those with no motor deficits (avg. 4.32 and 4.51 respectively, p=0.027).

Conclusion

The majority of intraop and early postop comps. after surgery for severe spinal deformity resolve by 2yr po. There are no significant differences in SRS scores between patients with comps. compared to those with none. Patients with unresolved comps. at 2 yrs have lower function and satisfaction scores than those whose comps have resolved.

Take Home Message

There is a high rate of complications in severe spinal deformity. Most resolve by 2yr po. Patients with unresolved comps. at 2 yrs have lower function and satisfaction scores.

Difference of 2 yrs SRS between unresolved complication group and resolved complications group

	Pain- 2 yrs	Self-Image- 2 yrs	Function-2yrs	Mental Health-2 yrs	Satisfaction-2 yrs (not included in total)	Total-2 yrs
all complications resolved group (postop) (N=222)	4.246486 ± 0.837643	4.118919 ± 0.631240	4.305180 ± 0.614517	4.233559 ± 0.620146	4.502262 ± 0.685064	4.222182 ± 0.522246
unresolved complications group (N=9)	3.970000 ± 0.886059	3.733333 ± 0.948683	3.622222 ± 0.961480	4.030000 ± 0.946097	3.944444 ± 0.768295	3.854444 ± 0.795913
P Value	0.270177	0.236235	0.026416	0.702654	0.010102	0.137011

Difference of SRS change from preop to 2 yrs between unresolved complication group and complications resolved group

	Pain-change	Self-Image-change	Function-change	Mental Health-change	Satisfaction-change (not included in total)	Total-change
all complications resolved group (postop) (N=222)	0.582432 ± 0.962654	1.467117 ± 0.976998	0.622072 ± 0.819673	0.431081 ± 0.774954	1.538288 ± 1.686283	0.683570 ± 0.787609
unresolved complication group (N=9)	0.166667 ± 1.315295	0.644444 ± 1.028483	0.088889 ± 0.906152	-0.033333 ± 0.927362	1.666667 ± 2.193741	0.232229 ± 0.895786
P Value	0.794695	0.034585	0.135671	0.169732	0.804043	0.099130

Difference of 2 yrs SRS between non motor deficit complication group and motor deficit complication group

	Pain- 2 yrs	Self-Image- 2 yrs	Function-2yrs	Mental Health-2 yrs	Satisfaction-2 yrs (not included in total)	Total-2 yrs
motor deficit group (postop) (N=34)	4.368529 ± 0.651135	4.041176 ± 0.701132	4.170588 ± 0.686020	4.349118 ± 0.708068	4.323529 ± 0.638207	4.236471 ± 0.532427
non motor deficit group (N=197)	4.212792 ± 0.866942	4.114721 ± 0.639544	4.297208 ± 0.634433	4.204315 ± 0.620068	4.507653 ± 0.702518	4.202718 ± 0.540043
P Value	0.669855	0.649762	0.279186	0.096162	0.027130	0.716227

Analysis

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118. Surgical Treatment of Severe Pediatric Spinal Deformity Significantly Improves Pulmonary Function

Munish C. Gupta, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; David B. Bumpass, MD; Mark A. Erickson, MD; Sumeet Garg, MD; Richard E. McCarthy, MD; Peter O. Newton, MD; Joshua M. Pahys, MD; Amer F. Samdani, MD; Suken A. Shah, MD; Harry L. Shufflebarger, MD; Paul D. Sponseller, MD; Daniel J. Sucato, MD, MS; Burt Yaszay, MD; Brenda A. Sides, MA; Michael P. Kelly, MD; Fox Pediatric Spinal Deformity Study

Summary
Surgical treatment of severe pediatric deformity is challenging. The 2 yr pulmonary function results of 124 pts. was significantly improved but only correlated with the amount of deformity correction in the coronal plane.

Hypothesis
Surgical treatment of severe pediatric spinal deformity improves pulmonary function at 2 yrs.

Design
Prospective observational multi center cohort of pediatric patients treated surgically for severe spinal deformity.

Introduction
Severe pediatric spinal deformity can markedly decrease pulmonary function. Surgical treatment improves the cosmesis and prevents deformity progression but the effect of surgical treatment on pulmonary function in severe pediatric deformity patients is not fully known.

Methods
Pts with severe spinal deformity (min. 100° or planned VCR) were included with min. 2 yr f/u. We studied the preop curve size, % of coronal and sagittal plane curve correction, location of the deformity apex and type of procedure performed as related to PFT changes postop.

Results
242/311 pts had a min 2 yr f/u; 124/242 (51%) had both preop and 2 yr PFT data. Significant correction was obtained at 2yrs. Preop coronal avg. was 91° (0-175°) corrected to 49° avg. (4-100°) and sagittal curve 101° (17-176°) corrected to 58° avg. (0-115°). PFT's were improved at 2 yrs postop FEV1 (avg. 1.52 to 1.78, p<0.001) and FVC (avg. 1.77 to 2.01, p<0.001).The % of coronal correction (43%, 0-82) correlated with improved FEV1 (p=0.001, r=0.3) and FVC (p=0.001, r=0.3) at 2 yr. Sagittal correction (41%, 0-100) did not correlate with PFT improvement (FEV1 p=0.487; FVC p=0.537). No correlation was found between PFTs and the predominant preop deformity of scoliosis or kyphosis ,in the preop Cobb angle (coronal; FEV1 p=0.962, FVC p=0.813) (sagittal; FEV1 p=0.511, FVC p=0.382), apex of preop deformities in either the coronal or sagittal plane or in the C-DAR or S-DAR. PFT improvement was not correlated with the, type of surgical procedure (ant/post vs post) or 3 column osteotomies (PSO and VCR).

Conclusion
Pulmonary function is significantly improved after surgical correction but is only correlated with the percentage of correction in the coronal plane. Curve size, curve apex, approach, or 3 column osteotomies did not affect improvement

Take Home Message
Surgical correction of severe pediatric spinal deformity results in improved pulmonary function at 2 yr. This improvement was correlated with the percent of deformity correction in the coronal plane.

	Mean	SD	P value
FEV1 PREOP	1.515360	0.700765	0.000001
FEV1 2YRS	1.783520	0.722546	
FVC PREOP	1.765040	0.798641	0.000198
FVC 2YRS	2.007087	0.829602	
%FEV1 preop	58.405600	24.265555	0.675244
%FEV1 2yrs	57.417600	19.391934	
%FVC1 preop	60.985600	24.259154	0.144177
%FVC 2yrs	58.016000	21.813352	
Change of FEV1 PREOP to 2YRS	0.268160	0.628360	
Change of FVC PREOP to 2YRS	0.256613	0.744135	
Change of %FEV1preop PREOP to 2YRS	-0.988000	21.320048	
Change of %FVC2yrs PREOP to 2YRS	-2.969600	24.499099	

	Change : FEV1	Change : FVC	Change : % Predicted FEV1	Change : % Predicted FVC
% of deformity correction in the coronal planes	Correction:YES p value=0.001 r=0.297	Correction:YES p value=0.001 r=0.283	Correction: NO p value=0.172 r=0.123	Correction: NO p value=0.083 r=0.156
% of deformity correction in the lateral planes	Correction: NO p value=0.487 r=-0.063	Correction: NO p value=0.537 r=-0.056	Correction: NO p value=0.500 r=-0.061	Correction:NO p value=0.199 r=-0.116

Pulmonary Function Analysis

119. The Influence of Rib Resection on Pulmonary Function after Vertebral Column Resection in the Thoracic Spine

Satoru Demura, MD, PhD; Satoshi Kato, PhD; Kazuya Shinmura, PhD; Noritaka Yonezawa, MD; Takaki Shimizu, MD; Norihiro Oku, MD; Ryo Kitagawa, MD; Makoto Handa, MD; Ryohei Annen, MD; Hiroyuki Tsuchiya, PhD

Summary
The influence of rib resection on pulmonary function was analyzed after en bloc vertebrectomy in the thoracic spine. A greater number of rib resection showed significant decrease in forced vital capacity 1 year after surgery.

Hypothesis
A number of rib resection negatively impacts pulmonary function after vertebral column resection.

Design
Retrospective single center study

Introduction
The posterior three column resection is performed to achieve a local control of malignant spinal tumor, or is performed in the management of sharp angular spinal deformity. However, the

procedure in the thoracic spine technically requires bilateral rib resection to excise the vertebral body. The objective of this study was to evaluate whether a number of rib resection negatively impacts pulmonary function after en bloc vertebrectomy.

Methods
Pulmonary function testing (PFT) of 31 patients undergoing en bloc vertebrectomy was completed. There were 17 male and 14 female with a mean age of 54.1 years. PFT was performed prior to surgery and at 1 month, 6 months, 1-year post-operative visits. Any patients with obstructive lung disease, asthma history, and smokers were excluded from this study. Associations between a number of rib resection, and the results of PFT were analyzed based on the resected level of the thoracic spine.

Results
There was a significant decrease in forced vital capacity (FVC) at 1 month (71% of preoperative value), 6 months (88%) and 1 year (90%). Meanwhile, the FEV1.0% remained stable. Patients who underwent vertebrectomy at 3 levels (3 pairs of rib resection) showed significant decrease in FVC (83.5% of preoperative value) compared to vertebrectomy at single level (1 pair of rib resection, 93.2%). Patients with upper-middle thoracic rib resection had a trend of lower recovery rate in FVC than those with lower thoracic rib resection.

Conclusion
Forced vital capacity decreased 1 month after en bloc vertebrectomy and returned to 90% of preoperative value at 1 year. Three pairs of rib resection showed significant decrease in FVC, suggesting a possible influence of a greater numbers of rib resection on pulmonary function.

Take Home Message
A greater number of rib resection showed significant decrease in forced vital capacity after surgery.

120. Vertebral Column Resection by Concave Pedicle Drilling in Severe Kyphoscoliosis

Anjaneyulu R. Devireddy, MBBS, MS; Bijjawara H Mahesh, MBBS, MS; Bidre Upendra, MBBS, MS; Raghavendra Rao, MBBS, MS; V.N. Ravi Varma, MBBS, MS

Summary
60 patients with Harington factor (cobb/no of vertebra) > 10 who underwent PVCR. (single stage).An average of vertebrae were resected 1.7.Average Harrington factor of 16.9 preoperatively improved to 10.02 postoperatively. The average preoperative cobb of 93.4 was corrected to 47.53 postoperatively. The PVCR technique with concave pedicle drilling reduces cord tension, making vertebral resection and cantilever correction safer. The operative time was lower as all these surgeries were done with two trained spine surgeons, with an assistant working together.

Hypothesis
The PVCR technique with concave pedicle drilling reduces cord tension, making vertebral resection and cantilever correction safer.

Design
Retrospective study

Introduction
Posterior vertebral column resection (PVCR) for the correction of spinal deformities for severe rigid curves is challenging. The authors describe results of vertebral column resections with drilling of concave pedicles followed by convex body resection for correction under neuromonitoring.

Methods
We retrospectively reviewed patients having thoracic or thoracolumbar severe deformities with Harington factor (cobb/no of vertebra) > 10 who underwent PVCR. The average age was 21.5 years and had an average follow-up of minimum 2years (range 2-8years). 60 patients were included in the study and all surgeries were done in single stage. Operative time, blood loss, loss in neuromonitoring, vertebrae resected, deformity correction apical fusion and neurological status were evaluated.

Results
The mean operating time was 235 minutes (range 150-360 minutes) with an average operative blood loss of 762 ml (range 300-1850 ml). An average of vertebrae were resected 1.7(range 1-4). The mean fusion / instrumentation extent was 9 vertebrae (range - C6-Ilium). The average preoperative cobb of 93.4 was corrected to 47.53 postoperatively. The correction of deformity was 49.1%, with loss of correction of 6.6 degrees at final follow up. Average Harrington factor of 16.9 preoperatively improved to 10.02 postoperatively. There was loss of neuromonitoring signals in 14 patients and recovered intraoperatively. There were 9 patients with transient weakness in lower limbs which improved. 12 patients required ICU care for pneumothorax, 7 patients had dural tears, 4 patients had SSI.

Conclusion
The PVCR technique with concave pedicle drilling reduces cord tension, making vertebral resection and cantilever correction safer. The operative time was lower in these patients as all these surgeries were done with two trained spine surgeons, with an assistant working together.

Take Home Message
The PVCR technique with concave pedicle drilling reduces cord tension, making vertebral resection and cantilever correction safer.

121. Medical Complications and Health Related Quality of Life in Complex Pediatric Spine Deformities Exceeding 100 Degrees or Treated By 3CO.

Kwadwo Poku Yankey, MD; Henry Ofori Duah, MPH; Arthur Sackeyfio, MD; Lawrence G. Lenke, MD; Paul D. Sponseller, MD; Suken A. Shah, MD; Mark A. Erickson, MD; Brenda A. Sides, MA; Peter O. Newton, MD; David B. Bumpass, MD; Irene Wulff, MD; Munish C. Gupta, MD; Oheneba Boachie-Adjei, MD; Fox Pediatric Spinal Deformity Study

Summary
We reviewed data of a large international multi-center cohort of

complex pediatric spine deformity patients for the incidence and impact post-operative medical complications. The cumulative incidence of medical complications was 11.9%. Pulmonary complications were the most common medical complication (9.56%). Long term HRQoL scores were not adversely affected by medical complications.

Hypothesis
Post-operative medical complications do not adversely affect HRQoL of patients

Design
Prospective multicenter international observational study

Introduction
Severe pediatric spine deformity poses a great challenge to the treating physician and carries a high complication rate. Pulmonary complications are the most life threatening. The onus is on the treating surgeon to identify patients who are high risk and institute measures to mitigate the risk for successful outcomes.

Methods
Data of 251/311pts from FOX pediatric database from 17 international sites was queried for incidence of major medical complications. Comparative analysis was done to determine the impact on HRQoL.

Results
251/311pts had min 2 yr f/u. 142F/109M, average age 14.61yrs. Etiologies included 96 Cong,94 Idiopathic, 14- Post TB, 12-NM,12-NF,10-syndromic,8 others. Curve type included Scoliosis-121, Kyphoscoliosis 72, Kyphosis 58. Coronal and sag cobb avg 88.02deg ± 41.47 and 91.92deg±39.17, respectively. Deformity apices was in the thoracic region in 88% of patients. Pre-op co-morbidities included 54 (21.5%) cardiopulmonary; 7(2.79%) Genitounrinary;13 (5.18%) GIT;13 (5.18%) Anxiety/depression; neurological 24 (9.56%); HGT was utilized in 103pts (41%) at an average duration of 68days. Mean OR time was 459min, blood loss averaged 1465ml. VCR was performed in 120(47.81%), PSO in 16 pts (6.37%), SPO in 145pts (57.77%), Thoracoplasty in 132 pts (52.8%). 96% had blood transfusion. There were 35 post-op medical complications occurring in 30pts (11.95%). Event-specific cumulative incidence was 24(9.56%) pulmonary, 2(0.80%) GU, 5(1.99%) GIT, (1.6%) cardiovascular. There was no mortality. There was significant improvement in SRS total and Domain scores at 2yr FU irrespective of medical complication (Figure 1)

Conclusion
Medical complications are common among pediatric patients undergoing complex spine surgery for severe deformity. However the HQoRL are not affected by the occurrence of complications.

Take Home Message
Pulmonary complications are the most common medical events after complex pediatric spine deformity surgery. However, medical complications do not adversely affect the long-term HRQoL

Table 1A: Average SRS scores after surgery (All patients)

	Pre-op	2yr	Δ	p-value
Function	3.29	4.13	0.83	P<0.01
Pain	3.36	4.10	0.74	P<0.01
Appearance	3.76	4.39	0.62	P<0.01
Mental	3.50	4.22	0.72	P<0.01
satisfaction	3.12	4.50	1.38	P<0.01
SRS Total	3.42	4.25	0.83	P<0.01

Table IB Average SRS scores after surgery stratified by complication status

	Medical Complication Status: No				Medical Complication Status: yes			
SRS-Domains	Pre-op	2yr	Δ	p-value	Pre-op	2yr	Δ	p-value
Function	3.26	4.11	0.84	P<0.01	3.47	4.26	0.78	P<0.01
Pain	3.30	4.07	0.77	P<0.01	3.79	4.35	0.56	P<0.01
Appearance	3.71	4.37	0.66	P<0.01	4.16	4.52	0.35	P<0.01
Mental	3.43	4.18	0.75	P<0.01	3.92	4.45	0.53	P<0.01
satisfaction	3.06	4.50	1.43	P<0.01	3.53	4.57	1.03	P<0.01
SRS Total	3.36	4.23	086	P<0.01	3.78	4.43	0.64	P<0.01

Long term outcome of HRQoL

122. Reducing Revision Rates following 3-Column Osteotomy Surgery: A Single-center Experience of Trends over Seven Years

Tanvir J. Bari, MD; Dennis W. Hallager, MD, PhD; Lars V. Hansen, MD; Benny T. Dahl, DMSc; Martin Gehrchen, MD, PhD

Summary
We assessed the effects of continuous improvements in clinical practice on postoperative complications following 3-column osteotomy (3CO). In a seven-year study period, mechanical complications were markedly reduced.

Hypothesis
Mechanical complications decreased in the study period.

Design
Retrospective, single-center.

Introduction
Although surgically advantageous, 3CO is related to considerable risks of mechanical complications. At our quaternary spine institute, improvements in clinical practice have been continuously implemented in the last decade in efforts to decrease surgery-related risks following 3CO in patients with Adult Spinal Deformity (ASD).

Methods
We included all patients undergoing 3CO for ASD from 2010-2016. Changes to clinical practice were introduced continuously, including more rigorous patient selection; inter-disciplinary conferences; implant-material; number of surgeons; surgeon experience; and perioperative standardized protocols for pain, antibiotics and blood-loss management. Postoperative complications were recorded in the 2-year follow-up period. Competing risk survival analysis was used to estimate the incidence of revision surgery due to mechanical complications, and the Mann-Kendall test for trend analyses.

Results
In 207 included patients, vertebral level of 3CO changed over the study period ($p<0.01$) with L3 being the most common level in 2010 compared to L4 in 2016. Both preoperative and surgical correction of sagittal vertical axis were larger towards

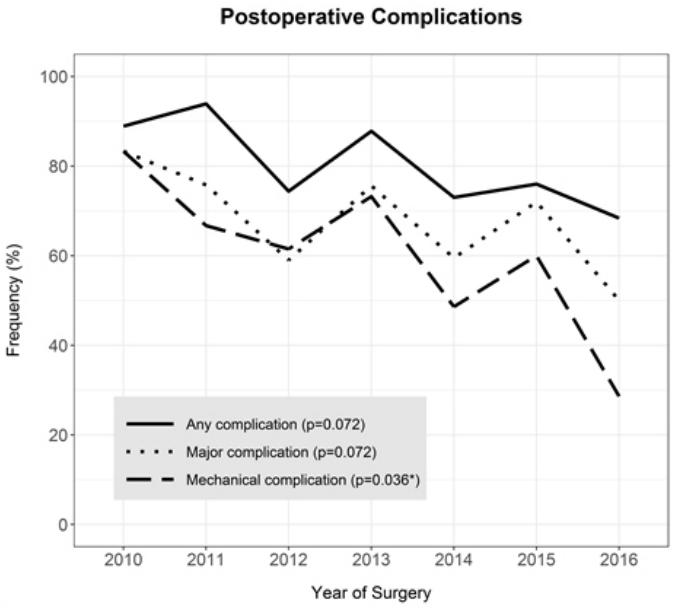
the end of the study period. The 2-year revision rate due to mechanical complication steadily declined from 52% in 2010 to 14% for patients treated in 2016, although without significant trend (P=0.072). The cumulative 1-year revision risk, and overall rates of mechanical complications, rod breakage and proximal junctional failure showed significant decreasing trends (P=0.035, 0.036, 0.036 and 0.048).

Conclusion

We observed decreased mechanical complications following 3CO in patients with ASD over a seven-year period. We attribute this reduction to improvements in patient selection, surgical planning, surgical techniques and more standardized perioperative care.

Take Home Message

Continuous improvements in clinical practice can markedly reduce mechanical complications after 3CO surgery.



Time trend

Podium Presentation—Spondylolisthesis/Congenital/Miscellaneous

123. Can Surgery Restore Normal Quality of Life after Failed Conservative Treatment of Pediatric Low-Grade Spondylolisthesis?

Jean-Marc Mac-Thiong, MD, PhD; Julie Joncas, RN; James Choueiry, MD; Stefan Parent, MD, PhD; Soraya Barchi, BSc; Hubert Labelle, MD

Summary
This retrospective matched cohort study compared the quality of life (QoL) of 24 patients with successful conservative treatment vs. 24 matched patients requiring surgery for pediatric low-grade spondylolisthesis. Conservative treatment did not improve QoL in either group. The main factors associated with the need for surgery were low scores in pain and function domains. Surgery restored normal scores for pain, mental health, self-image and function in 54%, 88%, 79% and 67% of patients, respectively.

Hypothesis
Surgery can successfully restore normal quality of life (QoL) after failed conservative treatment of pediatric low-grade spondylolisthesis

Design
Retrospective matched cohort study comparing the QoL of patients with pediatric low-grade spondylolisthesis after 1) successful conservative treatment, or 2) surgical treatment after failed conservative treatment

Introduction
The benefits of surgery after unsuccessful conservative treatment of low-grade spondylolisthesis remains unclear, mainly because previous studies did not prospectively assess the QoL using validated questionnaires

Methods
A retrospective cohort of 24 patients with pediatric low-grade spondylolisthesis undergoing posterolateral instrumented fusion after unsuccessful conservative treatment was compared to a cohort of 24 non-surgical patients matched by age, sex, grade and level of spondylolisthesis. QoL was assessed using the SRS-23 questionnaire at initial visit, after conservative treatment, and minimum 2 years postoperatively if surgery was performed. Normal QoL was defined as a score within 2 standard deviations of the mean for healthy subjects with similar socio-demographic characteristics

Results
The normal scores for pain, mental health, self-image and function scores were significantly worse at initial visit in the surgical group (Table). A greater percentage of patients in the conservative group had abnormal pain and function scores. The domain scores and percentage of patients with normal scores were not improved by conservative treatment in either group. Surgery significantly improved the scores and percentage of patients with normal scores only for pain and function domains

Conclusion
Surprisingly, conservative treatment was not effective in improving QoL. The main factors associated with the need for surgery were low scores in pain and function domains. Surgery resulted in normal scores for pain, mental health, self-image and function in 54%, 88%, 79% and 67% of patients, respectively.

Take Home Message
The main indications for surgery in pediatric low-grade spondylolisthesis are pain and poor function. Surgery restores normal quality of life in the majority of patients after failed conservative treatment.

		SRS-23 domains			
Cohort	Timepoint	Pain	Mental health	Self-image	Function
Surgical	Baseline	2.96±0.82 16.7%	3.47±0.70 79.2%	3.73±0.68 66.7%	3.62±0.72 25.0%
	Preoperative	2.88±0.75 12.5%	3.41±0.73 87.5%	3.71±0.52 79.2%	3.53±0.70 20.8%
	Postoperative	3.59±1.10 54.2%	3.71±0.86 87.5%	4.02±0.85 79.2%	4.10±0.66 66.7%
Conservative	Baseline	4.12±0.79 75.0%	4.16±0.77 95.8%	4.10±0.69 91.7%	4.33±0.77 79.2%
	Last follow-up	4.28±0.66 87.5%	4.28±0.56 95.8%	4.12±0.66 79.2%	4.35±0.37 75%

Mean scores of the SRS-23 domains (±SD) for the surgical and non-surgical groups, and proportion of patients within 2 standard deviations from the mean scores of healthy subjects

124. Does Meyerding Slippage Reduction in Spondylolisthesis Correlate with Patient Outcomes?

Rory R. Mayer, MD; Dean Chou, MD; Brenton Pennicooke, MD; Praveen V. Mummaneni, MD

Summary
Reduction of Meyerding grade is often a goal during spondylolisthesis surgery; however, correlation with patient reported outcomes (PROs) is rarely reported. The Quality Outcomes Database was queried for patients undergoing lumbar fusion for spondylolisthesis with 2-year follow-up, and quantitative correlation between Meyerding slippage reduction and PROs was performed. Significant improvement was found in terms of all patient-reported outcomes in patients undergoing decompression and fusion for lumbar spondylolisthesis. There was no correlation with clinical outcomes and magnitude of Meyerding slippage reduction.

Hypothesis
There is no significant difference in patient reported outcomes when comparing patients with or without Meyerding grade reduction of spondylolisthesis during posterior lumbar fusion surgery.

Design
Retrospective review of prospectively collected data from multi-institutional spine registry

Introduction
Reduction of Meyerding grade is often a goal during spondylolisthesis surgery. Although radiographic appearance may improve, correlation with patient reported outcomes (PROs) is rarely reported.

Methods
The Quality Outcomes Database was queried for patients

undergoing posterior lumbar fusion for spondylolisthesis with minimum 2-year follow up, and correlation between Meyerding slippage reduction and PROs was performed. Baseline and 24-month PROs, including ODI, EQ-5D, NRS-BP, NRS-LP, and satisfaction were noted. Multivariable regression models were fitted for 24-month PROs and complications after adjusting for preoperative variables. Data were analyzed for magnitude of slippage reduction and correlated with PROs. Patients were divided into two groups: < 3 mm reduction and ≥ 3 mm reduction.

Results
206 patients were identified in the QOD. 104 patients underwent lumbar decompression and fusion with slippage reduction ≥ 3 mm (mean 5.13, range 3 to 12), and 102 patients underwent lumbar decompression and fusion with slippage reduction less than 3 mm (mean 0.44 mm, range -2 to 2). Patients in both groups (slippage reduction greater than 3 mm, and slippage reduction less than 3 mm) reported significant improvement in all primary patient reported outcomes (all $p < 0.001$). There was no significant difference with regard to the PROs between patients with or without intraoperative reduction of listhesis on univariate and multivariate analysis.

Conclusion
Significant improvement was found in terms of all patient-reported outcomes in patients undergoing decompression and fusion for lumbar spondylolisthesis. There was no correlation with clinical outcomes and magnitude of Meyerding slippage reduction.

Take Home Message
Magnitude of Meyerding grade slippage reduction does not correlate with patient reported outcomes in lumbar spondylolisthesis surgery.

125. Health-Related Quality of Life (HRQOL) of Instrumented Reduction with Circumferential Arthrodesis for Pediatric Spondylolisthesis: A Comparison with Age and Gender Matched Healthy Controls

Ella Virkki, MD; Hanna Oksanen, RN; Linda Helenius, MD; Olli T. Pajulo, MD; Elias Diarbakerli, PhD; Paul Gerdhem, MD; Bernd Pape, PhD; Ilkka J. Helenius, MD

Summary
A prospective comparative study on HRQOL of 26 adolescents with spondylolisthesis who underwent instrumented reduction and circumferential arthrodesis vs. 52 age and gender matched controls (1:2). Risk of non-union was low (12%) and HRQOL improved significantly in SRS pain and activity domains but remained significantly lower compared to controls in all domains expect activity.

Hypothesis
HRQOL improves after surgery and is at similar level at FFU than in healthy controls.

Design
A prospective study on clinical, radiographic, and HRQOL outcomes in adolescents with spondylolisthesis undergoing instrumented reduction compared with healthy controls.

Introduction
Limited knowledge on HRQOL exists after reduction and arthrodesis for pediatric spondylolisthesis and no studies comparing it with healthy controls.

Methods
26 consecutive adolescents (mean age, 14.7 [10-18] yrs, follow-up 3.2 [range, 2.0-8.0] yrs) undergoing instrumented reduction with intercorporeal arthrodesis for spondylolisthesis (11 low, 15 high-grade) by a single surgeon were included and two healthy controls matched by age and gender. The HRQOL was measured with SRS-24 questionnaire preoperatively, at 6 months and 2 years postoperatively.

Results
Mean slip (50% vs. 15%) and lumbosacral kyphosis (13° vs. 10°) improved significantly ($p<0.05$). None developed persistent neurologic deficit. Three (12%) developed non-union. Seven (27%) had reoperation (4 iliac screw removal, 2 non-union, 1 extended). SRS-24 pain and activity domains improved from preoperative to 2-year FU ($p\leq0.007$, table). SRS scores in pain, self-image, function and total score remained lower in the patients than in healthy controls ($p<0.05$).

Conclusion
Risk of non-union is relatively low after instrumented reduction and circumferential (TLIF) arthrodesis in adolescents with spondylolisthesis. HRQOL improves significantly but remains at lower level at 2-year follow-up than in healthy controls.

Take Home Message
HRQOL improves significantly after instrumented reduction and circumferential arthrodesis in adolescents with spondylolisthesis but remains at statistically lower level at two-year follow-up than in healthy matched controls.

SRS domain	Preoperative (n=22)	2-year (n=23)	p value*	healthy controls (n=52)	p value**
Total	3.59 ± 0.61	4.10 ± 0.76	0.059	4.73 ± 0.33	<0.0001
Pain	3.27 ± 0.93	3.97 ± 1.02	0.007	4.76 ± 0.43	<0.001
Self-image	4.03 ± 0.63	4.28 ± 0.57	0.052	4.57 ± 0.50	0.018
Function	3.85 ± 0.50	4.09 ± 0.46	0.065	4.91 ± 0.19	<0.0001
Activity	3.53 ± 1.06	4.22 ± 1.25	0.001	4.66 ± 0.46	0.482

* preop vs. 2-yr FU ** 2-year follow-up scores excluding the questions regarding postoperative state compared to healthy controls

126. Complications of the Surgical Treatment of Pediatric High-Grade Spondylolisthesis: A Prospective Multicenter Study

Jean-Marc Mac-Thiong, MD, PhD; Michael T. Hresko, MD; Abdulmajeed Alzakri, MD; Stefan Parent, MD, PhD; Daniel J. Sucato, MD, MS; Lawrence G. Lenke, MD; Michelle Claire Marks, PT; Hubert Labelle, MD

Summary
Complications after surgical treatment of high-grade spondylolisthesis were collected with a minimum follow-up of 2 years for a prospective cohort of 60 patients treated in 4 pediatric centers specialized in spine surgery. The overall rate of complications and reoperations was 20% and 10%, respectively. Transient and persistent motor radiculopathy occurred in 4 and 2 patients, respectively. Six patients underwent revision surgery for dural leak, junctional spondylolisthesis (3 patients), malpositioned screw, and prominent implants.

Hypothesis
Surgical treatment of high-grade spondylolisthesis can be done safely in pediatric centers specialized in spine surgery

Design
Prospective multicenter longitudinal study of a cohort of 60 patients with high-grade spondylolisthesis treated surgically.

Introduction
Surgical treatment of high-grade spondylolisthesis can lead to major complications. The complication rates vary widely in previous studies. Unfortunately, most previous studies are limited by their retrospective design.

Methods
A prospective cohort of 60 patients with pediatric high-grade spondylolisthesis (14.4+/-2.7 years at surgery) was recruited from 4 institutions. Data collection including complications were collected from standardized forms after a minimum follow-up of 2 years after surgery.

Results
One patient had uninstrumented L4-S1 posterior fusion. Of the 59 patients receiving pedicle screws, L4-S1, L5-S1, L4-ilium and L5-ilium were instrumented in 20, 28, 11 and 1 patients, respectively. L5-S1 interbody fusion was performed using PLIF/TLIF, L5-S1 transfixation from S1 pedicle screws, or a combination of L5-S1 transfixating cage plus L5-S1 transfixation from S1 pedicle screws in 36, 7 and 3 patients, respectively. Neuromonitoring was used in 53 patients. Six patients required reoperation: 1) repair of a dural leak, 2) 3 patients with proximal extension to L4 for junctional spondylolisthesis, 3) revision of transfixation screw protruding anteriorly at L5 vertebral body, and 4) removal of prominent implants. Four patients had transient L5 radiculopathy, and 2 had persistent motor radiculopathy (1 at L5 and one at S1). There were 3 patients with a dural tear primarily repaired during the index surgery. One patient had transient meralgia paresthetica and another had a proximal deep vein thrombosis.

Conclusion
The overall complication rate was 20%, with only 10% of patients requiring reoperation. Six patients (10%) were affected by onset of L5 or S1 radiculopathy after surgery, including 2 (3.3%) that were persistent.

Take Home Message
Surgical treatment of high-grade spondylolisthesis can lead to major complications. However, the risk of complications and reoperations remains low when performed in pediatric centers specialized in spine surgery.

127. What is the Optimal Surgical Method for Achieving Successful Symptom Relief in Paediatric High Grade Spondylolisthesis?

Brett Rocos, MD; Reinhard D. Zeller, MD, FRCS(C); Stephen J. Lewis, MD, FRCS(C); Yongyao Tan, MS; David E. Lebel, MD, PhD

Summary
: In this study we compare partial reduction and fusion (PRF) with reduction and interbody fusion (RIF) for high grade spondylolisthesis in children and show that PRF is associated a lower incidence of neurological deficit, post-operative complications and revision surgery.

Hypothesis
PRF shows equivalent rates of neurological and postoperative complications to RIF in children being treated for high grade spondylolisthesis.

Design
Retrospective case series

Introduction
Options for the surgical management of paediatric high grade spondylolisthesis include partial reduction and fusion (PRF) or reduction and interbody fusion (RIF). It is not clear which strategy leads to the optimal radiological outcome or lowest rates of complication and revision surgery.

Methods
We conducted a retrospective consecutive case-series investigation of high grade spondylolisthesis treated surgically between 2006 and 2017. Children with an L5-S1 slip ≥ 50% treated with either PRF or RIF were included. Post-operative complications and symptoms, revision surgery and change in radiological parameters to a minimum of 2 years were assessed.

Results
31 eligible patients were identified with a mean follow up of 41 months. The two groups showed no difference in age (mean 13.6 years), Meyerding grade, Labelle classification, L5/S1 angle (p=0.29) slip angle (p=0.27) or pelvic tilt (p=0.07). Presenting symptoms were similar between the groups. Of 11 treated with PRF, 2 had post-operative weakness with all having resolved by 2 years. None underwent further surgery. Slip angle reduced by a mean of 9°, pelvic tilt (PT) and sacral slope (SS) were unchanged and C7 sagittal vertical line (SVL) reduced by a mean of 42mm (p=0.17). In the group treated with RIF group, 4 sustained dural tears, 1 a laminar fracture and 7 had post-operative weakness or dysaesthesia, 4 of which had resolved by 2 years. 8 patients underwent unplanned further surgery, 3 for pseudarthrosis. Slip angle reduced by a mean of 15°, PT and SS were unchanged and C7 SVL reduced by a mean of 27mm.

Conclusion
Both PRF and RIF are viable options in the management of high grade spondylolisthesis with each being associated with an

appreciable risk of early and late complications. To 2 years, RIF is associated with a higher rate of surgical and neurological complications and unplanned return to surgery.

Take Home Message
Treating paediatric high grade spondylolisthesis carries a risk of complications regardless of treatment strategy. At 2 years, RIF shows a higher rate of unplanned return to surgery and neurological changes.

128. Types, Timing, Impact, and Predictors of Reoperations following Surgery for Lumbar Spondylolisthesis

Andrew K. Chan, MD; Erica F. Bisson, MD; Mohamad Bydon, MD; Kevin T. Foley, MD; Steven D. Glassman, MD; Christopher I. Shaffrey, MD; Michael Y. Wang, MD; Paul Park, MD; Eric Potts, MD; Mark E. Shaffrey, MD; Domagoj Coric, MD; John J. Knightly, MD; Kai-Ming Gregory Fu, MD; Jonathan R. Slotkin, MD; Anthony L. Asher, MD; Michael S. Virk, MD, PhD; Panagiotis Kerezoudis, MD, MS; Mohammed A. Alvi, MBBS; Jian Guan, MD; Regis W. Haid Jr., MD; Praveen V. Mummaneni, MD

Summary
It is unclear whether decompression alone versus decompression and fusion differentially impact reoperation rates following degenerative lumbar spondylolisthesis (DLS) surgery. In a prospective registry, 608 patients underwent single-segment surgery for grade 1 DLS. Fusions had a higher reoperation rate 30 days postoperatively, whereas decompression surgery was associated with a higher rate between 30 days and 1 year. When reoperations occurred, they had a negative impact on long-term outcomes. Shorter lengths of surgery were associated with an increased odds of reoperation.

Hypothesis
Decompression and fusion versus decompression alone surgeries may differentially impact the types and timing of reoperations following spondylolisthesis surgery.

Design
Retrospective study of a multicenter prospective registry

Introduction
It is unclear whether surgical approach (decompression alone versus decompression with fusion) impacts reoperation rates following surgery for degenerative lumbar spondylolisthesis (DLS).

Methods
Data from the prospective Quality Outcomes Database spondylolisthesis module was queried and we found 608 patients undergoing elective single-segment surgery for grade 1 DLS. The primary outcome was reoperation deemed related to the index surgery, assessed at 30-day, 1-year, 2-year, and 3-year time points.

Results
468 (77.0%) patients underwent fusion [140 (23.0%) underwent decompression alone]. The overall reoperation rate was 6.9% (42 patients with 44 reoperations). There were a similar proportion of reoperations for decompression and fusion cohorts (9.3% vs. 6.2%, p=0.21). The timing and types of reoperation by cohort are presented in Table 1 and 2. There were significantly more reoperations within 30 days for the fusion cohort (p=0.02), whereas there were significantly more reoperations from 30 days to 1 year for the decompression cohort (p=0.01). There were no significant differences at other time points (p>0.05). Reoperations were independently associated with inferior change in ODI (β = 10.1, 95%CI(4.5-15.7), p<0.001), NRS Back Pain (β = 1.1, 95%CI(0.1-2.1), p=0.03), NRS Leg Pain (β = 1.6, 95%CI(0.6-2.5), p<0.001), EQ-5D (β = -0.07, 95%CI(-0.14- -0.003), p=0.04), and NASS Satisfaction (OR = 3.1, 95%CI(1.7-5.5), p<0.001) at 24-month follow up. In multivariable analysis, shorter length of surgery was the only factor predictive of reoperation (OR = 1.01 per min shorter, 95%CI(1.003-1.013), p=0.004).

Conclusion
Fusions have a higher rate of reoperation 30 days following surgery, whereas decompression surgery was associated with a higher rate between 30 days and 1 year. When reoperations occur, they have a negative impact on long-term outcomes. Shorter lengths of surgery were associated with an increased odds of reoperation.

Take Home Message
Fusion and decompression surgeries have different reoperation profiles. When reoperations occur, they have a negative impact on long-term outcomes. Shorter operative time was associated with an increased odds of reoperation.

Table 1. Timing of Reoperations	Decompression	Fusion	p-value
< 30 days	0 (0%)	11 (35.5%)	0.02
30 days to 1 year	8 (61.5%)	6 (19.4%)	0.01
1 to 2 years	3 (23.1%)	10 (32.3%)	0.72
2 to 3 years	2 (15.4%)	4 (12.9%)	>0.99
Total	13 (100%)	31 (29 patients) (100%)	

Table 2. Types of Reoperations	Decompression	Fusion
Decompression	7 (53.8%) (6 same level, 1 adjacent level)	1 (3.2%) (for adjacent segment disease)
Fusion	6 (46.2%) (1 same level, 5 adjacent levels)	13 (41.9%) (8 for adjacent segment disease, 5 for pseudarthrosis)
Miscellaneous	0 (0%)	17 (54.8%) (8 surgical site infection, 6 implant revision/removal, 1 hematoma evac, 1 wound revision for suture granuloma, 1 spinal cord stimulator)

129. Congenital Scoliosis Patients Can Attain Similar Curve Correction and Perioperative Outcomes to AIS Patients without the Need for Hemivertebra Excision

Vishal Sarwahi, MD, MBBS; Jesse Galina, BS; Jordan Fakhoury, DO; Thomas J. Dowling III, MD; Sayyida Hasan, BS; Yungtai Lo, PhD; Terry D. Amaral, MD

Summary
Patients with congenital scoliosis, in most cases, can avoid hemivertebra excision, while obtaining similar curve correction and perioperative outcomes to AIS patients.

Hypothesis
Correction of congenital scoliosis can be achieved through the

use of pedicle screws and a posterior-only approach without the need for hemivertebra excision in most cases

Design
Retrospective case-controlled matched

Introduction
Hemivertebra excision in patients with congenital scoliosis is believed to give the best possible correction. It is however a technically challenging procedure and complications can include spinal cord injury, nerve root injury and CSF leak. We have utilized a hemivertebra-sparing approach in these pts alongside multi-level Ponte osteotomies and all pedicle screw constructs.

Methods
24 pts with congenital scoliosis and associated hemivertebra were included. These 24 pts were compared with the most recent 54 AIS correction surgeries with 2-year follow up. An additional rigorous analysis was done to match hemivertebra patients from a database of 330 AIS patients. Pts were matched based on gender, age, BMI, and preop Cobb. Overall, 12 pairs (24 patients) were matched and analyzed.

Results
When comparing hemivertebra to AIS patients, age (p=0.81), BMI (p=0.24) and preop Cobb (p=0.06) were similar. Postop Cobb (p=0.048) was significantly larger for AIS patients, however, overall Cobb correction was similar (p=0.29). Blood loss was similar (p=0.09) while surgical time (p<0.001) and length of stay (p<0.001) were significantly longer for hemivertebra patients. After matching patients, postop Cobb (p=1.0) and overall correction (p=0.97) were similar. Patients had a similar number of levels fused (p=0.23) and fixation points (p=0.23). Surgical time (p=0.41) and blood loss (p=0.95) were similar. The only significant difference was that hemivertebra patients had longer hospital stay (p=0.001).

Conclusion
Pts with hemivertebra can benefit from hemivertebra sparing approach. The XR and periop outcomes were similar to AIS pts. This approach is safer compared to hemivertebra excision with similar or better curve correction than previously reported. Choosing fusion levels on similar principles akin to AIS leads to avoidance of hemivertebra excision in most cases including lumbosacral hemivertebra cases.

Take Home Message
Surgeons treating congenital scoliosis can avoid hemivertebra excision when using all pedicle screw constructs and judicious use of Ponte type osteotomies.

130. Failure of Initial Curve Correction Increases the Risk of Postoperative Curve Progression in Patients with Congenital Scoliosis: Mean 16-year Follow-up

Noriaki Kawakami, MD, PhD; Hiroko Matsumoto, PhD; Toshiki Saito, MD, PhD; Ryoji Tauchi, MD, PhD; Tetsuya Ohara, MD

Summary
Risk factors associated with curve progression requiring unplanned return to the operating room (UPROR) remain unclear. Our study found that 19.8% of patients with congenital scoliosis who underwent fusion required UPROR due to postoperative curve progression within in the average 16-year follow-up. Patients whose curve remained >20° after the initial fusion had 3.2 times increased risk of the UPROR compared to those who were corrected to □20°.

Hypothesis
Failure to achieve a certain magnitude of curve correction at initial fusion contributes to long-term postoperative curve progression requiring UPROR in pediatric patients with congenital scoliosis.

Design
Retrospective cohort study

Introduction
Some pediatric patients who underwent fusion for their congenital scoliosis require UPROR for revision surgery to correct postoperative curve progression; however, factors associated with the risk remain unclear.

Methods
Patients with congenital scoliosis who underwent spinal fusion at <18 years old with at least 10-year follow-up were identified. The outcome was UPROR due to the postoperative progression of spinal curvature (>35°). Patients whose curve were corrected down to□20° at the initial surgery were compared to those with >20° curve remaining after the surgery.

Results
86 consecutive patients (10.4±3.7 years at surgery) met inclusion criteria. There were 41 patients (47.7%) and 45 patients (52.3%) in the corrected and the uncorrected groups respectively. Age, gender, height, weight and sagittal curve did not differ preoperatively between these two cohorts; however, preoperative major coronal curve was significantly smaller in the corrected group (38.6° vs 67.3°, p<0.001). There was a total of 17 UPROR (19.8%) due to postoperative curve progression at 16.4±4.9-year follow-up evaluation when patients were 27.4 ±6.3 years old. 4 patients (9.8%) in the corrected group and 13 (28.9%) in the uncorrected group required the UPROR (p=0.032). Multiple regression adjusting for preoperative major coronal curve demonstrated that the uncorrected group had 3.2 times increased risk of the UPROR compared to the corrected group (95CI%: 0.74; 12.5, p=0.119).

Conclusion
Long-term postoperative curve progression requiring UPROR is not uncommon after initial surgery in patients with congenital scoliosis. Not achieving □20° correction at fusion increases the risk of the long-term UPROR due to curve progression in patients with congenital scoliosis.

Take Home Message
Achieving curve correction down to □20° at initial fusion is important to avoid long-term UPROR due to curve progression in patients with congenital scoliosis.

Podium Presentation—Spondylolisthesis/Congenital/Miscellaneous

131. Reconstruction after Total En Bloc Spondylectomy: Does Bony Fusion Mean Long-term Stability?

Yat Wa Wong, MD, MBBS; Kenny Kwan, MD

Summary
This review studies the long-term stability after total en bloc spondylectomy (TES) and factors associated with instrumentation failure. It may occur many years without any tell-tale radiological feature.

Hypothesis
Bony union is not strong enough to support the torso after TES despite radiological feature of bony union. Long-term stability relies on the implants.

Design
Retrospective case series

Introduction
TES of spinal tumours results in huge vertebral defect. The object of this study was to investigate late instrumentation failure and its related factors.

Methods
20 patients (mean age: 31; range: 12-70) with either primary spinal tumours or solitary metastasis underwent TES with anterior and posterior reconstruction. Bone grafting was performed with autologous bone graft (n=12) or allograft (N=8). Minimal follow-up was 36 months (mean: 96 months; range: 36-204 months). Fusion was defined as visible bony bridges with trabeculae across the vertebral defect in either the anterior or posterior column as seen on x-ray or CT scan. There were 11 giant cell tumours, 3 haemangiopericytomas, 3 primary sarcomas, 2 solitary metastases and 1 chordoma. Spondylectomies involved 1 (15 cases), 2 (2 cases), 3 (1 case), 4 (1 case) and 5 (1 case) vertebrae from T1 to L5.

Results
5 patients (25%) suffered from instrumentation failure requiring revision on an average of 7 years (range: 3-15 years) after spondylectomy. All failure had dual rods construct. All patients presented with sudden back pain and rod breakage. 2 patients had associated cage breakage. None of the patients suffered from screw breakage, loosening or pull-out. Three patients received allograft and the rods broke between 3 and 7 years. The remaining 2 patients received iliac crest autologous bone graft and the rods broke 7 and 15 years after the TES. None of the patients experienced tumour recurrence or neurological deterioration upon instrumentation failure. 4 patients were found to have vascularized posterior fusion mass during the revision surgery signifying viable.

Conclusion
Instrumentation failure may occur despite apparent bony union. Autologous cancellous bone and 4 rods construct may reduce instrumentation failure.

Take Home Message
Instrumentation failure is always possible after TES

132. Does Thoracic Paravertebral Block Improve Postoperative Pain Scores in Scoliosis Patients Undergoing Anterior Vertebral Body Tethering?

Smitha Mathew, MBBS, MS; Todd A. Milbrandt, MD, MS; D. Dean Potter, MD; Dawit T Haile, MD; A. Noelle Larson, MD

Summary
Lower VAS pain scores and decreased length of stay were noted in scoliosis patients who received thoracic paravertebral block (PVB) and intrathecal hydromorphone injection (IT) following anterior vertebral body tethering compared to those who received IT alone.

Hypothesis
Thoracic paravertebral block (PVB) in combination with intrathecal hydromorphone injection would improve postoperative VAS scores and reduce length of stay in scoliosis patients undergoing anterior vertebral body tethering (AVBT).

Design
Retrospective review.

Introduction
AVBT procedures are increasingly being performed in the US, yet postoperative pain management has not yet been optimized. The goals of any postoperative pain management program are to provide analgesia, achieve early mobilization and reduce length of hospital stay. The addition of a thoracic PVB could provide greater pain relief, reduce length of hospital stay and improve patient satisfaction.

Methods
Patients who underwent AVBT at a single tertiary referral center were retrospectively reviewed. Patients either received a single shot intrathecal hydromorphone (IT) injection or a combination of intrathecal hydromorphone and thoracic paravertebral catheter with lidocaine infusion (PVB) which was left in place for 4-6 days. IT hydromorphone is routinely used for all scoliosis surgical patients at our center. The maximum postoperative VAS pain score and length of hospital stay were recorded.

Results
55 patients met inclusion criteria; including 9 males (16%) and 46 females (84%). 22 (40%) patients had been administrated intrathecal hydromorphone alone (IT) while 33 (60%) patients received a combination of intrathecal hydromorphone and thoracic PVB. Maximum postoperative VAS pain scores of >5 were reported in 14 out of the 22 patients (64%) that were administered IT alone and in 11 out of the 33 patients (33%) that received a combination of IT and thoracic PVB ($p = 0.03$). Mean length of hospital stay in the intrathecal group was 3.8 days while in the combination group it was 2.9 days ($p < 0.001$) (Table 2). There were no complications associated with use of the PVB.

Conclusion
In this series, postoperative VAS pain scores and length of hos-

pital stay were decreased in the group that received a thoracic PVB. Therefore, thoracic PVB provided good postoperative analgesia and reduced length of stay.

Take Home Message
Use of a paravertebral block resulted in decreased length of stay, improved pain scores, and decreased chest tube pain in patients undergoing AVBT.

Table: Patients thoracic paravertebral block had decreased length of stay and improve pain scores

	Patients with intrathecal hydromorphone alone (n = 22)	Patients with intrathecal hydromorphone and thoracic paravertebral block (n = 33)	
Age	13.3	13.0	
Mean length of stay (days)	3.8	2.9	P<0.001
Pain score >5	14 (64%)	11 (33%)	P = 0.03

Thoracic PVB decreased length of stay and improved pain scores

133. Radiation Exposure with Use of Intraoperative CT Guidance in Spinal Deformity Surgery

Bhumit R. Desai, MD; *Gonzalo Sumarriva, MD*; Alaa Mohammed, MPH; Paul C. Celestre, MD

Summary
Third generation CT-based intraoperative spinal navigation involves the potential for increased radiation exposure to the patient relative to free-hand techniques. A retrospective analysis of 80 patients showed increased effective radiation dose incurred and revealed specific associations with surgical factors. This is the first study to quantify the radiation exposure from third-generation navigation for pedicle screw placement with quantitative comparisons to fluoroscopic methods.

Hypothesis
Patients undergoing spinal procedures with third-generation intraoperative CT-guided imaging will have more radiation incurred per procedure than patients undergoing imaging with traditional fluoroscopy.

Design
The study objective was to evaluate current practice by quantifying radiation exposure in patients undergoing correction of spinal deformity using third-generation intraoperative CT-based navigation. Effective radiation dose was calculated using specific conversion factors based on patient procedure dose reports to quantify total effective radiation dose.

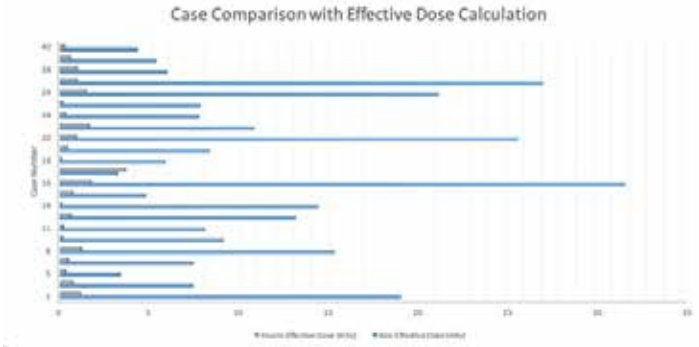
Introduction
3D-based navigation allows improved visualization of patient anatomy and more accurate placement of instrumentation with the potential for increased radiation exposure relative to free-hand techniques. Current guidelines recommend no more than 20 mSv per year averaged over 5 years or no more than 50 mSv in a single year.

Methods
Forty patients undergoing spinal deformity surgery with third-generation iCT were retrospectively evaluated and matched with forty patients undergoing procedures with traditional fluoroscopy. Dose reports were used to calculate effective radiation dose. The total DAP for fluoro and the total DLP for iCT were used to compute effective dose.

Results
46 viable cases yielded an average radiation dose of 0.60 ± 0.73 mSv per patient in the fluoro cohort and 10.27 ± 7.75 in the iCT cohort. Wilcoxon two-sample t-test yielded a Z-score of -6.8 and a p-value of <0.001 given a 95% confidence interval.

Conclusion
The highest quartile of radiation exposure within the iCT cohort was associated with an increased number of intraoperative navigation spins, longer procedure time, and an increased number of vertebral levels requiring pedicle screw placement. Patients in the lowest quartile had lower associated procedure times, one navigation spin, and on average only four vertebral levels of pedicle screw placement.

Take Home Message
The balance between technical accuracy and its clinical implications when using third-generation navigation systems are important for patient radiation safety and should be considered when managing patients with spinal deformity.



Per case comparison of effective dose calculation between the Airo cohort and fluoroscopy only cohort.

134. An Audit of the Radiation Exposures in Children and Adults during the Treatment of Spinal Deformities

Jwalant S. Mehta, FRCS (Orth), MCh (Orth), MS (Orth), D Orth; Ravindra Thimmaiah, FRCS Tr & Orth; James Kho, MD; Upasana Topiwala, BS; Vijay Sawlani, MD; Rajesh Botchu, MD

Summary
The treating clinicians should be cognizant of the levels of radiation doses that the patients are exposed to. The doses are higher when surgery is undertaken. Clinicians should take due steps to minimize the radiation exposure and look at safer alternatives in the outpatients, intra-operative and post-operative settings. Radiation exposures in newer technologies should be at the forefront of discussions, in the interest of patients' long-term safety.

Hypothesis
To define the dose of radiation that a child or an adult are exposed to during the treatment of spinal deformity.

Podium Presentation—Spondylolisthesis/Congenital/Miscellaneous

Design
Retrospective review of prospectively collected radiation dose data.

Introduction
The perceived risks of radiation poses a challenge to the treating clinicians. There are no studies or guidelines that document the radiation doses during routine monitoring and when undertaking surgical corrections, of children and adults. Our objective is to document the radiation exposure doses in various clinical settings for spinal deformity patients.

Methods
The radiation dose database identified 25,745 exposures on children and adults treated in the spinal unit between Jan 1, 2008 and 31 Dec 2016. We excluded all the non-deformity patients and patients undergoing any procedure that would not involve intra-operative exposure to ionising radiation. All the doses for plain radiographs, CT scans and intra-operative fluoroscopy were unified to a single unit by the medical physicists (cGycm2).

Results
The non-operative group comprised of 5043 patients with a mean age of 26.97 (males 1768) with a mean total exposure for each patient 600.42. The surgical group comprised 974 (267 males) with a mean age of 16.88, and a mean radiation dose of 1302.29. We assessed the under 18 age group separately. There were 2976 patients treated non-operatively with an average age of 12.15 and a total dose of 358.69, with the surgical group having 789 patients with a mean age of 12.35 and dose exposure of 1096.59. There was a very significant ($p<0.001$) difference between the radiation exposures between the surgical and the non-operative groups in adults and children. There were mean 7.9 x-rays and 0.45 CT scans performed per patient in the surgical group and mean 2.8 x-rays and 0.16 CT scans in the non-operative group ($p<0.0001$).

Conclusion
Spinal deformity treatments are radiation heavy. The dose exposure is 2 to 3 times higher when surgical treatment is undertaken. There are more x-rays and CT based exposures for the surgical groups. This highlights the need for careful appraisal of radiation exposure in patients with spinal deformities.

Take Home Message
It is imperative for clinicians treating spinal deformities of consider the long-term radiation exposure, and look at ways to minimise this and appraise newer technology in this light.

Parameter	Number	Age Mean ± sem	Dose Mean ± sem	P values
Non-operative: all	5043	26.97 ±0.32	600.42 ± 81.43	< 0.0001
Operative: all	973	16.88 ± 0.42	1302.29 ± 46.37	
Non-operative: < 18 yr	2976	12.15 ± 0.08	358.69 ± 29.74	< 0.0001
Operative: < 18 yr	789	12.35 ± 0.14	1096.59 ± 36.95	
Number of Xrays / patient				
Non-operative group	2.83 ± 0.03			< 0.0001
Operative group	7.89 ± 0. 14			
Number of CT's / patient				< 0.0001
Non-operative group	0.16 ± 0.01			
Operative group	0.45 ± 0.02			

Summary of results

Podium Presentations—Adult Spinal Deformity II

135. A Propensity-score Matched Comparison of National vs. Single-institution Databases: Analysis of Unplanned Readmissions in Patients Undergoing Posterior Lumbar Fusion

Amir Taree, BS; Varun Arvind, BS; *Eric Geng, BS*; Kush Mody, BS; Christopher Mikhail, MD; Samuel K. Cho, MD

Summary
This study is a propensity-score matched comparison of risk factors associated with unplanned readmission in patients undergoing posterior lumbar surgery from a national database compared to patients from a single-institution. This study demonstrates that risk factors in unplanned readmission differ between NSQIP and a single institutional data. While NSQIP is valuable for assessing national trends, it is also important for surgeons to consider their own institutional data in assessing patient risk.

Hypothesis
We hypothesize that risk factors for unplanned readmission identified from national and single institutional data in patients undergoing posterior lumbar fusion will differ.

Design
A propensity-score matched retrospective analysis of patients from a single institutional and national database.

Introduction
Studies using national databases, such as the ACS-National Surgical Quality Improvement Program (ACS-NSQIP) have identified risk factors associated with spinal surgery. While many surgeons rely on these data for clinical decision making, the concordance of these findings has not been compared to risk factors identified from single-institutions. Therefore, the purpose of this study was to compare risk factors associated with unplanned readmission identified from the NSQIP and single institutional data.

Methods
A propensity-score analysis was conducted to match 9,613 patients from the NSQIP database undergoing posterior lumbar fusion to 162 patients from a single institution. Risk factors analyzed include age, ASA score, BMI, sex, length of stay (LOS), diabetes, congestive heart failure, pulmonary hypertension, and renal disease. Significant odds ratios for comorbidities associated with unplanned readmission were calculated and compared between the two databases.

Results
Data analysis from the single institution show that LOS (P=<0.0001), diabetes (P=0.036), and renal disease (P=0.0087) were significantly associated with unplanned readmission following posterior lumbar fusion. By contrast, analysis of the NSQIP database showed that only LOS (P=0.047) was significantly associated with unplanned readmission. Odds ratio for LOS differed significantly ($p < 0.05$) between the single institution (OR: 13.4) and NSQIP (OR: 3.1).

Conclusion
National databases have proven powerful in quality improvement endeavors. However, while these databases, such as NSQIP, allow for analysis of nationwide trends they may not concordant with data from a single institution. Therefore, it may be prudent for surgeon groups to focus on institutional data in implementing the most effective quality improvement initiatives.

Take Home Message
While studies on national databases have demonstrated value in capturing national trends, this study shows that they may not accurately reflect risk factors of patients from a single institution.

136. Patient-Reported Outcomes After Complex Adult Spinal Deformity Surgery: 5-year Follow-Up Results of the Scoli-RISK-1 Study

Scott Zuckerman, MD; Meghan Cerpa, MPH; Lawrence G. Lenke, MD; Zeeshan M. Sardar, MD; Meghana Vulapalli ; Eric Leung, BS; Michael P. Kelly, MD; Christopher I. Shaffrey, MD; Yong Qiu, MD; Frank J. Schwab, MD; Leah Y. Carreon, MD; Kenneth Cheung, MD, MBBS, FRCS; Oheneba Boachie-Adjei, MD; Ames P. Christopher, MD; Ferran Pellisé, MD, PhD; Justin S. Smith, MD, PhD; Yukihiro Matsuyama, MD, PhD; Khaled M. Kebaish, MD

Summary
Comparing baseline to 5-year data following complex adult spinal deformity (ASD) surgery, significant improvement was seen in ODI, SF-36 PCS/MCS, SRS-22, and NRS-back pain. In long-term follow-up, durable and sustained improvement was seen at 5-years in nearly all PROs however, at 5-years NRS leg pain scores were similar to baseline.

Hypothesis
To prospectively evaluate patient-reported outcomes (PROs) up to 5-years after complex ASD surgery

Design
Prospective, multicenter, international, observational Scoli-RISK-1study

Introduction
Long-term patient-reported outcomes (PROs) after complex adult spinal deformity (ASD) are important yet sparsely reported

Methods
The Scoli-RISK-1 study enrolled 272 ASD patients undergoing surgery from 15 centers. Inclusion criteria was Cobb angle of >80, corrective osteotomy for congenital or revision deformity, and/or 3-column osteotomy. The following PROs were measured prospectively at intervals up to 5-years: ODI, SF-36 PCS/MCS, SRS-22, NRS back/leg. Comparisons were made from baseline to, 2-years, and 5-years postoperative. Mixed effects models were used for analysis in order to account for those lost to follow-up

Results
Of the 272 patients enrolled, 217 (79.8%) and 77 (28.3%) were seen at 2 yr and 5 yr. postoperative respectively. 7 Comparing 5-year to baseline data, significant improvement was seen in ODI (31.8 vs. 45.7, p<0.001), SF-36 PCS (38.3 vs. 31.8, p<0.001), SF-36 MCS (46.6 vs. 42.6, p=0.003), SRS-22 (3.46 vs. 2.71, p<0.001), NRS back pain (3.22 vs. 5.99, p<0.001). Even though we could see significant improvement in NRS leg pain at 6-weeks,

6-months, and 2-years postoperative (2.46, 2.54, 2.78; p<0.001) at 5-years NRS leg pain was similar to baseline (3.53 vs. 3.79, p=0.844).

Conclusion
In long-term follow-up of complex ASD surgical patients, durable and sustained improvement was seen at 5-years postoperative in nearly all PROs, including ODI, SF-36 PCS/MCS, SRS-22, and NRS-back pain; however, at 5-years postoperative NRS leg pain scores were similar to baseline

Take Home Message
5-years postoperative in complex ASD patients, significant improvement was seen ODI, SF-36PCS/MCS, SRS-22, and NRS-back-pain compared to baseline. Sustained improvement was seen in nearly all PROs except NRS-leg-pain at 5-years.

137. Do Readmissions and Reoperations Adversely Affect Patient-Reported Outcomes Associated with Complex Adult Spinal Deformity Surgery at a Minimum 2 Year Postoperative?

Nathan J. Lee, MD; Jun Kim, MD; Andrew C. Vivas, MD; Joseph M. Lombardi, MD; Jay S. Reidler, MD; Scott Zuckerman, MD; Daniel Hong, MD; Paul J. Park, MD; Meghan Cerpa, MPH; Eric Leung, BS; Zeeshan M. Sardar, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Summary
Complications after "complex" Adult Spinal Deformity (ASD) surgery can be significant and associated with a high rate of readmissions/reoperations. The 2-year readmission (16.6%) and reoperation (12.0%) rates were related to potentially optimizable factors. However, readmitted and revised patients had significant improvements in their HRQoL scores at 2 years compared to preoperative baseline and 1-year values.

Hypothesis
Complications are significant, but potentially modifiable

Design
Retrospective cohort study

Introduction
Unplanned readmissions and reoperations are known to be associated with undesirable costs and outcomes in ASD surgery. Few prior studies have examined predictors for readmissions and reoperations at 2 year follow up and the impact on patient-reported outcomes (PROs) in this population.

Methods
Consecutively collected adult (>=18years) patients who underwent complex spinal deformity surgery at a single institution from 2015 to 2018 and with minimum 2 year follow up. Missing data was removed. Univariate/multivariate analyses performed on perioperative factors.

Results
A total of 175 patients (72% female, mean age 52.6+-16.4) with a minimum follow up of 2 years underwent complex ASD surgery. The mean total instrumented/fused levels was 13.3 (4.1), range 6 to 25. The readmission and reoperation rates were 16.6% and 12% respectively. The top reasons for reoperation were pseudoarthrosis (5.1%), proximal junctional kyphosis (5.1 %), and implant failure (3.4%). At 2 years, 86.4% and 68.2% of patients reached MCID for SRS and ODI, respectively. Patients who did not require a readmission had significantly higher PROs compared to preoperative values (SRS 87.1 vs. 65.2) and those who required a readmission (SRS 87.1 vs. 78.8) at 1 year follow up. Those who required a readmission had significant increases in SRS and reductions in ODI at 2 years (SRS 90.6, ODI 17.7) compared to 1 year (SRS 78.8, ODI 26) and preoperative baseline values (SRS 60.4, ODI 44.9). Significant risk factors for readmissions within 2 years included pulmonary comorbidity, depression, gastroenterology comorbidity, VCR, and TLIF.

Conclusion
The 2-year readmission and reoperation rates following complex ASD surgery was 16.6% and 12% respectively with readmissions most often related to pseudoarthrosis, PJK, and implant failure requiring reoperations. However, readmitted and revised patients significantly improved their HRQoL scores at 2 years compared to preoperative baseline and 1-year values.

Take Home Message
ASD surgery carries risk, but this may be reduced with pre-optimization stratification. Readmitted/re-operated patients can significantly improve their HRQoL by 2-year follow up.

Top Complications Requiring Readmission (patients had ≥1 complication)	N	%	Median Days after DC (Range)	
2-Year Readmission *Includes Reoperations	29	16.6%	173 (6 to 716)	
2-Year Reoperation	21	12.0%	227 (16 to 716)	
Pseudoarthrosis	9	5.1%	572 (56 to 659)	
Proximal Junctional Kyphosis	9	5.1%	366 (56 to 608)	
Implant Failure	6	3.4%	490 (109 to 659)	
Other Pain requiring admission	5	2.9%	173 (6 to 602)	
Wound Complication	4	2.3%	24.5 (16 to 50)	
Mean SRS Scores	**Baseline**	**1 Year**	**2 Year**	
All	65.8 (15.5)	87.3 (14.7)	87.9 (14.9)	
No Read/Reop	65.2 (16.3)	87.1 (13.2)	87.4 (15.9)	
Readmitted	60.4 (10.8)	78.8 (19)	90.6 (7.4)	P<0.001
Revised	56.6 (9.7)	71 (18.8)	90.8 (7.8)	P<0.001
Mean ODI Scores	**Baseline**	**1 Year**	**2 Year**	
All	32.6 (20.5)	18.5 (17.1)	18.2 (15.8)	
No Read/Reop	33.4 (19.8)	18. 7 (15.1)	18.2 (16.5)	
Readmitted	44.9 (14.6)	26 (21.6)	17.7 (13.5)	P<0.001
Revised	45.6 (15.9)	23.8 (22.6)	15.7 (13.5)	P=0.002
Top 2yr Readmission Risk Factors (C-stat = 0.868, HL=0.1)	**Odds Ratio**	**95% Confidence Interval**		**P-value**
GI Comorbidity	11.9	3.0	47.2	**<0.001**
TLIF	12.2	2.4	63.3	**0.003**
Pulmonary Comorbidity	5.6	1.8	17.8	**0.004**
VCR	8.0	1.6	40.2	**0.012**
Depression	4.0	1.3	12.7	**0.018**
Cardiac Comorbidity	2.8	1.0	7.8	0.053
OSH Revision Surgery	2.7	0.9	7.9	0.071
Hypothyroidism	0.4	0.1	1.7	0.198

Podium Presentations—Adult Spinal Deformity II

138. Complication Profile Associated with S1 Pedicle Subtraction Osteotomy Compared to Three Column Osteotomies at Other Thoracolumbar Spinal Levels: Series of 405 Patients with 9 Sacral Osteotomies

Darryl Lau, MD; Alexander Haddad, BS; Rushikesh S. Joshi, BS; Vedat Deviren, MD; Christopher P. Ames, MD

Summary
Based on a study of 405 ASD patients who underwent three-column osteotomy, S1 PSO was effective in achieving correction of rigid sagittal imbalance secondary to artificially high PI: SVA (14.8 vs. 6.7 cm, p=0.004) and PI-LL mismatch (31.7 vs. 9.6 degrees, p=0.025). However, S1 PSO was independently associated with higher odds of overall (66.6%) (OR 7.93, p=0.013), surgical (44.4%) (OR 20.66 p=0.010), and neurologic (44.4%) (OR 14.75, p=0.007) complications.

Hypothesis
S1 PSO is effective for correction of rigid sagittal imbalance secondary to artificially high PI but associated with high morbidity.

Design
Single surgeon, retrospective comparative study.

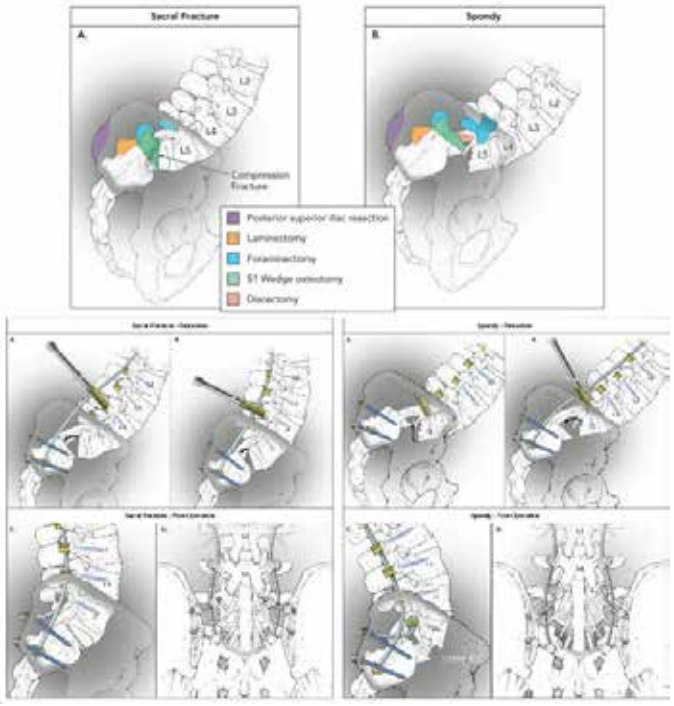
Introduction
S1 PSO is indicated for correction of rigid sagittal imbalance secondary to artificially elevated PI, but its morbidity is not well described. In this study we evaluate the complication risks associated with S1 PSO.

Methods
A retrospective review of ASD patients who underwent three-column osteotomy (3CO) for thoracolumbar deformity from 2006 to 2019 was performed. Multivariate analysis was used to compared the risk of S1 PSO to 3CO at other levels (lower T-L5).

Results
405 patients underwent 3CO: T (55), L1 (25), L2 (29), L3 (141), L4 (129), L5 (17), and S1 (9). Mean age was 64.5 years and 40.5% were male. S1 PSO resulted in significant improvement in SVA (14.8 vs. 6.7 cm, p=0.004) and PI-LL mismatch (31.7 vs. 9.6 degrees, p=0.025) secondary to decrease PI (80.3 vs. 65.9 degrees, p=0.006). LL remained unchanged (48.7 vs 57.8 degrees, p=0.360). Overall complication rate was 27.4%: surgical (7.7%), neurologic (6.2%), and medical (20.0%). S1 PSO was associated with significantly higher rates of overall complication: T-L5 (11.8% to 32.6%) vs. S1 (66.7%) (p=0.018), specifically higher rates of surgical (T-L5 (4.0% to 10.9%) vs. S1 (44.4%), p=0.006) and neurologic (T-L5 (2.8% to 9.1%) and S1 (44.4%), p<0.001) complications. S1 PSO was independently associated with higher odds of overall (OR 7.93, p=0.013), surgical (OR 20.66 p=0.010), and neurologic (OR 14.75, p=0.007) complications. Mean case length was 307.5 minutes. Blood loss was 2006.0 ml. ICU and hospital stay were 2.4 days and 8.7 days. There were no differences among these secondary outcomes by osteotomy levels.

Conclusion
S1 PSO is a powerful technique for correction of rigid sagittal imbalance secondary to artificially elevated PI in ASD patients with rigid high-grade spondylolisthesis and chronic sacral fractures. However, S1 PSO can be challenging and associated with high rates of surgical and neurologic complications.

Take Home Message
S1 PSO is a powerful and effective technique for the correction of rigid sagittal imbalance secondary to artificially elevated PI but is associated with high surgical and neurologic related complications.



139. Management of Severe Adult Spinal Deformity (ASD) with Circumferential Minimally Invasive Surgical (CMIS) Strategies: A 13 Year Study

Neel Anand, MD; Edward K. Nomoto, MD; Christopher Kong, MD; Alisa Alayan, MD; Babak Khandehroo, MD; Sheila Kahwaty, PA-C

Summary
Appropriately applied CMIS approaches are very promising for treatment of severe ASD (Cobb>50 or SVA>95mm or PI-LL>20, PT>30) to improve the clinical and functional outcomes and to lessen the complications.

Hypothesis
CMIS approach for correction of severe ASD improves clinical and functional outcomes.

Design
A retrospective study

Introduction
Severe ASD historically have been treated with open surgical procedures including facet resections or posterior column osteotomies, which is associated with high comorbidities and complications. MIS approaches have been gaining popularity for

correction of ASD. However, safety, effectiveness and the long-term outcomes of these approaches for treatment of severe ASD are still surgeons' concern.

Methods

This is a retrospective review of 344 consecutive ASD patients who underwent CMIS correction from Jan.2007-Jan.2018. Considering marked SRS-Schwab sagittal modifiers (Cobb>50, SVA>95mm, PI-LL>20, PT>30),+3 levels and +2 year FU included 125patients. In all patients, multilevel LLIF±L5-S1 ALIF was done in the first stage. The patients were ambulated after a standing Xray obtained 2days later and further correction of alignment was planned for the 2nd stage accordingly. 3days later MIS pedicle screws with aggressive rod contouring and derotation/translation was done.

Results

Mean age:63yrs (21-85). Mean FU: 79.5 months (24-154). Total of 883 levels fused with a mean of 7(3-16)/patient. Mean hospital stay: 9days (3-26). Mean blood loss: Stage1: 287 ml (25-900), Stage 2: 392ml (20-1700). Mean OR time: Stage 1: 228min (83-538), stage 2: 270min (71-550). Mean baseline HRQOL scores (VAS, TIS, ODI, SF-36 and SRS-22) were significantly improved at 6wk, 1year and final FU (Table 1). The mean pre-op radiographic parameters had a significant improvement at the post-op and the last FU ($p<0.05$) (Table 2). The 30-day postop complication rate was 4% (n=5) including: 1 during surgery and 4 during post-op hospital stay who needed corrective/revised operation during initial hospitalization (Table 3). There were total of 23 complications (>30 days postop) that needed readmission and revision surgery (rate: 18.4%) (Table 4).

Conclusion

Significant improvement in clinical and functional outcomes and very low incidence of psuedoarthrosis and PJK suggest that the CMIS may be a safe and effective approach for treatment of severe ASD.

Take Home Message

CMIS correction is a safe and effective approach in treatment of severe ASD.

Table 1: Clinical and functional outcomes

	Pre-op	6 wks	1 year	Last FU	P value
VAS	6 (2-10)	3.6 (0-9)	2.4 (0-7)	2.3 (0-7)	<0.05
TIS	50.4 (0-96)	33.7 (0-92)	28.1 (0-80)	26.5 (0-65)	<0.05
ODI	43.6 (4-82)	35.6 (0-68)	25.1 (0-73)	27.1 (0-72)	<0.05
SF 36	56.3 (5-131)	49.3 (2-96)	83.8 (7-157)	94.5 (16-168)	<0.05
SRS-22	2.9 (1.2-4.5)	3.1 (1.9-5)	3.6 (1.8-4.9)	3.7 (1.6-5)	<0.05

Table 2: Radiographic Outcomes

	Pre-op	Post-op	Last Follow-up	P value
COBB Angle	38.4 (15.5-74.7) SD 14.9	16.1 (0-48.3) SD 9.6	14.7 (0-42.8) SD 9.8	P<0.05
Lumbar Lordosis	38.4 (2.4-84.2) SD 17.9	45.6 (8.9-71.6) SD 11.8	46.6 (18.3-71.8) SD 11.8	P<0.05
PI/LL Mismatch	22 (0.3-83.6) SD 15.9	13.4 (0.1-47.3) SD 10.5	11.5 (0-34.2) SD 9	P<0.05
SVA	69.7 (9.5-223) SD 48.6	41.9 (0-127) SD 33.9	38 (0-129.5) SD 30.5	P<0.05

Table 3: The 30-day Complications

Complications	Qty	When?	Intervention
Avulsed segmental artery	1	Intra-op	Repair of segmental artery
Cerebellar Hemorrhage and obstructive hydrocephalus	1	Post-op Hospital stay	Craniectomy Evacuation of Hematoma,Ventriculostomy
Ureteral Injury	2	Post-op Hospital stay	Ureteral stent placement
Misplaced screw	1	Post-op Hospital stay	Removal of hardware and reinstrumentation

Table 4: Post-op (>30days) Complications

Complication	Qty	Intervention
Adjacent segment degeneration	7	Removal of Hardware and reinstrumentation
Hardwar Failure	1	Removal of Hardware and reinstrumentation
Painful Hardware (Prominent Hardware)	1	Removal of Hardware
PJK	3	Revision surgery and extended posterior instrumentation
Pseudarthrosis	6	Hardware removal and reinstrumentation
Radiculopathy (Foraminal stenosis)	1	Decompression
Wound Dehiscence	4	I & D

140. Residual Coronal Malalignment Results in Less Improvement in Pain and Disability After ASD Surgery

Amit Jain, MD; Emmanuel McNeely, MS; Brian J. Neuman, MD; Jeffrey L. Gum, MD; Shay Bess, MD; Richard Hostin, MD; Virginie Lafage, PhD; Samrat Yeramaneni, PhD; Eric O. Klineberg, MD; Renaud Lafage, MS; Munish C. Gupta, MD; Justin S. Smith, MD, PhD; Douglas C. Burton, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Khaled M. Kebaish, MD; International Spine Study Group

Summary

In patients with primarily coronal malalignment undergoing ASD surgery, under-correction of the coronal malalignment is associated with worse HRQOL outcomes. While the sagittal plane remains the predominant driver of improved outcomes after ASD surgery, nearly half of patients with preoperative coronal malalignment remain under-corrected following ASD surgery.

Hypothesis

Under correction of coronal malalignment in ASD patients results in less improvements in pain and physical function following ASD surgery.

Design

Retrospective review of a multi-center database.

Introduction

Prior literature has shown that correction of sagittal plane deformity in ASD patients has resulted in improvements in health-related quality of life (HRQOL) outcomes. The aim of this study was to evaluate the impact of coronal alignment correction on HRQOL outcomes in adult spinal deformity.

Methods

Using a prospective, multi-center database, we identified 1992

surgical patients. Of these, 522 patients had preoperative coronal malalignment greater than 40 mm. We excluded anyone who had SVA greater than 50 mm to exclude patients with severe sagittal deformity. We then compared 2-year post HRQOL outcomes in patients that had their coronal malalignment corrected (CVA < 40mm) vs. those who did not.

Results

Mean age was 54 ± 15 years, 91% females. 79 patients were identified with primarily coronal plane deformity undergoing primary ASD surgery. Of these, 38 (48%) were under-corrected and 41 (52%) had their coronal alignment corrected to <40mm. Compared to the corrected group, the uncorrected group had a higher ODI (26.0± 2.9 vs 14.7± 2.5; p=0.002) and lower SRS-22r Activity (3.6± 0.14 vs 4.2±0.11; p=.002, SRS-22r Appearance (3.3± 0.16 vs 3.9± 0.12, p=.001), SRS-22r total (3.6± 0.12 vs 4.1± 0.11, p=.004), SF-36 Physical Component Summary (40.8 ± 1.3 vs 46.8± 1.6; p=.005), SF-36 Physical Function (40.5± 1.7 vs 46.0± 1.5, p=.01), SF-36 Bodily Pain (41.7± 1.6 vs 47.8± 1.5, p=.006), SF-36 General Health (47.2± 1.8 vs 52.2± 1.4, p=.03), SF-36 Social Functioning (45.9± 2.1 vs 51.7± 1.4, p=.03), SF-36 Mental Health (48.9± 1.9 vs 54.2± 1.8, p=.048) at 2 years following index surgery.

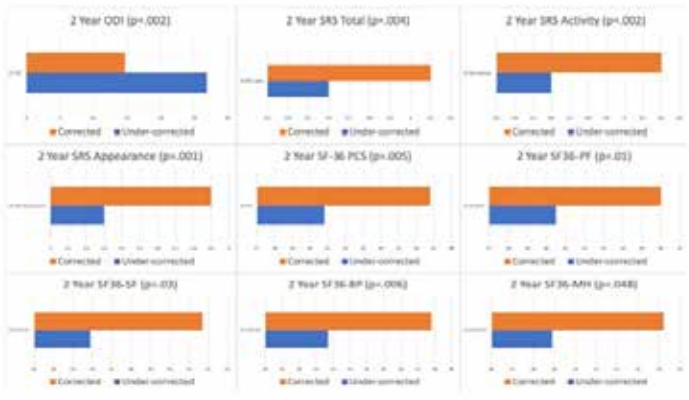
Conclusion

In patients with primarily coronal malalignment undergoing ASD surgery, under-correction of coronal malalignment is associated with worse HRQOL outcomes. Although the sagittal plane has been the predominant driver of improved outcomes after ASD surgery, deformity in the coronal plane is of important consideration.

Take Home Message

Patients with coronal malalignment and little sagittal plane deformity experience worse improvement in pain and disability, with under-correction of their coronal plane deformity.

Figure 1



141. Examination of Adult Spinal Deformity Patients Undergoing Surgery with and without Implanted Spinal Cord Stimulators and Intrathecal Pumps

Alan H. Daniels, MD; Wesley M. Durand, BS; Alyssa Steinbaum, BS; Renaud Lafage, MS; D. Kojo Hamilton, MD; Peter G. Passias, MD; Han Jo Kim, MD; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Jeffrey L. Gum, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Khaled M. Kebaish, MD; Alex Soroceanu, MPH; Richard Hostin, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; Robert A. Hart, MD; International Spine Study Group

Summary

While patients with spinal cord stimulators or intrathecal pumps exhibited worse disability at both baseline and 2 years post-operatively, their HRQOL improved comparably to patients without stimulators and pumps and additionally had no increase in complication rate.

Hypothesis

Adult spinal deformity patients with spinal cord stimulators (SCS) or intrathecal medication pumps (ITP) would benefit from surgery, as measured by improved HRQOL from baseline.

Design

Retrospective cohort study of a prospectively collected multi-center database of adult spinal deformity (ASD) patients.

Introduction

ASD patients may receive pain management with SCS/ITP pre-operatively. There is a paucity of research on outcomes among this cohort.

Methods

Patients undergoing ASD surgery and eligible for 2-year follow-up were included. Pre-operative radiographs were reviewed for the presence of SCS/ITP. Outcome measures included complications, ODI, SF-36 MCS, and SRS pain domain. MCID in ODI was set at 12.8. Bivariable and multivariable analyses were conducted; the latter adjusting for age, gender, CCI, and surgical invasiveness.

Results

In total, 1,034 patients were analyzed. Pre-operative SCS/ITP were present in 3.0% (n=31). SCS/ITP were removed intra-operatively in the majority of patients (58.1%, n=18). In bivariable analyses, the overall complication rate among patients with vs. without SCS/ITP was 77.4% vs. 58.4% (p=0.0342), though this difference was non-significant in multivariable analysis (p=0.1122). At baseline, mean ODI among patients with vs. without SCS/ITP was 58.9 vs. 44.7 (p<0.0001). In multivariable analysis, SCS/ITP patients exhibited worse ODI, SF-36 MCS, and SRS pain domain scores at baseline and 2-year follow-up (all p<0.05). No significant difference was observed, however, in the magnitude of improvement between the two groups for any HRQOL metric (all p>0.3). 50.0% vs. 56.0% of patients with vs. without SCS/ITP exhibited 2-year MCID in ODI (p=0.5768).

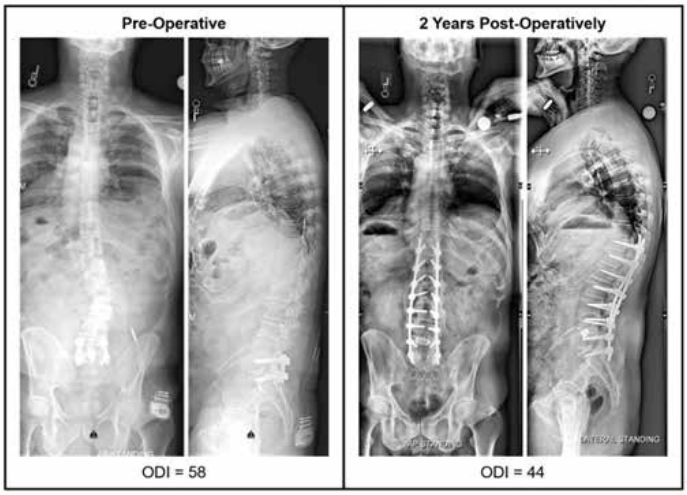
Conclusion

While patients with spinal cord stimulators or intrathecal pumps exhibited worse preoperative and post-operative HRQOL, the mean improvement was not significantly different from patients without SCS/ITP. No significant differences in complications were observed between patients with versus without SCS/ITP. ASD

surgery among patients with spinal stimulators or pain pumps is both safe and beneficial with most reaching MCID in ODI scores.

Take Home Message
ASD surgery among patients with spinal stimulators or pain pumps is both safe and beneficial from a HRQOL perspective.

Figure 1: Pre- and Post-Operative Radiograph of a Patient with Pre-Operative Spinal Cord Stimulator Removed at the Time of Surgery



142. Correlation of Desoxypiridinoline Levels and Frequency of Pseudarthrosis Formation in Patients with Degenerative Spine Deformity

Sergey Kolesov, MD, PhD; Natalia Morozova, MD, PhD; Andrey Panteleyev, MD

Summary
There is a need for methods to evaluate risk of fusion failure in spine deformity surgery. Desoxypiridinoline can be used as cheap and reliable method to predict pseudarthrosis.

Hypothesis
Desoxypiridinoline can provide a reliable marker of bone fusion failure.

Design
Prospective single-center cohort study.

Introduction
Patients with degenerative spine deformities are characterized by complications associated with the instability of metal structures caused by the formation of pseudarthrosis. Urine DPID level is a promising diagnostic marker for bone resorption, which allows predicting the frequency of these complications and assessing the feasibility of metal fixation in this category of patients.

Methods
165 patients with degenerative deformity (118 f, 47 m) aged 39 to 72 (avg 51.4). All patients underwent standard instrumentation with PLIF. Two groups were formed: group I with pseudarthrosis and group II with confirmed spinal fusion on CT and x-rays. CT VAS, SRS22, and Oswestry questionnaires were used to evaluate results. Pseudarthrosis was defined as no bone bridges in the fusion zone and "double halo" around implants. Follow-up was 2 years.

Results
On x-rays and CT scans 2 years after surgery, signs of pseudoarthrosis were detected in 24 (14.6%) patients. These patients were group I (n24). Remaining patients with signs of complete bone fusion were group II (n141). Average extent of fixation was 5.9±3.4 levels. Average long-term postoperative T-score was -2.5±1.1: -3.4±0.7 in group I and -1.4±0.4 in group II. Average DPID urine levels were 6.1±8.7 nmol/mmol in total. In group I, the values were significantly higher: 18.4±5.3 nmol/mmol compared with 4.1±2.2 in group II. Improvements in pain were observed in both groups compared with preoperative VAS values of 6.1±2.8. However, 2 years after surgery, the average values in group I were significantly higher: 3.8±1.9 in group I and 1.9±1.3 in group II. No statistically significant differences in SRS22 and ODI were observed in the long-term postoperative period.

Conclusion
There is high specificity of DPID as a marker of bone resorption and a predictor of pseudarthrosis in degenerative spine deformity patients.

Take Home Message
Desoxypiridinoline is a potent predictor of pseudarthrosis formation.

143. The Rate of Perioperative Neurologic Complications Associated with Transforaminal Lumbar Interbody Fusion in Patients Undergoing Adult Spinal Deformity Surgery

Michael Dinizo, MD; Thomas J. Errico, MD; *Tina Raman, MD*

Summary
A common technique to aid in deformity correction and achieve fusion at the base of a long construct is to incorporate anterior column instrumentation by performing a TLIF. We report a 4.1% neurologic complication rate for TLIF procedure performed at the base of a long construct, with associated 90-day revision rate at the TLIF site of 2.8%. At 3 year follow up, 85% of patients exhibited resolution of symptoms related to the neurologic complication sustained during the TLIF procedure.

Hypothesis
The incidence of neurologic complications associated with the TLIF procedure in patients undergoing ASD surgery is low.

Design
Retrospective review of prospectively collected database.

Introduction
It has been reported that interbody fusion confers two-fold increased risk for neurologic complications after ASD surgery. To date, there are no studies assessing the neurologic complication rate specifically related to the TLIF procedure, when performed as a component of these larger, complex surgeries.

Methods

316 patients (Age: 62 ± 12 y; mFI: .66 ± .73; Levels fused: 10 ± 5) underwent TLIF procedure with a titanium cage as part of a long construct extending to the pelvis. Outcomes evaluated were the rate of neurologic injury specifically related to the TLIF procedure.

Results

The neurologic complication rate related to the TLIF procedure performed was 4.1% (13/316). In all 13 patients, postoperative symptoms manifested as new onset unilateral radiculopathy. 10/13 patients (77%) had associated motor or sensory deficits on postoperative physical exam. Nerve root injury was incurred by encroachment of the interbody device into the foramen (n=2), mispositioned pedicle screw at the cephalad level (n=2), or residual bony or disc fragment compression (n=5). In the remaining 4 patients, suspected causes were nerve root retraction, distraction of the disc space, or deformity correction. 9/13 patients (69%) required unplanned reoperation for revision/exploration specifically at the TLIF site; 6 patients underwent reoperation during the index admission, and 3 patients were readmitted within 90 days for reoperation. There were no instances of cauda equina related to the TLIF level. 11/13 patients had complete resolution of the radiculopathy, including motor or sensory deficits, at 3 year follow up.

Conclusion

The rate of neurologic complications related to TLIF procedure performed for ASD surgery was 4.1%, with unplanned reoperation for instrumentation revision or revision decompression required in 2.8% of patients. At 3 year follow-up, 85% of patients had resolution of radiculopathy symptoms and neurologic deficit.

Take Home Message

We report a 4.1% rate of neurologic complications related to TLIF procedure performed for ASD surgery, with a 2.8% rate of unplanned reoperation for complications related to the TLIF procedure.

Podium Presentations—Basic Science

144. LncAIS: A Novel and Significant Long Non-coding RNA Identified by Microarray Analysis which is Implicated in the Pathogenesis of AIS and Associated Osteopenia

Qianyu Zhuang, MD; Jianguo Zhang, MD

Summary
This study reports the differential Long non-coding RNAs (LncRNA) expression profiles of bone marrow mesenchymal stem cells (BM-MSCs) from AIS patients and related potential pathways for the first time. "LncAIS", a significant LncRNA was selected from our 1483 differentially expressed lncRNAs, which was found to regulate osteogenic differentiation of Mesenchymal stem cells (MSCs) from AIS patients. These findings partly explained underlying etiological mechanisms of AIS and associated osteopenia.

Hypothesis
There are key lncRNAs that regulates osteogenic differentiation of AIS-MSCs, therefore playing a significant role in not only the causal mechanism of osteopenia in AIS, but also the AIS initiation and development.

Design
Microarray approach, bioinformatic analysis and functional experiments

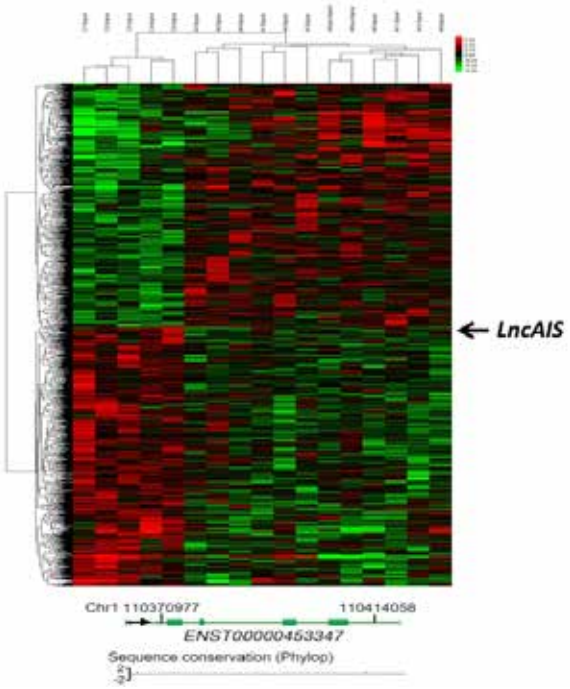
Introduction
The pathogenesis of AIS and the accompanying generalized osteopenia remain unclear. Our previous study (2016 IMAST, Whitecloud Best Basic Research Paper Prize Nomination; 2020 IMAST) suggested increased proliferation ability and decreased osteogenic differentiation ability of BM-MSCs of AIS. However, the underlying mechanism required further research and elucidation.

Methods
Microarray analyses were performed in BM-MSCs derived from 5 healthy donors and 12 AIS patients. Comprehensive bioinformatics analyses were then used to enrich datasets for Gene Ontology and pathway. Among the top downregulated lncRNAs in AIS BM-MSCs, we focused on an uncharacterized lncRNA that we called "lncAIS". Further functional experiments were finally used to explore the regulated mechanism.

Results
A total of 1483 lncRNAs were differentially expressed in AIS BM-MSCs versus normal BM-MSCs. Pathway analysis revealed dysregulated MAPK signaling pathway; PI3K-Akt signaling pathway, and Notch signaling pathway, all of which have been reported to play important role in regulating the osteogenic differentiation of MSCs. Among the top downregulated lncRNAs in AIS BM-MSCs, "lncAIS" was selected. LncAIS-ILF3-HOXD8-RUNX2 pathway was found to be associated with osteogenic differentiation of normal BM-MSCs.

Conclusion
This study reports the differential lncRNAs expression profiles of BM-MSCs from AIS patients and related potential pathways for the first time. We demonstrate that "lncAIS", a significant lncRNA regulates osteogenic differentiation of MSCs from AIS patients, therefore playing a significant role in not only the causal mechanism of osteopenia in AIS, but also the AIS initiation and development.

Take Home Message
"LncAIS" identified by our microarray analysis can regulate osteogenic differentiation of AIS-MSCs, therefore playing a significant role in the causal mechanism of osteopenia in AIS.



Differentially expressed lncRNAs were analyzed by microarray analysis

145. Collagen X Biomarker (CXM) is Predictive of Growth Cessation in Idiopathic Scoliosis

Michelle C. Welborn, MD; Ryan Coghlan, MS; James O. Sanders, MD; Joseph Stone, MD; Amer F. Samdani, MD; Vishwas R. Talwalkar, MD; Daniel Bouton, MD; William Horton, MD; Susan Sienko, PhD

Summary
Assessment of the cessation of growth is important for determining brace duration for scoliosis. Sanders stage and Risser score poorly predict growth cessation. CXM levels appear to predict growth cessation

Hypothesis
In this study we sought to evaluate if SS7 patients still had measureable growth and if CXM levels were predictive of cessation of growth

Design
IRB approved Prospective Comparative Study

Introduction
Assessment of cessation of growth for is critical for determining

surgical and brace treatment of scoliosis patients. Risser score (RS) was the gold standard but it has been shown that it can result in the mistreatment of 1/4 braced patients with AIS. Additional studies showed over 20% of Sanders stage (SS) 7 pts had curve progression at cessation of bracing. Type X collagen (COLX) is produced in the growing physis during enchondral ossification. CXM is a breakdown product of COLX. CXM, thus, is a direct measure of enchondral ossification and longitudinal bone growth

Methods

Q6mo anthropometrics and spine PA biplanar slot scanner images including the hand were assessed for major curve magnitude, RS, triradiate cartilage status (TRC), Greulich and Pyle bone age (BA), and SS. Serial Dried Blood Spots (DBS) to obtain CXM levels were collected 3 consecutive days Q1-2months based on SS

Results

During the 2.5 year period of the study 39 (POR) 10 (LEX) 10 (PHL) 9 (UNC) patients with idiopathic scoliosis, Cobb ≥20 were enrolled. Only SS7 patients were included in this subanalysis, 18 patients became SS7/8 during that period. CXM levels were assayed in quadruplicate for a total of 333 readings. CXM results were highly reproducible with an interassay coefficient of variation of 3%, and interassay of 11%. No patient with an ave CXM level between visits <5ng/ml had remaining growth.

Conclusion

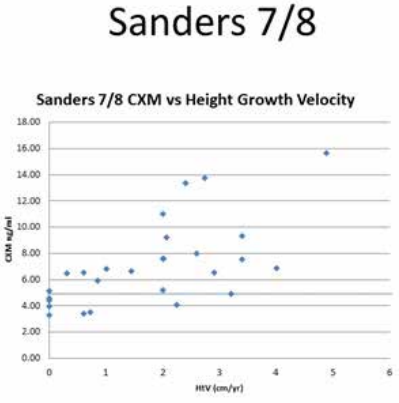
CXM is the first biomarker specific to longitudinal bone growth. We previously established that it is a patient-specific, real time measure of growth velocity with high correlation to anthropometric and radiographic measures of growth. In this study we found that all SS7 patients with a CXM >5ng/ml had remaining growth and none of the patients <5ng/ml had remaining growth

Take Home Message

home message: CXM levels are predictive of growth cessation. No patients with a CXM <5ng/ml experienced remaining growth

ID	SS	HtV	CXM ng/ml at most recent visit
1003-A	7	1.44	6.65
1003-B	7	0.85	5.92
1003-C	8	0.72	3.49
1006-A	7	2.74	13.76
1014-A	7	4	6.85
1014-B	7	0	4.43
1014-C	7	0	5.13
1014-D	8	0	3.31
1015-A	7	4.88	15.68
1015-B	7	3.4	7.56
1021-A	7	3.2	4.92
1021-B	7	0.6	3.38
1022-A	7	2.06	9.22
1022-B	7	1	6.80
1024-A	7	2.4	13.35
1027-A	7	3.4	9.35
1027-B	7	0.6	6.51
1027-C	7	0	4.58
1028-A**	7	2.25	4.10
1033-A	7	2.6	8.00
1033-B	7	0.3	6.46
1036-A	7	2.01	7.59
1036-B	8	0	3.96
1039-A	7	2	11.00
1039-A	7	2.91	6.53
1044-A	7	2	7.58
1047-A	7	2	5.19

*Remaining growth defined as >1cm/yr as 1cm/yr = measurement error for height measurements
** Pt 1028 had CXM >5ng/dl for the Ave CXM between the previous visit and the most recent visit



146. Fourteen Novel Susceptibility Loci and Genetic Architecture in Adolescent Idiopathic Scoliosis

Nao Otomo, MD; Kazuki Takeda, MD, PhD; Yoji Ogura, MD, PhD; Yohei Takahashi, MD, PhD; Noriaki Kawakami, MD, PhD; Koki Uno, MD, PhD; Manabu Ito, MD, PhD; Shohei Minami, MD, PhD; Hiroshi Taneichi, MD, PhD; Satoshi Inami, MD, PhD; Teppei Suzuki, MD, PhD; Hideki Sudo, MD, PhD; Ikuho Yonezawa, MD, PhD; Takashi Kaito, MD, PhD; Kei Watanabe, MD, PhD; Yuki Taniguchi, MD, PhD; Katsumi Harimaya, MD, PhD; Toshiaki Kotani, MD, PhD; Nobuyuki Fujita, MD, PhD; Mitsuru Yagi, MD, PhD; Kazuhiro Chiba, MD, PhD; Naobumi Hosogane, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Eijiro Okada, MD, PhD; Tatsuya Sato, MD, PhD; Tsutomu Akazawa, MD, PhD; Kotaro Nishida, MD, PhD; Hideki Shigematsu, MD, PhD; Takahiro Iida, MD, PhD; Satoru Demura, MD, PhD; Kenichiro Kakutani, MD, PhD; Ryo Sugawara, MD, PhD; Taichi Tsuji, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Chikashi Terao, MD, PhD; Shiro Ikegawa, MD, PhD; Kota Watanabe, MD, PhD

Summary

We conducted genome-wide association study (GWAS) to reveal genetic background of adolescent idiopathic scoliosis (AIS) using a total of about 5327 cases and 73884 controls which is largest sample size in the world. We identified 14 novel AIS susceptibility loci. We identified unreported genetic correlations between AIS and other diseases/phenotypes and critical cell types with strong heritability enrichment.

Hypothesis

AIS is a highly polygenic disease. Genome-wide association study (GWAS) using a large number of participants would reveal genetic background of AIS in deeper resolution.

Design

Prospective multi center cohort study.

Introduction

AIS is a common polygenic disease and the most common type of scoliosis. Although recent GWAS identified several susceptibility loci of AIS, genetic background of AIS is largely unexplored. To further identify novel AIS loci, we extended the GWAS by increasing the number of individuals and single nucleotide polymorphisms (SNPs).

Methods

We recruited 3254 individuals with AIS (mean age, 15.73 ± 4.52) and 63252 controls for the extended GWAS. We genotyped them and analyzed 4 million SNPs by imputation. GWAS using logistic regression was conducted by Plink2.0. We combined the results with those of two previous AIS GWASs in the Japanese with a meta-analysis. A total of about 5327 cases and about 73884 controls were examined. To further gain insight of AIS, we conducted two post GWAS bioinformatics analyses including genetic correlation and heritability enrichment analysis using the GWAS summary statistics.

Results

We identified 20 genome-wide significant (p value<5x10-8)

loci: 14 loci were novel. Six previously reported loci were replicated. The heritability analysis showed the genetic heritability of AIS was 0.45 (95%CI=0.03). We identified negative correlation of genetic background between AIS and body-mass Index(p=3.14x10-5), type2 diabetes(p=1.28x10-5), uric acid(p=1.2x10-5) and myocardial infarction(p=2.32x10-5). In the cell type specificity analysis, significant enrichment was observed in six cell type groups: cardiovascular(p=1.07x10-5), skeletal muscle(p=7.53x10-5), connective or bone (p=1.55x10-4), Center nerve system(p=3.25x10-3) and other(p=3.25x10-3).

Conclusion
We identified 14 novel susceptibility loci of AIS and clarified new part of the genetic background of AIS. However, results of the heritability enrichment analysis showed stronger heterogeneity in etiology and pathogenesis of AIS than we expected. Our study will be a starting point for international multi-ethnic GWAS and functional studies for AIS susceptibility genes.

Take Home Message
Extended GWAS for AIS with largest sample size identified 14 novel loci of AIS. And post GWAS analyses revealed various genetic aspects of AIS.

147. Investigation of In-vivo Three-dimensional Changes of the Spinal Canal after Corrective Surgeries of the Adolescent Idiopathic Scoliosis

Yong Hai, MD, PhD; Chaofan Han, MD, PhD; Guoan Li, PhD

Summary
To determine the 3D length changes of the spinal canal corrective surgeries and their association with the radiographic and clinical outcomes of idiopathic scoliosis patients.

Hypothesis
It was hypothesized that the spinal canal of idiopathic scoliosis experiences inhomogeneous deformation after corrective surgeries

Design
A retrospective study

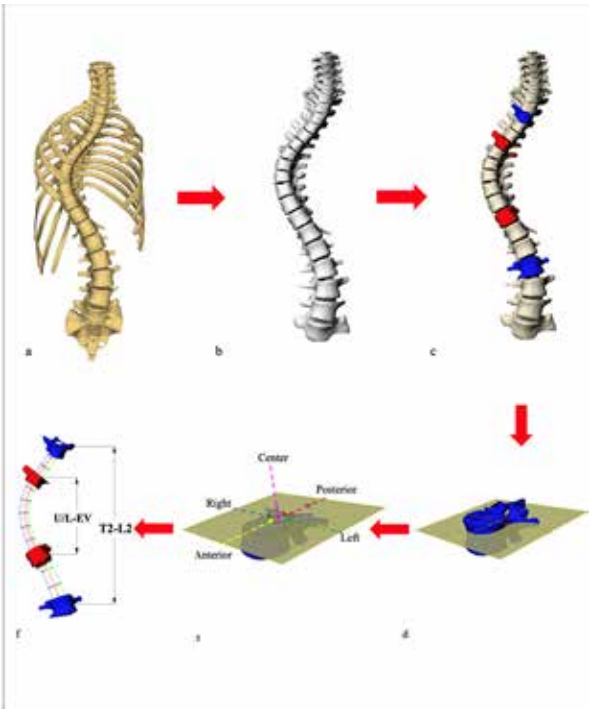
Introduction
Although the neurological complications due to over-stretch of the spinal cord during scoliotic operations is fatal, the maximum elongation of the spinal cord is still unknown. The spinal canal length, in strong association with spinal cord length, is helpful to understand the maximum correction of the deformity.

Methods
Twenty-seven scoliotic patients were studied by analyzing their 3D models reconstructed using computed tomography (CT) images before and after corrective surgeries. The spinal canal lengths between the upper and lower end vertebrae (U/L-EV) were measured at five different locations. In addition, we measured the radiographic parameters of the spine and the patient reported outcome (PRO) scores of each patient. The correlations of the changes of the SCL with the PRO scores and the radiographic parameters were analyzed.

Results
The SCL between the U/L-EV changed non-uniformly at different locations of the spinal canal after the surgery. The post-operative SCL was significantly elongated by 7.5±3.5mm (6.0±2.5%,) at the concave side and compressed by -2.6±2.6mm (-1.9±1.9%, $p < 0.001$) at the convex side. Elongations of the concave and posterior SCLs were correlated with the radiographic parameters including the main Cobb angles (r=0.511, p=0.006; r=0.613, p=0.001) and pre-operative apical vertebral translation (AVT) (r=0.481, p=0.011; r=0.684, p=0.000). No PRO scores were found to correlate with the SCL changes.

Conclusion
The surgeries of idiopathic scoliosis patients cause elongations of the SCLs mainly at the concave side and compression at the convex side. The radiographic parameters were moderately associated with the changes of SCLs. No PRO scores were found to associate with the changes of SCLs. The data could be used as conservative references for future improvement of corrective surgeries that are aimed to maximize the correction of the spine deformity and minimize the negative effect on spinal cord to prevent neurological complications.

Take Home Message
The SCL elongated mostly at concavity and compressed at convexity. The data is helpful for future improvement of corrective surgeries that aim to maximize the correction.



Podium Presentations—Basic Science

148. Tether Tension Declines Over Time: A Biomechanical Study

Vincent Ruggieri, BS; *Benjamin Sinder, PhD*; Jason B. Anari, MD; Patrick J. Cahill, MD

Summary
After setting the tension in a vertebral tether cord to a clinically relevant level of 300N, the tension in the tether rapidly declines by more than 30% in less than a day.

Hypothesis
We hypothesize that tension in the tether will decrease from its initially set value despite no change in displacement.

Design
Basic Science

Introduction
Vertebral tethering is an emerging strategy for the correction of adolescent idiopathic scoliosis, with recent HDE approval. The tension placed in the tether is recognized as a key factor regulating the subsequent patient response. Indeed, companies supply devices specifically designed to quantify the amount of tension placed in the tether by the surgeon. While the initial tension placed in the tether may be instructive, the actual tension of the tether in the patient will govern their adaptive response. Therefore, the purpose of this study was to determine if tether tension was constant over time, or would change from the initial level set by a surgeon.

Methods
Using mechanical testing machine calibrated to ASTM standards, we tested pieces of PET tether (n=4) from implants commercially produced for clinical use (i.e. "out-of-the-box). After loading the tether to 300N, tension was monitored at that displacement level at the following time points: 30 sec., 2 min., 1 hour, and 10 hours. Data are mean ± stdev, and analyzed by paired t-test.

Results
After tensioning the tether to a clinically relevant level (300N) and maintaining at 300N for 5 seconds, we then held the tether at that displacement to determine if the force was maintained at 300N or declined. We found that after 30 seconds, the force had already significantly declined ($p<0.05$) from 300N to 265.6±6.2 N, an 11.4% reduction. After 2 minutes, the force had further declined to 251.8N±8.7N, and after 1 hour was 217.8N±14.7N. After 10 hours the tension was 189.9N±26.0N, a 37% reduction from its initially set value.

Conclusion
The tension in the tether exhibits significant stress relaxation and this information may immediately inform predictive models of tethering based growth and our understanding of the patient response.

Take Home Message
The tensile force in the tether declines from the initially set value.

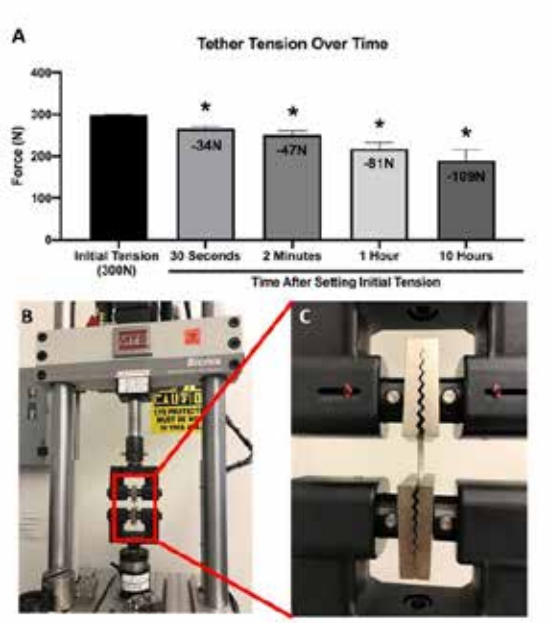


Figure: A) Clinical tether cord was tensioned to 300N, held at a fixed displacement, and tension in the tether monitored over time (n=4, *p<0.05 relative to Initial Tension). Statistical comparisons and absolute force reductions shown are relative to the initial tension of 300N. B,C) A diagram of the entire testing set-up is shown (B), as well as a high magnification of tether cord in the grips (C).

149. Are Pre-Contoured Spinal Rods Mechanically Superior to Manually Contoured Rods?

Kenneth A. Shaw, DO; Dennis P. Devito, MD; Michael L. Schmitz, MD; *Joshua S. Murphy, MD*

Summary
Manually contoured 6.0mm cobalt chrome rods required significantly greater reduction load compared to 6.0mm roll-formed pre-contoured rods. Both 5.5mm and 6.0mm manually contoured rods showed significantly less plastic deformation when compared to roll-formed pre-contoured rods.

Hypothesis
Post-manufacturing roll-formed, pre-contoured cobalt chrome spinal rods will show increased resistance to mechanical load and decreased plastic deformation when compared to manually contoured spinal rods of the same diameter.

Design
Biomechanical

Introduction
Pre-contoured spinal rods are growing in their utilization for spinal deformity. Although there are theoretical advantages to pre-contouring rods, no previous studies have compared pre-contoured and manually contoured rods for their ability to resist plastic deformation and mechanical load.

Methods
An ultra high molecular weight polyethylene (UHMWPe) block was fixated with pedicle screws. Roll-formed pre-contoured and manually contoured 5.5mm and 6.0mm cobalt chromium (Co-Cr) rods were reduced to the model with a load cell attached to the apical screw to measure reduction force. Rods remained reduced

in the model for 20 minutes and rod contour re-measured after removal for plastic deformation.

Results

Twenty-four rods were tested with 6 rods per group (Table 1). The reduction load was significantly lower in 5.5mm rods compared to 6.0mm rods (95% C.I. -254.0 - -61.42; p=0.008). There was no difference in the reduction load for manual and pre-contoured 5.5 mm rods (p=0.722). However, the pre-contoured 6.0mm rods required significantly less reduction load compared to the manually contoured 6.0mm rods (95% C.I. -134.42 - -5.317; p=0.039). Additionally, rod contour for the manual group showed significantly less plastic deformation than the pre-contoured group in both 5.5mm and 6.0mm rods (5.5mm: 57.1% vs 61.6%, p=0.006; 6.0mm: 54.3% vs 62.28%, p=0.003).

Conclusion

Post-manufacturing, roll formed, pre-contoured Co-Cr rods demonstrated significantly greater plastic deformation when compared with manually contoured rods of the same diameter. Furthermore, 6.0mm pre-contoured rods required significantly less reduction force to flatten the rod. Post-manufacturing, roll-formed, pre-contouring of Co-Cr spinal rods may impair the rods mechanical properties and may be considered clinically when restoring thoracic kyphosis in pediatric and adolescent scoliosis surgery.

Take Home Message

Manually contoured 6.0mm cobalt chrome spinal rods are stiffer and have less plastic deformation when compared to post-manufacturing, roll formed, pre-contoured rods of the same diameter.

Rod	Initial Rod Contour (°SD)	Final Rod Contour (°SD)	Force to Rod Reduction (N)	Change in Sagittal Contour (%)
5.5 mm Manually Contoured	51.67 (±0.52)	22.17 (±0.75)	437.01 (±37.21)	57.1 (±1.2)
5.5 mm Precontoured	48.2 (±2.1)	18.5 (±1.87)	428.38 (±51.06)	61.6 (±3.1)
6.0 mm Manually Contoured	49.67 (±1.5)	22.67 (±0.81)	655.97 (±31.99)	54.3 (±1.48)
6.0 mm Precontoured	49.5 (±1.5)	18.67 (±2.06)	586.09 (±57.04)	62.2 (±4.01)

Average values according to rod size and contouring method

150. 3D Cone-Beam Tomosynthesis (CBT) Offered Accurate Magnitude of Pedicle Width Measurement and Pedicle Breach Assessment at Lower Radiation Dose than Computed Tomography (CT)

Vidyadhar V. Upasani, MD; Harsha Bandaralage, MS; Christine L. Farnsworth, MS

Summary

CT is the standard for axial imaging of orthopedic procedures. CBT technology is being developed, allowing real-time intraoperative imaging and 3D surgical guidance. CBT may deliver useful axial imaging quicker with less radiation than current technologies. Although CBT axial image quality appeared subjectively inferior to CT, it enabled consistent assessment of pedicle width and screw breach, at half time and 10x lower radiation exposure. With continued refinements, CBT technology may allow for adequate intra-operative axial imaging using low radiation exposure.

Hypothesis

CBT imaging provides images allowing the same spinal measurements compared with standard CT imaging

Design

Two imaging modalities compared using porcine spines

Introduction

Intra-operative axial imaging is more commonly being used to assess pedicle screw position in adolescent scoliosis surgery. This study uses a porcine model to compare 3D CBT to CT by looking at radiation exposure, image acquisition time, pedicle width measurement with and without implants, breach grade, and image artifact.

Methods

Porcine spines (n=6) were instrumented with bilateral pedicle screws at 6 levels connected with 5.5mm diameter titanium or cobalt chrome rods. Dosimeters were attached to dorsal, ventral, right and left surfaces of each spine to collect radiation exposure. CBT (stereotactic prototype) and CT (0.625mm slice VCT) images were acquired before and after instrumentation (FIGURE). Image acquisition and 3D reconstruction times were recorded. Pedicle widths were measured before and after instrumentation. Screw medial breaches were graded (0: no breach, 1: <2mm, 2: 2-4mm, 3: >4mm). Artifact and/or distortion of each image was ranked (0=none, 1=mild, 2=moderate, 3=large). Image acquisition and reconstruction times, radiation dose, pedicle width, screw breach and artifact were compared between modalities.

Results

Image acquisition and reconstruction times of CBT were significantly less than CT (54±9sec vs. 122±28sec; p=0.014). CT had significantly greater overall average radiation exposure than CBT (0.682±0.125 vs. 0.066±0.026 rad, p<0.001). There were no differences in pedicle width measurements pre-implant (p=0.483), post-implant (p=0.247), and no difference in the change between pre and post (p=0.786). There was no significant difference in breach assessment (Grades 0, 1, 2, 3) between the CBT and CT

(p=0.1). CBT images consistently had lower artifact grades than CT images.

Conclusion
Although the CBT axial image quality appeared subjectively inferior to CT, it enabled consistent assessment of pedicle width and screw breach, at half time and 10x lower radiation exposure.

Take Home Message
CBT technology may allow for intra-operative axial imaging to accurately assess pedicle screw position with low radiation. Future studies should compare this technology to current 2D and 3D fluoroscopic techniques.

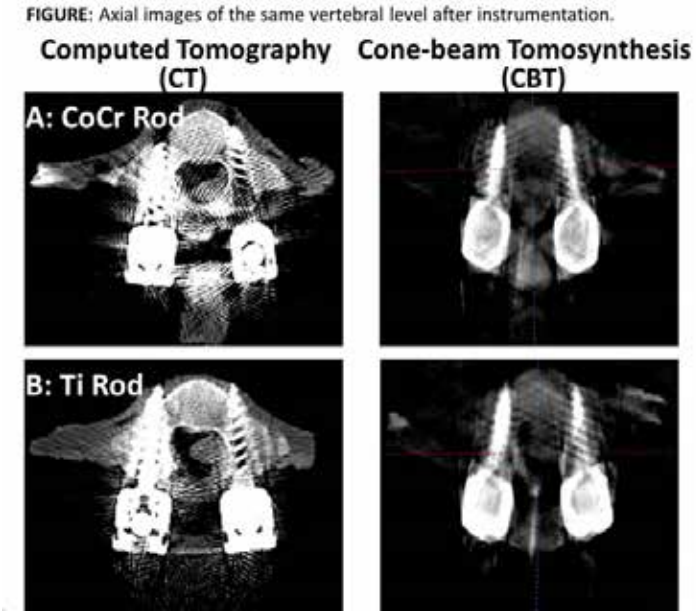


FIGURE: Axial images of the same vertebral level after instrumentation.

151. Does the Bone Mineral Density of the Pedicles Correlate with DEXA T-Score? A Cadaver-Based Analysis of CT Densitometry

Khalid Odeh, MD; Ashish Mittal, MD; Alexander Rosinski, MS; Joseph Pourtabib, BS; Jeremi Leasure, MS; Dimitriy Kondrashov, MD

Summary
Low BMD is a major risk factor for spine construct failure. The purpose of this study was to investigate whether DEXA T-scores correlate with the BMD of the pedicles and six other anatomical regions of the lumbar spine. There was a relatively strong correlation between T-score and the BMD of the lumbar pedicle and vertebral body. However, the cortical and cancellous BMD of the lamina and transverse process were less correlated with T-score and therefore less affected by osteoporosis.

Hypothesis
Spine T-score is strongly correlated with the cortical and cancellous BMD of the pedicles.

Design
Controlled laboratory study.

Introduction
Pedicle screw loosening is a known complication of posterior spinal fusion in osteoporotic patients and can lead to suboptimal outcomes including the need for revision surgery. While useful in the diagnosis of osteoporosis, dual x-ray absorptiometry scans are less able to detect variations in bone mineral density (BMD) within specific regions of the vertebrae used for spinal fixation. The purpose of this study was to investigate whether spine T-scores correlate with the cortical and cancellous BMD of the pedicles and six other anatomical regions of the lumbar spine.

Methods
Using CT images, eleven cadaveric spines with known T-scores were digitally isolated by applying filters for cortical and cancellous bone. Eleven L5 lumbar vertebrae were separated into seven anatomical regions of interest using 3D software modeling. The average Hounsfield units (HU) was determined for each region and converted to cortical and cancellous BMD with calibration phantoms of known BMD. Correlations between T-scores and HU values were calculated using the Pearson correlation coefficient.

Results
The mean T-score was 0.15 and ranged from -3.3 to 3.2. The relationship between T-score and the BMD of each vertebral region are shown in Figure 1. The cortical BMD of the pedicles was strongly correlated with T-score ($R2 = 0.74$, $p < 0.05$). There was a moderate and weak correlation between T-score and the cortical BMD of the lamina and transverse process ($R2 = 0.55$ and 0.16; $p < 0.05$ respectively). The cancellous BMD of the vertebral body was strongly correlated with T-score ($R2 = 0.82$, $p < 0.05$). There was a mild correlation between T-score and the cancellous BMD of the lamina and transverse process ($R2 = 0.29$ and 0.40; $p=0.72$ and $p<0.05$ respectively).

Conclusion
There is a relatively strong correlation between T-score and the BMD of the lumbar pedicle and vertebral body. However, the cortical and cancellous BMD of the lamina and transverse process were less correlated with T-score and therefore less affected by osteoporosis.

Take Home Message
The cortical and cancellous BMD of the lamina and transverse process are less correlated with dual x-ray absorptiometry T-score and therefore less affected by osteoporosis.

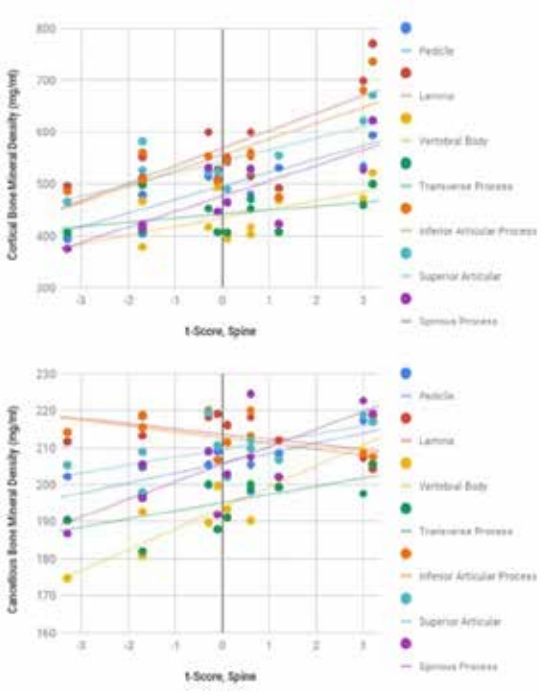


Figure 1

152. Allograft Reconstructed Iliac Bone-graft Donor Site Remodels to Viable Bone and Its Preliminary Clinical Effectiveness in Revision Fusion

Glenn Robin Buttermann, MD; Andrew Freeman, MS; Byron H. Simmons, MD

Summary
RIBG using cancellous bone allograft remodels into viable bone autograft based on histology obtained at secondary fusions. The study demonstrates the feasibility of RIBG in revision fusion and seems useful if IBG or BMP cannot be used in secondary fusion cases.

Hypothesis
Allograft reconstructed iliac bone-graft donor site may be a source of bone graft in patients with multiple prior fusions.

Design
Histologic and 2 cohort clinical prospective study.

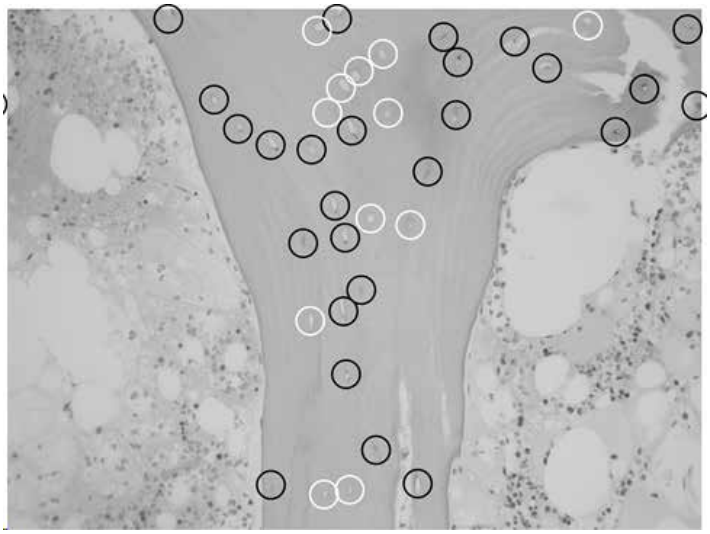
Introduction
Bone autograft options may be limited for revision spinal fusion. The purpose of this study was to assess the viability of bone graft donor sites reconstructed with bone allograft. A secondary purpose of this prospective cohort study was to ascertain whether the reconstructed iliac bone graft, RIBG, sites could be re-harvested for successful arthrodesis in revision fusion.

Methods
Revision spinal fusion patients, n=16, who had their iliac bone graft donor site backfilled with allograft bone at their initial fusion and subsequently had secondary fusion surgery for a pseudarthrosis repair or fusion extension had biopsies obtained at the time of secondary fusion. Histology analyzed the RIBG biopsies for viability and was compared to controls. One year postop CT scans and outcomes measures (LBP VAS & ODI) evaluated the clinical success of the secondary fusion surgery using RIBG and compared to revision fusion controls using IBG.

Results
Histology found filled lacunae in 83% ± 14%, and the bone marrow was hypocellular in 2/3 of cases. Control patients had 87% ± 8% and no hypocellularity. CT scans of the lumbar fusions utilizing RIBG, often combined with bone growth stimulator or bone morphogenic protein (BMP), demonstrated solid fusions in 15 of 16 patients. CT scan fusion rates of the IBG and BMP control cohorts were approximately 80%. Clinical improvement over 2 years was significant but modest which is typical for revision fusion cases (LBP VAS decreased by 3.8, ODI improved by 16.5) and was slightly better than the 36 IBG controls.

Conclusion
RIBG using cancellous bone allograft can remodel into viable bone autograft. This study is the first to report the histological viability of RIBG site and assess the feasibility of its use in revision fusion. RIBG may be useful in secondary fusion procedures if IBG or BMP are of limited availability.

Take Home Message
If the donor IBG site is reconstructed with allograft chips at the time of primary fusion, it is a source of viable bone graft for subsequent spinal fusions.



Typical lacunar histology of RIBG

153. Effectiveness of Partial Polyacrylic Acid Silver Salt as a Local Hemostatic Agent in Surgical Treatment of Degenerative Spine Disease

Sergey Kolesov, MD, PhD; Natalia Morozova, MD, PhD; Andrey Panteleyev, MD

Summary
Effectiveness of partial silver salt of polyacrylic acid as a local hemostatic agent in medium-volume surgical interventions on the spine is assessed.

Hypothesis
Partial polyacrylic acid silver salt can be an effective local hemostatic alternative.

Design
A prospective, randomized, controlled, multicenter trial.

Introduction
Incomplete silver salt of polyacrylic acid is a local hemostatic, bactericidal and bacteriostatic agent, the mechanism of action of which is based on the formation of a clot with blood plasma proteins (mainly albumin). The use of the drug is a promising direction in this field of research.

Methods
Three research centers underwent surgical treatment of 228 (163 f, 65 m) consecutively admitted patients with DDD of lumbosacral spine. Patients were randomized into two groups. All patients underwent standard decompression-stabilizing operations. The length of fixation ranged from 3 to 5 levels. Group I consisted of 117 patients in whom an incomplete silver salt of polyacrylic acid was used as the hemostatic agent during the operation. Group II consisted of 111 patients who used a hemostatic sponge and a solution of hydrogen peroxide for local hemostasis. The volumes of blood loss, the duration of the operation, and the frequency of postoperative complications were estimated.

Results
There were no statistically significant preoperative differences in demographic indicators. Intraoperative blood loss (M ± σ) in group I was 267.04 ± 172.23 ml, in group II - 412.64 ± 181.53 ml ($p < 0.001$). Postoperative blood loss (M ± σ) in group I was 83.22 ± 74.08, in group II - 154.34 ± 79.71 ($p < 0.001$). The duration of the operation in group I was on average 121.35 ± 82.3 minutes; in group II, the average duration of the operation was 149.24 ± 93.7 minutes. These differences were statistically significant. The lower duration of the operation in group I is most likely associated with less time spent on intraoperative hemostatic operations. In nonparametric comparison of postoperative complications, statistically significant differences were revealed only in the frequency of infectious complications of 1.3% in group I and 4.5% in group II.

Conclusion
Partial Polyacrylic Acid Silver Salt has demonstrated its potential as an effective local hemostatic agent in spine surgery.

Take Home Message
Liquid local hemostatic agent can reduce spine surgery complication rates.

154. Standing Balance and Postural Compensation Among Common Degenerative Spinal Pathologies

Ram Haddas, PhD; Thomas Kosztowski, MD; Damon Mar, PhD; Isador H. Lieberman, MD

Summary
Degenerative spinal pathologies are often associated with loss of postural stability during standing which in turn can greatly affect quality of daily life. Objective measures of patient balance were evaluated among six common degenerative spinal pathologies and healthy control subjects. Degenerative patients exhibited significantly increased postural sway and dynamic compensation compared to healthy controls. The results of this study provide improved understanding of pathology-specific balance characteristics and highlight the prevalence of standing postural instability across a range of degenerative pathologies.

Hypothesis
Degenerative spinal pathology patients will exhibit significantly greater postural instability compared to healthy controls.

Design
Retrospective review of balance data from 300 spinal degeneration patients and 40 healthy subjects (H).

Introduction
Degenerative spinal pathologies can severely compromise patient's balance and reduce quality of daily life. Functional evaluations provide detailed information about balance effort and compensatory mechanisms. It is unknown if the degree of balance loss is equal across common degenerative spinal pathologies.

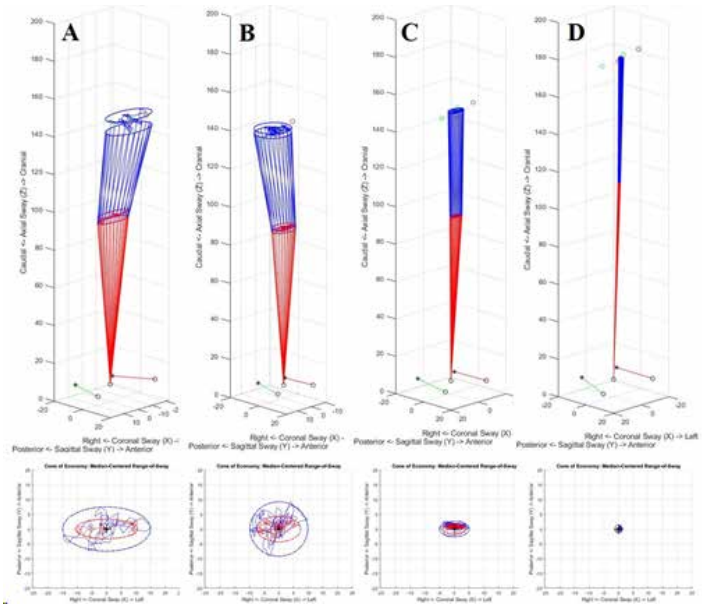
Methods
Degenerative groups included cervical spondylotic myelopathy (CSM), adult degenerative scoliosis (ADS), sacroiliac dysfunction (SIJD), degenerative lumbar spondylolisthesis (DLS), single-level lumbar degeneration (LD), and failed back syndrome (FBS). Kinematic analysis was used to evaluate patient balance during a 60s standing test.

Results
All degenerative pathologies (ALL) exhibited significantly greater head range-of-sway (RoS) in both coronal (ALL=3.6cm, H=1.8cm, $p=0.002$) and sagittal planes (ALL=7.0cm, H=4.2cm, $p<0.001$). Total sway distance (TSD) of the head was also significantly greater for degenerative groups (ALL=72.7cm, H=44.5cm, $p<0.001$). Degenerative pathologies also exhibited significantly greater anterior postural compensation including increases in ankle dorsiflexion (ALL=4.9°, H=2.8°, $p=0.031$), knee flexion (ALL=5.4°, H=2.4°, $p<0.001$), hip flexion (ALL=4.6°, H=3.0°, $p=0.002$), pelvic anteversion (ALL=2.0°, H=1.3°, $p=0.029$), and trunk tilt (ALL=2.0°, H=1.0°, $p=0.033$).

Conclusion
A global trend in significantly greater postural instability and increased standing effort was found among patients with degenerative spinal pathologies. Balance should be recognized as a key factor in assessing patient function and that its relevance is equally important across a range of degenerative pathologies.

Take Home Message
Diminished balance performance was found across all degenerative spinal pathologies. Functional balance measures should be considered an important aspect of evaluating patient disability regardless of their underlying pathology.

Podium Presentations—Basic Science



Representation of Cone of Economy and Range of Sway LDS (A), ADS (B), and FBS (C) and Healthy Control (D)

155. Comparison of the Load Delivered to Scoliosis Patients Using Different Halo Gravity Traction Systems: A Bench Study

Jonathan Poli, MS; Robert Aylor, BS; Christopher Howard, MBA; Walter F. Krengel III, MD; Klane K. White, MD; Gregory Redding, MD; *Jennifer M. Bauer, MD*

Summary
4 different halo gravity traction systems were tested on a patient model to determine the actual load experienced by a patient, with variations in the load seen depending on type of system and patient maneuver.

Hypothesis
We expect variable actual loads to be experienced by patients treated with different HGT systems.

Design
Biomechanical study

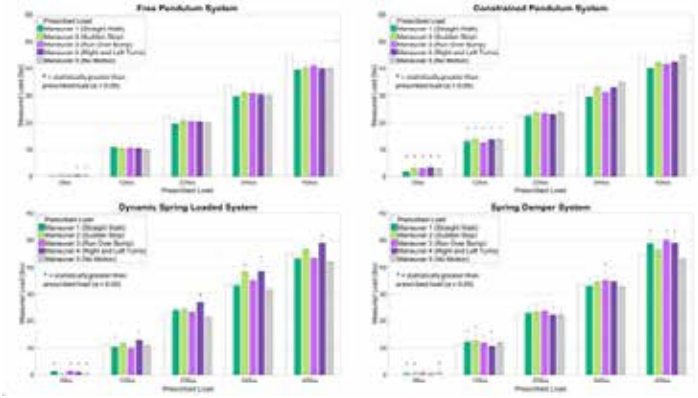
Introduction
Several different halo gravity traction (HGT) system designs exist, but little is known whether the prescribed weight is the actual load experienced by patients treated with HGT.

Methods
Four HGT wheelchair designs were used with a 62lb simulated patient model: free pendulum (FP) system, constrained pendulum (CP) system, dynamic spring-loaded (DSL) system, and a spring damper (SD) system. These four were tested using a rigid halo bale connection and non-rigid rope connection. Each combination underwent 5 maneuvers: straight walk, sudden stop, rolling over a bump, left and right hand turning. Each maneuver was performed with five different prescribed loads ranging from 0-45lbs. Measured load was collected using an S-type load cell placed between the HGT system and patient interface. The data was assessed for normality, and the mean and standard deviation were computed. Variables were analyzed using ANOVA with multiple-comparisons testing. Precision was determined using a one-tailed t-test comparing the measured load to the prescribed load for each combination of factors.

Results
Of the systems, the FP delivered the prescribed load most precisely (96% of the combinations), followed by the DSL system (80%), SD system (80%), and the CD system (76%). All measured loads that were significantly different than prescribed load delivered greater than the prescribed load. The CP system delivered greater loads for each combination at low weight and resolved at higher loads. Left and right turns on the DSL system delivered greater than prescribed loads throughout the entire weight range. Greater than prescribed loads were also observed on the SD system as well, but no maneuver trend was obvious. The FP system delivered less than prescribed load for loads > 0lbs. Patient interface did not have a significant effect on measured load.

Conclusion
Depending on what HGT system is used, the prescribed load may be different than the load experienced by patient.

Take Home Message
Some HGT systems may provide more than the prescribed load to a patient. More work is needed to determine clinical significance/safety.



HDC-AIS. Does Intraoperative Correction during Anterior Vertebral Body Tethering Predict Correction Seen on 1st Erect Radiograph?

Abdul Fettah Buyuk, MD; Todd A. Milbrandt, MD, MS; Smitha Mathew, MBBS, MS; D. Dean Potter, MD; A. Noelle Larson, MD

Summary
For 57 patients undergoing anterior vertebral body tethering, intraoperative major Cobb correction (68%) surpassed that obtained on preoperative bending films (55%), but worsened by a mean of 10 degrees (SD 5) on 1st erect imaging to achieve a mean 49% correction.

Hypothesis
1st erect images after AVBT show a significant loss of correction

compared to intraoperative x-rays obtained in the lateral decubitus position.

Design
Single center cohort retrospective review/retrospective review of prospectively collected data.

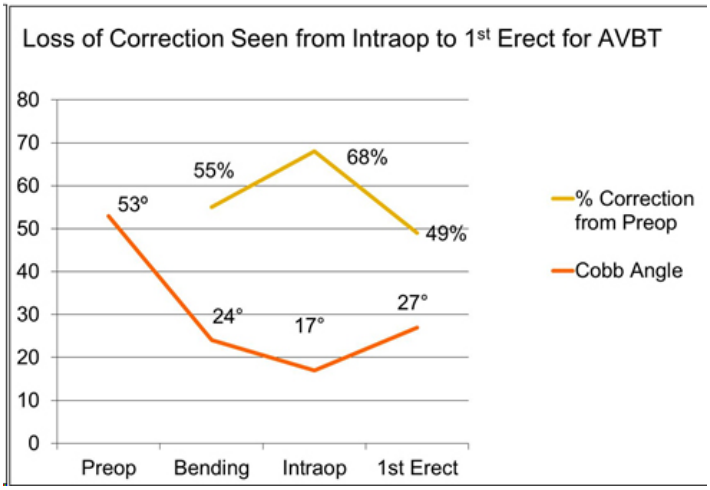
Introduction
Anterior vertebral body tethering (AVBT) is an emerging approach for idiopathic scoliosis. However, overcorrection and undercorrection are common causes of revision surgery, and much remains to be learned about intraoperative techniques and tensioning in order to achieve a predictable result.

Methods
57 patients underwent anterior body tethering between June of 2015 and January of 2020. After the cord was tensioned, intraoperative radiographs were obtained in the lateral position and compared to preoperative bending films and first erect standing radiographs. Tensioning was achieved by intraoperative positioning, twisting the cord, and use of the Dynesys/Tether tensioning device.

Results
Preoperative major Cobb angle measured 53 degrees (range, 41-78 degrees). Preoperatively major Cobb angle on bending films was 24 degrees. Intraoperative film in the lateral position showed correction to a mean of 17 degrees. Postoperative erect standing radiographs showed correction to a mean of 27 degrees. There was a mean 10-degree (SD 5) difference in Cobb angle between intraoperative radiograph in the lateral decubitus position and postoperative standing radiograph. Greater than 5 degrees loss of correction was observed 89% of patients (51/57). 65% patients had 10 degrees or more loss of correction (37/57). Four patients with atypical curve patterns had a mean of loss of correction of 19 degrees at first erect.

Conclusion
Surgeons should expect curves to be 5 to 15 degrees worse on 1st erect radiograph compared to intraoperative films obtained in the lateral decubitus position. The greatest loss of correction was seen in patients with atypical curve patterns.

Take Home Message
For AVBT patients, 1st erect imaging worsened by a mean of 10 degrees compared to correction obtained on the table in the lateral decubitus position.



HDC-AIS. Rate Of Scoliosis Correction Correlates with Height Velocity and Slows Substantially at 2 Years after Anterior Spinal Growth Tethering (ASGT) for AIS

Yohei Takahashi, MD, PhD; Wataru Saito, MD, PhD; Burt Yaszay, MD; Carrie E. Bartley, MA; Tracey P. Bastrom, MA; *Peter O. Newton, MD*

Summary
In 23 immature AIS patients 2-5 years after anterior spinal growth tethering, thoracic segments (T5-L1) corrected at an average rate of ~2 degrees per segment per year for the first 2 years. Further correction decreased on average after 2 years. Scoliosis correction mainly correlated with the height velocity during the period of 1-2 years postoperatively.

Hypothesis
Adolescent idiopathic scoliosis (AIS) correction due to ASGT is related to time and growth after implantation.

Design
Retrospective

Introduction
ASGT has been introduced as a means to progressively correct scoliosis without fusion due to growth. The purpose of this study was to evaluate associations between changes in screw angulation and overall height after ASGT.

Methods
Patients with ASGT for AIS between 2012-2016 and >2yrs of follow-up were retrospectively studied. Screw angulation (more accurate than endplates) of each tethered segments was measured at all postop time points with corresponding patient height measurements. We calculated each segment's screw angulation rate of change (deg/month) and height velocity (cm/month) between each patient's visits (range 3-12 visits/pt) and divided visits into four groups by duration after ASGT (<1yr, 1-2yr, 2-3yr, >3yr). Data was excluded after tether breakage, tether or screw removal.

Results
We analyzed 23 patients (16F,7M) aged 12.2±1.6 years with thoracic AIS of 53±8°. All patients were immature at the time of surgery (Risser 0-1, Sanders 2-3). Mean follow-up was 3.5±1.1 (range 2-5) years. Screw plowing was not identified. In total, we calculated 654 between visit screw angulation changes. The rate of change for each segment's screw angulation after ASGT at <1yr, 1-2yr, 2-3yr, and >3yr was -0.17, -0.15, -0.05, and 0.02 deg/mo [(-) values indicate reduction in scoliosis], and height velocity was 0.63, 0.47, 0.29, and 0.19 cm/mo, respectively. There were significant correlations between changes in screw angulation and increases in height in the group 1-2 years ($r=-0.45$, $p<0.001$) and the group 2-3 years ($r=-0.21$, $p<0.015$) after ASGT.

Conclusion
Correction was associated with overall height changes and occurred primarily within 2 years of surgery in this cohort of largely Risser 0 patients. The correction rate was ~2 deg/segment/year for the first 2 years after which correction decreased (2-3yr) and ceased (>3yrs). Surgical timing and height velocity are important factors in generating postoperative correction after ASGT.

Take Home Message
There is a correlation between the rate of scoliosis correction and height velocity for 1-2 years following anterior spinal growth tethering for AIS.

The Rates of Change for Intersegmental Screw Angulation (Degrees/Month)

Level	N	<1year(N)	1-2years(N)	2-3years(N)	3+years(N)
T5/T6	52	-0.26 (16)	-0.14 (20)	-0.05 (11)	-0.07 (5)
T6/T7	107	-0.23 (28)	-0.18 (35)	-0.09 (23)	0.03 (21)
T7/T8	117	-0.16 (31)	-0.15 (38)	-0.07 (27)	-0.02 (21)
T8/T9	107	-0.17 (31)	-0.15 (37)	0.07 (22)	-0.01 (17)
T9/T10	113	-0.07 (31)	-0.16 (38)	-0.04 (24)	0.07 (20)
T10/T11	105	-0.23 (31)	-0.13 (38)	-0.02 (21)	0.08 (15)
T11/T12	48	-0.16 (14)	-0.13 (17)	-0.26 (8)	0.01 (9)
T12/L1	5	-0.09 (3)	-0.17 (2)	-	-
Total	654	-0.17 (185)	-0.15 (225)	-0.05 (136)	0.02 (108)

HDC-AIS. Anterior Vertebral Body Tethering for Immature Idiopathic Scoliosis: Results on Patients Reaching Skeletal Maturity

Amer F. Samdani, MD; Joshua M. Pahys, MD; Solomon Samuel, D. Eng.; Erica Johnson, BS; Alejandro Quinonez, BS; Glenn Pelletier, MD; Harsh Grewal, MD; Steven W. Hwang, MD

Summary
Anterior vertebral body tethering offers a fusionless option for children with scoliosis. Very limited literature exists on patient outcomes at skeletal maturity for a procedure that relies on growth modulation. We analyzed 83 such patients and found progressive correction of scoliosis over two years with a rebound in Cobb angle at most recent follow-up. The enthusiasm for this technology should be tempered by the reoperation rate of 2.17%, although only 3.6% of patients went on to fusion.

Hypothesis
Anterior vertebral body tethering provides sustained control of idiopathic scoliosis until skeletal maturity.

Design
Single center retrospective chart review.

Introduction
Anterior vertebral body tethering (VBT) is a promising new technique with several 2-year follow-up studies documenting its benefits. However, outcomes of VBT patients who reach skeletal maturity are necessary to assess sustainability of growth modulation.

Methods
After IRB approval, the clinical and radiographic data was reviewed of a consecutive series of 385 skeletally immature idiopathic scoliosis (IS) patients who underwent VBT. Patients who had reached skeletal maturity (Risser: girls≥4, boys≥5) were selected and data collected from preop, first erect (FE), 2 year (2yr), and most recent (MR) f/u.

Results
83 patients met our inclusion criteria with a mean age of 12.2 ± 1.2 years with 5 ± 1 yr f/u. Pre-op, all were skeletally immature (Risser: 0.3 ± 0.7). A mean of 8.0 ± 1.2 levels (single side: 75, double: 8). Mean pre-op thoracic Cobb angle was 48 ± 11° and corrected to 22 ± 10° on FE and to 15 ± 11° at 2 yr, with some loss of correction to 22 ± 13° at most recent f/u. A similar corrective pattern was seen with the lumbar curve (pre-op: 29 ± 11°, FE: 17 ± 7°, 2 yr: 13 ± 9°, MR: 16 ± 9°). Sagittal measurements remained stable (T5-T12 kyphosis: pre-op: 20 ± 11°, FE: 23 ± 11°, 2 yr: 22 ± 13°, MR: 24 ± 13°; lumbar lordosis: pre-op: 44 ± 13°, FE: 41 ± 12°, 2 yr: 44± 12°, MR: 47 ± 13°). No major neurologic complications occurred, with 1 patient having a wound infection. 2 patients had delayed pleural effusions requiring chest tube reinsertion. There were 18 reoperations (21.7%) in our cohort with 11 for overcorrection and 3 patients going on to eventual fusion.

Conclusion
Anterior vertebral body tethering offers an alternative to fusion for patients with idiopathic scoliosis. There is some loss of correction observed at most recent follow-up when patients are followed to skeletal maturity. In addition, the enthusiasm for this promising technology needs to be tempered by the relatively high reoperation rate.

Take Home Message
Vertebral body tethering offers an alternative to fusion for patients with idiopathic scoliosis. Reoperations are not uncommon, but the vast majority of patients will avoid fusion surgery.

Podium Presentations—Basic Science

	Main Thoracic Curve (°)	Lumbar Curve (°)	Proximal Thoracic Curve (°)	Thoracic Kyphosis (°)	Lumbar lordosis (°)
Pre-op	48.4 ± 10.7 (30 – 74.4)	28.9 ± 10.8 (5.8 – 58.1)	22.6 ± 9.8 (3.3 – 45.1)	19.7 ± 11.4 (3.7 – 51.3)	44.3 ± 12.7 (7.1 – 70.2)
1st Erect	22.0 ± 10.4 (3.8 – 53.5)	16.5 ± 7.3 (5.1 – 39.4)	16.2 ± 7.5 (0.7 – 31.6)	22.6 ± 10.9 (1 – 50)	41.1 ± 11.7 (8.8 – 70.3)
2 year	14.9 ± 10.7 (0.1 – 44.6)	12.7 ± 9.0 (1.4 – 40.6)	13.1 ± 8.2 (2.0 – 32.8)	22.4 ± 12.7 (0.2 – 46.9)	44.3 ± 11.7 (21.7 – 65.8)
Most Recent	21.5 ± 12.6 (2 – 49.5)	16.4 ± 9 (3.5 – 41.5)	13.8 ± 7.4 (3.9 – 34.6)	24.2 ± 13.4 (2.4 – 48.3)	46.9 ± 12.8 (19.8 – 84.5)
p-Value†	<0.001	<0.001	<0.001	NS	NS
p-Value††	<0.01	NS	NS	NS	NS
p-Value†††	NS	NS	NS	NS	<.05

† Preop vs. most recent
†† 2 year vs. most recent
††† First erect vs. most recent
NS: Not Significant

HDC-AIS. Shoulder Balance in Patients with Lenke Type 1 and 2 Idiopathic Scoliosis Appears Satisfactory at Two Years Following Anterior Vertebral Body Tethering of the Spine

Firoz Miyanji, MD; Michael Fields, BS; Joshua S. Murphy, MD; Hiroko Matsumoto, PhD; Benjamin D. Roye, MD; David L. Skaggs, MD; Ron El-Hawary, MD; *Michael G. Vitale, MD*; Stefan Parent, MD, PhD; Pediatric Spine Study Group

Summary
38 skeletally immature patients with idiopathic scoliosis (IS) who underwent anterior vertebral body tethering (AVBT) were evaluated for postoperative shoulder balance. Absolute clavicular and T1 tilt angle were 2.8±2.3 and 4.7±3.6 preoperatively and 2.1±1.7 and 5.0±4.3 at two year follow up. 13.2% of patients had shoulder imbalance >2cm at follow up. These findings compare favorably with reports in patients who underwent selective thoracic fusion (STF).

Hypothesis
Patients undergoing anterior vertebral body tethering (AVBT) for idiopathic scoliosis (IS) will exhibit more shoulder imbalance than patients undergoing STF.

Design
Retrospective cohort study.

Introduction
Shoulder balance is an important factor for patient satisfaction after surgery for IS. There is no literature reporting the effect of AVBT on shoulder balance.

Methods
Patients enrolled in a multicenter EOS registry who underwent AVBT from 2013 to 2017 in two Canadian centers were identified. The primary outcome was shoulder imbalance defined as an absolute radiographic shoulder height of >2cm at two year follow up (range: 22 months-30 months). Clavicular and T1 tilt angle were also collected.

Results
Of 38 patients identified (92.1% female; preop age: 12.0±1.2, Risser 0-2), there were 31 (81.6%) Lenke 1 and 7 (18.4%) Lenke 2 curves. The mean Cobb angles of the proximal thoracic and main thoracic curves were 23.4±8.6 and 49.2±8.6 preoperatively and 13.8±7.1 and 25.3±9.8 at a mean follow up time of 2.1 years. Absolute clavicular and T1 tilt angle were 2.8±2.3 and 4.7±3.6 preoperatively and 2.1±1.7 and 5.0±4.3 at two year follow up. Preoperatively, absolute shoulder height averaged 15.6±10.6mm and 12 (31.6%) patients had shoulder imbalance. At two year follow up, absolute shoulder height averaged 10.5±8.5mm and 5 (13.2%) patients had shoulder imbalance. Of patients who had balanced shoulders preoperatively, 3 (7.9%) became imbalanced at postop follow up. There were no differences among Lenke type 1 or 2 in terms of shoulder imbalance.

Conclusion
Postoperative shoulder imbalance in this early cohort of patients with IS undergoing AVBT was seen in 13.2% of patients, within the reported range of shoulder imbalance in studies of similar patients undergoing STF. Our results may be secondary to careful selection of curve type in this early cohort.

Take Home Message
Compared with historical controls who have undergone posterior spinal fusion, this study demonstrated that this early cohort who underwent AVBT treatment had comparable shoulder balance.

	Pre-Operative	Immediate Postop	1 Year Postop	2 Year Postop
Proximal Thoracic	23.4 ± 8.6 (0.0-43.4)	16.4 ± 8.7 (3.8-36)	13.0 ± 8.0 (0.2-33.4)	13.8 ± 7.1 (1.2-29)
MT Curve	49.2 ± 8.6 (32.0-75.0)	27.1 ± 9.1 (14.0-52.0)	22.8 ± 9.1 (4.0-41.0)	25.3 ± 9.8 (6.0-46.0)
TL Curve	33.0 ± 7.1 (18.0-46.0)	25.5 ± 7.4 (11.0-42.0)	21.7 ± 7.7 (11.0-40.0)	22.0 ± 7.8 (11.0-39.0)
* Clavicular Angle	-1.9 ± 3.2 (-7.8-3.6)	1.0 ± 2.3 (-6.3-5.0)	1.6 ± 2.5 (-4.1-6.5)	1.3 ± 2.4 (-3.6-7.4)
|Clavicular Angle|	2.8 ± 2.3 (0.0-7.8)	2.0 ± 1.5 (0.0-6.3)	2.4 ± 1.7 (0.0-6.5)	2.1 ± 1.7 (0.0-7.4)
* T1 Angle	-1.0 ± 5.9 (-12.4-10.7)	2.6 ± 5.3 (-7.8-14.2)	2.8 ± 4.6 (-7.4-12.1)	3.1 ± 5.9 (-9.2-18.2)
|T1 Angle|	4.7 ± 3.6 (0.0-12.4)	4.8 ± 3.5 (0.0-14.2)	4.2 ± 3.3 (0.0-12.1)	5.0 ± 4.3 (0.0-18.2)
* Shoulder Height	-12.3 ± 14.4 (-41.1-13.4)	2.6 ± 11.3 (-24.3-26.5)	7.1 ± 12.7 (-24.0-29.6)	3.6 ± 13.2 (-20.1-32.4)
|Shoulder Height|	15.6 ± 10.6 (0.0-41.1)	8.8 ± 7.5 (0.0-26.5)	12.1 ± 7.8 (0.0-29.6)	10.5 ± 8.5 (0.0-32.4)
C7CSVL	4.3 ± 16.7 (-33.6-35.0)	0.1 ± 14.2 (-24.3-30.3)	1.3 ± 13.1 (-23-27.5)	1.0 ± 13.0 (-21.6-24.3)
|C7CSVL|	13.3 ± 10.9 (0.0-39.0)	11.3 ± 8.4 (0.0-30.3)	10.1 ± 8.2 (0.0-27.3)	10.6 ± 7.4 (0.0-24.3)
Shoulder Balance				
Balanced	26 (68.4%)	35 (92.1%)	32 (84.2%)	33 (86.8%)
Imbalanced	12 (31.6%)	3 (7.9%)	6 (15.8%)	5 (13.2%)

*Negative values indicate right side up/left side down

Radiographic parameters following AVBT.

HDC-AIS. Reoperations After Anterior Vertebral Body Tethering: Analysis of a Cohort of 218 Patients

Amer F. Samdani, MD; Joshua M. Pahys, MD; Solomon Samuel, D. Eng.; Erica Johnson, BS; Alejandro Quinonez, BS; Firoz Miyanji, MD; Steven W. Hwang, MD

Summary
In this cohort of 218 patients with minimum 2-year follow-up after VBT, we found a 17.7% reoperation rate with the most likely cause being over correction. Tether release improves the over correction. 3% of patients have gone on to posterior fusion which can be accomplished effectively without removal of anterior tether instrumentation. Too much remaining growth, such as in patients with open triradiate cartilages, predisposes to reoperations. In addition, we now recommend less tension on the tether for select patients.

Hypothesis
Reoperation rates after VBT will be high, with overcorrection being the most common cause.

Design
Single center retrospective review.

Podium Presentations—Basic Science

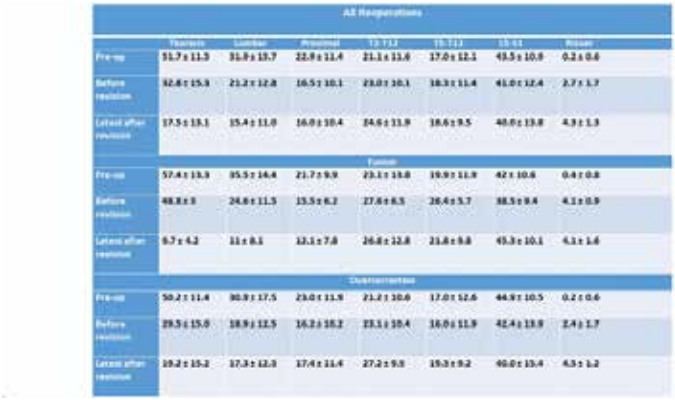
Introduction
Anterior vertebral body tethering (VBT) is a promising new technology for children with scoliosis. To date, majority of studies have described benefits, with minimal literature on reoperations. This report analyzes the incidence, major causes, and outcomes of reoperations after VBT.

Methods
From a cohort of 218 subjects with minimum 2 year f/u who underwent VBT at a single institution, we identified all patients who required reoperation and collected pertinent clinical and radiographic data. The reasons for reoperation were determined to be: 1) tether release for overcorrection, 2) lengthening of tether construct for adding on, 3) replacement of tether for breakage, and 4) posterior fusion.

Results
38 patients (17.4%) were identified with a mean follow-up of 3.4 ± 1.3 years. Reoperated patients had a significantly higher percentage of open triradiate cartilages (66% versus 26%, $p < 0.05$). Reoperations occurred 27.7 ± 11.4 months after initial surgery. Overcorrection requiring tether release was the most common reason for reoperation (24/38=63%), followed by posterior spinal fusion (7/38=18%). Adding on occurred in 4 patients (11%), and replacement of tether for breakage in 3 (8%). Of the patients with overcorrection, at initial surgery their major Cobb angle measured 50 ± 11º and overcorrected to 29 ± 15º with most recent being 19 ± 15º, demonstrating some improvement after tether release. The eventual fusion patients at initial surgery measured 57 ± 14º and prior to fusion were 49 + 3º. After fusion, major Cobb angle measured 8.2 ± 4.8º. PSF did not require removal of anterior tether implants.

Conclusion
Reoperations occurred in 17.4% of 218 patients undergoing VBT, with the most common reason being over correction requiring tether release. Not over tightening the tether and waiting for triradiate cartilages to close may decrease this incidence. 7 patients have undergone eventual posterior fusion. This did not require removal of the anterior implants and resulted in acceptable radiographic results.

Take Home Message
Reoperations are not uncommon after VBT with the most common cause being over correction. Too much remaining growth, as indicated by open triradiate cartilages, predisposes to reoperation.



Reoperations

HDC-AIS. The Clinical Significance of Tether Breakages in Anterior Vertebral Body Growth Modulation: A Two–year Post-operative Analysis

Jesse Shen, MSc; Julie Joncas, RN; Marjolaine Roy-Beaudry, MSc; Isabelle Turgeon, BSc; Imad S. Nahle, MD; *Stefan Parent, MD, PhD*

Summary
This study compares outcomes in patients experiencing post-operative tether failure to non-complicated cases. Our current results suggest that these two cohorts have similar post-operative courses in terms of quality of life. Curve progression needs to be closely followed in patients with tether failure.

Hypothesis
Patients with post-operative tether failure have similar outcomes compared with patients with no complications.

Design
Prospective cohort

Introduction
Anterior vertebral body growth modulation (AVBGM) aims to treat skeletally immature patients with progressive idiopathic scoliosis (IS). Early results are promising, but tether failure is a concern. We aim to evaluate post-op evolution in patients who have experienced tether failures compared with patients without other major complications.

Methods
A retrospective review of a prospectively maintained database of IS patients operated with AVBGM from 2013 to 2020 was performed. All patients having at least two-year clinical follow-up were included. Patients with tether breakages and those without failures were analyzed. SRS-30 scores and radiological parameters were evaluated and compared using Wilcoxon Rank-sum test.

Results
66 patients were identified: 21 patients with tether failures and 34 patients without complications were analyzed. Patients with complications other than tether breakage or having revision surgery were excluded (11). Average age for index surgery was 11.9 for both groups. Average time to tether breakage is 31.5 months

and mean last follow-up was 42.8 months for breakage group. Pre-op SRS QoL were significantly different for function, satisfaction and total scores. The effect sizes were small to moderate for all SRS QoL components when comparing both groups at last follow-up. SRS scores for function decreased post-operatively for patients with failures compared to MCID and MDMD. Pre-op Cobb angle were similar between both groups (48 vs 50). Final Cobb angle were statistically significantly higher in the tether breakage group (29.6 vs 17.9). 2 of the 21 patients were awaiting fusion due to curve progression.

Conclusion

Although QoL outcome scores for function were similar between groups, lower scores were reported for the tether failure group. Patients without failures may have greater satisfaction post-operatively. Progression of curves was noted in patients with tether failures and must be closely monitored.

Take Home Message

Tether failures may lead to lower post-operative quality of life scores and need to be followed closely. These patients may also be at risk of curve progression.

Table 1. Summary of results

	No complications Pre-op (n = 34)	Tether Break Pre-op (n = 21)	P value	No complications Last FU (n = 34)	Tether Break Last FU (n = 21)	P value	Absolute Difference No complications vs Tether breakLast FU	Absolute difference Pre-op to LFU No complications	Absolute difference Pre-op to LFU Tether break	MDMD Kelly et al. 2019	MCID Carreon et al. 2010
Function	4.18 ± 0.50	4.41 ± 0.33	0.0432	4.12 ± 0.23	4.06 ± 0.39	0.3562	0.06	0.06	0.35	0.24	0.08
Pain	4.10 ± 0.67	4.40 ± 0.52	0.1047	4.23 ± 0.56	4.04 ± 0.79	0.4420	0.19	0.13	0.36	0.3	0.2
Self Image	3.88 ± 0.48	3.93 ± 0.68	0.5621	4.22 ± 0.39	3.98 ± 0.59	0.2092	0.24	0.34	0.05	0.3	0.98
Mental	4.15 ± 0.60	4.23 ± 0.67	0.4913	4.07 ± 0.55	4.08 ± 0.53	0.9092	0.1	0.08	0.15	NA	NA
Satisfaction	3.63 ± 0.90	4.09 ± 0.86	0.0465	4.54 ±0.61	4.1 ± 1.13	0.2252	0.44	0.91	0.01	NA	NA
Total score	3.98 ± 0.44	4.21 ± 0.49	0.0351	4.24 ± 0.34	4.05 ± 0.52	0.1879	0.19	0.23	0.16	NA	NA

Summary of results

HDC-AIS. Anterior Vertebral Body Tethering for Adolescent Idiopathic Scoliosis Preserves Trunk Motion Compared to Posterior Spinal Fusion at Two Year Follow-up

Joshua M. Pahys, MD; Amer F. Samdani, MD; Steven W. Hwang, MD; Spencer Warshauer, MS; Ross Chafetz, PhD

Summary

A consecutive series of adolescent idiopathic scoliosis patients underwent trunk kinematic evaluation preoperatively and two years after posterior spinal fusion (PSF) or anterior vertebral body tethering (VBT). PSF patients exhibited a significant and progressive loss of trunk motion with each additional lowest instrumented vertebra (LIV). VBT patients experienced minimal loss of motion after their procedure for each additional LIV except L4 at two years postoperative. Preoperative curve magnitude had no significant impact on trunk motion in either group.

Hypothesis

Posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS) results in more loss of trunk motion with each additional caudal lowest instrumented vertebra (LIV) compared to anterior vertebral body tethering (VBT).

Design

Single center retrospective review of a consecutive series of AIS patients undergoing trunk kinematic evaluation.

Introduction

Prior studies have demonstrated a progressive loss of trunk motion with additional caudal LIV after PSF for AIS. This is the first study to use an established computerized 3D model to compare trunk motion between PSF and VBT and analyze its relationship to LIV.

Methods

Beginning in 2016, all skeletally immature AIS patients underwent motion analysis prior to PSF or VBT and at 6 months (n=193) and 2 years (n=57) post-op. Patients were divided into four groups based on LIV (< L1, L2, L3, and L4). Computerized 3D kinematic evaluations included trunk flexion/extension, side bending, and rotation.

Results

Patients were stratified by LIV: < L1 (VBT n=78; PSF n=34), L2 (VBT n=8; PSF n=12), L3 (VBT n=21; PSF n=24), L4 (VBT n=3; PSF n=13). PSF patients had a statistically significant loss of trunk ROM in all planes at 6 months and 2 years post-op with each additional caudal LIV (LIV < L1: 16% loss vs. LIV L4: 59% loss, $p<0.001$). VBT patients had statistically significant but clinically insignificant (LIV <L1: 6% loss vs. LIV L4: 8% loss, $p<0.01$) loss of trunk motion at 6 months. At 2 years, this trend was similar for all VBT patients except LIV=L4 (n=3), which declined from 6 months to 2 years post-op (8% to 23% flexion loss, $p<0.01$). Pre-op curve size did not have any significant impact on trunk motion for VBT vs. PSF.

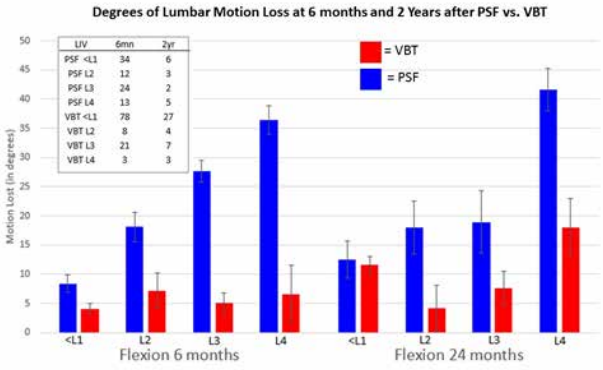
Conclusion

Anterior vertebral body tethering (VBT) patients experienced minimal loss of motion at two years post-op. Posterior spinal fusion patients lost significant motion in all planes which increased with each additional lowest instrumented vertebra (LIV) from L1 to L4, with the greatest loss in forward flexion. VBT patients did not experience additional loss of motion between the 6 month and 2 year time points, except for those instrumented to L4.

Take Home Message

Vertebral body tethering retained significantly more trunk motion regardless of lowest instrumented vertebra compared to posterior spinal fusion for AIS at six months and 2 years post-operative.

Podium Presentations—Basic Science



HDC-AIS. Vertebral Body Tethering Compared to the Gold Standard Spinal Fusion: Matched Analysis 2 Years Post-operatively

Lily Q. Eaker, BA; Jonathan S. Markowitz, MD; *Baron Lonner, MD*

Summary
25 patients who underwent vertebral body tethering (VBT) were compared to 25 curve- and age-matched patients who underwent posterior spinal fusion (PSF) by a single surgeon. VBT patients had significantly less blood loss, while operative time and number of levels instrumented did not differ. No differences were found in major or minor curve correction and SRS-22 outcomes between groups. There were 2 major complications in the PSF group and 0 in the VBT although cord breakage occurred in 3 patients.

Hypothesis
VBT and PSF have comparable clinical, radiographic, and SRS-22 outcomes.

Design
Retrospective, matched pairs analysis

Introduction
VBT is a motion-sparing alternative to spinal arthrodesis for correction of AIS. There is a paucity of data comparing outcomes of VBT with the gold standard PSF. We planned to compare outcomes of the two procedures.

Methods
50 consecutive patients with AIS treated by a single surgeon with VBT or PSF were matched by Lenke type, major curve ±8º, age ± 1year, and T5-T12 kyphosis ± 10º. Radiographic (Major curve measured by the Cobb method), clinical, and SRS-22 outcomes were assessed at 2 YR FU. Continuous variables were compared using student t-tests and categorical variables were compared using chi-square.

Results
Patients in each group had similar baseline characteristics (Table). In the VBT group there were 6 thoracic (T) tethers, 7 thoracolumbar (TL), and 12 both. Major curve correction was similar (p=0.0506), however, TL major curve correction was greater for VBT (p=0.0172). 3-D kyphosis restoration was greater for VBT. There was no difference in T inclinometer improvement (p=0.7440), but TL inclinometer improvement was greater in PSF (p=0.0296). Overall minor curve correction was comparable (p=0.2417); but, T minor curve correction was greater in VBT (p=0.0463), 5/9 had T curve instrumented vs 3/9 in PSF. Operative time (223.5 PSF vs. 191.8 VBT) and number of levels instrumented (8.6 PSF vs. 7.4 VBT) did not differ (p=0.0992 and p=0.1248 respectively). VBT had less EBL than PSF (173.0±83.8 vs 1068.0±740.3, respectively [p<0.0001]). SRS-22 outcomes in all domains were similar at FU (p>0.05). PSF had 2 major complications (1 misplaced screw requiring reoperation; 1 wound infection) and 3 VBT patients had cord breakage with no regional loss of correction at this time.

Conclusion
VBT and PSF patients can expect comparable curve correction at 2 YR FU. No differences in SRS-22 outcomes were found. 2 major complications occurred in the PSF group and there were 3 VBT cord breakages without significant loss of correction.

Take Home Message
Patients who undergo VBT can expect comparable curve correction, clinical outcomes and improved kyphosis restoration to those who undergo PSF without increased complications.

Demographics						
Age						
PSF	13.7±1.1					
VBT	13.8±1.1					
Gender						
PSF	21 F| 4 M					
VBT	21 F| 4 M					
Lenke Curve Type Per Group						
Lenke 1	14					
Lenke 3	1					
Lenke 5	9					
Lenke 6	1					
	Baseline	P-Value	1st Erect	P-Value	2 YR FU	P-Value
Major Curve						
PSF	50.8±5.7	0.7253	20.7±8.0 (59.3±16.3%)	0.5136	24.1±6.4 (56.5±17.5%)	0.0506
VBT	50.2±7.0		18.9±10.7 (63.4±19.2%)		18.8±11.2 (63.1±21.2%)	
Thoracic Major Curve						
PSF	52.4±6.1	0.8662	18.4±6.0	0.1446	22.9±6.7	0.5042
VBT	51.9±7.2		22.9±9.7		20.4±11.8	
Thoracolumbar Major Curve						
PSF	48.9±4.7	0.4513	23.6±9.5	0.0110	26.1±5.9	0.0172
VBT	47.1±5.8		11.9±8.8		15.8±10.1	
Minor Curve						
PSF	37.4±8.3	0.3301	20.6±10.4	0.1894	20.32±10.7	0.2417
VBT	40.0±9.5		16.3±12.0		16.4±12.6	
Thoracic Minor Curve						
PSF	38.4±7.2	0.8914	25.5±10.8	0.1164	25.7±10.6	0.0463
VBT	37.8±11.6		18.0±7.9		16.0±9.4	
Thoracolumbar Minor Curve						
PSF	36.6±9.4	0.1733	16.8±8.6	0.7656	16.1±8.9	0.9019
VBT	41.3±8.2		15.3±13.8		16.6±14.4	
3-D T5-T12 Kyphosis						
PSF	7.6±10.1	0.9288	-	-	20.9±8.2	0.0199
VBT	7.3±11.4		-		27.7±11.4	
Thoracic Inclinometer Measurements						
PSF	13.4±5.6	0.9806	-	-	5.9±2.9	0.7440
VBT	13.3±4.3		-		6.4±3.7	
Thoracolumbar Inclinometer Measurements						
PSF	14.4±5.7	0.8581	-	-	3.0±2.1	0.0296
VBT	14.9±7.3		-		6.0±3.3	

Table. PSF and VBT radiographic and clinical outcomes.

HDC-AIS. Comparative analysis of Post-op Motion between Spinal Fusion and VBT

Firoz Miyanji, MD; Michelle Claire Marks, PT; Amer F. Samdani, MD; Suken A. Shah, MD; Maty Petcharaporn, BS; Tracey P. Bastrom, MA; Peter O. Newton, MD

Summary
Intervertebral motion (IVM) following vertebral body tethering (VBT) is significantly different from spinal fusion (SF). This

difference is highlighted most significantly in the uninstrumented, nonfused levels with significantly greater summed L4-S1 intervertebral motion demonstrated in the fusion group. This increased intervertebral motion below a fusion to maintain flexibility may have implications around degenerative changes over time lending VBT to potentially be an attractive alternative to standard fusion in idiopathic scoliosis.

Hypothesis
IVM in distal uninstrumented, nonfused segments will be greater in patients treated with SF compared to VBT

Design
Cross-sectional comparative cohort

Introduction
Emerging reports of VBT have shown an acceptable safety and efficacy profile; however no clinical studies have evaluated segmental spinal mobility following VBT to determine whether motion is truly preserved. Our aim was to compare postop motion between a cohort of VBT patients and those that had undergone standard SF.

Methods
Segmental spinal motion was assessed by standardized x-rays acquired in maximum right, left and forward bending(FB) for patients treated with either VBT or SF. Patients were matched for LIV and fusion length. An independent observer measured the intervertebral angles via digital x-ray measuring software. FB IVM was measured by adding the static angle on the upright lateral x-ray with the static angle on the FB lateral x-ray. IVM in the coronal plane was measured by adding the static angle on the right bending PA x-ray and the left bending PA x-ray and termed side bending (SB).IVM was measured in unfused segments in the SF group and in instrumented and uninstrumented segments in the VBT group.

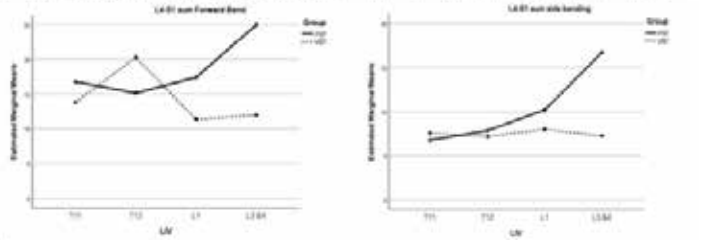
Results
25 VBT patients were matched 1:2 to 50 SF patients with minimum 2 yr f/u. Total FB IVM between the groups was not significantly different(43.6°+/-11.3°SF/43.4°+/-13°VBT;p=0.8);however FB motion of the unfused segments was significantly less in the VBT group compared to SF(31°+/-13.6°vs 39°+/-11.6°;p=0.003) with no LIV interaction(p=0.4).FB IVM from L4-S1 also showed significantly less motion post VBT compared to SF(14.9°+/-6.9°vs17.8°+/-7.9°;p=0.03).VBT total SB IVM showed greater motion than SF(p=0.013) with no difference in SB IVM in the nonfused, uninstrumented segments between groups(0.9).L4-S1 SB IVM showed significantly greater motion post SF(9.5°+/-6.6°) compared to VBT(7.5°+/-3.6°)(p=0.046) and this motion was greater the more distal the LIV.

Conclusion
VBT maintains IVM through the tethered segments allowing for a more even distribution of motion not demonstrated following SF. SF resulted in greater motion through nonfused segments in particular L4 to S1 which may have significant future implications on disc health.

Take Home Message
VBT more uniformly preserves intervertebral motion compared to spinal fusion.

Patient Demographics	VBT	Spinal Fusion(SF)
Age (yrs)	12 +/-1.2	16.1+/-3.5
Sex	4 M; 21 F	2 M; 48 F
Pre-op Major Cobb (°)	57+/-10.2	49.1+/-8.2
Post-op Major Cobb (°)	22.2+/-8.9	20.9+/-7.8
Mean Number Levels Instrumented	9.4 (5-12)	8.4 (5-13)
% Curve Correction	61%	57%
LIV (N)	T11:9; T12:7; L1:5 L3:3; L4:1	T11:18; T12:14; L1:10 L3:6; L4:2

Post-op IVM Motion (°)	FORWARD BEND (FB)		p-value	SIDE BEND (SB)		p-value
	VBT	SF		VBT	SF	
Total	43.4+/-13	43.6+/-11.3	0.8	51.2+/-13.8	42.8+/-12	0.013*
Un-Instrumented Total	31+/-13.6	39+/-11.6	0.003*	38.3+/-14	37+/-12.19	0.9
Summed L4 to S1	14.9+/-6.9	17.8+/-7.9	0.03*	7.5+/-3.6	9.5+/-6.7	0.046*



HDC-Safety. The Patient Demographics, Radiographic Index and Surgical Invasiveness for Mechanical Failure (PRISM) Model Established for Adult Spinal Deformity Surgery

Mitsuru Yagi, MD, PhD; Satoshi Suzuki, MD, PhD; Eijiro Okada, MD, PhD; Satoshi Nori, MD, PhD; Osahiko Tsuji, MD, PhD; Narihito Nagoshi, MD, PhD; Nobuyuki Fujita, MD, PhD; Naobumi Hosogane, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Kota Watanabe, MD, PhD

Summary
Surgical risk stratification for MF following ASD surgery was established base on the combination of demographic, radiographic data and surgical invasiveness. Our risk-stratification scoring model successfully predicted complications MF following ASD surgery using patient demographics and radiographic parameters that would normally be collected routinely when considering surgical treatment for a patient with ASD. This simple, easy-to-read predictive model can help physicians identify patients with a high risk of MF, treat modifiable risk variables, and plan appropriate surgical strategies.

Hypothesis
Risk for mechanical failure (MF) can be predicted with demographic and surgical invasiveness. following adult spinal deformity (ASD) surgery.

Design
Multicenter retrospective case series.

Introduction
Predicting a patient's risk of MF is difficult, despite several potential risk factors have been reported. This study aimed to establish a model for predicting the risk of MF in a retrospective case series.

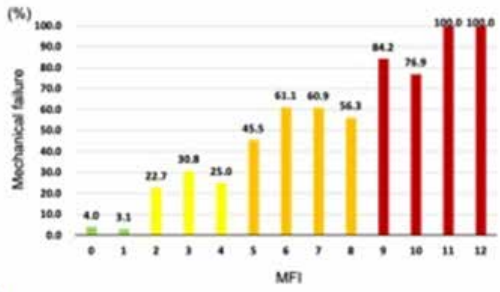
Methods
This study included 257 surgically treated ASDs (2y f/u) from multi-center database (53 ± 18yr, 91%F). Variables which included demographic, radiographic and surgical invasiveness. Logistic regression analysis was performed to identify the independent risk factor for MF. Each risk factor identified was assigned a value based on its regression coefficient, and the values of all risk factors were summed to obtain the PRISM score (range 0–12).

Results
MF developed in 40% (n=104) of the cohort. The BMI, BMD, PT, and frailty were independent risk factors for MF (BMI: OR 1.7[1.0-2.9], BMD: OR 3.8[1.9-7.7], PT: OR 2.6[1.8-3.9], frailty: OR 5.9[1.1-3.2]). PRISM showed good calibration and discrimination in the patient cohort; the complication rate increased with and correlated well with the risk grade using ROC curves and (r2 = .96, AUROC of .81 [95% CI .76–.86]).

Conclusion
We established readily accessible indicators to predict a patient's risk of MF and this model can help surgeons adjust treatment strategies for high-risk patients.

Take Home Message
Easy-to-read risk-stratification model can help physicians identify patients with a high risk of mechanical failure, treat modifiable risk variables, and plan appropriate surgical strategies for ASD surgery.

	B regression coefficient	SE	Score	Categories
PT				
<20°			0	Total score: 0-1 Low risk
20-30°	1.53	0.40	2	
>30°	2.51	0.39	3	
BMD (T-score)				
>= -1.5			0	Total score: 2-4 Moderate
< -1.5	1.51	0.31	2	
BMI				
<18.5kg/m²			0	Total score: 5-8 high
18.5-25kg/m²	0.95	0.35	1	
>25kg/m²	1.87	0.46	2	
LIV				
L5 and above			0	Total score: 8-12 Very high
Pelvis)	1.69	0.28	2	
Frailty				
Robust			0	
Prefrail	1.49	0.30	1	
Frail	2.08	0.60	2	
Age				
< 60yrs			0	
>= 60yrs			1	
MFI: 0 - 12				
PT (0, 2, 3)+BMD (0, 2)+BMI (0, 2)+LIV (0, 2)+Frailty (0, 1, 2)+ Age (0, 1)				



PRISM and MF rate according to the PRISM score

HDC-Safety. Artificial Intelligence Clustering of Adult Spinal Deformity Morphology Predicts Surgical Characteristics, Alignment, and Outcomes

Wesley M. Durand, BS; Renaud Lafage, MS; D. Kojo Hamilton, MD; Peter G. Passias, MD; Han Jo Kim, MD; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Jeffrey L. Gum, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Khaled M. Kebaish, MD; Alex Soroceanu, MPH; Richard Hostin, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; Robert A. Hart, MD; Alan H. Daniels, MD; International Spine Study Group

Summary
This study developed a model that clustered pre-operative lateral radiographs of ASD patients into clinically meaningful groups with highly distinct spinal morphology, predicting alignment, surgical characteristics, HRQOL, and PJK/PJF risk.

Hypothesis
A neural-network-based artificial intelligence (AI) algorithm would cluster preop lateral radiographs of into groups with distinct morphology

Design
Retrospective

Introduction
AI algorithms have shown substantial promise in medical image analysis. Previous studies of ASD clusters have analyzed alignment metrics – this study sought to complement these efforts by directly analyzing images of anatomical landmarks

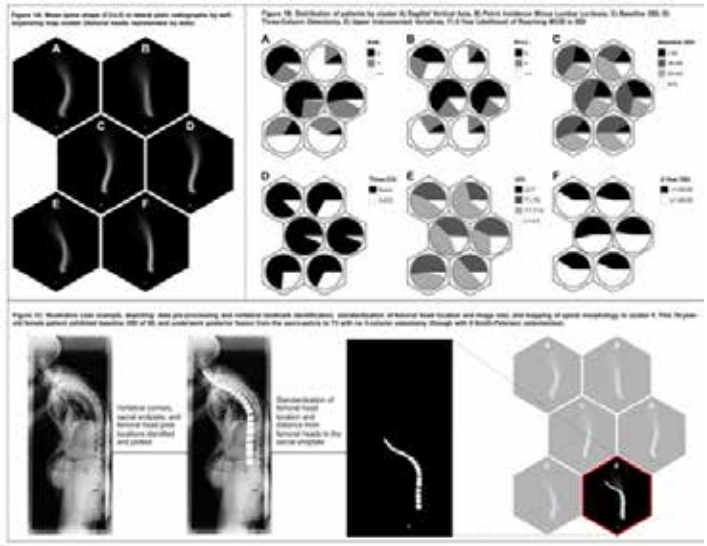
Methods
Vertebral locations for C3-L5, sacral endplate, and femoral heads were measured on lateral radiographs. Pixel locations were used to create a black-and-white overlay to the image, which was subsequently standardized for size and position using the femoral heads and sacral endplate. These images were used to train a self-organizing map (SOM). SOMs are a form of artificial neural network frequently employed in unsupervised classification tasks

Results
In total, 915 preop lateral radiographs were analyzed. A 2x3, toroidal SOM was trained. The mean spine shape was plotted for each cluster. (Fig1A) Alignment, surgical characteristics, and outcomes were compared between clusters. (Fig1B) Clusters C and D exhibited a particularly high proportion of patients with optimal (i.e., modifier 0) values of PI-LL (65.0% and 68.5%) and SVA (72.8% and 53.1%). Conversely, clusters B, E, and F tended to have poor (i.e., modifier ++) PI-LL (74.8%, 66.9%, and 74.6%) and SVA (75.5%, 48.6%, and 58.7%). 3-CO was most common among cluster A (26.8%), cluster B (32.6%), and cluster F (32.7%). UIV at T7-T12 was most common among cluster B (51.1%) and cluster F (60.3%). ODI <30 was most prevalent among cluster D (31.4%). There was little difference between groups in likelihood of reaching MCID in ODI at 2yr follow-up. PJK and PJF were

particularly prevalent among clusters A (51.2% and 15.5%) and E (50.4% and 18.7%)

Conclusion
This study developed a self-organizing map that clustered preop lateral radiographs of ASD patients into groups with highly distinct overall spinal morphology. These clusters predicted alignment, surgical characteristics, and HRQOL. Further studies of this classification approach will expand to compare pre and postop radiographs

Take Home Message
A neural-network-based algorithm clustered preoperative lateral radiographs of ASD patients into clinically meaningful groups with highly distinct spinal morphology.



HDC-Safety. Enhanced Perioperative Protocols Can Improve Infection Outcomes in Adult Spinal Deformity (ASD) Surgery

Suzanne E. Kent, BS; Daniel Kent ; Brian Hollenbeck, MD; Samuel Golenbock, MS; Stephen Camer, MD; *Frank Rand, MD*

Summary
Despite complex procedures in a population with many risk factors for surgical site infections, our study demonstrates exceptional infection outcomes, with only three superficial infections and zero deep infections over 5 years. This study demonstrates that traditional risk factors for post-operative infection, including advanced age, long surgical duration, high invasiveness index, smoking and diabetes can all be safely mitigated by following enhanced perioperative protocols for infection prevention.

Hypothesis
A high surgical invasiveness index (SII) score does not predict more infections in ASD surgery when utilizing enhanced perioperative procedures.

Design
Retrospective study to evaluate a population of ASD fusion patients over a five-year span for various surgical site infection risk factors. Determine the standard infection ratio (SIR) and utilize this number to assess if a high surgical invasiveness index (SII) score predicts more infections in ASD surgery and report perioperative protocols.

Introduction
Adult spinal deformity (ASD) surgery can lead to more complications such as infection than other spine procedures due to long operation times and complex multilevel instrumentation. Increasing surgical invasiveness index (SII), a measurement of procedural factors, has been shown to correlate with increasing risk of complication including surgical site infection.

Methods
We conducted a retrospective chart review of spine fusion procedures performed by an adult spinal deformity surgeon from 2013-2017. The number of predicted infections was calculated using procedure-specific models designed by the National Healthcare Safety Network (NHSN) and SIR was calculated. The specific enhanced perioperative protocol used during procedures is additionally described.

Results
349 ASD procedures were assessed. Average age was 64.4, 72% were female, and patients were mostly white (99%). 142 were primary fusion and 207 were revision fusions. The average SII was 18.7. Observed incidence of SSI was 0.7% among primary fusions (n=1) and 1.0% among revisions (n=2). All 3 infections were superficial incisional infections, No deep or organ/space infections occurred over this 5-year timeframe. Risk adjustment models predicted 22.7 total surgical site infections (6.5%) and the overall SIR was 0.132.

Conclusion
Despite an average SII score of 18.7 over 349 procedures, only three superficial infections and no deep or organ/space infections occurred. Traditional risk factors such as surgical duration, SII, smoking, and advanced age did not increase risk of infection in this cohort.

Take Home Message
Multilevel ASD fusion surgery can be performed with very low infection rates when following enhanced perioperative infection prevention protocols.

Perioperative protocol

Podium Presentations—Basic Science

HDC-Safety. The Impact of Metabolic Disorders of Bone Mineralization on Long Term Outcomes Following Surgery for Adult Spinal Deformity Surgery: Analysis of 2-year Surveillance

Bassel G. Diebo, MD; George A. Beyer, MS; Alexander Rompala, BS; Neil V. Shah, MD, MS; Adam J. Wolfert, BS; Frank A. Segreto, BS; Salem Najjar, BA; Peter G. Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Carl B. Paulino, MD

Summary
Adult spinal deformity (ASD) patients with metabolic bone mineralization disorders (MBDs) experienced higher rates of postoperative 2-year complications than patients without MBD.

Hypothesis
ASD patients with MBDs have comparable rates of outcomes following PSF

Design
Retrospective cohort

Introduction
MBDs are well established risk factors for spinal fusion. MBDs and ASD (ASD) are two highly prevalent disorders in the aging population. Long-term clinical outcomes in patients with MBD undergoing long spinal fusions for ASD are not well reported. This study addresses whether patients with MBD undergoing ASD surgery had higher rates of 2-yr postop complications.

Methods
ASD pts undergoing ≥4-level fusion with ≥2-year surveillance were selected from New York State Statewide Planning and Research Cooperative System (SPARCS). Patients were grouped by codes for the following MBDs (vitamin D deficiency, hyperparathyroidism, osteomalacia, and, rickets) and were compared patients without MBDs. Pts with osteoporosis or systemic/endocrine disorders affecting bone quality were excluded. Patients with traumatic/infection/neoplastic reoperations were compared. Logistic regression was used to identify independent predictors of complications.

Results
6,132 patients (MBD, n=117 (1.95%); no-MBD, n=6,015) were identified. MBD patients and no-MBD patients had comparable ages (59.6 years vs. 57.6 years) and sex (53.8% F vs. 49.1% F). MBD patients had similar charges ($111,644 vs. $109,744) and length of stay (0.98 days vs. 0.62 days) to no-MBD patients. Deyo index at was greater in the MBD pts (0.98 vs 0.62, p<0.001). MBD pts had higher rates of renal failure (17.9% vs. 8.10%), DVT (7.70% vs. 2.90%), transfusion (50.4 vs. 35.9%) and MI (7.70% vs. 2.60%); all p≤0.01. Both cohorts had similar rates of wound complications, pseudarthrosis, PE, pneumonia, UTI, and implant related complications. MBDs predicted 2-Year medical complications (OR=1.76) and reoperations (OR=1.88).

Conclusion
ASD patients with MBD experienced higher rates of postoperative 2-year complications than patients without MBD. MBD was independently associated with increased postoperative medical complications and reoperations. Patients with MBD necessitate further pre-operative planning prior to ASD surgery.

Take Home Message
These data underscore the need for further pre-op planning for patients with metabolic bone diseases undergoing corrective surgery for adult spinal deformity.

HDC-Safety. Not So Sweet: Determining Hemoglobin A1C Cutoffs in Diabetic Patients Prior to Posterior Spinal Fusion

Nicholas A. O'Malley, BS; Charmie Mehta, BS; Eaman Balouch, MD, PhD; Carolyn Stickley, BS; Jack R. Zhong, BS; Carlos Leon, BE; Constance Maglaras, PhD; *Aaron J. Buckland, MBBS, FRCSA*

Summary
Diabetic patients are at higher risk of developing complications after surgery than their non-diabetic peers. This is especially true of wound complications (WC), including wound infections (WI). This study demonstrates that preoperative Hemoglobin A1C (HbA1C) is a strong independent predictor of WC for HbA1C above 6.65% and WI above 7.95% in the perioperative period.

Hypothesis
Diabetics with higher preoperative HbA1C levels will have higher rates of WC and WI above a determinable threshold.

Design
Single-center retrospective cohort study

Introduction
Patients with high HbA1Cs are at increased risk for a number of comorbidities perioperatively, especially wound complications.

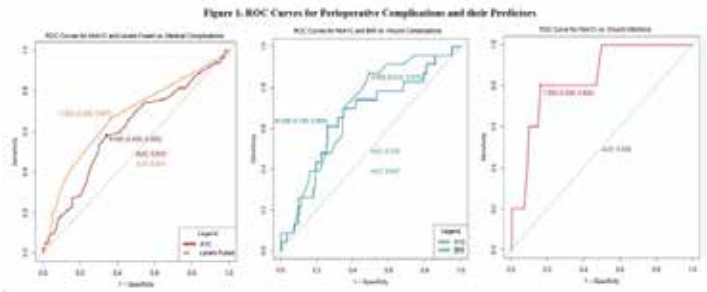
Methods
Patients diagnosed with DM who underwent thoracic, lumbar, or thoracolumbar posterior spinal fusion (PSF) from 2013-2018 with preoperative HbA1C values. WC were defined as dehiscence, infection, or seroma requiring aspiration. Excluded: Patients without preoperative HbA1C and cervical fusion surgeries. Significant complications were determined using t-test and chi-square analyses. Complications were tested against confounding factors using binary logistic regressions. Efficacy of HbA1C as a biomarker for complication was determined using Receiver Operating Characteristic (ROC) analyses. Cutoff points were calculated by Youden's index. Significance set at p<0.05.

Results
Patient population: 227 patients. Age, CCI, gender, and smoking status were not significant. Mean HbA1C (7.3±1.43, p=0.006) and levels fused (3.80±3.79,p<.001) were higher in those with medical complications. HbA1C (OR:1.487[1.166-1.898],p=.001) and levels fused (OR:1.204[1.093-1.326],p<.001) were independent predictors of these complications. Patients who developed WC had significantly higher HbA1C (7.85±1.79, p<.001) and BMI (35.29±7.24,p=0.013). Both HbA1C (OR:1.487[1.166-1.898],p<.001) and BMI (OR:1.105[1.029-1.187],p=0.006) independently predicted this complication subset. Patients who acquired WI had significantly higher HbA1C (8.96±2.32,p<.001)

than non-infected. Only HbA1C (OR:2.217[1.227-4.005],p<.001) independently predicted WI. ROC analyses demonstrated poor performance in predicting medical complications (AUC=0.610[0.523-0.688]), and good performance in predicting WC (AUC= 0.702[0.599-.805]) and WI (AUC=0.836[0.669-1.00]). WC cutoff point was HbA1C 6.65% (Spec:51.0%,Sens:87.0%) and WI cutoff point was HbA1C 7.95% (Spec:83.8%, Sens:80.0%).

Conclusion
Above HbA1C 6.65% and 7.95% patients with DM are at increased risk of WC and WI, respectively.

Take Home Message
Diabetic patients with elevated HbA1C are at increased risk of wound complications. Diabetic patients undergoing PSF should be encouraged to lower their HbA1C to below 6.65% before surgery, if possible.



HDC-Safety. Complication Rate in Obese vs Non-obese Patients Undergoing Minimally Invasive Surgery for Correction of Adult Spinal Deformity: Evaluation of 2 Year Prospective Data

Richard G. Fessler, MD; Kai-Ming Gregory Fu, MD; Paul Park, MD; Dean Chou, MD; Robert K. Eastlack, MD; Gregory M. Mundis, MD; Khoi D. Than, MD; Neel Anand, MD; David O. Okonkwo, MD; Michael Y. Wang, MD; Adam S. Kanter, MD; Pierce D. Nunley, MD; Praveen V. Mummaneni, MD; International Spine Study Group

Summary
Previous research on the complication rate in obese adult patients undergoing minimally invasive surgery for correction of deformity has yielded mixed results, with some publications suggesting increased rates of complications and others suggesting the opposite. However, these reports have been limited in their validity due to their retrospective design. This study prospectively evaluated the complication rate in obese and non-obese patients undergoing MIS surgery with minimum of 2 year follow up.

Hypothesis
Patients with obesity have a higher rate of complications with MIS surgery

Design
Multicenter prospective evaluation of an adult spinal deformity database.

Introduction
Previous research on the complication rate in obese adult patients undergoing minimally invasive surgery for correction of deformity has yielded mixed results, with some publications suggesting increased rates of complications and others suggesting the opposite. However, these reports have been limited in their validity due to their retrospective design. This study prospectively evaluated the complication rate in obese and non-obese patients undergoing MIS surgery with minimum of 2 year follow up.

Methods
A total of 106 patients were included: BMI < 35 = 86; BMI ≥ 35 = 20. Demographic and prospectively collected complications were assessed. An obesity threshold BMI of 35 was selected to accurately reflect common surgical practices. A prospectively collected database was analyzed using paired t-test ($p < .05$) for continuous variables and Chi-Square analysis for categorical variables.

Results
There were no significant differences in age, sex or number of levels fused between the obese and non-obese patients. Implant complications were significantly higher in the obese group ($p < .007$) compared to the non-obese group. Correlated to this, the re-operative rate approached significance as well ($p < .085$). There were no significant differences in any of the other variables, including major or minor complications, cardiac, gastrointestinal, infection, neurologic, renal, wound, operative, radiographic, or overall complication rate.

Conclusion
In this prospectively collected data base, there were no significant differences in complication rates between obese and non-obese patients undergoing MIS correction of adult deformity on any measure, except those related to the implant.

Take Home Message
With the exception of implant complications, MIS surgery results in a similar level of complications in both the obese and non-obese.

HDC-Safety. High Radiation Burden of Minimally Invasive Approaches for Adult Spinal Deformity

Jakub Godzik, MD; Gregory M. Mundis, MD; Jay D. Turner, MD; Juan S. S. Uribe, MD; Robert K. Eastlack, MD

Summary
Minimally invasive (MIS) techniques for deformity correction are growing in popularity. While efficacious and well-tolerated by patients, the occupational hazard resulting from dependence on x-ray technology has never previously been evaluated. The current study investigated the radiation emission associated with complex deformity correction using MIS techniques, along with factors associated with increased x-ray utilization. Our results demonstrate significant radiation emission, irrespective of surgical and demographic factors. This study highlights the occupational risk associated with MIS approaches to adult spinal deformity.

Hypothesis
Increased radiographic complexity of deformity would be associated with greater radiation emission.

Design
Retrospective analysis of prospectively collected data

Introduction
Minimally invasive spine surgery relies on image guidance, including intraoperative fluoroscopy. As such, the subject of radiation exposure to the patient and surgeon is of concern. We aimed to quantify the total radiation emission with circumferential minimally invasive deformity surgery (cMIS) for adult spinal deformity (ASD), and identify factors associated with increased radiation.

Methods
Patients with ASD from two institutions undergoing cMIS were identified using a prospectively collected database. Inclusion criteria were: coronal cobb ≥20°, pelvic incidence – lumbar lordosis >10°, sagittal vertical axis ≥5cm, pelvic tilt≥25°, or thoracic kyphosis≥60°, undergoing cMIS with more ≥3 intervertebral levels fused, and use of percutaneous screws. Fluoroscopy time and mGy for all patients undergoing cMIS was abstracted from the medical records; emission data were compared to risk thresholds based published by the US Nuclear Commission (5 mGy).

Results
52 patients underwent cMIS deformity correction. Average age was 70±9 years, 41% were female with average BMI 29.4±5.4 and bone mineral density T-score of 1.4±0.6 (spine). Mean preoperative SVA was 9±12cm, with preoperative PI-LL of 14±14°. On average, patients underwent a 5±1 level fusion, with 3±1 levels of lateral interbody fusion (LLIF); 40% of cases were revisions. Mean total fluoroscopic time was 223±155 seconds, with mean radiation emission of 179±191 mGy (33-1038mGy); the average emission dose exceeded the annual risk threshold 36 times. Radiation dose was not associated with age (p=0.81), number of levels (p=0.37), number of LLIF's (p=0.9), sagittal imbalance (p=0.09), and coronal imbalance (p=0.05). The greatest association was with spine T-score (p=0.004).

Conclusion
Given the high dose of radiation emission during MIS deformity correction, measures need to be taken to minimize exposure to the patient and surgeon. It is imperative that we consider and investigate strategies to reduce the radiation burden in the setting of MIS deformity treatment.

Take Home Message
Radiation burden associated with minimally invasive approaches to spinal deformity correction is high. Strategies for radiation monitoring and commensurate radiation reduction are paramount to reduce occupational risk of such procedures.

HDC-Safety. 3D Printed Spine Model Improves the Efficiency and Safety of the Severe Congenital Spine Deformity Correction Surgery

Yong Hai, MD, PhD; Hongtao Ding, MS; *Aixing Pan, MD, PhD*

Summary
Severe congenital spine deformity cases underwent posterior correction surgery under the assist of spine model 3D printing technology are reviewed. The results show 3D printed spine model guided correction surgery is safer and more efficiently in the management of severe congenital spine deformity than surgery without the assist of model 3D printed model.

Hypothesis
We suppose that 3D printed spine model plays a significant role in the severe congenital spine deformity correction surgery.

Design
Retrospective cohort study using propensity score matching (PSM) analysis.

Introduction
3D printing technology is increasingly used in the medical field, especially in surgery. The aim of this study is to evaluate the role of 3-dimensional (3D) printed spine model in the severe congenital spine deformity correction surgery.

Methods
Thirty-five severe congenital spine deformity cases underwent posterior correction surgery with the assist of spine model 3D printing technology are reviewed (3D printing group). Thirty-five deformity cases managed without the 3D printing assistance during the same period are selected as the control group after one-to-one propensity score matching. The correction rate, pedicle screw accuracy and perioperative complications are analyzed between the groups.

Results
A total of 10 males and 25 females are enrolled in the 3D printing group with the average age of 25.37±11.06 years old. In the control group, there are 9 males and 16 females with the average age of 26.14±8.73 years old. The pre-op and surgical baseline data are similar between the two groups. The operation time is shorter and blood loss is less in the 3D printing group (P<0.05). 366 pedicle screws were inserted in the 3D printing group, among which there are 366 grade A (62.89%), 56 grade B (9.62%), 82 grade C(14.09%), 44 grade D (7.56%), and 4 grade E (0.69%), according to the criteria of Gertzbein and Robbins. The total pedicle screw accuracy is 422/582 (72.51%). In the control group, a total of 575 screws were placed, grade A (57.04%), grade B (12.00%), grade C (18.61%), grade D (10.78%), and grade E (1.57%). The pedicle screw accuracy is 397/575(69.04%). The classification difference of screw placement accuracy is statistically significant between the groups (P=0.02). There is no significant difference between the screw related complication rate (3/35 vs. 5/35, P=0.45).

Conclusion
3D printed spine model guided correction surgery is safer and

more efficiently in the management of severe congenital spine deformity.

Take Home Message

3D printed spine model guided correction surgery is safer and more efficiently in the management of severe congenital spine deformity.

General data

		3D Model Group	Freehand Group		p
Gender (Male: Female)		10:25	9:26	U/595.00 (Man-Whitney)	0.790
Age		25.37±11.06	26.14±8.73	-0.32	0.747
Diagnosis	ADIS	11	13	0.25	0.615
	CS	14	15	0.06	0.808
	NF	6	5	0.11	0.743
	NM	4	2	0.73	0.393
	ADIS:CS:NF:NM	11:14:6:4	13:15:5:2	0.96	0.811

Figure 1

HDC-Safety. Power-Assisted Pedicle Screw Technique Protects Against Risk of Surgeon Overuse Injury: A Real-Time EMG Study

David L. Skaggs, MD; Amy A. Claeson, PhD; Frank J. Schwab, MD; Anup A. Gandhi, PhD

Summary

Use of power-assisted tools may relieve spine surgeons of musculoskeletal burden, but to what extent? EMG records muscle exertion during all steps of manual and powered pedicle cannulation and screw placement; exertion is normalized by the maximum voluntary isometric contraction of each muscle group. Exertion >20% MVIC increases risk of overuse injury. Powered technique protects against overuse injury as exertion remains <20% MVIC between 93% and 100% of the procedure's time.

Hypothesis

Powered technique protects against risk of overuse injury.

Design

Cadaver study

Introduction

An SRS member survey reports rates of neck pain, rotator cuff disease, lateral epicondylitis, and cervical radiculopathy at 3, 5, 10 and 100x greater than the general population. We record real-time muscle exertion from pedicle cannulation to screw insertion using manual and powered technique and compare data to literature linking exertion to risk of overuse injury.

Methods

Pedicle preparation and screw placement was performed bilaterally from T4-L5 in four torsos by two spine surgeons. Manual technique included pedicle tract development with a Lenke probe, undertapping by Ø1.0mm, and placing Ø5.5mm pedicle screws; powered technique used a Ø2.4mm drill bit, Ø3.2mm reamer probe, and Ø5.5mm screws. EMG recorded muscle activity from the flexor carpi radialis (FCR), extensor carpi radialis (ECR), biceps, triceps, and deltoid. Exertion for each muscle group was normalized by its respective MVIC. MVIC was categorized with regards to risk of overuse injury from literature: low- (0-20%), medium- (20-45%), high- (45-70%), and maximum-risk (70-100%). Histograms determined how long each muscle group was active in each range. Multiple paired t-tests assessed differences in duration of low-risk exertion between techniques. Significance $p<0.05$.

Results

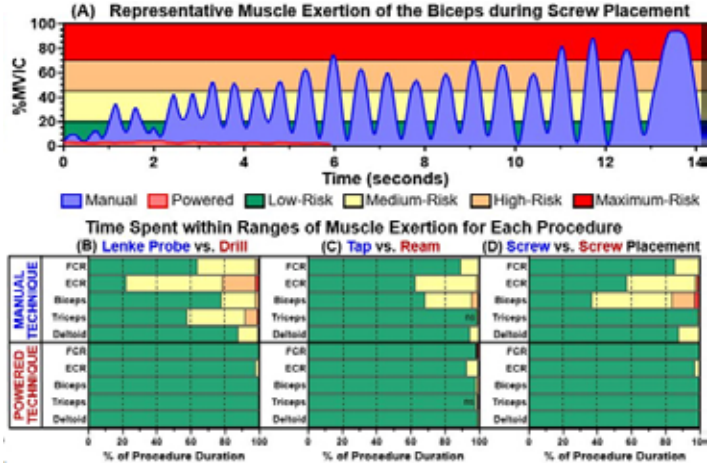
Manual technique requires more effort than powered as significantly less time is spent at low-risk muscle exertions ($p<0.05$). Manual technique is demanding of the ECR, operating above low-risk exertion between 37% and 78% of procedure time. Even after cannulation and tapping, the biceps operate above the low-risk range while placing screws for 63% of the procedure, 3% of which is at maximum-risk. At most, 7% of any procedure time is at medium-risk with powered technique, a 91% decrease from manual.

Conclusion

Power-assisted tools protect against risk of overuse injury; their use maintains surgeons' muscle exertion <20% MVIC between 93% and 100% of procedure time. Maximum-risk exertions appear in the ECR and biceps with manual technique; these high amplitude, short duration exposures could further induce sudden onset elbow injury.

Take Home Message

Surgeons are at risk of overuse injury; power-assisted technique for pedicle preparation and screw placement is protective.



200. Impact of Body Mass Index on Outcomes and Cervical Alignment Following Posterior Cervical Fusion Surgery

Nida Fatima, MD

Summary
Posterior cervical fusion surgery for DCSD is safe and effective for patients regardless of BMI.

Hypothesis
To evaluate the impact of BMI on postoperative neurological and radiographic cervical alignment outcomes following posterior fusion surgery for degenerative cervical spine disease (DCSD).

Design
Retrospective

Introduction
With the increasing prevalence of obesity, there is a need to understand the impact of body mass index (BMI) on spine surgery outcomes

Methods
Patients were categorized into 4 groups based upon the BMI as (i) normal weight (<25.0 kg/m2, 28.6%), (ii) overweight (25.0-29.9 kg/m2, 46.2%), (iii) obese I (30.0-34.9 kg/m2, 19.7%), and (iv) obese II-III (≥35 kg/m2, 5.6%). For each BMI cohort, univariable association with postoperative outcomes were first determined using logistic regression, and a predictive model was then constructed using all characteristics significant at the 0.10 alpha level. All associations were reported as odds ratio (OR) with 95% confidence interval (CI).

Results
Overall no significant association existed between BMI and postoperative neurological outcomes and complications (p<0.05). However, multivariable regression analysis revealed that obese I patients had a 2.9-folds higher likelihood of postoperative C2-C7 Sagittal Vertical Axis (SVA) >40 mm (OR: 2.96, 95%CI: 1.36-6.44, p=0.006) and 2.2-folds higher risk of T1 slope minus C2-C7 lordosis (T1S-CL) ≥25◦ (OR: 2.24, 95%CI: 0.96-5.24, p=0.06) at last follow-up evaluation. Furthermore, patients under BMI<25.0 kg/m2 had 62% and 63% less likelihood of postoperative C2-C7 SVA >40 mm (OR: 0.38, 95%CI: 0.17-0.88, p=0.02) and T1S-CL ≥25◦ (OR: 0.37, 95%CI: 0.13-1.02, p=0.05) at the last follow-up respectively.

Conclusion
Our results corroborate that regardless of BMI, patients should be counseled to expect the comparable rate of complications and neurological improvement following surgery. However, patients with higher BMI should expect comparable derangement in their cervical radiographic alignment.

Take Home Message
Posterior cervical fusion surgery for DCSD is safe and effective for patients regardless of BMI.

201. The Effect of Lordotic Angle of Cages on Sagittal Balance in Patients Who Underwent 1- or 2-level Posterior Lumbar Interbody Fusion

Jae Hwan Cho, MD, PhD; Chang Ju Hwang, MD, PhD; Jae Woo Park, MD; Dong-Ho Lee, MD, PhD; Choon Sung Lee, MD, PhD

Summary
There are no differences in postoperative sagittal alignment following posterior lumbar interbody fusion (PLIF) between 4° and 8° cages. Improvement of sagittal parameters was not expected in cases of the involvement of L5-S1 even with the use of 8° cages. So, it should be cautious to use PLIF at the L5-S1 level because the aggravation of sagittal alignment could be caused.

Hypothesis
Sagittal alignment might be better with the use of more lordotic cages following PLIF

Design
Retrospective comparative study

Introduction
There have been few studies to address the effect of lordotic angle of cages on sagittal balance in patients who underwent PLIF. The aim of this study was to reveal the effect of lordotic angle of cages on sagittal alignment in patients who underwent PLIF.

Methods
Patients who underwent 1- or 2-level PLIF were included (n=298). These patients were divided into 2 groups by the lordotic angle of cages (4°, n=224; 8°, n=74). Various sagittal parameters were measured. ODI and EQ-5D were used as clinical parameters. These parameters were compared statistically. Subgroup analyses were conducted by the number of fused segments and by the involvement of L5-S1.

Results
All clinical parameters improved postoperatively, but no differences were found between the 2 groups. Although all regional (segmental angle[SA], LL) and global (C7-S1 SVA, PI-LL) sagittal parameters improved postoperatively, there were also no differences between 2 groups. In addition, the lordotic angle of cages did not cause any differences in sagittal alignment even in 2-level PLIF cases. However, SA aggravated postoperatively (18.8° to 16.3°, P=0.051) and LL, C7-S1 SVA, PI-LL showed no improvement in cases involving L5-S1 with 4° cages. Sagittal parameters did not improve postoperatively even with 8° cages (P>0.05) in those cases.

Conclusion
There were no differences in clinical and radiological outcomes by the lordotic angle of cages. Improvement of sagittal parameters was not expected in cases of the involvement of L5-S1 even with the use of 8° cages. So, it should be cautious to use PLIF at the L5-S1 level because of possible aggravation of sagittal alignment.

Take Home Message
Surgeons should be cautious when they performed PLIF at the L5-S1 level because sagittal alignment could be aggravated even with 8° cages.

202. What Financial Incentives are Created by our Current Reimbursement System for the Use of Traditional versus Magnetic Growing Rods?

John L. Valentino, BS; Jacob Neary, BS; R. Carter Clement, MBA

Summary
This study identified conflicting financial incentives for providers versus patients created by the current reimbursement environment.

Hypothesis
We hypothesized that the current reimbursement system for the two treatment options considered of similar efficacy and cost for early onset scoliosis (EOS), magnetically-controlled growing rods (MCGR) and traditional growing rods (TGR), might create misaligned financial incentives between patients and providers.

Design
Economic Financial Incentive Analysis

Introduction
Typical cost-analysis studies attempt to analyze financial differences in current treatment practices from multiple healthcare perspectives but fail to give insight on the incentives created for each stakeholder.

Methods
The financial incentive of hospitals, surgeons, and device companies were estimated using Medicare fee schedules and current published literature. Patient and insurance company incentive was estimated by modeling an annual insurance deductible of $3000 plus a 20% co-insurance with a maximum out-of-pocket payment of $8000.

Results
TGR treatment positively impacts both hospital and surgeon contribution margins by $101,410 and $5,738 respectively. Hospital reimbursement variation is due to a $3441 per TGR lengthening reimbursement and a significant decrease in implant cost (MCGR: $35,000 | TGR: $1500). $961/lengthening for TGR vs $176/lengthening for MCGR is the main variant in surgeon reimbursement. The patient experiences an out-of-pocket expense of $11,145.20 more with TGR treatment. The 3rd-party payer experiences a loss of $29,002.80 more with TGR treatment.

Conclusion
Physicians and hospitals have a very strong financial bias toward TGR use, while MCGR are favorable from a patient perspective. To optimize outcomes, a healthcare reimbursement system should align the incentives of providers and patients, rather than potentially encouraging doctors and hospitals to pursue care that patients do not prefer. A handful of potential solutions exist, such as paying physicians to manage a specific disease over a long period of time rather than for each intervention, but this approach requires robust risk adjustment to avoid other adverse incentives such as “cherry picking” and withholding care.

Take Home Message
Current financial incentives for the treatment of early onset scoliosis favor traditional growing rod use over magnetically-controlled growing rods at the expense of the patient and insurance companies.

Table 1. Financial Differences in Treatments for Providers

		TGR	MCGR
Surgeon	Initial Implant	+ $2476	+ $2476
	Lengthening (TGR:10 | MCGR:22)	+ $961	+ $176
	Exchange	+ $1629	+ $1629
	Removal & Final Fusion	+ $3861	+ $3861
	Difference	+ $5738	
Hospital		TGR	MCGR
	Initial Implant	+ $32106	+ $32106
	Lengthening (TGR:10 | MCGR:22)	+ $3441	-
	Exchange	+ $11066	+$11066
	Removal & Final Fusion	+ $32106	+ $32106
	Difference	+ $101410	

TGR: Traditional Growing Rods
MCGR: Magnetically-Controlled Growing Rods
Assumption: Average of 10 lengthening surgeries for TGR & 22 clinic lengthening visits for MCGR.

Table 2. Annual Financial Impact for Patients and Payers

		TGR	MCGR
Patient	Year 1	- $8000	- $8000
	Year 2	- $4160.80	- $704
	Year 3	- $5819.40	- $5044.60
	Year 4	- $4160.80	- $704
	Year 5	- $4160.80	- $704
	Year 6	- $8000	- $8000
	Difference	- $11145.20	
Payer		TGR	MCGR
	Year 1	- $30984	- $27110
	Year 2	- $4643.20	-
	Year 3	- $11277.60	- $8178.4
	Year 4	- $4643.20	-
	Year 5	- $4643.20	-
	Year 6	- $36771	- $28671
	Difference	-$29002.80	

203. Is it Safe to Stop at C7 During Multi-Level Posterior Cervical Decompression and Fusion? - Multi-Center Analysis

Eeric Truumees, MD; Devender Singh, PhD; William F. Lavelle, MD; Ron I. Riesenburger, MD; *Matthew Geck, MD*; Swamy Kurra, MD; Anthony Yu, MS; Daniel Grits, BS; Thomas Mroz, MD; Robert Winkelman, MS; John Stokes, MD

Summary
Due to paucity of data in the literature, the advantages of routine extension of posterior cervical fusions into the thoracic spine remains unclear.

Hypothesis
Extension of posterior cervical fusions into the upper thoracic spine improved clinical outcomes while decreasing kyphosis.

Design
Analysis of routinely collected data

Introduction
We aimed to investigate if it is safe to stop at C7 in patients undergoing multi-level posterior cervical decompression and fusion.

Methods
Analysis of multicenter radiographic and clinical databases of patients that had undergone a three or more-level posterior cervical fusion. Patients were divided into three groups: Group I (fusion terminating at C6), Group II (fusion terminating at C7), Group III (fusion extending into the thoracic spine).

Results
Group I contained 80 patients, Group II (n=88) and Group III (n=96). Mean estimated blood loss (EBL), operative time (OR) and length of hospital stay (LOS) were significantly higher in Group III. Mean cervical lordosis at two years post-operative (post-op) improved in all groups. Similarly, there were no significant differences in change for mean C2-C7 sagittal plumbline and T1 slope (2 wk. vs. 2-year post-op) between the three groups. Rate of revision was not clinically or statistically significantly different between the groups. The majority of the revision surgeries occurred between two to five years post-op. Groups I and II

had greater number of subjacent degeneration/spondylolisthesis compared to Group III. There were significant improvements in mean clinical outcomes (i.e. visual analog scale and oswestry disability index) at two years post-op in the three groups.

Conclusion
All groups had similar clinical and radiographic outcomes and comparable revision rates. Higher EBL, OR and LOS in group III suggest that, absent focal C7-T1 pathology, extension of posterior cervical fusions into the thoracic spine may not be necessary. Extension of posterior cervical fusions into the thoracic spine may be recommended for higher risk patients with limitations to strong C7 bone anchorage. In others, it is safe to stop at C7.

Take Home Message
It is safe to stop at C7 during multi-level posterior cervical decompression and fusion surgery.

204. Surgical Treatment for Cervical Kyphosis in Children

Ziming Yao, PhD; Chengxin Li, PhD; Xuejun Zhang, MD

Summary
In this study, we investigated surgical outcomes and complications of cervical kyphosis in patients under age 16 years. The results indicated that both anterior approach and combination of anterioposterior approach could achieve satisfactory corrective outcomes. The most common complication is junctional kyphosis.

Hypothesis
Surgical treatment for cervical kyphosis in children could obtain satisfactory outcomes without any complications.

Design
Retrospective case series study

Introduction
Cervical kyphosis may occur with neurofibromatosis type 1 (NF-1), diastrophic dysplasia (DD), or congenital deformity. Outcomes of cervical spinal fusion in pediatric patients with cervical kyphosis are not well described because of the rarity of the condition. We aimed to characterize the clinical presentation of cervical kyphosis and report the outcomes of surgical treatment for the condition in these children.

Methods
Twelve patients with severe cervical kyphosis (Cobb angle>50°) underwent anterior or anterioposterior cervical decompression and fusion from May 2015 to June 2016 were studied retrospectively. There were 5 males and 7 females. The average age was 6.7 years ranging from 2.0 to 15.4 years. According to the etiology, 4 had NF-1, 3 patients had iatrogenic deformity (post-laminectomy), 3 had DD, 2 had Pott's deformity. The cervical kyphosis was measured by two-line Cobb method. Motor evoked potential and somatosensory evoked potential were applied intraoperation as the spinal cord monitor. All patients had been followed for a minimum of 2 years. The outcomes and complications of surgery in these children were reviewed.

Results
Six children presented with neck pain; 4 with a neurologic deficit, and 2 only with cervical deformity. Preoperative halo traction was used for 5 patients with an average of 8.6 days, and it reduced the mean preoperative kyphosis by 32%. Six patients underwent anterior and 6 underwent anteroposterior surgery. At the time of final follow-up, all spinal fusion sites had healed and the cervical kyphosis was corrected from 67° to 10° (mean correction, 85%). The cervical kyphosis correction was significantly better after the anteroposterior procedures (89%) than after the anterior-only procedures (78%) (P = 0.043). Four patients (33%) had junctional kyphosis.

Conclusion
Surgical treatment was a safe and effective method for children's cervical kyphosis. Anteroposterior surgery provided better correction than anterior-only spinal fusion and junctional kyphosis was the most common complication.

Take Home Message
Surgical treatment was a safe and effective method for children's cervical kyphosis. Anteroposterior surgery provided better correction than anterior-only spinal fusion and junctional kyphosis was the most common complication.

205. Development and Validation of Models Predicting Postoperative T1 Pelvic Angle and Pelvic Tilt

Jeffrey M. Hills, MD; Ben Lane, MS; Jesse Spencer-Smith, PhD; Benjamin M. Weisenthal, MD; John Wanner, MD; Byron F. Stephens, MD

Summary
We reviewed 145 adult deformity patients to develop models predicting postoperative T1 Pelvic Angle and Pelvic Tilt, using comorbidities, preoperative alignment, and postoperative segmental lordosis. Linear regression performed best for TPA (RMSE = 4.01; r2 = 0.87) and PT (RMSE = 4.57; r2 = 0.77). The models were internally validated using bootstrap resampling, and coverage probabilities for each observation were determined. By adjusting for preoperative factors, lumbar alignment targets can be selected to achieve the desired TPA and PT.

Hypothesis
Patient comorbidities, preoperative alignment, and postoperative lumbar measures are predictive of postoperative T1-Pelvic Angle (TPA) and pelvic tilt (PT).

Design
Retrospective Cohort

Introduction
TPA and PT are important measures of spinal deformity that correlate with quality of life and complications. However, predictive models for TPA and PT based on preoperative factors and postoperative lumbar alignment are lacking. The purpose of this study was to develop predictive models for TPA and PT based on comorbidities, preoperative alignment, and postoperative lumbar alignment.

Methods
Patients undergoing adult deformity surgery between 2009

and 2017 with minimum 2-year follow-up were retrospectively reviewed. Primary outcomes were initial postoperative TPA and PT. Patient factors and preoperative and postoperative alignment measures were collected. A reduced predictor set was selected using relaxed LASSO regression. Regression and tree-based models were fit, and the best performing model identified by minimizing RMSE with 5-fold cross validation. Internal model validation was performed using bootstrap resampling on 3000 training and testing sets. True coverage probabilities were determined by the proportion of times the prediction intervals captured the observed outcome in the testing set.

Results

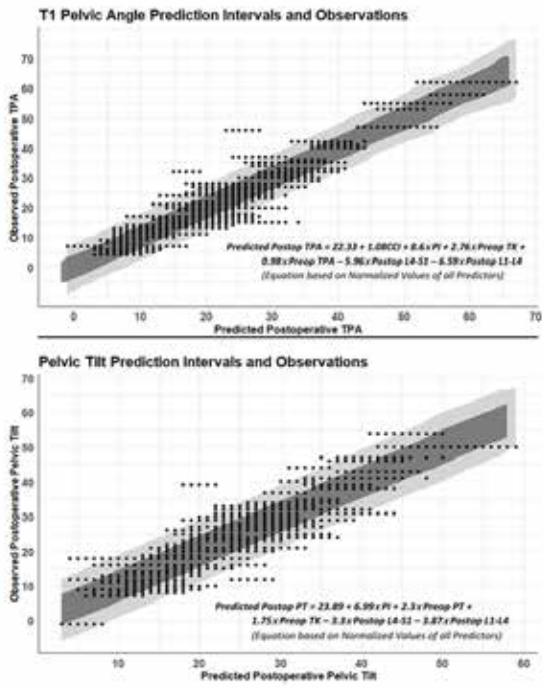
Among 145 patients included, median postoperative TPA and PT was 21 (IQR: 15, 28) and 23 (IQR: 17, 30), respectively. The final TPA predictors included Charlson Comorbidity Index, PI, preoperative TPA and TK, and postoperative L4-S1 and L1-L4 lordosis. Final PT predictors included PI, preoperative PT and TK, and postoperative L4-S1 and L1-L4 lordosis. Linear regression outperformed all models for TPA (RMSE = 4.01; r2 = 0.87) and PT (RMSE = 4.57; r2 = 0.77).

Conclusion

We report accurate predictive models for postoperative TPA and PT based on baseline factors and postoperative segmental lumbar lordosis. This approach can aid surgical planning by identifying lumbar alignment targets that are likely to achieve the desired TPA and PT.

Take Home Message

Baseline patient factors, alignment, and postoperative lumbar segmental lordosis accurately predict postoperative TPA and PT. Lumbar alignment targets can be generated to achieve the desired postoperative TPA and PT.



Predictions were rounded to whole values for calculating 95% (light gray) and 67% (dark gray) bootstrapped prediction intervals.

206. Can Rapid Progression In Cerebral Palsy Scoliosis Be Predicted Using Humeral Head Ossification?

Joshua T. Bram, BS; Alexa J. Karkenny, MD; Ronit Shah, BS; Divya Talwar, PhD; *Keith Baldwin, MD*; John (Jack) M. Flynn, MD

Summary

Despite higher complication rates compared to idiopathic scoliosis, estimation of skeletal maturity and prediction of curve progression in Cerebral Palsy scoliosis (CPS) has been difficult. Based on a validated proximal humerus-based maturity staging system, our findings suggest that the transition from stage 3 to 4 represents the period of curve greatest progression past 70˚ in CP scoliosis patients, a cutoff known to increase surgical complications in CPS.

Hypothesis

A proximal humerus-based staging system can be used to identify a "tipping point" at which a CPS may progress rapidly, thus indicating timely surgical intervention.

Design

Retrospective case series

Introduction

Patients with CPS experience higher complication rates compared to idiopathic scoliosis (IS) and often present for surgery with larger curves. Prediction of an inflection point has proven difficult. A proximal humerus-based skeletal maturity staging system (HS) has been recently validated and is commonly visible on the PA radiograph.

Methods

A retrospective review was conducted for pediatric patients who presented with non-ambulatory CPS between 2009-2018 at our institution. All patients were considered for inclusion regardless of operative or non-operative management. Patients who were skeletally mature at initial evaluation or had prior spine surgery were excluded. We analyzed radiographs for each patient in each HS of skeletal maturity available. We used multiple imputation to correct for missing data points. Survival was calculated for cutoffs of 50˚ (a surgical indication) and 60˚/70˚ (numbers found to increase complications in surgery for CPS).

Results

86 patients with CPS were identified (54 male). Cobb angle increased significantly between HS1-2 (28.4˚-43.5˚, p=0.004) and HS 3-4 (52.7˚-66.8˚, p=0.002). The proportion of curves >70˚ were significantly different between HS (p<0.001), with the greatest increase in curve magnitude between HS 3-4 (25.0%-47.2% >70 degrees). Survival, defined by percent of patients with curves below 50˚, 60˚, and 70˚ respectively during each HS, is shown in Figure 1 (p<0.001). The largest drop in each survival curve was between HS 3 and 4. In sub-analysis, 56.3% of patients with curves >40˚ but <70˚ in stage 3 would progress >70˚ by stage 4.

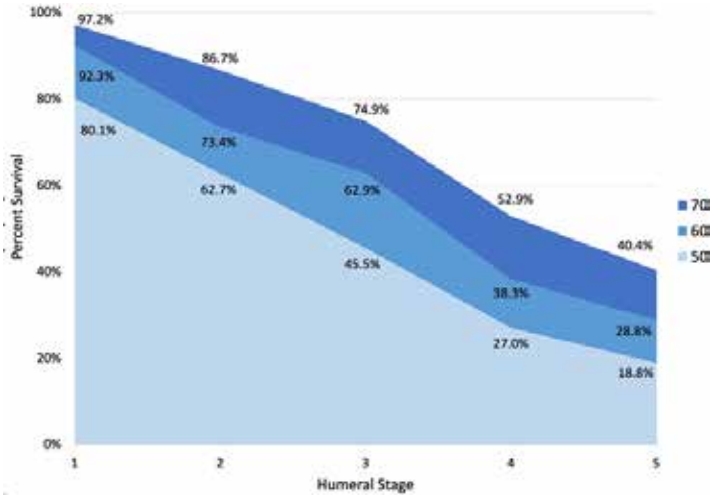
Conclusion

Identifying a 'tipping point' of rapid curve progression may guide

surgical planning before CPS curves become large, stiff and more perilous to fix. Our findings suggest that the HS 3 to 4 transition represents the time of greatest risk of progression.

Take Home Message

Risk of progression is highest for CP scoliosis between stages 3 and 4. Strongly consider a surgical discussion for CP patients with NMS of >40˚ who are HS 3.



Survival of Curve Below Critical Value by Humeral Stage

207. Is Sustained Postoperative Fever Without Evident Cause After Spinal Instrumentation Operation An Indicator of Surgical Site Infection?

Chang Ju Hwang, MD, PhD; *Sehan Park, MD*; Dong-Ho Lee, MD, PhD; Jae Woo Park, MD; Jae Hwan Cho, MD, PhD; Choon Sung Lee, MD, PhD

Summary

Sustained postoperative fever without evident diagnosis as a cause of fever is frequently encountered. Surgical site infection, which is one of the most dreaded cause of fever can be discriminated on the basis of fever pattern, inflammatory marker results. Furthermore, sustained postoperative fever was significantly related with surgical site infection. MRI frequently results in false-negative interpretation especially within 1 month after the operation.

Hypothesis

Fever pattern, inflammatory markers, and MRI are diagnostic clues that can discriminate surgical site infection after spine instrumentation surgery from postoperative fever patients without evident cause

Design

Retrospective review study

Introduction

Late-onset or sustained fever increases suspicion of comorbid conditions such as surgical site infection (SSI). This study is a retrospective cohort study conducted to identify the incidence and risk factors of sustained or late-onset postoperative fever after spine instrumentation operations and determine its relationship with surgical site infection.

Methods

Data from 608 consecutive patients who underwent lumbar or thoracic spine instrumentation operation were retrospectively reviewed. The sustained fever (SF) group included patients with sustained or late-onset fever without an identifiable cause. The non-febrile (NF group) included patients with fever that did not meet the inclusion and exclusion criteria for SF and patients without fever. Patients diagnosed with SSI were included in the SSI group. The clinical characteristics, surgical factors, prophylactic antibiotics usage, fever pattern, and laboratory findings were recorded for all patients using electronic medical chart review.

Results

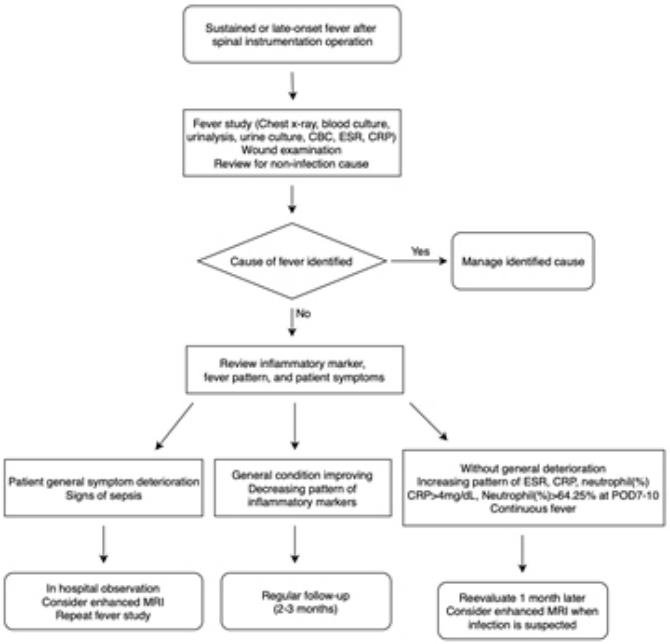
Among the 608 patients, 78 (12.8%) had sustained or late-onset fever. Rate of SSI were significantly higher when patient demonstrated sustained fever (9.7%, 9/78 vs 0.9%, 5/530; p<0.01). Comparison of the SF and SSI group showed that continuous fever, increasing pattern of inflammatory markers, neutrophil >64.25% and CRP >4 mg/dL at POD 7–10 were risk factors for SSI. The sensitivity and specificity of postoperative magnetic resonance imaging (MRI) for detecting SSI were 40.0% and 90.9%, respectively when MRI was performed within 1 month after surgery.

Conclusion

Sustained fever was significantly related increased rate of SSI. Continuous fever, increasing patterns of inflammatory markers, and high neutrophil % and CRP at POD 7–10 were risk factors for SSI (Figure 1).

Take Home Message

When encountering sustained postoperative fever without evident diagnosis, fever pattern, inflammatory markers are diagnostic clues that can discriminate surgical site infection. MRI frequently results in false negative interpretation.



Diagnostic algorithm for approach to sustained or late-onset postoperative fever patients.

208. PSO in Lateral Position for Severe Kyphosis with Closed Hips Secondary to Ankylosing Spondylitis

Lu Chen, MD, PhD; Kai Cao, MD, PhD; Rongping Zhou, MD, PhD; Yurong Gu, MD; Zhenhai Zhou, MD, PhD; Wenbing Wan, MD, PhD; Honggui Yu, MD, PhD; Zhimin Pan, MD, PhD

Summary
Ankylosing spondylitis(AS) patients suffered from severe kyphosis and closed hips are frequently impossible to be placed in a prone position for osteotomy. Twelve such patients who underwent PSO in lateral position first and total hip arthroplasty(THA) in a second stage were included in this study. Related radiographical parameters and acetabular abduction and anteversion were measured pre- and post-operatively and compared. The results showed that PSO in lateral position is feasible and safe for such patients.

Hypothesis
PSO in lateral position can be an alternative for severe kyphosis combined with closed hips secondary to AS.

Design
A retrospective study.

Introduction
PSO and THA are usual surgical interventions to improve quality of life for AS patients. Performing THA previous to PSO results in a higher dislocation rate of hip than PSO at first. Therefore, PSO first seems more logical. However, osteotomy in a prone position for AS patients suffered from severe kyphosis and closed hips is frequently impossible. So this study reviewed the clinical outcomes of such patients who underwent PSO in a lateral position.

Methods
A total of 12 consecutive AS patients with severe kyphosis and closed hips who underwent two-level PSO in lateral position at first, then THA in the second stage were analyzed retrospectively. Radiographical measurements included coronal balance(CB), chin brow vertical angle(CBVA), center of acoustic meati point-center of hip axis angle(CAM-HA), global kyphosis(GK), thoracic kyphosis(TK), lumbar lordosis(LL), pelvic incidence(PI), sacral slope(SS), pelvic tilt(PT), anterior pelvic plane angle(APPA). Acetabular abduction and anteversion were measured on CT scans of the pelvis before PSO and after THA. The preoperative and postoperative parameters were compared by the paired samples t test.

Results
CB, CBVA, CAM-HA, GK, TK, LL, SS, PT, APAA were significantly corrected from 32.2±5.1mm, 31.9±6.3°, 34.7±8.2°, 110.6±8.6°, 91.2±7.4°, 18.7±10.5°, 13.7±7.7°, 43.4±9.0°, 30.6±10.3°to 9.2±5.3mm, 3.8±1.1°, 1.6±1.3°, 51.4±11.8°, 47.6±9.5°, -36.1±10.6°, 29.3±8.1°, 17.2±8.1°, 9.8±6.4°, respectively($p<0.001$). Acetabular abduction and anteversion statistically decreased from 60.3±5.1°, 32.8±7.3° before PSO to 50.7±5.5°, 21.1±4.2° after THA, respectively($p<0.001$). The sugical time of PSO in lateral position was 7.3±1.2h with 833±181ml EBL. Temporary neurological deficit occurred in 2 patients, and no hip dislocation was observed in this cohort.

Conclusion
PSO in lateral position can be implemented availably and safely for AS patients combined with severe kyphosis and closed hips in spite of learning curve.

Take Home Message
PSO in lateral position first and THA in the second stage for AS patients with severe kyphosis and closed hips is logical, which could decrease the rate of hip dislocation.

209. Is Growth-Friendly Surgery Effective for the Treatment of Spinal Deformity in Patients with Arthrogryposis Multiplex Congenita?

Bram P. Verhofste, MD; John B. Emans, MD; Patricia E. Miller, MS; George H. Thompson, MD; Amer F. Samdani, MD; Francisco Javier S. Perez-Grueso, MD; Anna McClung, RN, BSN; Pediatric Spine Study Group ; Michael P. Glotzbecker, MD

Summary
This is a large matched cohort of children with arthrogryposis multiplex congenital (AMC) treated with growth-friendly instrumentation (GFI). GFI is effective for treating spinal deformities in children with AMC. Patients with AMC experienced less initial correction, however, similar complications, revisions, and final curves were seen compared to idiopathic early-onset scoliosis (EOS) patients at latest GFI.

Hypothesis
Study aims were: 1) to evaluate GFI outcomes in patients with AMC and EOS; 2) to compare these results to a matched cohort of idiopathic EOS patients to determine whether spinal rigidity and extremity contractures influenced GFI outcomes.

Design
Matched Case-Control Study

Introduction
AMC is a rare summation of disorders used to describe neonates with 2+ congenital contractures. Scoliosis is found in 30-70%, but little literature exists on the presentation or outcomes of GFI in patients with AMC and EOS.

Methods
36 children (n=36) with AMC treated with GFI and two-year follow-up (median 5 yrs; range 2-22 yrs) were identified from two multicenter databases (1997-2017). An idiopathic cohort of 158 patients served as controls. Of the 36 AMC patients, propensity scoring matched a total of 35 AMC patients (mean age 6.2 years) to 112 idiopathic patients (mean age 6.4 years) based on age, sex, construct, and initial curve. Linear mixed modeling was used to compare the change in curve across groups.

Results
Presenting mean curves were comparable across AMC (76°; range 31-101°) and idiopathic (75°; range 40-130°) groups ($p=0.81$). Index surgery resulted in less mean absolute correction (27° vs. 33°; $p=0.02$) and less % correction (35% vs. 44%; $p=0.01$) in patients with AMC, but comparable curve magnitudes were seen at the final follow-up or latest GFI (55° vs. 49°; $p=0.12$). Median number of complications (2 vs. 1; $p=0.09$) and revisions

(1 vs. 1; p=0.88) were similar in AMC and idiopathic groups, respectively.

Conclusion
GFI is effective for treating spinal deformity in children with AMC. Less initial correction was seen in AMC, but long-term outcomes were comparable to idiopathic EOS patients.

Take Home Message
Patients with AMC had less initial curve correction, however, long-term results, final curve magnitude, complications, and revisions were similar to children with idiopathic EOS.

Table 1. Cohort Summary (n=147)	Arthrogryposis (n=35)			Idiopathic (n=112)			
Patient Demographics	**Freq.**	**(%)**	**Range**	**Freq.**	**(%)**	**Range**	**P**
Age at initial surgery (years; *mean ± SD*)	6.2	± 2.2	2.1-9.9	6.4	± 2.0	1.9-10	0.65
Sex (% male)	15	43%		46	41%		0.85
Prior treatment with bracing or casting	17	49%		58	52%		0.74
Construct type							0.69
TGR	16	46%		55	49%		
MCGR	10	29%		18	16%		
VEPTR	8	23%		31	28%		
Shilla	1	3%		8	7%		
GFI duration (*years; mean ± SD*)	5	± 2.4	2.1-11.2	5.7	± 2.6	0-11.9	0.18
Follow-up duration (*years; median (IQR)*)	5	3-9	2-22	7	4-11	2.1-17.3	0.03*
Curve Characteristics [a]	**Mean**	**± SD**	**Range**	**Mean**	**± SD**	**Range**	**P**
Major curve at presentation	76	± 16.0	31-101	75	± 16.1	40-130	0.81
Major curve post-index	49	± 16.1	21-84	42	± 15.1	12-88	0.03*
Absolute change	27	± 14.2	1-51	33	± 14.3	0-68	0.02*
% Correction [b]	35%	± 16%	1%-56%	44%	± 17%	1%-82%	0.01*
Last GFI or pre-definitive fusion	55	± 22.8	22-109	49	± 18.3	9-105	0.12
Absolute change	20.1	± 26.3	-40-60	26	± 19.4	-21-76	0.21
% Correction [c]	24%	± 37%	-79%-68%	34%	± 24%	-25%-83%	0.08
Definitive procedure	14	40%		67	60%		0.04*
Post-fusion	50	± 18.7	19-83	39	± 18.5	12-80	0.07
Latest post-fusion follow-up	55	± 25.4	23-123	43	± 50.7	16-112	0.11
Complications	**Median**	**IQR**	**Range**	**Median**	**IQR**	**Range**	
Complications	2	1-4	0-14	1	0-2	0-14	0.09
Revisions	1	0-2	0-7	1	0-3	0-13	0.88

Abbreviations: SD (standard deviation); IQR (interquartile range); TGR (traditional growing rods); MCGR (magnetically controlled growing rods); VEPTR (vertical expandable prosthetic titanium rib); PSF (posterior spinal fusion); GFI (growth-friendly instrumentation);
[a] 35 of 36 patients with AMC were able to be matched to 112 of 158 control patients with idiopathic EOS;
[b] All indicate degrees unless otherwise specified;
[c] % Correction: ((pre-index – post-index) / (pre-index)) x 100%;
[d] % Correction: ((last-GFI or pre-definitive – post-definitive) / (last GI or pre-definitive)) x 100%;
* Denotes significant values.

Cohort Summary

210. Predicting Severe Clinically Relevant Distal Junctional Kyphosis Development Following Adult Cervical Deformity Surgery with Further Distinction from Mild Asymptomatic Episodes

Peter G. Passias, MD; Sara Naessig, BS; Renaud Lafage, MS; Virginie Lafage, PhD; Bassel G. Diebo, MD; Themistocles S. Protopsaltis, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Alex Soroceanu, MPH; Eric O. Klineberg, MD; Robert A. Hart, MD; Douglas C. Burton, MD; Shay Bess, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; International Spine Study Group

Summary
While advances have been made in the surgical management of distal junctional kyphosis(DJK), complication rates remain high. Our study identified a DJK rate of 32.2%. Predictive models were created that can be utilized with high reliability to help distinguish between sever symptomatic DJK(sym) and mild asymptomatic(Asym)through the use of surgical factors, radiographic parameters, and patient variables. More specifically, symptomatic can be further distinguished from asymptomatic by taking into account pelvic incidence and cervico thoracic deformity severity.

Hypothesis
Sym DJK can be differentiated from (Asym) by use of predictive modeling

Design
Retrospective

Introduction
Many of these cases are mild and have no clinical relevance

Methods
CD patients(pts) with minimum 1 Year follow up were stratified into Asym and Sym DJK. DJK angle(DJKA) was defined>10° change in kyphosis between LIV and LIV-2 and a>10° index angle. Sym: 1)DJKA>10° and either reop due to DJK or>1 new-onset neurological sequelae related to DJK or 2)pts who had either a DJKA>20° or ΔDJKA>20°. Asym:ΔDJK>10° in the absence neurologic sequelae. Stepwise logistic regressions were used to identify patient, surgical, and radiographic factors associated with these types of DJK. Decision tree analysis established cut-offs for variables.

Results
116 CD pts included(61yrs, 66%F). 31.8% developed DJK(44.8% Asym, 48.3% Sym). 37.5% of Asym pts received a reop versus 62.5% Sym pts. At BL, Asym pts had a greater BMI(28.5 vs 23kg/m2) and NSR back pain(5.2 vs 4.6; all p<0.05). Conditional inference trees identified top factors for Sym vs no DJK and Sym vs Asym pts(Table 1). Multivariate analysis identified independent radiographic and surgical factors for developing Sym DJK: [Radiographic] BL PI(1.02[0.9-1.07]), cervical flexibility(1.04[1.0-1.07]) and 3M C2-T3(1.04[0.9-1.1]; [Surgical] combined approach (6.2[1.4-27]; all p<0.05). Having abnormal hyper kyphosis in the thoracic spine, more so than abnormal cervical lordosis, was an independent factor for developing Sym when analyzed against Asym pts(1.2[0.01-115]). Multivariate modeling identified myelopathy(mJOA score:12-14), combined approach, UIV=C3 or C4, preoperative hypermobility, and >7 levels fused(AUC: 0.89) to be predictive of Sym pts. A predictive model for Sym versus Asym pts yielded an AUC of 85% and included being frail, having a TS-CL>20, and a PI>46.3.

Conclusion
Overall 32.2% cervical deformed patients suffered from DJK. Severe symptomatic DJK can be predicted with high reliability. It can be further distinguished from asymptomatic occurrences by taking into account pelvic incidence and baseline cervico thoracic deformity severity.

Take Home Message
Factors such as spinal cord dysfunction, mobility, frailty, and surgical factors including end levels, number of levels fused and use of a combined approach can predict severe DJK.

Table 1. Patient-specific, Surgical, and Radiographic Top Predictors Associated with Symptomatic and Asymptomatic DJK

Top Factors for Symptomatic VS No DJK
• Osteoporosis
• UIV
• Primary Driver Apex
Top Factors for Symptomatic vs Asymptomatic
• Baseline EQ5D >0.65
• UIV Cephalad to C2
• C2-C7 Apex Caudal to C5

211. At What Point Should the Thoracolumbar Region be Addressed in Patients Undergoing Corrective Cervical Deformity Surgery?

Peter G. Passias, MD; Katherine E. Pierce, BS; Renaud Lafage, MS; Virginie Lafage, PhD; Eric O. Klineberg, MD; Bassel G. Diebo, MD; Themistocles S. Protopsaltis, MD; D. Kojo Hamilton, MD; Shaleen Vira, MD; Breton G. Line, BS; Robert A. Hart, MD; Douglas C. Burton, MD; Shay Bess, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; International Spine Study Group

Summary
Thoracolumbar malalignment is often seen in patients presenting with cervical deformities. For operative cervical deformity (CD) patients, it is unknown whether certain thoracolumbar parameters play a large role in poor outcomes (complications, DJK, reoperation) and whether addressment of such parameters is warranted. This study sought to determine the impact of cervical/thoracolumbar ratios on poor outcomes. Several key ratios correlated with the occurrence of sub-optimal realignment and clinical outcomes.

Hypothesis
Certain ratios of cervical to thoracolumbar ratios will impact occurrence of poor outcomes in CD corrective surgery.

Design
Retrospective

Introduction
Consideration of the distal regional and global alignment is a critical determinant of outcomes in CD surgery.

Methods
Included: surgical CD pts(C2-C7 Cobb>10°, CL>10°, cSVA>4cm, or CBVA>25°) with full baseline and 1-year data. Patients were assessed for ratios of preop cervical and global parameters including: C2 Slope/T1 slope, TS-CL/PI-LL, cSVA/SVA. Deformity classification ratios of cervical(Ames-ISSG) to spinopelvic(SRS-Schwab) were investigated: cSVA modifier/SVA modifier, TS-CL modifier/PI-LL modifier. Cervical to thoracic ratios included C2-C7 lordosis/T4-T12 kyphosis. Correlations assessed the relationship between ratios and poor outcome (major complication, reoperation, HRQL decline or failure to meet MCID). Decision tree analysis through multiple iterations of multivariate regressions) assessed cut-offs for ratios for acquiring suboptimal outcomes.

Results
110 CD pts included(61.5yrs, 66%F, 28.8kg/m2). By approach, 18.2% underwent anterior-only procedures, 46.4% posterior, and 35.4% combined(levels fused: 7.7). The average preoperative radiographic ratios assessed included a C2 slope/T1 slope of 1.56, TS-CL/PI-LL of 11.1, cSVA/SVA of 5.4, CL/TK of 0.26. Ames-ISSG and SRS-Schwab modifier ratios of cSVA/SVA 0.1 and TS-CL/PI-LL of 0.35. Pearson correlations demonstrated a relationship between major complications and the baseline TS-CL/PI-LL, Ames TS-CL/Schwab PI-LL modifiers, and the CL/TK ratios($p<0.050$). Reoperation had a significant correlation with the TS-CL/PI-LL and the cSVA/SVA ratios. Postoperative DJK had a correlation with the C2 slope/T1 slope and CL/TK ratios. Not meeting MCID for NDI correlated with the CL/TK ratio and not meeting MCID for EQ5D correlated with the Ames TS-CL/Schwab PI-LL. Cut-offs for significant ratios predicting poor radiographic and clinical outcomes can be seen in Table 1.

Conclusion
Consideration of cervical to global alignment is a critical determinant of outcomes in cervical deformity corrective surgery.

Take Home Message
Key ratios of cervical to global alignment correlate with sub-optimal clinical outcomes. A larger cervical lordosis to thoracic kyphosis predicted a complication, DJK, and not meeting MCID for NDI.

Table 1. Cut-offs for significant ratios predicting poor radiographic and clinical outcomes.

	Major Complication	
	Cut-Off	P-Value
TS-CL/PI-LL	>12.72	0.034
Ames TS-CL/Schwab PI-LL	>0.482	0.019
CL/TK	>0.814	0.050
	Reoperation	
TS-CL/PI-LL	>5.819	0.009
cSVA/SVA	>3.79	0.002
	Distal Junctional Kyphosis	
C2 slope/T1 slope	>1.59	0.017
CL/TK	>0.692	0.029
	Not Meeting MCID for NDI	
CL/TK	>1.402	0.016
	Not Meeting MCID for EQ5D	
Ames TS-CL/Schwab PI-LL	>0.564	0.010

212. Powered Pedicle Screw Placement Decreases Screw Wobble

David L. Skaggs, MD; Amy A. Claeson, PhD; Frank J. Schwab, MD; Anup A. Gandhi, PhD

Summary
Loosening of pedicle screws placed manually occurs in up to 21% of patients between three to six months post-op, and retrospective analyses of clinical outcomes show screws placed with power fail less frequently. Inertial measurement units track the extraneous motion of screws placed manually and with power. Powered screw placement decreases screw wobble via outcome metrics of total path length and wobble area. Decreasing extraneous pedicle screw motion during placement may preserve the bone/screw interface and increase pullout strength.

Hypothesis
Powered technique decreases screw wobble compared to manual technique.

Design
Cadaver study

Introduction
Retrospective analyses of clinical outcomes show pedicle screws placed with powered instruments fail less than those placed with manual technique. Investigating screw wobble may explain these findings. A screw succumbing to wobble may erode the bone at the bone/screw interface, decrease purchase and reduce pullout strength.

Methods
Pedicle preparation and screw placement using four torsos was performed by two spine surgeons experienced in both tech-

niques. Pedicles of T4-L5 vertebrae were prepared and screws inserted bilaterally using manual and powered technique. Manual technique included pedicle cannulation with a Lenke probe, undertapping by Ø1.0mm, and driving Ø5.5mmx35-45mm screws; powered technique used a Ø2.4mm drill bit, Ø3.2mm reamer probe, and screws of matched size. Inertial measurement units affixed to both manual and powered drivers recorded the angular rotation of the instruments about three planes at 100Hz over the duration of screw placement. Within the angular rotation data, a LOESS filter identified the intended trajectory, and wobble was deemed the rotational deviation from that trajectory. Wobble path length was quantified as the cumulative displacement of extraneous screw motion, and wobble area as an ellipse fit to the in-plane projection of the wobble path. Two one-way ANOVAs with multiple comparisons and Tukey's correction assessed outcomes as a function of both technique and screw length. Significance $p<0.05$.

Results

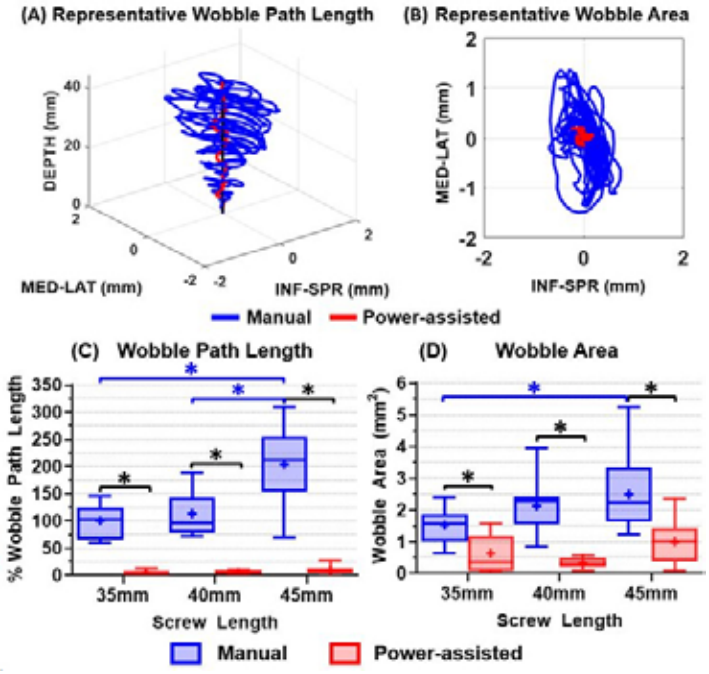
Powered technique reduces both wobble path length and wobble area ($p<0.05$). Path length of 45mm screws using manual technique twice the length of 35-40mm screws, whereas the matched powered path length was 93% shorter. Powered technique reduced wobble area by 59%, 84%, and 59% for matched 35-45mm screws ($p<0.05$).

Conclusion

Powered pedicle screw placement decreases screw wobble. Use of power-assisted tools for screw placement may reduce work of placing screws, and the propensity of screws to loosen.

Take Home Message

Powered pedicle screw placement decreases screw wobble, which may decrease the propensity of screws to loosen preserving the integrity of the bone/screw interface.



Powered pedicle screw placement decreases both wobble path length and wobble area. Wobble path length normalized to mean of 35mm, manual. +: mean, *:$p<0.05$

213. Disparities in Etiology, Clinical Presentation and Determinants for Distal Junctional Kyphosis Based on Timing of Occurrence: Are We Treating Two Separate Issues?

Katherine E. Pierce, BS; *Peter G. Passias, MD*; Renaud Lafage, MS; Virginie Lafage, PhD; Han Jo Kim, MD; Alan H. Daniels, MD; Robert K. Eastlack, MD; Eric O. Klineberg, MD; Breton G. Line, BS; Praveen V. Mummaneni, MD; Themistocles S. Protopsaltis, MD; Douglas C. Burton, MD; Shay Bess, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; International Spine Study Group

Summary

This study sought to investigate the timing of DJK development following CD corrective surgery. We found while the majority of DJK development occurs within 6 months, late DJK occurs and differs in etiologic factors. Early DJK was associated with severe radiographic presentation, combined approach with neurological decline. Late DJK is more likely mild radiographically and associated with suboptimal cervical realignment and lack of addressing secondary drivers

Hypothesis

Timing of DJK development following CD corrective surgery will have different etiologic presentations.

Design

Retrospective Cohort study

Introduction

The timing of DJK onset has yet to be investigated

Methods

Included: surgical CD patients(C2-C7 Cobb>10°, CL>10°, cSVA>4cm, or CBVA>25°) without pre-op DJK. DJK angle was defined as the change in kyphosis between LIV)and LIV-2 from preop to postop(<-10). X2 analysis and post-hoc testing assessed annual and overall incidence of Early(3M follow-u) and Late(after 3M) DJK development. Pearson correlations determined significant variables associated with development of Early versus Late DJK. Severe DJK was defined as DJK angle <-20°. DJK was considered symptomatic if associated with reoperation or the previously published thresholds of NDI>24 or mJOA<14. The natural progression of the disease was predicted with the use of a Kaplan-Meier survivorship analysis.

Results

139 patients were included(16 re-op) (61.8yrs, 62.3%F, 29.1kg/m2). Incidence of DJK from 2013-2018: 23%. Early: 9.4%, Late: 10.1%. No differences were observed between op and reop for development of Early or Late DJK at all f/u($p>0.050$). Significant factors correlating with Early and Late DJK are in Table 1. Between Early and Late groups, 41.7% of Early DJK were severe, while 0% of Late($p=0.010$); symptomatic DJK between the two groups was not significant($p=0.941$). Kaplan-Meier survivorship analysis determined patients have a 91.1% probability of main-

taining non-DJK status by 3-month follow-up, 85.9% at 6-month, 80% at 1-year, and 77.0% by 2-year follow-up.

Conclusion
Early DJK occurrence is more likely to be severe radiographically, associated with neurological decline, and is related to biomechanical factors such as combined approach. Contrarily, although equally likely to be symptomatic as reflected in loss of clinical gains, late DJK is more likely mild radiographically and associated with suboptimal cervical realignment and lack of addressing secondary drivers, likely related to negative compensatory mechanisms. Customized prophylactic approaches for both occurrences is mandated.

Take Home Message
Patients undergoing CD surgery have incidence of early and late DJK. While the majority of DJK development occurs within 6 months, late DJK occurs and differs in etiologic factors

Significant Factors Correlating with Early DJK	
Upgoing plantar response at baseline neuro exam	
C2-C7 angle	
T1-C2 angle	
CBVA	
Combined approach	
T4-T12 Angle (p=0.024)	Early: -57.9°
	Late: -40°
Significant Factors Correlating with Late DJK	
History of tumor	
History of pulmonary disease	
Pelvic Incidence	
T10-L2 angle	
L4 Pelvic Angle (p=0.009)	Late: 14.5°
	Early: 9.1°
Apex of the secondary driver (p=0.023)	Late: T10
	Early: T2/3

214. Oh No, HO! Heterotopic Ossification Foils Magnetically Controlled Growing Rod Lengthening: A Case Report

Laura Tillman, DNP; *Tenner Guillaume, MD*; Daniel J. Miller, MD

Summary
This case report details 2 cases of heterotopic ossification (HO) surrounding the telescoping portion of a magnetically controlled growing rod (MCGR) resulting in lengthening failure. To our knowledge, HO has not been previously documented as a potential cause for failure of MCGRs. This report highlights the need to monitor for this potential complication as well as offers a suggestion for management.

Hypothesis
HO formation surrounding the telescoping portion of a MCGR should be considered when MCGR fails to lengthen. Resection of HO and placement of Polytetrafluoroethylene (PTFE) liner around the telescoping rod and housing will restore expansion capabilities.

Design
Case Report

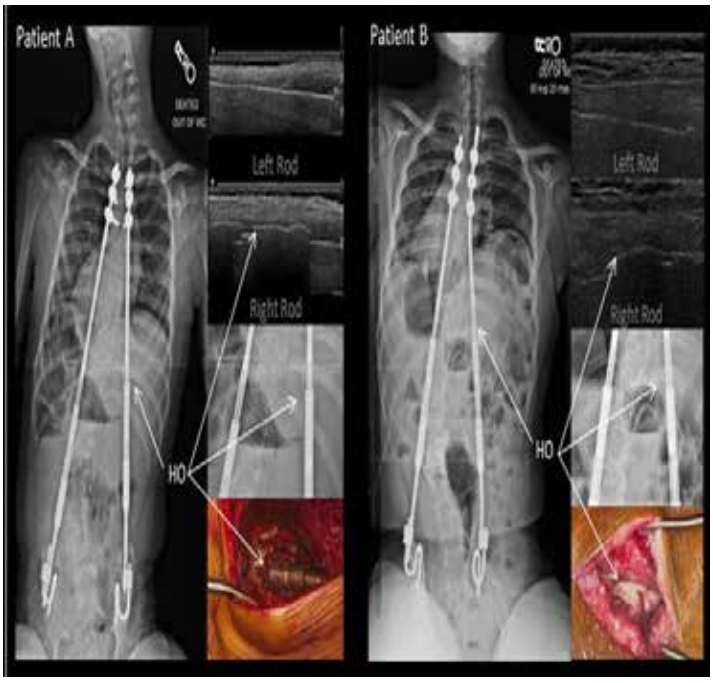
Introduction
Individuals treated with MCGRs are subject to a number of complications. A previously undocumented complication is HO surrounding the telescoping portion of the rod preventing lengthening. This report details 2 cases of HO and its treatment.

Methods
A chart review of 2 patients with HO was conducted including history, imaging, surgical procedure and postoperative outcomes.

Results
2 patients (1 male, 1 female, both neuromuscular scoliosis) were found to have HO on the telescoping hub of a MCGR preventing lengthening. Age at MCGR surgery was 7yrs2mo and 8yrs. Both had T3-T5 fusion with T3-pelvis posterior segmental instrumentation utilizing 5.5mm x 90mm standard rods. Pre MCGR surgery cobb angles were 77° and 110°, post 29° and 44°, respectively. HO was noted on the right concave rods 24 and 27 mo later at the 7th and 6th lengthenings, respectively. Average days between lengthenings were 102 and 143 (goal was 90-120). Prior to failure, mean concave length attempted/achieved per lengthening was 4mm/3mm and 4.3mm/5.2mm and convex was 4mm/4mm and 5mm/4.2mm, respectively. A combination of osteotomes and a Leksell rongeur were used to resect HO overlying the telescoping portion of the rod. Periosteal elevators were used to free the rod circumferentially. PTFE liner was passed ventral to the rod around the cranial housing and the proximal telescoping portion. It was sutured around the rod and to local soft tissues to prevent cranial migration with rod expansion. Intraoperatively, post HO resection, the affected rods were successfully lengthened 8 and 6mm, respectively.

Conclusion
Circumferential HO at the telescoping portion of MCGRs is one potential complication causing failure of rods to lengthen. Resection and placement of a liner around the rod was a successful treatment in the 2 cases detailed in this report.

Take Home Message
In patients whose MCGR rod(s) fail to lengthen, HO formation should be considered as a possible cause. If found, resection and placement of PTFE liner can restore proper function.



Radiograph, ultrasound, and intraoperative imaging showing HO

215. Pelvic Non-Responders, Postoperative Cervical Malalignment, and Proximal Junctional Kyphosis Following Treatment of Adult Spinal Deformity: Influence of Realignment Strategies on Occurrence

Peter G. Passias, MD; Katherine E. Pierce, BS; Virginie Lafage, PhD; Renaud Lafage, MS; Themistocles S. Protopsaltis, MD; Bassel G. Diebo, MD; Praveen V. Mummaneni, MD; Khaled M. Kebaish, MD; Christopher P. Ames, MD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Douglas C. Burton, MD; Michael P. Kelly, MD; Robert A. Hart, MD; Shay Bess, MD; Frank J. Schwab, MD; Munish C. Gupta, MD; International Spine Study Group

Summary
For surgical adult spinal deformity (ASD) patients, determining optimal restoration of alignment and spinal shape is an active area of research. Complex corrective measures taken are in ASD. Use of complex realignment schemas (SRS-Schwab, age-adjusted, Roussouly shape, proportion) decreased rates of pelvic nonresponse, PJK and postop cervical deformity development.

Hypothesis
Alignment outcomes(pelvic non-response[PNR], PJK, cervical deformity[CD]) following ASD surgery will depend on complex plans.

Design
Retrospective

Introduction
Incidence of specific alignment outcomes has yet to be investigated in various complex realignment.

Methods
ASD patients with preop, 6-week(6W), and 2-year (2Y) data included. PNR: 10-year mismatch(Undercorrection; unimproved) from age-adjusted PT at 6W and maintained at 2Y. Pelvic responder[PR]: improved in PT(±10 match age-adjusted alignment). Patients were stratified by incremental corrective schemas [a]Improvement in Schwab SVA [b]Matching age-adjusted PI-LL [c]Match "theoretical" Roussouly [d]Improvement in 6W spinal proportionality score. PNR, PJK, and CD by 2Y were compared within groups, as well as simultaneous improvement/match of measures. In a sub-analysis, patients were stratified by severity of baseline PT, Low(<20°), Moderate(20-30°), and Severe(>30°) to determine which alignment schema achieves less PNR, PJK and CD.

Results
468 patients(56.3yrs, 76.5%F; 25.6% PNR, 40.6% PR) included. Rates of postop PJK(PNR:49.2% vs PR:59.5%, p=0.038) and CD(18.3% vs 25.8%, p=0.002) were less in the PNR group. PNR, PJK and CD rates across 6W alignment schemas are in Table 1. Incremental addition: Schwab with age-adjusted(20.9%) had less PNR(28.6% vs 38.7%) than only Schwab. Addition of the Roussouly(18.3%) had less PNR and PJK than Schwab&age-adjusted, p<0.05. Lastly, addition of spine proportion(16.7%) had 0% PNR and CD. By baseline PT severity, the Low group had the least incidence of PNR(7.7%), CD(10.3%) and PJK(41.3%) when matching Roussouly at 6W(all p<0.05). This remained the same for Moderate PT for PNR and PJK, except Schwab improvement decreased CD(21.2%, p=0.049). Severe PT assessment determined PNR(20%), PJK(37.5%) and CD(19.4%) were the lowest with improvement of proportion at 6W(p<0.05).

Conclusion
Following ASD-corrective surgery, 25.6% of patients showed residual pelvic malalignment, qualifying as pelvic non-responders. Severe(>30°) baseline pelvic tilt requires particular emphasis of spine proportionality.

Take Home Message
Use of complex realignment schemas (SRS-Schwab, age-adjusted, Roussouly shape, proportion) decreased rates of pelvic nonresponse, PJK and postop cervical deformity development.

Table 1. Pelvic non-response(PNR), proximal junctional kyphosis (PJK), and postop CD across 6-week alignment schemas.

Alignment Schema at 6-weeks Postop		PNR	p-value	PJK	p-value	CD Development	p-value
SRS-Schwab SVA	Improvement	36%	0.161	57.8%	0.796	22.4%	0.593
	Same	38.3%		59.5%		21.5%	
	Deteriorate	52.8%		53.3%		28.9%	
Age-adjusted PI-LL	Matched	32.6%	<0.001	60.6%	<0.001	22.0%	0.885
	Overcorrected	6.4%		68.2%		24.3%	
	Undercorrected	60.1%		39.3%		22.8%	
Roussouly	Matched	17.8%	0.002	54.5%	0.537	26.1%	0.483
	Unmatched	42.3%		58.2%		22.6%	
Proportionality	Proportional	19.7%	<0.001	59.4%	0.005	23.8%	0.780
	Moderately Disproportionate	27.4%		65.3%		24.7%	
	Severely Disproportionate	58.8%		46.5%		21.3%	

216. Assessment of Lateral Thoracolumbar Listhesis as a Predictor of Disability in Adult Scoliosis Patients Prior to and Following Surgical Realignment Surgery

Alan H. Daniels, MD; Wesley M. Durand, BS; Renaud Lafage, MS; D. Kojo Hamilton, MD; Peter G. Passias, MD; Han Jo Kim, MD; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; Justin S. Smith, MD, PhD; Christopher I. Shaffrey, MD; Munish C. Gupta, MD; Eric O. Klineberg, MD; Frank J. Schwab, MD; Jeffrey L. Gum, MD; Gregory M. Mundis, MD; Robert K. Eastlack, MD; Khaled M. Kebaish, MD; Alex Soroceanu, MPH; Richard Hostin, MD; Douglas C. Burton, MD; Shay Bess, MD; Christopher P. Ames, MD; Robert A. Hart, MD; International Spine Study Group

Summary
Lateral listhesis was associated with worse preoperative disability. Resolution of severe lateral listhesis following surgery was associated with achievement of clinical success in HRQOL.

Hypothesis
Correction of lateral thoracolumbar listhesis is independently associated with improved HRQOL.

Design
Retrospective multi-center analysis

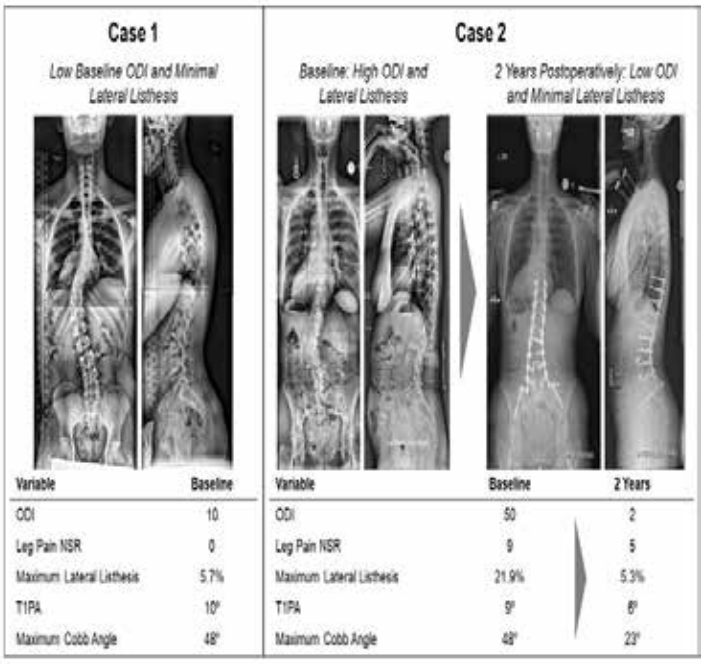
Introduction
Lateral (i.e., coronal plane) vertebral listhesis may contribute to disability in adult scoliosis patients. It is possible that the degree of listhesis is independently associated with inferior patient outcomes. This study sought to add to a previous study of lateral listhesis (Schwab, 2002) by analyzing pre- vs. post-operative change in alignment and HRQOL.

Methods
Patients eligible for a minimum of 2-year follow-up and with coronal plane deformity (defined as Cobb angle ≥20º) were included (n=724). The primary outcome measures in this study were ODI and leg pain numeric scale rating (NSR). Lateral thoracolumbar listhesis was measured as the maximum vertebral listhesis as a percent of the superior endplate across T1-L5 levels. Linear and logistic regression were utilized, as appropriate. Multivariable analyses adjusted for demographics, comorbidities, surgical invasiveness, maximum Cobb angle, and TPA. MCID in ODI at 2 years was defined as a 12.8-unit decrease.

Results
Among adult patients with scoliosis >20º, the mean baseline maximum lateral thoracolumbar listhesis was 18.3% (SD 9.7%). The optimal statistical grouping for lateral listhesis was empirically determined to be none/mild (<6.7%), moderate (6.7-15.4%), and severe (≥15.4%). In multivariable analysis, listhesis of moderate/severe vs. none/mild was associated with worse baseline ODI (none/mild=33.7; moderate=41.6; severe=43.9; p<0.001 for moderate and severe vs. none/mild) and leg pain NSR (none/mild=2.9, moderate=4.0, severe=5.1, p<0.05). Resolution of severe lateral listhesis to none/mild was independently associated with increased likelihood of reaching MCID in ODI at 2 years post-operatively (OR 2.2, p=0.0084).

Conclusion
Lateral thoracolumbar listhesis is associated with worse baseline disability among adult scoliosis patients. Resolution of severe lateral listhesis was independently associated with increased likelihood of reaching MCID in ODI at 2-year follow-up.

Take Home Message
Resolution of lateral thoracolumbar listhesis is independently associated with improved HRQOL at 2-year follow-up.



217. Ambulatory NMS Patients have Similar Rates of Infection, Perioperative Complication, and Revision to AIS Patients

Vishal Sarwahi, MD, MBBS; Aaron M. Atlas, BS; Jesse Galina, BS; Sayyida Hasan, BS; Marina Moguilevtch, MD; Chhavi Katyal, MD; Yungtai Lo, PhD; Terry D. Amaral, MD

Summary
NMS patients usually have severe curves with more comorbidities and procedural complexity. These patients require extensive fusion levels, increased blood loss, and suffer increased perioperative complications. However, NMS patients have a variable spectrum of severity. Our study finds that ambulatory NMS patients can achieve perioperative outcomes similar to AIS patients with regards to surgical complication rate, infections, revisions, and blood loss.

Hypothesis
Ambulatory NMS periop outcomes compare similarly to AIS patients

Design
Retrospective review

Introduction
It is well known that patients with NMS are victims of severe pathological progression. When examined as a collective group, NMS has a worse prognosis and surgical outcomes than AIS. However, not all operative patients with diagnoses of Cerebral Palsy, Duchenne Muscular Dystrophy, or other NMS pathology necessarily suffer the same poor outcomes. Our aim is to examine more mildly affected NMS patients to determine whether their surgical outcomes are comparable to AIS.

Methods
NMS and AIS patients undergoing PSF with pedicle screws from 2005-2018. Group 1: NMS patients who could ambulate without assistance (GMFCS I-III). Group 2: AIS patients. Demographic, intraop, and radiographic measurements were collected.

Results
Group 1 (n = 48) and Group 2 (n = 158) were similar in age, sex, preop kyphosis, pre- and postoperative Cobb angle, and Cobb correction. Additionally, EBL (600mL v 500mL; p=0.14), postoperative transfusions (4 v 9; p=0.5), and perioperative complications within 30 days (4 v 10; p=0.5) were similar between groups. Specifically, infections (0 v 5; p = 0.592), DVT (0 v 1;p = 0.23), revisions (1 vs 4; p = 1.0), and mortality (p = 1.0) were statistically similar. However, group 2 NMS patients did have increased fusion levels (p<0.001), fixation points (p=0.002), pelvic fixation (p=0.002), anesthesia (p<0.001) and surgery time (p<0.001), ICU (p<0.001) and hospital stay (p<0.001), intraop transfusions, pulmonary complications (3 v 0; p=0.012) and fewer patients extubated in the OR (p<0.001).

Conclusion
NMS inherently confers high risk of blood loss, longer surgeries and fusions, complications, ICU and hospitals stays. Our data confirm longer fusion levels, surgical time, and hospital stay, with lower extubation rates. Infection rate, revisions, and overall complications were similar to the AIS population as were the radiographic outcomes. This suggests that NMS patients who are ambulating can expect surgical outcomes quite comparable to AIS patients with further room for improvement in surgical duration and anesthesia protocols.

Take Home Message
Following posterior spinal fusion (PSF), ambulatory NMS cases compare similarly in their safety profile to AIS patients.

218. Virtual Reality and Mixed Reality Technologies for Complex Spine Surgery

Haruki Funao, MD, PhD; Norihiro Isogai, MD; Maki Sugimoto, MD, PhD; Wataru Narita, MD; Yutaka Sasao, MD, PhD; Makoto Nishiyama, MD, PhD; Ken Ishii, MD, PhD

Summary
Although intraoperative fluoroscopy is commonly used in spinal surgeries, one of the drawbacks is radiation exposure as well as a limitation of two-dimensional images for a three-dimensional (3D) configuration. Virtual reality (VR) is computer-generated 3D graphics, and mixed reality (MR) can merge real and virtual environments. Here we utilized VR and MR technologies as a reference in complex spinal surgery. These technologies were useful for preoperative planning and anatomical identification in providing more information of hidden structures and unusual anatomy.

Hypothesis
Virtual reality and mixed reality technologies would be useful as a reference in complex spine surgery.

Design
Case report.

Introduction
Although intraoperative fluoroscopy is commonly used in spinal surgeries, one of the drawbacks of fluoroscopy is radiation exposure as well as a limitation of two-dimensional images for a three-dimensional (3D) configuration. Computed tomography (CT)-based navigation system is not universally available due to costs. Virtual reality (VR) is computer-generated 3D graphics. Mixed reality (MR) technology can merge real and virtual worlds, and dynamic 3D image is superimposed on the patient's actual body. Here we utilized VR/MR technologies as a reference in complex spinal surgery.

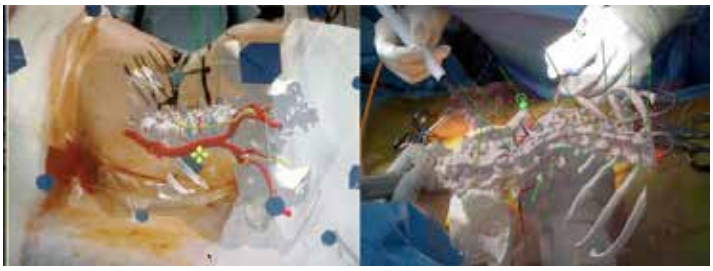
Methods
Three patients with degenerative spondylolisthesis, adult spinal deformity, and lung cancer metastasis to the thoracic spine were enrolled. Two-level lateral lumbar interbody fusion, circumferential spinal fusion from Th10 to the pelvis, and total en block spondylectomy combined with right upper lobectomy were performed. Raw data obtained from CT were reconstructed to volume rendering as polygon data. A Macintosh and a DICOM workstation OsiriX were used for VR and MR image analyses.

Results
The surgical team could plan surgical strategies based on VR images simulating surgical procedures preoperatively. MR images was helpful for anatomical identification of surgical targets, and

for ideal trajectories of both cage and screw insertion intraoperatively. Unexpected nerve, vessel, and organ injuries could be avoided in all procedures. Postoperative radiographs and CT images showed accurate instrumentation placements.

Conclusion
Although VR and MR technologies are still in research and development phase, these technologies were useful for preoperative planning and anatomical identification in providing more information of hidden structures and unusual anatomy.

Take Home Message
VR and MR technologies were useful for preoperative planning and anatomical identification in complicated spinal surgeries. It would be safe to provide more information of hidden structures and unusual anatomy.



Virtual reality and mixed reality technologies

219. Indications for Anterior Release and Outcomes in the Treatment of Severe Cerebral Palsy Scoliosis

Joseph Petfield, MD; Suken A. Shah, MD; Arun R. Hariharan, MD; Margaret Baldwin, MD; Petya Yorgova ; Burt Yaszay, MD; Firoz Miyanji, MD; Amer F. Samdani, MD; Stefan Parent, MD, PhD; Peter O. Newton, MD; Paul D. Sponseller, MD; Harms Study Group

Summary
A matched cohort study was attempted to compare severe CP scoliosis patients treated with anterior release and PSF versus PSF alone. Patients treated with anterior release demonstrated decreased curve flexibility preoperatively, correcting less than 30%. Patients treated with anterior release had similar postoperative scoliosis and pelvic obliquity correction, but experienced longer ICU/hospital stays and increased complications

Hypothesis
There is no difference in patients treated with anterior release and PSF vs PSF alone in CP scoliosis

Design
Matched cohort retrospective review from a prospectively collected multicenter registry

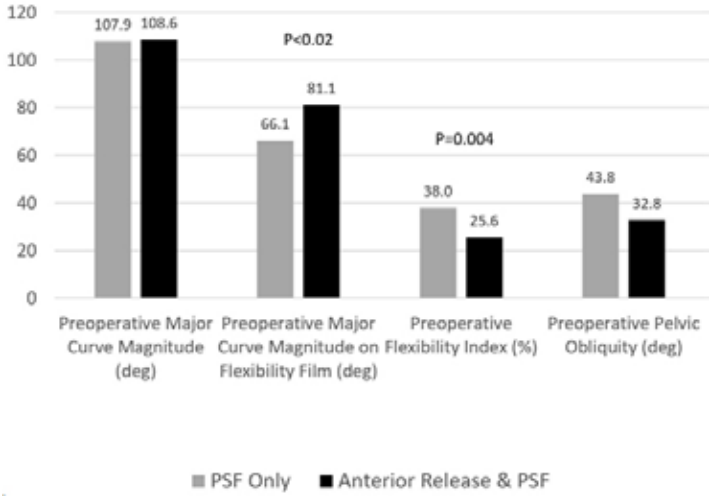
Introduction
Surgical treatment of severe CP scoliosis is posterior spinal fusion with or without anterior release; but, indications are unclear. Anterior release results in increased morbidity by increasing operative time, blood loss, pulmonary complications and hospital stay; however, is there any added value? We aim to identify factors which prompted surgeons to proceed with an anterior release and compare postoperative outcomes.

Methods
From a prospective multicenter CP scoliosis database, we matched patients who had anterior release and posterior spinal fusion (APSF) to those who had posterior spinal fusion (PSF) alone. Thirty-six patients were included with curves between 90 and 130 degrees, a minimum two year follow up, and Gross Motor Function Classification System (GMFCS) level IV or V.

Results
The groups had similar age (14.2 years, P=0.99), CPCHILD Scores (48.8 vs. 54.5, P=0.34), major curve magnitude (109 vs. 108 deg, P=0.83), lumbar lordosis (30 vs 35 deg, P=0.75) and pelvic obliquity (33 vs 44 deg, P=0.06) at the time of surgery; however children in the APSF group had curves which corrected less on traction or bending films (flexibility index 25.6% vs. 38.0%, P=0.004). Postoperatively, the groups had no difference in correction (40.0 vs. 41.7 degrees, P=0.75). Patients with APSF had longer ICU and hospital stays (ICU stay 11.7 vs. 5.7 days, P=0.005), (hospital stay 26.8 vs. 11.6 days, P=0.003). APSF patients had a higher rate of pulmonary complications (33% vs 0%, P=0.02) and a greater transfusion requirement.

Conclusion
Surgeons performed anterior release for curves which corrected less than 30% on preoperative traction or bending films. Despite rigidity, APSF resulted in similar scoliosis and pelvic obliquity correction compared to PSF alone in more flexible curves. APSF patients had increased ICU and hospital length of stay and complication rates.

Take Home Message
In severe CP scoliosis, despite the associated morbidity, anterior release may still be indicated in curves demonstrating less than 30% flexibility.



CP scoliosis treated with anterior release corrected less on preoperative flexibility X-rays

220. Ball Tip Technique for S2AI Screw Placement in Sacropelvic Fixation: A Compared Study with Conventional Freehand Technique

Zhenhai Zhou, MD, PhD; Zhimin Pan, MD, PhD; Kai Cao, MD, PhD; Honggui Yu, MD, PhD; Wenbing Wan, MD, PhD

Summary
Sixty-three patients who underwent sacropelvic fixation using ball tip technique or conventional freehand technique were divided into two groups. There is no any screw related complication occurred in all Pts. The ball tip technique enhances the accuracy of S2AI screw placement and is less time cost in sacropelvic fixation compared with conventional freehand technique.

Hypothesis
Ball tip technique for S2AI screw placement is safe and more accurate and efficient.

Design
A respective compared study.

Introduction
The S2AI screw placement is the most common method for sacropelvic fixation. S2AI screw insertion by navigation increases radiation exposure and inevitably disrupts workflow. Freehand technique is more popular but the learning curve is still steep. This study is to evaluate the accuracy and efficiency of ball tip technique for S2AI screw insertion.

Methods
Ball tip technique or conventional freehand technique were used in 63 Pts who underwent sacropelvic fixation. In ball tip technique group, after a Lenke pedicle probe just penetrated the SI joint, a ball-tipped probe consisted of a ball shaped metal tip with a flexible shaft was malletted to make a guide track within ilium. This ball-tipped probe could bend automatically away from the cortex and forward through the cancellous bone when the tip meeting the cortical lamina of ilium, which can avoid to penetrate the ilium(Fig.1). After repeating the procedures, a guide hole was gradually formed. S2AI screw was inserted along the guide hole after tapping. In the conventional freehand group, S2AI screw was placed according to the method described by Sponseller and Kebaish. After surgery, all Pts recieved pelvic CT to assess the accuracy of screws in both groups. The time cost of screw insertion and screw related complications were recorded.

Results
There were 36 Pts(72 screws) in ball tip technique group and 27 Pts(54 screws) in conventional freehand group. No screw-related complication occurred in all Pts. The time cost of screw insertion was 11.0±7.5 mins in ball tip group and 27.0±10.6 mins in conventional freehand group ($p<0.05$). Two screws penetrated iliac cortex in the ball tip group, versus 11 screws in conventional freehand group(3% vs. 20%) ($p<0.05$).

Conclusion
The ball tip technique enhances the accuracy of screw placement and is less time cost compared with conventional freehand technique.

Take Home Message
The ball tip technique keeps probe forward between the cortical lamina of ilium, which is not only safe, but more accurate and efficient for S2AI screw insertion.

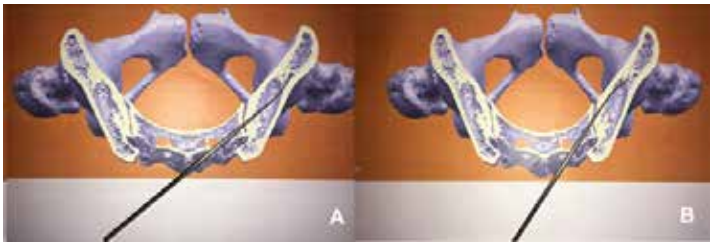


Fig.1, The ball-tipped probe bends automatically away from the latral(A), and medial(B) cortex of ilium.

221. Radiographic Outcomes and Pulmonary Function after Surgical Treatment in Non-Neuromuscular Scoliosis: Follow-up to a Landmark Study

Pablo L. Eamara, MD; Charles E. Johnston, MD; David C. Thornberg, BS

Summary
We reviewed 28 EOS patients with index surgery < age 9, minimum 5 yr f/u and serial PFTs. 18 patients (64%) had ≥ 50% pred PFTs and 17 (61%) had ≥ 18 cm of T1-T12 height. ≥18 cm T1-12 length did not improve pred %PFTs. Patients with pred %PFTs <50% had shorter index T1-12 heights, larger index Cobb angles or larger final residual curves.

Hypothesis
Achievement of 18 cm T1-12 threshold can improve pulmonary function results in Early Onset Scoliosis (EOS) patients

Design
Single institution, retrospective review / prospectively collected data

Introduction
Pulmonary function improvement following surgical intervention in EOS patients is uncertain. We compared pulmonary outcomes depending on age at index surgery (over/under 5) and T1-12 height (over/under 18cm) at f/u

Methods
Patients undergoing index surgery <age 9 between 2004-17 were reviewed, exclusion criteria were N-m scoliosis, skeletal dysplasia, pre-existing pulmonary disease, or <5 yr follow-up with serial PFTs. Patients were compared based on age at index surgery, T1-12 height, PFTs.

Results
28 patients (15 congenital, 11 syndromic, 2 idiopathic) were studied. 22 patients had growth sparing index surgery (mean age 4.8 yr), while 6 had definitive fusion (age 5.1). Index surgery before or after age 5 made no difference in post-op curve size or % pred PFTs. 18 patients (64%) had ≥ 50% pred PFTs and 17 (61%) had ≥ 18 cm of T1-12 height at f/u. Patients with ≥18 cm had actual FVC/FEV1 volumes greater than those <18cm (Table) but there were no differences in % pred PFTs based on over/under 18 cm (FVC pred 54 vs 53%, p=0.93; FEV1 pred 54 vs 49%, p=0.55). Patients with % pred PFTs < 50% had larger index and residual curves (82.9 vs 66.3 ˚, p=0.05; 60.1 vs 44.1 ˚, p=0.006) as well as shorter index T1-12 height (11.7 vs 14.7 cm, p=0.034).

Conclusion
Over/under 18 cm T1-12 threshold in EOS patients at minimum 5 yr post-index surgery showed no difference in % pred PFTs. Those with % pred PFTs < 50% had smaller index T1-12 height and larger index and residual Cobb angles. Over/under age 5 at index surgery showed no differences in post-op xray parameters or % pred PFTs.

Take Home Message
Surgery over/under age 5 did not affect Cobb or %PFTs at 5 yr followup. Over/under the T1-12 18 cm threshold did not affect the predicted %PFTs.

Patients at Latest Follow-Up, minimum 5 years after Index Surgery (N=28)	Under or Over 50% Predicted			Under or Over 18 cm T1-T12 Height			Under or Over 5 yo. at Index Surgery		
	< 50%	≥ 50%	p-value	< 18 cm	≥ 18 cm	p-value	< 5 yo	≥ 5 yo	p-value
Index Cobb (Degrees)	61.9°	44.3°	0.002	60°	47°	0.001	79.7°	49.2°	0.179
Index T1-T12 Height (mm)	117.2	140.7	0.004	106.1	131.6	0.000	119.6	133.6	0.018
Index T6 Chest Depth (mm)	68.8	73.3	0.197	67.6	71.0	0.400	69.8	69.2	0.889
Age at Index Surgery (yrs.)	4.37	6.14	0.344	3.56	5.89	0.008	3.52	6.93	0.001
Time between Surgery & Follow-Up (yrs.)	9.4	9.3	0.829	9.2	9.5	0.563	9.5	9.1	0.156
Age at Follow-up (yrs.)	13.8	15.5	0.166	12.7	14.2	0.127	12.9	14.7	0.066
Final T1-Major Cobb (Degrees)	46.2°	44.2	0.808	61.4°	47.5°	0.202	61.4°	47.3°	0.013
Final T1-T12 Height (cm)	19.8	19.9	0.952	18.93	21.05	0.000	17.65	20.47	0.001
Final T6 Chest Depth (mm)	89.9	89.6	0.779	89.4	90.7	0.851	91.1	91.2	0.979
FVC Actual (L) Final F/U	3.97	3.91	0.892	3.19	3.89	0.011	3.48	3.79	0.226
FEV1 Actual (L) Final F/U	3.46	3.44	0.880	2.86	3.46	0.004	3.19	3.43	0.317
FVC % Predicted Final F/U	91.9%	84.9%	0.068	90.4%	93.9%	0.303	92.2%	93.4%	0.691
FEV1 % Predicted Final F/U	92.9%	82.3%	0.005	84.2%	89.1%	0.540	90.8%	91.8%	0.892
Δ Cobb (Degrees) (Post – Pre)	-15.7°	-11.2°	0.461	-14.4°	-14.6°	0.911	-18.7°	-17.4°	0.614
Δ T1-T12 Height (cm) (Post – Pre)	10.6	10.3	0.877	9.99	9.79	0.691	9.19	9.91	0.402
Δ Chest Depth (mm) (Post – Pre)	19.8	16.5	0.406	21.87	21.87	0.419	21.1	21.9	0.814

Patient Data at Latest Followup

222. Is Percutaneous Pedicle Screws (PPS) Fixation Associated with Minimized Risk of Perioperative Proximal Junctional Kyphosis (PJK) in Adult Spinal Deformity?

Gregory M. Mundis, MD; Robert K. Eastlack, MD; Praveen V. Mummaneni, MD; Neel Anand, MD; Eric O. Klineberg, MD; Juan S. S. Uribe, MD; Han Jo Kim, MD; Michael Y. Wang, MD; Pierce D. Nunley, MD; Adam S. Kanter, MD; Shay Bess, MD; Frank J. Schwab, MD; Paul Park, MD; Khoi D. Than, MD; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD; Renaud Lafage, MS; International Spine Study Group

Summary
The use of percutaneous pedicle screws has been a topic of interest in prevention of proximal junctional kyphosis. This retrospective review of prospectively collected data compares adult deformity patients that were treated with circumferential minimally invasive techniques (CMIS) vs. open techniques, propensity matched the 2 groups to control for deformity, deformity correction and demographics. Patients with CMIS did not experience a reduction in PJK vs. Open.

Hypothesis
PPS is associated with minimized risk of perioperative PJK compared to traditional open techniques

Design
Retrospective review of prospective, multicenter ASD database

Introduction
Numerous strategies are used to minimize PJK in (ASD). The use of PPS is one such strategy. Studying this topic is difficult as there is a lack of homogeneity in the patient population being studied

Methods
Inclusion criteria are age >18, and one of the following: PT>25, PI-LL>10, or SVA>5 cm. Patients were grouped as MIS (all PPS no open component) or OPEN. Propensity matching was used to create 2 equal groups controlling for: age, BMI, Pre op (PI-LL, PI, TPA), and post op (PI-LL correction and posterior levels fused). PJK was evaluated in 2 groups: Mild (PJK10) 10 deg change from preop and severe (PJK20) a 20 deg change, as previously reported.

Results
1023 patients met criteria: 114 MIS and 909 OPEN. MIS were older with higher BMI. No significant difference was found between groups in preop alignment. OPEN had more levels fused (11.3 v 5.5), change in PI-LL (14.9 v 9.3) and LL (16.2 v 9.7; all p<0.01). After matching: 77 in each group with no difference in demographics or levels fused (6.26 +/- 3.7 OPEN; 6.23 +/- 3.4 MIS). At 1YR NRS leg, HRQOL were equal. MIS had improved NSR Back compared to OPEN (2.6 v 3.4; p=0.047). Alignment (PI-LL, TPA, SVA, LL, PT, PI) showed no difference preop, 6 weeks or 1YR. PJK10 was 23.9% OPEN v 20.3% in MIS at 6weeks and 28.6% and 19.5% at 1 YR (p>0.59). PJK20 was 2.6% in OPEN v 3.9% in MIS at 1YR (p=1). The PJK angle was not different (4.3 v 4.2). MIS had more interbodies (3.4 v 2.1; p=0.000). There was no difference in rate of revision surgery (14.3% OPEN v. 10.4%). Major complications occurred more frequently in OPEN (23.4% v 9.1%)

Conclusion
While the use of percutaneous fixation intuitively seems protective for PJK, our study found that when controlling for radiographic deformity, deformity correction, demographics and the magnitude of surgical intervention that percutaneous fixation is equivalent to open techniques in rate of perioperative PJK

Take Home Message
MIS screws are not protective against PJK compared to traditional open techniques in treating adults with symptomatic adult spinal deformity.

223. Should Prior Cervical Fusions be Considered During Level Selection in Adult Spinal Deformity Surgery?

Gregory M. Mundis, MD; Renaud Lafage, MS; Virginie Lafage, PhD; Robert K. Eastlack, MD; Eric O. Klineberg, MD; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Alex Soroceanu, MPH; Christopher I. Shaffrey, MD; Justin S. Smith, MD, PhD; Shay Bess, MD; Khaled M. Kebaish, MD; Munish C. Gupta, MD; Richard Hostin, MD; Michael P. Kelly, MD; Han Jo Kim, MD; International Spine Study Group

Summary
Many risk factors for PJK have been identified. The presence of a cervical fusion (CF) and its proximity to thoracolumbar fusion for adult spinal deformity has not been evaluated for its influence on PJK or UIV selection. CF was not found to be associated with PJK and this association did not change when taking UIV or

LIV into account. Propensity matching also found no association between preoperative CF and PJK.

Hypothesis
Prior cervical fusion would be a risk factor for PJK when upper thoracic UIV was selected.

Design
Retrospective review of prospective multi center database

Introduction
Many different risk factors for PJK have been identified in those having surgery for ASD. The presence of CF prior to Thoracolumbar fusion as a risk factor in this patient population has not been investigated.

Methods
Inclusion: age >18 and one of the following inclusion criteria was queried: PI-LL >10, PT >20, Max Cobb>10, SVA > 5 cm. 1023 patients were identified and grouped as CF (prior CF; n=101) and NoCF (n=922). Patients with 5 or fewer levels of CF and those without further cervical spine surgery at final follow up were included (cASD= 86; ASD= 910). After initial analysis propensity matching was performed controlling for: age, BMI, pre-op alignment (PI, PI-LL, TPA, SVA), change in alignment (PI-LL), and UIV/LIV.

Results
Among 996 patients the CF group was older (64 v 60; p<0.000), higher BMI (29.7 v 28; p<0.014), with equal gender distribution. PJK at 1 year was 34.9% (n=30) in CF and 34.7% (n=316) in NoCF. All had a min of 4 unfused levels between CF and TL fusion. No differences were found when stratifying by UIV (UT=upper thoracic; LT=Lower thoracic; L=lumbar). CF had worse pre-op deformity (PI-LL 21.3 v 17.2; TPA 27.3 v 23.6; SVA 90.6 v 68.5; p<0.05), with no difference in post op alignment. CF was more likely to have LT UIV (61.6% v 46%;p=0.045) and fusion to the ilium (93% v 81%; p=0.005). After propensity matching 79 were included in each group. CF had 68 patients with ACDF, 5 patients with PSF, and 6 with A/PSF. No difference in the rate of PJK (39.2 v 34.2%), PJK magnitude (13.4 v 13.7) or change in PJK angle (10.1 v 10.4). PJK rate and magnitude are not different by UT or LT as UIV.

Conclusion
The presence of CF is not associated with the development of PJK or PJK magnitude in this propensity matched cohort. All CF patients had a minimum of 4 segments unfused between the CF and the TL fusion which may act as a buffer and be protective of PJK.

Take Home Message
CF was not a risk factor for PJK after propensity matching in ASD patients when there were 4 segments unfused between the CF and TL surgery.

224. How Important is the Anterior Column Support in a Long Lumbopelvic Spinal Fixation? An In-Silico Biomechanics Analysis

Woojin Cho, MD, PhD; Wenhai Wang, PhD; Brandon Bucklen, PhD; Rafael De la Garza Ramos, MD; Reza Yassari, MD, MS

Summary
This study shows that in the absence of posterior biological fusion, the effect of poor spinal alignment can amplify the demands upon the rods. In these cases, anterior column support provides loading that is nearly equivalent to biological fusion without anterior support, when the spine is properly aligned.

Hypothesis
Anterior column support helps to alleviate the mechanical demand on the implant.

Design
In-Silico Biomechanics Analysis

Introduction
The addition of anterior column support at the bottom of a long construct has been proposed to support the lumbosacral junction and potentially prevent posterior lumbopelvic fixation failure. However, a retrospective study has shown that adding anterior column support is not sensitive to construct failure, highlighting the possibility that posterior fusion quality may be a more important factor than previously thought.

Methods
Finite element models (T10-Pelvis) were created to match the average spinal-pelvic parameters of two cohorts of patients reported in the literature: major-failure and non-failure groups. A load was applied at the T10 to simulate gravimetric loading in a standing position. Posterior solid fusion was simulated by applying spring elements attached to the adjacent vertebrae. Anterior column support was simulated by assigning cancellous bone properties to the L4-S1 disc.

Results
Upper body weight acting on the long instrumented spine resulted in 18% higher translation, 14% higher rotation, and 20% higher stress in the major failure group than in the non-failure group. Solid posterior fusion decreased translation and rotation, and also alleviated rod stress in the lower lumbar region. In this case, anterior support did not change the stress pattern. Conversely, simulated pseudoarthrosis produced stress patterns similar to those of the construct-only spine. In this case, adding anterior support dramatically alleviated stress at the index levels.

Conclusion
The spinopelvic parameters of the major-failure group produced increased gravity load, resulting in increased stresses in comparison to the non-failure group. Simulated posterior fusion helped reduce stresses in both major failure and non-failure patients. However, in cases with a simulated pseudoarthrosis, rod stresses were amplified by major failure spinal alignment. In this case, anterior column support was a major factor in reducing rod stress, and should be considered for patients with poor alignment.

Take Home Message
In cases with a simulated posterior pseudarthrosis, anterior column support was a major factor in reducing rod and S1 screw stresses, and should be considered for patients with poor alignment

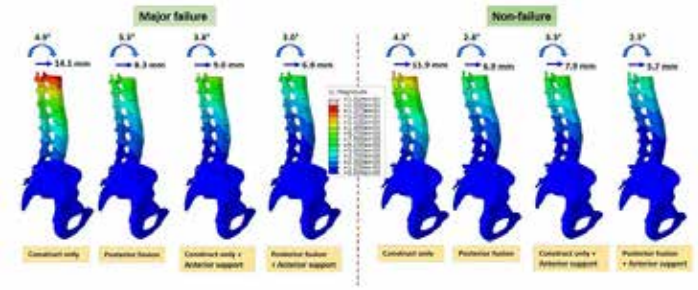


Figure 1. Load and displacement comparison between major failure and non-failure groups

225. Risk Factors for Lateral Translation in Adult Idiopathic Adolescent Scoliosis with Thoracolumbar/Lumbar Curves

Toshiaki Kotani, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Keita Nakayama, MD, PhD; Yasushi Iijima, MD, PhD; Tsutomu Akazawa, MD, PhD; Shohei Minami, MD, PhD; Kazuhide Inage, MD, PhD; Seiji Ohtori, MD

Summary
We investigated risk factors for lateral slip in pre-operative residual adolescent idiopathic scoliosis patients. Older age was a significant risk factor causing lateral slip (odds ratio: 1.199), with a cutoff value of 37 years old. These findings suggest that residual adolescent idiopathic scoliosis patients who need surgery should have surgery by age 37 to prevent lateral slip causing progression.

Hypothesis
Adult patients with residual adolescent idiopathic scoliosis with thoracolumbar/lumbar (TL/L) curves will develop a lateral slip as they age.

Design
Retrospective comparative study

Introduction
Although lateral vertebral translation is associated with inducing curve progression, no study has analyzed risk factors for lateral slip in residual idiopathic scoliosis patients. We investigated risk factors for lateral slip in residual adolescent idiopathic scoliosis.

Methods
Forty-one pre-operative patients with residual adolescent idiopathic scoliosis and TL/L curves were included (3 male, 38 female; age 41.9 ± 18.2 years, TL/L Cobb angle 55.5 ± 10.0 degrees). All patients were older than 20 years and had been diagnosed with adolescent idiopathic scoliosis during their adolescence. Lateral slip was defined as more than a 6 mm slip on coronal CT images.

Results
Patients were divided into slip (n=22) and non-slip (n=19) groups. There were significant differences in age, TL/L Cobb angle, apical vertebral rotation, apical vertebral translation, and L3 and L4 tilt between slip and non-slip groups. Multivariate analyses and receiver-operating characteristic curves demonstrated that only older age was a significant risk factor for lateral slip (odds ratio: 1.199; 95% confidence interval: 1.065-1.349; P<0.003), with a cutoff value of 37 years old.

Conclusion
This study demonstrated that older age, especially age > 37 years, is a risk factor for lateral slip in residual adolescent idiopathic patients. These findings suggest that residual adolescent idiopathic scoliosis patients who need surgery should have surgery by age 37 to prevent lateral slip causing progression.

Take Home Message
Residual adolescent idiopathic scoliosis patients who need surgery should have surgery by age 37 to prevent lateral slip causing additional progression.

	Non-slip group (n=19)	Slip group (n=22)	p
Age	26.5 ± 8.4	55.2 ± 13.1	<0.001*
Sex (Male: Female)	1:18	2:20	0.639
Cobb(TL/L)	49.9 ± 8.7	60.4 ± 8.5	<0.001*
C7 translation(cm)	-0.7 ± 1.4	-0.8 ± 2.6	0.908
AVT(cm)	4.2 ± 1.1	5.1 ± 1.4	0.039*
L1 tilt	12.6 ± 7.7	15.7 ± 8.3	0.218
L2 tilt	7.7 ± 4.6	9 ± 5.6	0.454
L3 tilt	14.6 ± 6.2	19.4 ± 7.5	0.034*
L4 tilt	14.8 ± 4.3	23.5 ± 6.6	<0.001*

* Statistically significant.

Demographic and clinical characteristics of the slip and non-slip groups.

226. Development of Thoracic Kyphosis after High Implant Density Posterior Correction and Fusion for Adolescent Idiopathic Scoliosis

Peter Obid, MD; Andreas Conta ; Philipp Drees, MD; Thomas Niemeyer, MD

Summary
Previous studies on thoracic kyphosis (TK) restoration have produced mixed findings on the ability of posterior instrumentations to achieve that goal. We report radiological results of 100 consecutive cases. Pre- and two-year postoperative data was analysed for the whole group and for preoperatively hypo-, normo- and hyperkyphotic patients (according to sagittal modifiers of the Lenke classification). TK significantly decreased in the whole group. The same applies for normo- and hyperkyphotic patients. In the hypokyphotic group TK significantly increased.

Hypothesis
Modern high implant density posterior spinal correction and fusion does not provide sufficient restoration of thoracic kyphosis.

Design
Retrospective analysis of radiological data.

Introduction
Posterior spinal fusion (PSF) provides good results in the coronal

plane. But pedicle screw based instrumentations tend to flatten the spine. With derotation the anterior column is lengthened which sacrifices kyphosis. Although there is a paucity of evidence to prove that this affects long-term outcome and quality of life, it is logical to assume that TK restoration may optimize global sagittal alignment and slow down lumbar and cervical disc degeneration.

Methods
Radiographs of 100 consecutive patients that underwent posterior correction and fusion for adolescent idiopathic scoliosis (AIS) at a single center were analysed. Implant density was 88%. 5.5mm diameter titanium or cobalt chromium rods were used. Thoracic Kyphosis (TK) was measured preoperatively and two years postoperatively for the whole group, and separately for hypo-, normo- and hyperkyphotic (according to sagittal modifiers of the Lenke classification) patients. A one-sided one-sample t-test was performed to compare pre- and postoperative values.

Results
For all patients mean TK significantly decreased by 3.8° ± 3.4 (p=0.005). For hyperkyphotic patients (n=9) mean TK significantly decreased by 18.9° ± 3.8 (p=0.006). For normokyphotic patients (n=75) mean TK significantly decreased by 3.9° ± 3.2 (p=0.001). For hypokyphotic patients (n=16) mean TK significantly increased by 4.9° ± 2.4 (p=0.005).

Conclusion
The results are ambivalent which is consistent with the literature. Except for the hyperkyphotic group the differences of mean values are within or close to the range of a measurement error. The main conflict of implant stiffness versus lnduction of lordosis with derotation remains unsolved. Additionally, it is difficult to define a TK for any given patient. Therefore restoration of TK remains challenging.

Take Home Message
Restoration or induction of thoracic kyphosis with PSF is not possible. However, in patients that are already hypokyphotic it is possible to achieve good coronal correction without sacrificing additional kyphosis.

227. Surgical Management of Complex Post Tuberculous Kyphosis Among African Patients: Clinical and Radiographic Outcomes for a Consecutive Series Treated at an SRS GOP Site in West Africa

Ali Maziad, MD, PhD; Owoicho Adogwa, MPH; Henry Ofori Duah, MPH; Kwadwo Poku Yankey, MD; Derrick Owusu Nyantakyi, ; Arthur Sackeyfio, MD; Mabel A. Owiredu, ; Tyler Wilps, BS; Gerhard Ofori-Amankwah, MD; Franklin Coleman, BS; Harry Akoto, MD; Irene Wulff, MD; Oheneba Boachie-Adjei, MD; FOCOS Spine Research Group

Summary
We reviewed data of 57 consecutive Post TB Kyphotic patients who underwent surgical treatment at a single site in West Africa. Halo-Gravity Traction(HGT)± posterior vertebral column resection (PVCR) provided excellent correction of severe sagittal deformities with good clinical, radiographic and HRQoL scores in a resource limited setting.

Hypothesis
Severe TB Kyphosis can be safely corrected in developing countries provided a good setup is established

Design
Retrospective review of consecutive series

Introduction
Post Tuberculous Kyphosis can lead to progressive pulmonary and neurological deterioration. Surgical correction is needed to decompress neural elements and correct the deformity. Although posterior vertebral column resection (PVCR) has been established as the treatment of choice for severe kyphosis, there is paucity of studies on the clinical outcomes among patients treated in West Africa.

Methods
Clinical & radiographic data of 57 pts who underwent surgical correction of Post TB Kyphosis at a single site in West Africa between 2013-2018 and a minimum 1-year f/u were reviewed (≥2yr FU in 48 pts, ≥1 year FU in 9 pts). Pre/Post-Op SRS scores and radiographic changes were compared using Paired t-test. Complications were reported.

Results
57 patients, 36M:21F Mean age 19 (11-57yrs). 22/57 pts (39.29%) underwent Pre-op HGT for an avg. duration of 86 days (8-144 days). HGT pts had a higher baseline regional kyphosis (125.120±20.9) compared to Non-HGT pts (64.580±31.80, p<0.001). Post-HGT the regional kyphosis corrected to 101.20 ± 23. 53 pts (92.98%) underwent posterior-only surgery, 4(7.02%) combined anterior-posterior surgery. 39(68.42%) had PVCR, 11(19.3%) PSO, 16 (28.07%) thoracoplasty. IOM changes were 23/57 (≈40%), dural tear 5 (8.77%), pleural tear 3(5.26%), ureteric injury 1, and vascular injury 1. Post-Op complications were 4(7.02%) infection, 3(5.26%) implant related, 2(3.51%) radiographic (1 PJK,1 DJK), 2(3.51%) Neurologic,1 wound problem, and 2 sacral ulcers. IOM changes were similar in the VCR (48.72 %) and Non-VCR (23.53 %) pts, p= 0.078. Complication rates were similar among HGT and non-HGT group. Significant improvements from baseline were seen in average SRS Total and domains scores and radiographic measurements (Table 1).

Conclusion
PVCR±HGT can provide safe and excellent correction in cases of severe post TB kyphoscoliosis with good clinical and radiographic outcomes in less a resourced setting

Take Home Message
Complex Post TB spinal deformities can be safely corrected in resource limited African countries by trained local surgeons at well-equipped clinical sites.

Table 1: Changes in Pre-op SRS scores and radiographic measurements at post –Op follow up

SRS-Scores	Pre-Op	Post-Op follow Up	P-vale
SRS Total	2.80±0.62	3.92±0.68	<0.001
Function	2.89±0.79	3.58±1.01	0.0017
Pain	3.13± 0.98	3.92±0.90	<0.001
Self-esteem	1.92±0.98	4.00±1.06	<0.001
Mental	3.37±0.52	4.04±0.90	<0.001
Satisfaction	2.27±1.39	4.25±0.73	<0.001
Sagittal Cobb measurements	**Pre-Op**	**Post-Op follow Up**	**P-vale**
T2-T5	0.16± 13.68	8.78±10.14	0.0023
T5-T12	46.11±52.09	30.91±19.69	0.0307
T2-T12	42.97± 47.95	37.55±18.47	0.3987
T10-L2	49.16± 50.48	14.74±15.84	<0.001
L1-S1	53.49±32.88	39.25 ±16.08	0.0061
Regional Kyphosis	91.14 ±38.67	27.93±16.75	<0.001
Sagittal Alignment			
SVA	42.99±54.17	32.35±37.11	0.1639

228. Changing Practice Over the Past 20 Years in Early Onset Scoliosis Surgery

Robert F. Murphy, MD; Tara Flynn, BS; John B. Emans, MD; John (Jack) M. Flynn, MD; Jason B. Anari, MD; Tricia St. Hilaire, MPH; Pediatric Spine Study Group ; Jeffrey R. Sawyer, MD

Summary
Growth friendly surgery for early onset scoliosis (EOS) has increased significantly over the past 20 years. Surgical criteria are evolving, including a trend toward older patients and smaller Cobb angle at index surgery.

Hypothesis
Over the past 20 years, there has been an evolution in surgical selection criteria and index implant type in growth friendly (GF) surgery for early onset scoliosis patients.

Design
Retrospective multi-center registry review

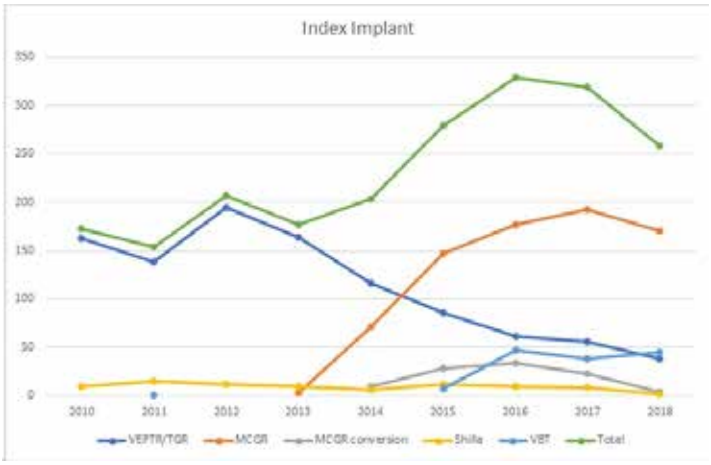
Introduction
Surgical intervention in early onset scoliosis is a dynamically changing field, with new technologies and techniques being introduced. Practice trends in this evolving field have not been studied.

Methods
A pediatric spine database was queried over a 20-year period in 5 year increments for patient age and Coronal cobb angle at time of index growth friendly surgery, and type of index growth friendly technique/implant (traditional spine/rib-based distraction [TGR/VEPTR], magnetically controlled growing rod [MCGR], Shilla, or vertebral body tether) performed.

Results
Twenty years of data were available (2000-2019), with 9 years of data detailing specific type of index growth friendly implant (2010-2018). The number of patients with an index growth friendly implant increased significantly over the study period from 246 in 2000-2004 to 1179 from 2015-2019, a 4.8X increase. Over the decade 2010 to 2018, the type of growth friendly implant changed dramatically, especially in regard to TGR/VEPTR (2010:163/173 (94%); 2018:38/259 (15%)) and the introduction of MCGR (2013:3/177 (2%); 2018:174/259 (67%)). Figure 1. Average age at index surgery increased significantly from 5.4 (yrs 2000-2004) to 8.3 (yrs 2015-2019). Furthermore, average Cobb angle at index surgery decreased over the study period from 74.5° (yrs 2000-2004) to 71.6° (yrs 2015-2019), with the most significant decrease in idiopathic patients 78° (yrs 2000-2004) to 63.6° (yrs 2015-2019).

Conclusion
There has been a significant increase in growth friendly surgery for early onset scoliosis over the past 20 years, with MCGR comprising the majority of recent implants (67%). Age at index surgery has increased significantly, from 5 to 8 years, with a corresponding decrease in the Cobb angle at index surgery, especially in idiopathic patients.

Take Home Message
GF surgery for EOS has increased significantly over the past 20 years. Surgical criteria are evolving, including a trend toward older patients and smaller Cobb angle at index surgery.



Type of Index Implant by Year

229. The Association between the Utilization of Traction and Postoperative Complications following Growing Rod Instrumentation

Benjamin D. Roye, MD; Michael Fields, BS; Hiroko Matsumoto, PhD; Paul D. Sponseller, MD; Francisco Javier S. Perez-Grueso, MD; Oheneba Boachie-Adjei, MD; Kim W. Hammerberg, MD; Michelle C. Welborn, MD; Michael G. Vitale, MD; Pediatric Spine Study Group

Summary
An association between the use of cranial traction and complications following growing rod instrumentation at two year follow-up was examined in 382 patients with early onset scoliosis (EOS) queried from multi-center registries. Intraoperative cranial traction resulted in a reduced likelihood of postoperative complications including unplanned return to the operating room (UPROR) in non-idiopathic patients with hyper-kyphosis.

Hypothesis
Patients that receive cranial traction prior to implantation of a growing rod will have a lower risk of postoperative complica-

tions compared to those that do not undergo traction at 2 years follow-up.

Design
Retrospective cohort study.

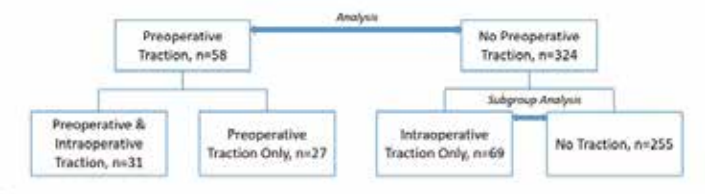
Introduction
Cranial traction preop/intraop allows for pre-instrumentation correction of the spinal deformity in children with EOS. It has been suggested that by reducing implant associated stresses, traction can act as a protective factor against complications in growing rod therapy.

Methods
In this multi-center retrospective cohort study, patients with EOS who underwent growth rod instrumentation prior to 2017 were identified from two registries including 6 centers. Patients were divided into two groups: preop traction group vs. no preop traction group. A subgroup analysis was done to compare intraop traction vs no traction (Figure). Data was collected on any postoperative complication from implantation to up to two years post implantation.

Results
Of 382 patients (53.4% female) identified, 58 (15.1%) and 69 (18%) patients received preop and intraop traction, respectively. Patient etiology included: 20% congenital, 37% neuromuscular, 24% syndromic and 19% idiopathic. There was no association found between the use of preop traction and any postoperative complication. However, fewer postoperative complications were reported in the intraop traction group than in the no traction group (25 (36.2%) vs. 123 (48.2%); p=0.076). Among non-idiopathic, hyper-kyphotic patients, those who received intraop traction were 61% less likely to experience any postop complication (p = 0.067). Overall, UPROR was 4 times more likely in the non-traction group vs. intraop traction group (20.8% vs 5.8%, p = 0.004). Specifically, among the non-idiopathic, hyper-kyphotic patients, those who received intraop traction were 74% less likely to experience UPROR when compared to patients without traction (p = 0.091).

Conclusion
Non-idiopathic, hyper-kyphotic patients receiving intraop traction were less likely to experience postop complications including UPROR than those that did not receive traction.

Take Home Message
Intraoperative cranial traction may provide a protective effect against complications including unplanned return to the operating room in non-idiopathic EOS patients with hyper-kyphosis.



230. PLIF vs PLF: Which has the Lower Operative Nonunion Rate? Analysis of a Cohort of over 3000 Patients from a National Spine Registry

Kern H. Guppy, MD, PhD; Kathryn E. Royse, MPH, MSPH; Elizabeth P. Norheim, MD; David J. Moller, MD; Patrick W. Suen, MD; Shayan U. Rahman, MD; Jessica Harris, MS; Harsimran S. Brara, MD

Summary
Although fusion rates in PLFs and PLIFs are well documented in literature, there is no consensus on which technique has lower operative nonunion rates. Using a National Spine Registry, a cohort of 3065 patients with greater than 4 years of follow-up found no difference in operative nonunion between PLFs and PLIFs. Increased risk of nonunion was predominately from constructs that included L5-S1 and 3-level fusions.

Hypothesis
Reoperation rates for nonunions (operative nonunion rates) are different between posterolateral fusions with pedicle screws (PLFs) and posterior lumbar interbody fusion with pedicle screws (PLIFs).

Design
Retrospective cohort study

Introduction
Although PLF and PLIF fusion rates are well documented, there is no consensus on which has a lower operative nonunion rate. Most studies use radiographic imaging; yet many of these nonunions are asymptomatic. A more clinically useful measure is the operative nonunion rate. We report the operative nonunion rates between these two procedures.

Methods
Using data from the Kaiser Permanente Spine Registry (2009-2018), adult patients (≥18 years old) with degenerative disc disease with primary elective PLFs and PLIFs between L1 and S1 with 1-level, 2-level, and 3-level fusions were followed until validated operative nonunion, membership termination, death, or 03/31/2019. Two-year incidence rates and adjusted, multivariable Cox-Proportional Hazards models for operative nonunions were calculated by fusion-level, fusion type (PLF vs. PLIF), and levels fused.

Results
We identified 3,065 patients with a near 3:1 ratio of PLF to PLIF fusions (PLF:71.6% and 28.4% PLIF). Average age was 65.0±11.7, average follow-up time was 4.8±3.1 years, and average time to operative nonunion was 1.6 (±1.3) years. Single- and multilevel fusion incidence rates were similar except for 3-Level: (: PLF: 2.9% (95% CI=1.0-6.7) vs PLIF: 7.1% (95% CI=0.2-33.9). There were no operative nonunion risk differences by fusion type (PLIF vs. PLF: adjHR: 0.8, 95% CI=0.4-1.6). Compared to patients without, patients with L5-S1 construct fusions had 2.3 times the risk of operative non-union (HR=2.3, 95% CI=1.2-4.4). Risk of operative non-union was 3.8 times higher in patients with 3-level compared to 1-level (adjHR 3.8, 95% CI=1.5-9.5).

Conclusion
A large cohort of patients with greater than 4 years of follow-up found no difference in operative nonunion between PLF and PLIF. Increased risk of non-union was predominately from constructs that included L5-S1 and nonunion rates were highest for 3-level fusions.

Take Home Message
Cohort of 3065 patients with > 4 years of follow-up found no difference in operative nonunions between PLFs and PLIFs. Increased nonunions were constructs that included L5-S1 and 3-level fusions.

231. Ponte Osteotomies in a Matched Series of Large AIS Patients Increase Surgical Risk Without Improving Coronal or Sagittal Correction or Patient Reported Outcomes

Lorena Floccari, MD; Kiley F. Poppino, BS; *Daniel J. Sucato, MD, MS*

Summary
In a closely matched group of patients, Ponte osteotomies for large curve AIS (>70 degree) results in mild improvement in the coronal plane without a difference in the sagittal plane or patient-reported outcomes but is associated with increased critical intraoperative neuromonitoring changes. Given the small gains seen with potentially higher neurologic risk, the routine use of this technique in large AIS curves should be called into question.

Hypothesis
We hypothesize that the use of Ponte osteotomies in AIS will not improve outcomes.

Design
A retrospective matched cohort of prospectively collected data.

Introduction
The benefit of Ponte osteotomies for AIS surgery is controversial with conflicting data in the coronal plane and little analysis in the sagittal plane or with patient outcomes.

Methods
A consecutive prospectively-collected series of AIS patients from a single institution with larger preoperative larger curves were retrospectively reviewed. Two cohorts (PO=Ponte; NP=no Ponte) were matched by age, gender, Lenke classification, maximum coronal & sagittal Cobb angles. Measured and adjusted values (3D-derived published formula) for preoperative sagittal T5-T12 were used. Patient reported outcomes (PROs) were assessed with the SRS and the Spinal Appearance Questionnaire (SAQ).

Results
There were 68 patients without differences between the PO and NP in age (14.6 v 14.8), or preoperative coronal Cobb (75° v 71°), T5-T12 (28.0° v 27.6°), or adjusted T5-T12 (0.4° v 2.2°),(p>0.05). OR time or EBL did not differ but implant density was higher in the PO group (1.55 v, 1.31, p<0.001). The PO group had greater Cobb correction (69% v 59%, p<0.001) and smaller final Cobb (23° v 29°,p=0.01), however, there were no differences in final sagittal T5-T12 (23° v 25°, p=0.35) or T2-T12 (32 v 33, p=0.56). The PO group had more intraoperative neuromonitoring (IONM) changes (14.7% v 0%,p<0.05 The preoperative and 2 year total SRS scores showed no differences between PO and NP (3.84 v 3.75; 4.26 v 4.20). Total SAQ scores also showed no difference preoperatively (47.0 v 46.4; 43.8 v 45.2) or at two years (24.4 v 26.6; 24.8 v 25.0) for either parent or patient, respectively.

Conclusion
The use of Ponte osteotomies in the treatment of larger curves with AIS provides mild gains in coronal plane correction without any benefit in the sagittal plane or patient reported outcomes. Given the increased incidence of IONM changes, the routine use of this technique in large AIS curves should be called into question.

Take Home Message
Routine use of Ponte osteotomies in patients with AIS should be questioned due to only mild coronal gain and no benefit to the sagittal plane or PRO scores.

232. The Reliability of the AOSpine Thoracolumbar Spine Injury Classification System in Children. An International Validation Study

Andrew Z. Mo, MD; Daniel Hedequist, MD

Summary
We identified a series of 25 pediatric thoracolumbar spine injury cases. Imaging in the form of CT and MRI were distributed to 21 pediatric orthopaedic surgeons specializing in spine surgery to evaluate the cases utilizing the AOSpine Thoracolumbar Spine Injury Classification System. This was performed a second time after randomization of the cases. Interobserver reliability and intraobserver reproducibility were assessed to determine the effectiveness of the AOSpine Thoracolumbar Spine Injury Classification System in pediatric spine trauma.

Hypothesis
The new AOSpine thoracolumbar spine injury classification system is reliable and reproducible when applied to the pediatric population.

Design
Multicenter review of single-center retrospective case series.

Introduction
In the adult population, there have been significant endeavors in developing classification systems of thoracolumbar injuries. There does not yet exist a dedicated classification system for pediatric thoracolumbar fractures despite the discordance in presentation. Pediatric thoracolumbar fractures vary in morphology, severity, and morbidity.

Methods
A group of 21 SRS and POSNA member surgeons were sent MRI and CT imaging of twenty-five pediatric patients with thoracolumbar spine injuries organized into cases to review and classify. The evaluators classified injuries into 3 primary categories: A, B, and C. Interobserver reliability was assessed for the initial reading across all 21 raters by Fleiss's kappa coefficient (kF) along with 95% confidence intervals (CI). For A and B type injuries, sub-classification was conducted including A0-A4 and B1-B2 sub-

types. Interobserver reliability across subclasses was assessed using Krippendorff's alpha (αk) along with bootstrapped 95% CIs. Imaging was reviewed a second time by all 21 evaluators approximately 1 month from the initial read. All patient imaging was blinded and randomized for each read independently. Intraobserver reproducibility was assessed for the primary classifications using Fleiss's kappa and sub-classification reproducibility was assessed by Krippendorff's alpha (αk) along with 95% CIs.

Results
Twenty-five cases were read by 21 raters for a total of 525 initial and 525 repeated evaluations. Interobserver reliability was almost perfect (kF = 0.74; CI = 0.75 - 0.79) across all 21 raters. Sub-classification reliability was substantial (αK = 0.74; CI = 0.58 - 0.85). Intraobserver reproducibility was almost perfect (kF = 0.87; CI = 0.80 - 0.93) for both primary classifications and for sub-classifications (αk = 0.87; CI = 0.83 - 0.91).

Conclusion
The reliability for the AOSpine TL classification system was high amongst SRS and POSNA surgeons in the pediatric patients.

Take Home Message
The AOSpine TL classification system has promising applications in the pediatric population and may obviate the need to create a dedicated classification, saving time and resources.

233. Assessment of Spinopelvic Parameters Following Stand-alone Decompression in the Patients with Lumbar Spinal Stenosis (LSS)

Naveed Nabizadeh, MD; Mohammad E. Majd, MD; Sam Bemani, MD

Summary
The majority of LSS patients present with concomitant sagittal mal-alignment.

Hypothesis
To demonstrate that simple decompression can improve the sagittal alignment.

Design
Retrospective

Introduction
Buckling of flavum ligaments causes loss of lumbar lordosis. We assumed to restore normal alignment efficiently by only resection of offending posterior elements.

Methods
We included LSS patients who underwent simple decompression with/without discectomy.The exclusion criteria consisted of sagittal vertical axis(SVA) shift>100mm, previous surgery, thoracolumbar fracture, spondylolisthesis higher than grade I, lumbar scoliosis>20◦,neuromuscular diseases.50 patients were eligible and divided based on preoperative imaging into two groups: those with normal SVA<40 mm (n=23,46%) and those with abnormal SVA ranges 40-100 mm, (n=27,54%). The spinopelvic parameters were measured on the lateral upright radiographs obtained before surgery and in the last postoperative visit including SVA shift,PT,SS,PI,LL,PI-LL mismatch,TK,T1 spinopelvic inclination (T1SPi),T1 pelvic angle(T1PA) and spinopelvic angle(SPA). One, two and three levels of decompression was performed in 78.8%,15.4% and 5.8% of cases, respectively. The follow up period was 757.6 days (96-1358). The impact of BMI on the outcome was also evaluated.

Results
At last follow up visit, 47 patients (94%) had normal sagittal alignment and 3 patients (6%) remained malaligned. The PT and PI-LL mismatch dropped in both groups significantly (P=0.025, 0.000 respectively). SS and LL rose remarkably in both groups (P=0.024,0.000 respectively).T1SP inclination shifted toward negative amounts in both group but it was considerable only in the malaligned group(P=0.000).TK and SPA increased in both groups but a remarkable rise occurred in the malaligned group (P=value 0.000, 0.006 respectively). SVA shift and T1PA decreased in both group, but significant improvement presented in the malaligned group (P=0.000,0.006 respectively).Additionally, improvement of SVA in the malaligned group with high BMI was significant(P=0.034).

Conclusion
Regardless of the BMI, decompression alone can potentially improve LL,TK ,and sagittal alignment in patients with LSS particularly those with SVA shift 40-100mm.

Take Home Message
Sagittal alignment in the patients with SVA<100mm can improve by simple decompression.

234. Rapid Recovery Pathway Utilizing Intrathecal Morphine Decreases Overall Hospital Costs and Improves Quality of Care in Adolescent Idiopathic Scoliosis

Sayyida Hasan, BS; *Benita Liao, MD*; Michelle Kars, MD; Vishal Sarwahi, MD, MBBS; Terry D. Amaral, MD; Jesse Galina, BS; Yung-tai Lo, PhD; Aaron M. Atlas, BS

Summary
The RRP protocol following PSF had lower total hospital costs and lower home opioid requirements after surgery than the traditional PCA protocol.

Hypothesis
Utilization of a standardized RRP using multimodal analgesia without PCA improves patient quality of care, decreases opioid use, and costs less than traditional PCA methods.

Design
Retrospective chart review

Introduction
Posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS) is a complex procedure for which charges can exceed $150,000. Among the total costs, inpatient and intensive unit care contributed 22%. Many institutions have implemented rapid recovery pathways (RRP) to improve patient care following scoliosis surgery. This study aims to determine the effects of a multi-modal RRP, utilizing intrathecal morphine (ITM) in combi-

nation with oral pain medication, on hospital costs and patient management.

Methods
AIS patients undergoing PSF from 2013 – 2019 were retrospectively reviewed. RRP patients received ITM as part of their multimodal analgesia. Fusion level-matched control patients received hydromorphone PCA for postoperative pain management. At discharge, PCA patients received 14-day prescriptions for oxycodone compared to 7-day prescriptions in the ITM group. Perioperative data, requests for opioid refill, and overall costs were analyzed.

Results
363 patients were included (PCA: 255, RRP/ITM: 108). BMI (p=0.786) and preoperative Cobb (p=0.343) were similar. RRP patients had a significantly shorter length of stay (3 v 5 days, p<0.001). 65.2% of RRP patients ambulated by POD1 compared to 43.4% of PCA patients (p<0.001). The fraction of patients who requested opioid refills was similar (p=0.082). The cost of intraoperative anesthesia was significantly higher for RRP patients ($2,286.87 v $1,958.70, p<0.001). Perioperative hospital stay ($39,990.00 vs $55,680.00, p<0.001) was significantly lower for RRP patients. Due to different prescription durations, the cost of home opioid medications was $98.94 for PCA patients versus $56.28 for RRP.

Conclusion
With increasing concerns about opioid dependence and hospital costs, our RRP pathway, which incorporates microdose ITM injections, allows for optimum perioperative management, improved costs, with overall better outcomes than the traditional PCA.

Take Home Message
A Rapid Recovery Protocol following posterior spinal fusion results in lower hospital costs and fewer home opioid prescriptions compared to traditional protocols.

236. Surgery for Severe Pediatric Spinal Deformity Results in Improved Spinal Appearance Questionnaire Scores at 2 Years

Munish C. Gupta, MD; Lawrence G. Lenke, MD; Oheneba Boachie-Adjei, MD; David B. Bumpass, MD; Mark A. Erickson, MD; Sumeet Garg, MD; Richard E. McCarthy, MD; Peter O. Newton, MD; Joshua M. Pahys, MD; Amer F. Samdani, MD; Suken A. Shah, MD; Harry L. Shufflebarger, MD; Paul D. Sponseller, MD; Daniel J. Sucato, MD, MS; Burt Yaszay, MD; Brenda A. Sides, MA; Michael P. Kelly, MD; Fox Pediatric Spinal Deformity Study

Summary
Spinal Appearance Questionnaire scores demonstrate significant improvement from preop to 2 yr postop in pediatric patients with severe spinal deformity. This improvement in appearance perception and surgical expectation is correlated with the preop Cobb angle but not with the amount of surgical correction.

Hypothesis
SAQ scores improve at 2 yr po and are related to amount of deformity correction.

Design
Prospective observational multi center cohort of pediatric patients treated surgically for severe spinal deformity.

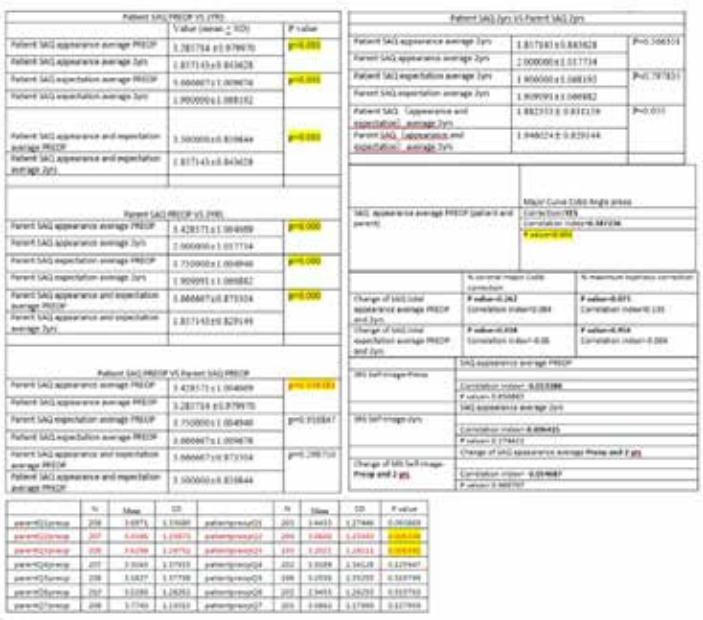
Introduction
The SAQ is a validated measure of self-image in AIS patients with a significant correlation with curve magnitude and is a measure of appearance perception and surgical expectations. However, its responsiveness in severe pediatric deformity pts is not fully known.

Methods
Pts with severe spinal def. (min. 100° or planned VCR) were included with min. 2 yr f/u. We studied the preop to 2 yr po change in patients/parents SAQ scores and analyzed them for correlation with various factors.

Results
242/311 (78%) pts had a min 2 yr f/u. Only questions answered preop and 2 yr po were analyzed; avg: N=204 patients (pts.) and 202 parents. All pts. and parent scores were significant preop to 2 yr po (p<0.001, p=0.000 respectively) . Question 2 (rib prominence) and 3 (flank prominence) were the only preop app. questions with a difference between pts. and parent (p=0.005, p<0.001). Preop pts. and parent SAQ appearance (app.) avg. was 3.29 and 3.43 respectively, p=0.038, but expectation (exp.) and combined app./exp. scores showed no difference between pts. and parent (3.67 v 3.75, p=0.917) (3.50 v 3.67, p=0.299), respectively. No difference was found in the 2yr scores comparing pts. and parent for appearance(1.86 v 2.00, p=0.566), exp. (1.90 v 1.91, p=0.80), or combined (1.88 v 1.95, p=0.055). The preop combined SAQ app. score correlated with the preop Cobb angle, p<0.001. However, there was no correlation between the % correction and the total app. or exp. avg. from preop to 2 yr (coronal; p=0.262 app., p=0.938 exp.) (sagittal; p=0.073 app., p=0.954 exp.). There was no correlation between SAQ and SRS score on self-image (preop p=0.857, 2yrs p=0.174, change preop to 2 yr p=0.547.

Conclusion
The average score of SAQ app. and exp. preop to 2 yrs po are statistically significant and correlated with the preop Cobb angle; however, there is no correlation between the amount of SAQ change and deformity correction.

Take Home Message
Average SAQ score preop to 2 yr po are significant and correlated with the preop Cobb angle; there is no correlation between the amount of SAQ change and deformity correction.



SAQ Analysis

237. Fusionless Bipolar Fixation: a Minimally Invasive Surgery in Severe Neuromuscular Scoliosis

Eugenio Dema, MD; Matteo Palmisani, MD; Stefano Cervellati, MD; Lotfi Miladi, MD; Massimo Girardo, MD; Rosa Palmisani, MD

Summary
Neuromuscular diseases are correlate with severe rapidly progressive spinal deformities with a poor bone quality. The conservative or conventional surgical treatment are followed with a high rate of post-op complication. We perform an alternative minimally invasive fusionless technique and compare it with a posterior segmental arthodesis surgical treatment and present a preliminary minimum 1 year post-op results with significant deformity and pelvic obliquity correction. The minimally invasive fusionless technique is hybrid instrumentation:proximal thoracic hooks and distal bilateral ileosacral screws fixation

Hypothesis
We analyze postop results of minimally invasive bipolar fixation technique and compared with conventional spinal fusion in neuromuscular scoliosis patients

Design
Comparative case series

Introduction
In neuromuscular scoliosis patients we perform a posterior segmental arthodesis as a systemic surgical treatment. Patients require a long hospital stay, blood loss and a high rate complications. Exist an alternative type of surgery performed with a minimally invasive approach.

Methods
We perform an alternative bipolar fixation technique with a bilateral double rod construct anchored proximally with a 2 couple of hooks and distally with bilateral ileosacral screws connected with connector and domino using a minimally invasive approach. 16 patients with a severe neuromuscular scoliosis (5 Rett Syndrome, 3 SMA, 8 CP), 8 male and 8 female with average age 14y.(11-22y) underwent to a surgery with intra-op traction and minimally invasive T1-T2 to sacral fusionless fixation. The patients were evaluated pre-op, post-op and at f.u (6-12-18-24 months) cobb angle, pelvic obl(PO) and balance. The average of pre-op T-L curves is 96°(88-128), kyphosis 94°(85-120), PO 33°(20-45).

Results
Patients were followed for min 2y and compared with a a conventional posterior spinal fusion in a similar neuromuscular patients group (age, severity, ASA). There are better results with a mean T-L curves 32°(12-50) correction 78%, kyphosis 25°(10-51), PO 4°(0-8) correction 88% with low rate of complication in a bipolar group. 1 cross-link dislocation and a nut unscrewing.

Conclusion
The neuromuscular scoliosis surgery requires a particular attention to altered bony, muscular anatomy, patients general condition. It's necessary a pre-op or intraop traction to create a stable construct with internal bipolar distraction system which provides a gradual detorsion at the two ends away from the apex of the deformity and allow to a spontaneous autofusion.The Bipolar fixation technique ensures significant correction of the sagittal and coronal curves with the added benefit of minimally invasive spine surgery, including limited blood loss and greatly reduced operative time comparing to a conventional spinal fusion.

Take Home Message
Bipolar fixation technique create a stable internal distraction system with allow to spontaneous autofusion. Significant sagittal and coronal curve correction, minimally invasive spine surgery, less blood loss and time surgery.

238. 3D Classification of the Right Thoracic Scoliotic Spine by the Means of Two View Spinal Radiographs: A Validation Study

Saba Pasha, PhD; Keith Baldwin, MD; Jason B. Anari, MD; Victor Ho-Fung, MD

Summary
We used a previously developed 3D classification of the right thoracic scoliotic spines and determined the variations in the sagittal and frontal characteristics of the subtypes. 5 observers used these characteristics to classify a cohort of the right thoracic patients using their frontal and sagittal radiographs. The manual classification by the raters was compared to the numerical 3D classification. The inter and intra--raters agreements were excellent among all raters.

Hypothesis
considering specific characteristics of the frontal and sagittal spinal curves in right thoracic scoliosis, right thoracic AIS can be classified reliably into 3D subtypes.

Design
retrospective

Introduction
Adolescent idiopathic scoliosis is a 3D deformity of the spine. Classification for surgical planning has been based on two dimensional radiographs. This could have been responsible in less than

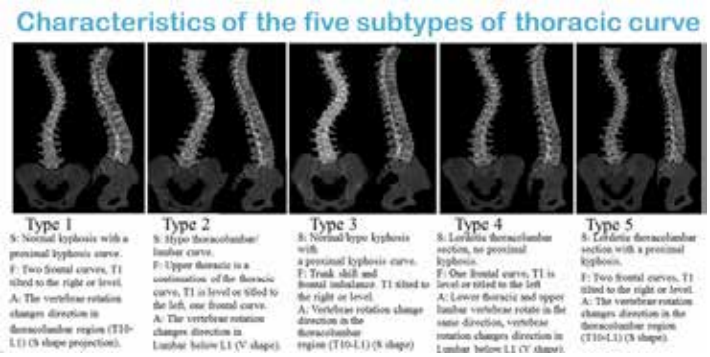
satisfactory surgical outcomes in some cases. The 3D classifications of the spine requires labor-intensive image processing and complicated computational methods. A 3D classification system based on the clinically available medical images is of critical need.

Methods
A total of 40 patients with posterior-anterior and lateral calibrated radiographs were included. The 3D model of the spine was generated and the spines were classified automatically based on a previously developed statistical model. The percent belonging of each spine to one of the previously spinal subtypes were determined in a way that the sum of belonging to all of the existing subtype is 100%. 5 raters classified the spines based on the characteristics of the curve on the two view radiographs (figure 1). The agreement between the raters and accordance between the raters (based on the 2D radiographs) and the automated method (based on the 3D model) were determined.

Results
The interobserver reliability was moderate to strong with a kappa value between 0.64 to 0.89. The raters had the lowest accuracy identifying Type 3 0.70, 95%CI [0.50, 0.90] had the highest accuracy identifying Type 1, 0.81, 95% CI [0.77,0.84].

Conclusion
With one session of training, radiologists and orthopedic surgeons were able to identify the 3D subtypes of right thoracic AIS from the patients' radiographs with excellent accuracy.

Take Home Message
A 3D classification of the right thoracic AIS, when only two view radiographs are available, was validated.



The frontal and sagittal views of the right thoracic 3D subtypes

239. Correlations of Pelvic Incidence-Based Relative Radiographic Parameters to Lower Extremity Compensations

Altug Yucekul, MD; Barkin Erdogan ; Duhan Kilickan ; Caglar Yilgor, MD; Tais Zulemyan, MD; Yasemin Yavuz, PhD; Javier Pizones, MD, PhD; Ibrahim Obeid, MD; Frank S. Kleinstueck, MD; Francisco Javier S. Perez-Grueso, MD; Emre R. Acaroglu, MD; Ferran Pellisé, MD, PhD; Ahmet Alanay, MD; European Spine Study Group

Summary
Using data from an adult spinal deformity (ASD) database including 193 patients that have preoperative and postoperative radiographs that include at least mid-femur or mid-tibia, correlations of sagittal radiographic parameters of Relative Pelvic Version (RPV), Relative Lumbar Lordosis (RLL) and Relative Spinopelvic Alignment (RSA) to lower extremity compensation angles of femoral obliquity angle (FOA), knee flexion angle (KFA) and global sagittal angle (GSA) were assessed. Strong correlations were identified. This information may be useful when whole-body imaging is not available.

Hypothesis
Relative radiographic parameters of the GAP Score correlate to lower extremity compensation angles

Design
Retrospective analysis of prospectively collected data

Introduction
As a response to positive sagittal malalignment, the human body progressively recruits compensatory mechanisms in the spine and/or non-spinal segments (i.e lower extremities) in an effort to maintain the gravity line and a horizontal gaze. Whole-body radiographic assessment is hence suggested for quantifying lower extremity compensation. Yet, such imaging modalities are not widely available. Relation of Relative Pelvic Version (RPV), Relative Lumbar Lordosis (RLL) and Relative Spinopelvic Alignment (RSA) to previously defined lower extremity compensation angles were investigated.

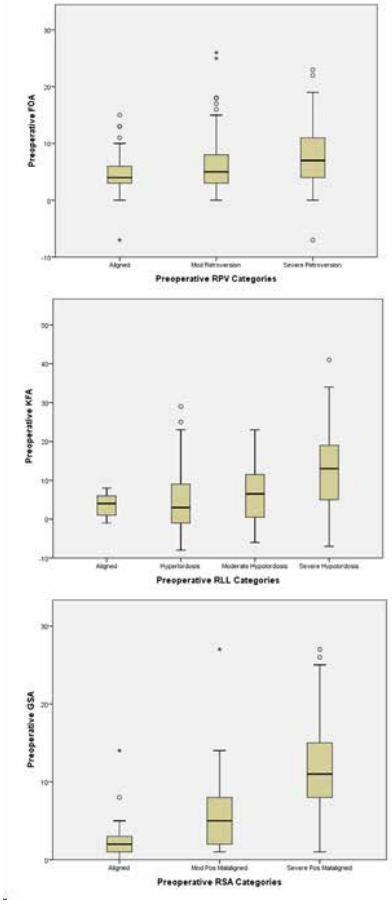
Methods
Inclusion: Having radiographs that include at least mid-femur or mid-tibia; ≥4-level fusion. Pre and postoperative RPV (measured minus ideal sacral slope), RLL (measured minus ideal lumbar lordosis), RSA (measured minus ideal global tilt), femoral obliquity angle (FOA), knee flexion angle (KFA) and global sagittal angle (GSA) were measured. Preoperatively, relations of relative radiographic parameters to lower extremity compensation angles were assessed by Kruskal-Wallis tests. Correlations of changes in RPV, RLL and RSA, from preoperative to postoperative radiographs, to changes in FOA, KFA and GSA were assessed by Spearman's correlations.

Results
193 patients (knee available in 144) (156F, 37M, 58±17 years) with a mean f-up of 36 (24-67) months were included. Preoperatively, FOA, KFA and GSA were significantly different in categories of RPV, RLL and RSA (for all comparisons, $p<0.01$). Changes in RPV, RLL and RSA were significantly correlated to changes in FOA, KFA and GSA (rho range, 0.351-0.767) (for all comparisons, $p<0.001$).

Conclusion
PI-Based relative radiographic parameters significantly correlate to measurements reflecting lower extremity compensation. This information may be useful when whole-body imaging is not available. Setting surgical goals in the sagittal plane on the basis of the parameters reflected by the GAP score may result in spontaneous resolution of lower extremity compensations.

Take Home Message
Preoperative to postoperative changes in PI-Based relative radiographic parameters of RPV, RLL and RSA, reflect into changes in

measurements quantifying lower extremity compensations such as FOA, KFA and GSA.



240. SRS-22r Score of a Prospective Evaluation of Elderly Deformity Surgery: A Prospective Observational, Multicenter Study

Stephen J. Lewis, MD, FRCS(C); Yong Qiu, MD; Lawrence G. Lenke, MD; Michael P. Kelly, MD; Marinus De Kleuver, MD; Benny T. Dahl, DMSc; Christopher I. Shaffrey, MD; Maarten Spruit, MD; Ferran Pellisé, MD, PhD; Kenneth Cheung, MD, MBBS, FRCS; Ahmet Alanay, MD; David W. Polly, MD; Jonathan N. Sembrano, MD; Yukihiro Matsuyama, MD, PhD; Sigurd H. Berven, MD

Summary
An international multicenter study in patients over 60 years of age was performed to determine the value of spinal deformity surgery in these patients.

Hypothesis
Patients over 60 years old will benefit from spinal deformity surgery.

Design
A Prospective Observational, Multicenter Study

Introduction
Questions arise regarding the suitability of older patients to undergo large spinal procedures. Whether the outcomes merit the risks involved are not well known.

Methods
A multicenter international prospective study of patients over 60 years of age, undergoing primary fusions of 5 or more levels for spinal deformity were reviewed. Radiographic, clinical assessment, and patient reported questionnaires (SRS 22r) were completed preoperative, at 10 weeks, 1 year and 2 years follow-up.

Results
219 of the 255 patients enrolled from 12 centers met the criteria for inclusion in the study. There were 176 females and 43 males with a mean age of 67.5 (range 60-83 years). There were 5 deaths: 2 early (< 33 days after first stage surgery) and 3 late (> 225 days after first stage surgery) of unrelated causes. Mean pre-op SRS-22r total score was 2.8, compared to 3.2 at 10 weeks, and 3.7 at 1 and 3.7 at 2 year follow up. Significant changes were found in SRS-22r from baseline to 12 months ($p<0.001$) and to 24 months ($p<0.001$). Similar findings were seen when comparing the mean SRS 22 total score among the various age groups: age 60-64 (2.9, 3.3, 3.8, 3.7), age 65-69 (2.8, 3.2, 3.6, 3.7), age 70-74 (2.8, 3.3, 3.7, 3.8), and >75 (2.7, 3.0, 3.7, 3.6), with significance in changes in all age groups from baseline to 12 months ($p<0.001$) and to 24 months ($p<0.001$). The observed mean SRS-22r subdomains scores at pre-op, 10 weeks, 1 year, and 2 year follow-up were: function (2.7, 2.7, 3.4, 3.5), pain (2.7, 2.9, 3.7, 3.7), self-image (2.3, 3.5, 3.7, 3.6), mental health (3.2, 3.4, 3.8, 3.8) and satisfaction (3.1, 4.0, 4.0, 4.1).

Conclusion
Despite the magnitude of the procedures, significant improvements in patient reported outcome was observed in all the domains of the SRS22r score at 1 and 2 years post-operatively compared to pre-op.Carefully selected healthy patients greater than 60 years old can benefit from multi-level spinal deformity surgery.

Take Home Message
Despite the magnitude of the procedures, significant improvements in patient reported outcome was observed in all domains of the SRS22r score at 1 and 2 years post-operatively compared to pre-op.

241. Efficacy of Topical versus Intravenous Tranexamic Acid in Pediatric Spinal Deformity

Karen A. Weissmann, MD; Virginie Lafage, PhD; *Renaud Lafage, MS*; Carlos Huaiquilaf, MD; Jonathan Elysee, MS; Francoise Descazeaux, MD

Summary
In this comparison of topical versus IV tranexamic acid (TXA) in pediatric deformity patients, there was no difference in total blood loss, intraoperative blood loss, surgical time, postoperative Ht/Hb, or intraoperative/postoperative transfusion rates. Patients who received topical TXA combined with IV TXA had significantly less postoperative bleeding than the control group with no TXA. Those who received IV TXA, with or without topical TXA, had their drains removed one day earlier than the no TXA group.

Hypothesis
Topical tranexamic acid is effective in diminishing intra- and post-operative bleeding in pediatric deformity patients.

Design
Retrospective cohort study with pediatric deformity patients that underwent posterior only fusion between 2009 and 2016.

Introduction
Increased blood loss during pediatric deformity surgery has been associated with increased complications. While intravenous tranexamic acid had positive results in controlling intraoperative bleeding, little is known regarding the effectiveness of topical tranexamic; a technique used in dental, cardiac and intra-articular surgical procedures with good results.

Methods
A total of 181 patients were included (78.6% F, 15.08 yo) and categorized in one of the following 4 groups: "No TXA" (n=35) if the wound was packed with sponges soaked in saline, "IV TXA" (n=37) if the patient received a 20 mg/kg bolus at the beginning of the surgery followed by a continuous infusion of 1mg/kg/hr until skin closure, "Topical TXA" (n=23) if the wound was packed with sponges soaked in 1g of TXA diluted in a 500ml saline solution, or "Combined TXA" (n=86) if the patient received both IV and topical TXA. Primary outcomes compared were: intraoperative/postop/total blood loss, duration of drain insertion in days, postoperative hematocrit and hemoglobin, # of transfusions, # of instrumented levels, surgical time and complications.

Results
No differences were found between the four groups in terms of intraoperative blood loss, surgical time, postoperative Ht/Hb, or intraoperative and postoperative transfusion rates. The "Combined TXA" group had significantly less postoperative bleeding than the control "no TXA" group (295.13±321.18mL, vs 480.58±447.61mL, p=0.05). Patients who received IV TXA (with or without Topical TXA) had their drains removed one day earlier than the no TXA group (p=0.048). There were no complications related to the use of tranexamic acid in this series.

Conclusion
There is a significant decrease in postoperative bleeding in pediatric deformity patients with the combined use of topical and IV tranexamic acid, without TXA related complications. This combined modality positively impact postoperative bleeding.

Take Home Message
The use of topical and intravenous tranexamic acid decreases postoperative bleeding in pediatric deformity patients.

242. Proximal Junctional Kyphosis After Spinal Deformity Correction in Cerebral Palsy

Margaret Baldwin, MD; Suken A. Shah, MD; Joseph Petfield, MD; Arun R. Hariharan, MD; Paul D. Sponseller, MD; Amit Jain, MD; Burt Yaszay, MD; Patrick J. Cahill, MD; Amer F. Samdani, MD; Harms Study Group

Summary
In this study of 281 patients with CP scoliosis followed for at least 2 years after PSF, 12.8% patients developed PJK and 8% underwent reoperation. Patients with PJK were more likely to be hyperkyphotic preoperatively and without severe cognitive impairment. No differences were found in construct type or proximal fusion level. PJK does have a negative effect on HRQoL and patient reported outcomes.

Hypothesis
There are identifiable risk factors for PJK after scoliosis surgery for CP

Design
Retrospective review of a prospectively collective multi-center cohort

Introduction
PJK is a common and clinically significant complication after surgery for spinal deformity. Multiple PJK risk factors have been identified in patients after surgery for AIS and ASD, but for neuromuscular scoliosis patients, little is known about the risk factors, reoperation rate or the effect of PJK on HRQoL

Methods
Patients with CP who underwent a spinal fusion for CP with minimum 2 yrs of follow up. PJK was defined radiographically as a change in kyphosis of greater than 10° above the UIV over 2 levels compared to first erect post-op imaging

Results
281patients were included in this analysis. The overall prevalence of PJK was 12.8% (36/281) and the average was 17° (range:10-35). In the PJK group, 16.7% (6/36) had a reoperation for: irrigation and debridement for infection, removal/revision of implants. There was a two-fold risk of implant complication in the PJK group compared to those w/o PJK. The PJK group was more likely to have no or little cognitive impairment compared to those w/o PJK (27.8% vs 16.7%, $p<0.05$). Comparing implant types, there was no statistically significant difference in the incidence of PJK between unit rod (17.6%), proximal hooks (10%) or proximal screws (13%). There was no difference in rate of PJK based on proximal level fused. Preop kyphosis (T2-T12) was higher in the PJK group (56 deg (17-91)), compared to 36° in the non-PJK group ($p<0.05$). There was a decrease in CPCHILD scores postop in 25% of the patients with PJK and 13% of parents noted their child deteriorated after surgery in the PJK group compared to 4% of children in the non-PJK group ($p <0.05$)

Conclusion
The incidence of PJK in patients with CP after surgery for scoliosis is 12.8% and 8% underwent reoperation for SSI/implant revision. Patients who developed PJK had more kyphosis preop and lower incidence of severe cognitive disability compared to those w/o PJK. This may be due their need to look at computers and books. Parents of children who developed PJK were more likely to note their child's QoL deteriorated after surgery

Take Home Message
PJK developed in 12.8% of patients after surgery for CP scoliosis. Preoperative risk factors include hyperkyphosis and little to no cognitive impairment.

243. Minimially Invasive Surgery for Neuromuscular Scoliosis: Case Control Study Comparing Correction Of Deformity And Perioperative Morbidity In 148 Consecutive Patients

Vishal Sarwahi, MD, MBBS; Jesse Galina, BS; Sayyida Hasan, BS; Aaron M. Atlas, BS; Terry D. Amaral, MD; Charlotte De Bodman, MD; Alexandre Ansorge, MD; Romain Dayer, MD

Summary
With minimally invasive surgery becoming more popular, it is beneficial to know if these techniques can be used in high risk patients. Minimally invasive scoliosis surgery for neuomuscular patients shows promise in significantly less blood loss, shorter surgeries, less pain, and shorter hospital stay.

Hypothesis
An MIS approach in neuromuscular scoliosis patients yields superior perioperative outcomes

Design
Retrospective review - Multicenter

Introduction
The posterior minimally invasive surgery (MIS) approach, equivalent to a Wiltse approach, is widely used for spinal trauma, degenerative, and neoplastic cases. The potential advantages of this technique over the standard midline posterior approach are a shorter LOS associated with a reduced soft tissue trauma lowering postoperative pain, EBL and transfusion rate. The aim of this case-control study was to report a retrospective, consecutive series of patients with neuromuscular scoliosis who were treated with posterior minimally invasive surgery (MIS) and to compare it to a control group operated through a standard posterior midline approach.

Methods
48 consecutive patients with neuromuscular scoliosis treated with MIS using one incision and a muscle-splitting approach by two senior surgeons in three tertiary medical centers between 2013 and 2018. Radiographic, perioperative, and postoperative data was collected. Data was case-controlled to standard PSF patients from 2005 – 2017.

Results
Patients were similar in age, BMI, preop Cobb, and preop pelvic obliquity ($p > 0.05$). Postop Cobb, percentage Cobb correction, postoperative pelvic obliquity and percentage pelvic obliquity correction were similar ($p > 0.05$). Operative time and blood loss were significantly less for MIS patients ($p < 0.001$). A significantly fewer number of patients were transfused ($p < 0.001$) and average hospital stay was 3 days fewer ($p = 0.119$). Intraoperative and overall perioperative complication rate were similar between the groups ($p = 0.05$).

Conclusion
MIS used for NMS patients provided adequate radiographic correction. This technique seems to be safer than the routine posterior open approach with significantly lower EBL and need for transfusion. Hospital stay was also reduced by 3 days. The results of this study show a promising future for these high-risk patients.

Take Home Message
MIS resulted in a significant correction of the deformity with a significantly lowered the need for allogenic blood transfusion and a mean ICU and hospital length of stay.

244. Change in Oswestry Disability Index at 24 months following Multilevel Spinal Deformity Surgery in Patients over 60 Years of Age: A Multicenter International Prospective Study

Stephen J. Lewis, MD, FRCS(C); Christopher J. Nielsen, MD; Sigurd H. Berven, MD; Lawrence G. Lenke, MD; Christopher I. Shaffrey, MD; Kenneth Cheung, MD, MBBS, FRCS; Yong Qiu, MD; Yukihiro Matsuyama, MD, PhD; Ferran Pellisé, MD, PhD; David W. Polly, MD; Jonathan N. Sembrano, MD; Benny T. Dahl, DMSc; Michael P. Kelly, MD; Marinus De Kleuver, MD; Maarten Spruit, MD; Ahmet Alanay, MD

Summary
A prospective international multicenter study in patients over 60 years of age was performed to determine the value of spinal deformity surgery.

Hypothesis
Carefully selected healthy patients greater than 60 years old can expect to see improvement in ODI from multi-level spinal deformity surgery.

Design
A prospective multicenter international study

Introduction
With the known risks and possible complications, counselling elderly patients on the utility of multilevel spinal fusion procedures can be difficult. Significant variation in procedures, comorbidities, and pathologies further complicates the matter.

Methods
A prospective multicenter study of patients over 60 years old, undergoing primary fusions of 5 or more levels were reviewed. The Oswestry Disability Index (ODI) was measured pre-operatively and at 24 months. Patients were divided into quintiles based on their pre-operative ODI score.

Results
219 of the 255 patients enrolled from 12 centers met the criteria for inclusion. There were 176 females and 43 males with a mean age of 67.5 (range 60-83 years). The mean number of levels fused was 10.4 (range 5-24). 210 patients completed 10 week, 188 completed 1 year, and 179 completed 2 year follow-up visits. 156 patients had completed pre-operative and 24 month ODI. Stratifying and comparing pre-operative and 24 month follow-up ODI into quintiles, 100 of 156 (64.1%) patients had improvement in their ODI. 47 (30.1%) remained in their original quintile ODI at 24 month, while 9 (5.8%) of patients reported worsening of their ODI. Preoperatively, 91 (58.3%) patients had ODIs greater than 40% compared to only 33 (21.1%) at 24 months. Pre-operatively, 10 (6.4%) patients had ODI between 0-20%, and 55 (35.3%) be-

tween 21-40%. At 24 months, 64 patients (41.0%) had ODI scores between 0-20% and 59 (37.8%) scored between 21-40%. Similarly, 69 patients (44.2%) had pre-operative ODI of 41-60% and 22 patients (14.1%) had ODI of 61-80%, compared to 24 months where this was significantly decreased to 28 (17.9%) patients with ODI of 41-60% and only 5 (3.2%) with ODI between 61-80%.

Conclusion
Despite undergoing multilevel spinal deformity surgeries, only 6% of patients showed worsening of their ODI, while 64.1% of patients improved at 24 month follow-up.

Take Home Message
Two-thirds of carefully selected healthy patients greater than 60 years old can expect to see improvement in ODI from multi-level spinal deformity surgery.

245. PROMIS Scores in Surgically Treated Idiopathic Scoliosis Patients: Impact of Curve Characteristics

Scott John Luhmann, MD; Ernst Etienne, BS; Nichelle Enata, MS

Summary
Posterior spinal fusion (PSF) is the most commonly performed surgical intervention for adolescent idiopathic scoliosis (AIS) patients with Cobb angles greater than 45 degrees. To date, no studies have provided information on the associations between curve characteristics and PROMIS scores in surgically treated AIS patients. This investigation analyzes the relationship between radiographic measures and PROMIS scores in 122 patients who underwent PSF surgery.

Hypothesis
1. Pain improvements after surgery for AIS would be detected by PROMIS 2. AIS surgery would have a negative impact on patient function. 3. An association will exist between the PROMIS Pain Interference domain and SRS-30 Pain subscores during the episode of care. 4. To measure the impact of curve characteristics on PROMIS scores for pain interference (PI), upper extremity (UE), mobility (MOB), and peer relationships (PR).

Design
Retrospective cohort

Introduction
Patient reported outcomes measure the impact of disease on patient health, function and effectiveness of disease treatment. PROMIS offers a simple, generalizable measure that can be applied across diseases.

Methods
Consecutive pts receiving PSF for AIS at single center. PROMIS PI, UE, MOB, and PR and SRS-30 were obtained at preop and postop visits. Demographics, operative data, and radiographic measurements were recorded. Statistical significance was at $p<0.05$.

Results
122 pts (83.6% female, mean age 14.2±1.6 yrs, mean Cobb 62.9±13.8 degrees preop). Postop, UE and MOB domain scores were significantly below preop values at 6 weeks and 6 months, and returned to baseline at 1 year postop. Postop PI scores at 6 weeks, 6 months and 3 years were similar to preop values. PR scores were not different until two yrs, when scores were higher ($p<0.05$). PROMIS scores were not associated with Lenke classification, number of vertebral levels fused or % Cobb correction at any postop time point. A statistically significant negative relationships between LIV and UE and MOB scores at 6 weeks and 1 yr postop, but not at 3 yrs postop. There were no significant differences noted in PI and PR PROMIS scores and LIV.

Conclusion
Overall, the PI domain did not identify any short-term or long-term improvements in pain after PSF. Patient function (UE and MOB) demonstrated lower scores in the early postoperative period but no change from baseline at 1+ years postop. AIS patients following PSF with more caudal LIVs had decreased upper extremity and mobility PROMIS scores in the early postoperative period (≤ 1 year). Curve characteristics were not associated with PROMIS scores at any postoperative time point.

Take Home Message
PROMIS scores demonstrated short-term decrease in UE and MOB after surgery (≤ 1 year). PROMIS score were not associated with the radiographic measures of AIS PSF surgery.

Table 1

Event Name	Mean (SD) N =Sample Size	Pain Interference	Upper Extremity	Mobility	Peer Relationships
Preoperative		49.7 (9.89) N = 80	52.5 (7.66) N = 79	49.0 (9.15) N = 79	53.8 (8.67) N = 76
Initial		52.6 (8.98) N = 81	42.2 (7.71) * N = 80	38.8 (6.77) * N = 81	53.1 (9.99) N = 69
Intermediate		48.4 (11.0) N = 88	48.6 (7.79) * N = 86	45.2 (8.62) * N = 87	54.6 (8.57) N = 83
One Year		43.7 (9.88) * N = 65	52.1 (6.51) N = 64	51.4 (9.08) N = 63	56.0 (9.33) N = 64
Two Year		45.6 (10.9) N = 61	54.2 (5.67) N =30	51.9 (9.65) N = 30	58.1 (9.33) * N = 30
Three Year		44.8 (9.52) N = 11	54.5 (4.77) N = 10	50.2 (9.10) N = 10	62.6 (5.77) * N = 10

* = p<0.5

PROMIS Scores after PSF

246. Effect of Age on Perioperative Morbidity in Anterior Lumbar Interbody Fusion During a Staged Spinal Reconstruction - A Retrospective Chart Review.

Isador H. Lieberman, MD; Stanley Kisinde, MD; Shea Hesselbacher

Summary
With the ageing population globally, surgeons are having to take care of older ASD patients with complicating comorbidities associated with advancing age, which would theoretically result in higher complication rates and poorer surgical outcomes. Amongst ASD patients that underwent anterior lumbar interbody fusion (ALIF), and comparing perioperative outcomes between those older than 65 years versus those at and below 65 years, we did not observe a significant difference in comorbidities between the groups.

Hypothesis
There is no difference in perioperative morbidity amongst ASD patients undergoing anterior lumbar interbody fusion.

Design
Retrospective chart review

Introduction
Because of the ageing population globally, Spine Surgeons are having to take care of more ASD patients that have complicating medical issues. This theoretically implies a higher rate of complications and poorer outcomes following surgery. We performed a retrospective comparison of perioperative morbidity, complication rates and rate of recovery among patients <= 65 years versus those older than 65 years, that underwent ALIF as part of a staged anterior-posterior reconstruction for ASD.

Methods
We retrospectively reviewed a Surgical database to identify patients that had undergone ALIF as part of a staged anterior posterior reconstruction from 2017 to 2019, and obtained data including: demographics, type of surgery, intra-operative blood loss, procedure time, perioperative complications, pre- and post op pain and disability scores, length of hospital stay, discharge disposition, and return to work / ADLs. We compared any differences between the two groups.

Results
101 patients, mean age 61.75 (20 – 80) years, F : M = 3 : 2, underwent the procedure during the specified period. The highest number of levels fused anteriorly was 4. The indications for surgery included scoliosis, degenerative disc disease, spondylolisthesis, adjacent segment degeneration, post-laminectomy syndrome, and infection. Only operative time was significantly lower in the older group (p = 0.002). The older group also had a lower mean BMI. There were only 2 complications in each of the groups directly related to the ALIF procedure. There was no difference in all other outcome measures.

Conclusion
Perioperative outcomes and morbidity associated with ALIF are similar in those over and under 65 years of age. There were fewer complications associated with the anterior than with the posterior procedure in both groups. Many older, less healthy individuals with vascular disease or previous abdominal and/or pelvic surgery were not offered an anterior procedure as part of their reconstruction.

Take Home Message
There is no difference in perioperative morbidity amongst ASD patients undergoing anterior lumbar interbody fusion, between those older than 65 years versus those at or younger than 65 years.

247. Comparison of Clinical and Functional Outcomes, Together with Quality of Life of Vertebral Body Tethering in Patients with Adolescent Idiopathic Scoliosis to Age-Gender-BMI Matched Healthy Controls

Tuna Pehlivanoglu, MD; Ismail Oltulu, MD; Emre Korkmaz, MD; Yigit Erdag, MD; Ender Sarioglu, MD; Ender Ofluoglu, MD; Mehmet Aydogan, MD

Summary
This study reported for the first time in the literature,that in skeletally immature patients with AIS,VBT by utilizing growth modulation was able to yield as sufficient lumbar range of motion lumbar anterior and lateral flexibility,trunk flexor-extensor endurance and trunk motor strength as those of age-gender-BMI matched healthy individuals.In addition to that, by yielding similar SRS-22 and SF-36 scores to healthy individuals,VBT was able to provide life quality and satisfaction at the almost same level of the age matched healthy individuals.

Hypothesis
In skeletally immature patients with AIS, VBT might yield equally good clinical and functional outcomes together with comparable life qualities to age-gender-BMI matched healthy individuals.

Design
Retrospective comparative

Introduction
It was proposed, that in skeletally immature patients with AIS, VBT, as a growth modulating, fusionless treatment option, might preserve normal spinal motion, while yielding good correction. The aim of this study was to compare the clinical and functional results of VBT to age matched healthy controls to assess, whether or not this technique is providing by growth modulation clinical and functional results comparable to those of healthy, age matched individuals.

Methods
21 patients (average age/average pre-op curve flexibility/pre-op-at the latest follow-up curve magnitude:11.1/41.2%/48.2°-9.1°), who underwent thoracolumbar (T4-L4) VBT (Group 1) and have a minimum follow-up duration of 36 months; and 21 age-gender-BMI matched healthy individuals (Group 2) were enrolled.

Results
Regarding the measurements of average lumbar range of motion (flexion-extension-lateral bending-rotation), anterior (hand to feet distance) – lateral (pre-post bending distance) lumbar bending flexibility , flexor (Kraus Weber test) and extensor (Biering Sorensen test) endurances of trunk, average motor strength of trunk muscles, average total SRS-22and SF-36 MCS/PCS scores, both groups were detected to have similar results with no statistical significance.(Table 1/Fig. 1)

Conclusion
This study reported for the first time in the literature, that in skeletally immature patients with AIS, VBT by utilizing growth modulation was able to yield as sufficient lumbar range of motion, lumbar anterior and lateral flexibility, trunk flexor-extensor endurance and trunk motor strength as those of age-gender-BMI matched healthy individuals. In addition to that, by yielding similar SRS-22 and SF-36 scores to healthy individuals, VBT was able to provide life quality and satisfaction at the almost same level of the age matched healthy individuals.

Take Home Message
In skeletally immature patients with AIS,VBT was able to yield as sufficient lumbar range of motion, flexibility, trunk endurance-motor strength and quality of life as those of matched healthy individuals.

Table 1

	Average Lumbar ROM (°)				Average Lumbar Bending Flexibility (cm)		Average Trunk Endurance (sec)		Average Motor Strength of Trunk Muscles	Average Total SRS-22	Average SF-36	
	Flex.	Ext.	Lat. Bend.	Rot.	Ant.	Lat.	Flex.	Ext.	Extensor-Ant/Lat/Obl Flexor		MCS	PCS
Group 1 (VBT)	78.2	34.6	34.4	45.4	3.7	22.4	65.1	60.8	4.7	4.9	56.9	57.2
Group 2 (Healthy Controls)	80.1	37.2	35.1	47.2	3.1	24.3	67.3	62.7	4.9	5.0	57.1	57.8
p - value	0.27	0.3	0.31	0.24	0.32	0.27	0.3	0.22	0.3	0.27	0.24	0.33

Table 1/Fig. 1

248. Use of Topical Tranexamic Acid Reduces Intra-operative Blood Loss and Transfusion Requirements in Spinal Deformity Correction in Patients with AIS

Subaraman Ramchandran, MD; Alexander Mihas, BS; Kevin George, BA; Ali Mansour, MD; Stephanie Urigüen, LPN; Nicole Orozco, BSN; Thomas J. Errico, MD; Stephen G. George, MD

Summary
Peri-operative outcomes were compared between two groups [30 patients each] of AIS patients stratified based on the use of intra-operative topical tranexamic acid (TXA). The EBL per level for the topical TXA group was significantly lower than then non-topical TXA group. Similarly, estimated blood volume loss was 38% less in the topical TXA group. 16.6% of patients in non-topical TXA group received transfusion whereas only 3% in the topical TXA received transfusion. No complications observed during use of topical TXA.

Hypothesis
Topical TXA used during correction of AIS effectively reduces blood loss.

Design
Retrospective.

Introduction
Systemic administration of TXA has shown to significantly reduce blood loss in spinal deformity correction. Limited studies have shown the potential benefit of application of topical TXA in reducing blood loss in posterior lumbar spine surgeries. Role of topical TXA in adolescent spinal deformity correction is unclear.

Methods
60 consecutive operative AIS patients were reviewed from a single institution and were divided into two groups with similar age, weight, gender, curve severity, number of levels fused, co-morbid conditions and medications. Standardized peri-operative blood salvage techniques were utilized in all patients. In the latter 30 patients, topical TXA soaked sponges (1g mixed in 100ml NS) was utilized for wound packing during surgical procedure compared to dry sponges as used in the former 30 patients. Both groups were compared for magnitude of deformity corrected, EBL per level, total EBL, Cell-saver and blood transfused, post-op drain, peri-operative complications, change in hemoglobin and length of stay.

Results
Sixty AIS patients (mean age: 14.4 y, 43 F, mean BMI: 21.5, mean levels: 10.7) were included. Both groups achieved similar change in Coronal Cobb correction. Mean estimated percentage of circulating blood volume lost in topical TXA group was 38% less than control group (11.2 vs. 18.3%, p=0.006). EBL per level was significantly lower in the topical TXA group (41 ± 30ml vs. 57 ± 26ml, p=0.03). 5 of 30 patients in the control group were transfused, whereas only 1 patient in topical TXA group required transfusion (16.6% vs. 3.3%, p=0.10). No differences were noted in post-operative drain output, change in hemoglobin levels and peri-operative complication rates.

Conclusion
When used as an adjunct to the conventional blood salvage techniques in spinal deformity correction, use of topical TXA sponges resulted in reduced intra-operative blood loss, and potentially decreased the need for blood transfusion. No complications were associated with the use of topical TXA.

Take Home Message
Topical tranexamic acid effectively reduces intra-operative blood loss in surgical correction of AIS with minimal complications.

Table: Comparison of pre- and peri-operative variables in 60 AIS patients undergoing posterior spinal fusion stratified on the basis of use of topical TXA in adjunct to conventional blood salvage techniques.

	Control group (N=30)	Topical TXA group (N=30)	P Value
Age (yrs)	14.2 ± 2.3	14.6 ± 2.1	0.4
BMI	20.9 ± 3.7	22.9 ± 5	0.07
Major Coronal Cobb (°)	51.3 ± 18.4	51.4 ±11.1	0.98
Truncal Shift (mm)	16.7 ± 13.4	13.2 ±10.8	0.08
Thoracic Kyphosis (°)	28.3 ± 10.4	27.5 ± 10.1	0.76
Lumbar Lordosis (°)	46.4 ± 10.2	41.2 ± 9.9	**0.04**
Levels fused	10.6 ± 2.4	10.8 ± 2.1	0.77
No. levels of Thoracoplasty	3.8 ± 1.0	4.3 ± 0.9	0.05
No. of levels of Ponte's Osteotomies	5.0 ± 1.0	8.2 ± 2.4	**< 0.001**
EBL (ml)	625 ± 366	455 ± 378	0.08
EBL per level fused (ml)	57.6 ± 26.3	41.3 ± 31	**0.03**
% Blood volume lost	18.3 ± 11.10	11.2 ± 7.8	**0.006**
No. of patients who were transfused intra-op	5 (16.6%)	1 (3%)	0.1
No. of patients transfused post-op	1 (3%)	1 (3%)	
Post-op drain output (ml)	163 ± 132	136 ± 191	0.52
Pre-op Hb (mg/dl)	13.3 ± 1.5	14.2 ± 1.5	0.02
Immediate post-op Hb	12.1 ± 1.5	12.2 ± 1.5	0.78
Day 1 post-op Hb	11.3 ± 1.4	11.4 ± 1.7	0.89
Day 2 post-op Hb	10 ± 1.5	10.4 ± 1.4	0.25
Change in Hb (mg/dl)	3.3 ± 1.6	3.7 ± 1.1	0.27

249. Choosing Touched Vertebrae With Grade 0/1 Rotation On Lying Down X-Rays Saves Fusion Levels, Decreases Risk Of Adding On, And Prevents Translation

Vishal Sarwahi, MD, MBBS; Jesse Galina, BS; Sayyida Hasan, BS; Aaron M. Atlas, BS; Stephen F. Wendolowski, BS; Yungtai Lo, PhD; Terry D. Amaral, MD

Summary
Mild to minimally rotated TV on prone xray is a better way to determine the lowest instrumented vertebra. At 2-year follow up, this study did not find coronal decompensation or adding on.

Hypothesis
Using TV with minimal rotation (Gd 0/1) as LIV on prone XR saves fusion levels with good correction and balance

Design
Retrospective control- cohort

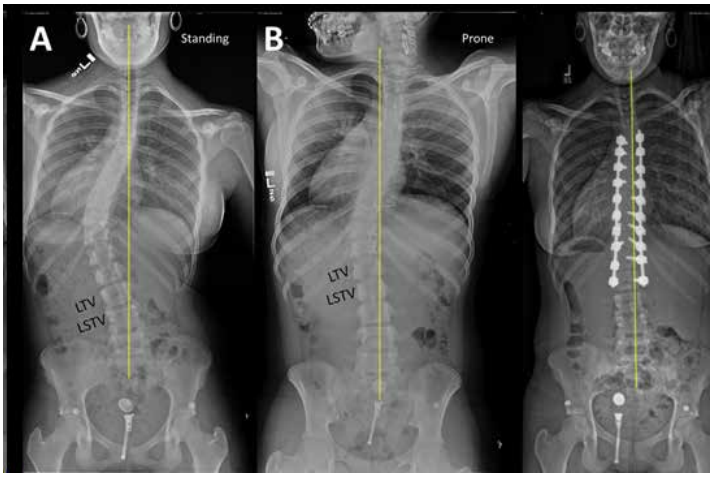
Introduction
TV is the 'touched' vertebra determined by CSVL on standing AP XRs. Fusion proximal to TV leads to suboptimal results, but fusing to TV on standing XRs can lead to longer fusions. The TV, however, moves proximally and its rotation also decreases on lying down.

Methods
Touched vertebra (TV): TV with minimal rotation (Gd 0/1) chosen as LIV. Non-TV (NTV): LIV proximal to TV or TV with >Gd 1 rotation. Cobb, fusion levels, LIV tilt, disc wedging, and LIV translation were analyzed pre-post- and final. Part II: Pts LIV on standing XRs (TVS) vs. prone x-rays (TVP) to determine levels saved.

Results
TV and NTV group had similar Cobb and LIV tilt ($p>0.05$). Disc wedging was significantly larger for NTV patients ($p<0.001$). LIV translation was significantly larger in NTV ($p<0.001$). Greater disc wedging and LIV translation were seen in Lenke 3 NTV pts. For Lenke 1, significantly larger percentage of NTV were at risk of adding-on ($p=0.04$). In part II, average of 11.7 levels were fused in TVP. 12.6 levels would have been fused if LIV was determined on standing XRs. Thus, utilizing prone XRs saved average 1.2 levels. In TVS, LIV was the TV on standing XR and an average of 12 levels were fused. However, determining LIV on prone XR showed an average of 10.8 levels. Thus, utilizing prone XRs would have saved 1.2 levels.

Conclusion
In AIS, fusing proximal to minimally rotated (Gd 0/1) TV or fusing to TV with > Gd1 rotation leads to an increased disc wedging and translation. Choosing minimally rotated (Gd 0/1) TV on prone XR saves levels without sacrificing outcomes.

Take Home Message
In AIS, using minimally rotated TV to determine LIV on lying down XR allows for shorter fusion, with acceptable LIV tilt, disc wedging, or coronal decompensation.



The last touched vertebra (LTV) and last substantially touched vertebra (LSTV) move proximally from standing (A) to prone (B) x-rays. Postoperative x-ray (C) demonstrates the second lumbar vertebra chosen as the lowest instrumented vertebra due to its LSTV quality, and Nash and Moe grade less than 2 on prone x-ray (B).

250. Breaking the Dogma: Does UIV have to be T2 in CP Patients Undergoing Spinal Fusion for their Neuromuscular Scoliosis?

Burt Yaszay, MD; Paul D. Sponseller, MD; Carrie E. Bartley, MA; Tracey P. Bastrom, MA; Suken A. Shah, MD; Patrick J. Cahill, MD; Mark Abel, MD; Firoz Miyanji, MD; Amer F. Samdani, MD; Peter O. Newton, MD

Summary
Outcomes between patients fused to T2 (the "gold standard") vs T3/T4 were compared in patients with CP and neuromuscular scoliosis. Fusing to T2 did not show benefits over T3/T4, but rather resulted in similar radiographic and clinical outcomes.

Hypothesis
Fusing to T2 will result in better clinical and radiographic outcomes than T3/T4.

Design
Longitudinal

Introduction
"T2 to the pelvis" has become the common term for the surgical treatment of CP patients with neuromuscular scoliosis. While some studies have analyzed the need to fuse to the pelvis, no studies have evaluated the need for an upper instrumented level (UIV) of T2. The purpose of this study was to compare the clinical and radiographic outcomes between T2 and T3/T4.

Methods
A prospective, multicenter registry was queried for patients with CP and scoliosis who underwent posterior spinal fusion with segmental screw fixation and minimum 2 years of follow-up. Patients were grouped according to UIV: T2 vs T3 or T4. All other UIVs were excluded due to low numbers. ANOVA with Bonferroni corrections were used to compare differences in radiographic and caregiver reported outcomes between the UIV groups.

Results
Analysis included 202 patients (65%) with UIV of T2 and 89 (29%) with UIV of T3 or T4. Preoperatively, the T2 group had smaller major curves (78º vs 88º, p<0.001), but similar T2-T12 kyphosis (41º vs 42º, p=0.9) and proximal thoracic kyphosis (-2° vs -0.7°, p=0.2) as compared to the T3/T4 group. GMFCS level distribution was similar between groups with the majority in each being level IV or V (p>0.05). The T2 group had longer surgical times (410 vs 367min, p=0.03) but similar blood loss (1418 vs 1226ml, p=0.2). Postoperatively, there were no differences found between groups in coronal curve correction (62% vs 59%, p=0.4), change in kyphosis (-6° vs -6°, p=1), change in sagittal balance (-3 vs -4cm, p=1), or PJK (6° vs 6°, p=0.8). Improvements in QOL and total CPChild scores were similar between groups (p>0.2).

Conclusion
This study supports the idea that surgeons most commonly choose T2 as their proximal level in CP scoliosis surgery. However, in doing so it may increase surgical time without resulting in significant radiographic or clinical benefits. For CP patients without severe kyphosis, surgeons need not be so dogmatic in selecting T2 as the upper instrumented level.

Take Home Message
Fusing to T2 did not seem to show benefits over T3/T4, but rather resulted in similar radiographic and clinical outcomes.

251. Are Patient-Reported Outcomes Measurement Information System (PROMIS) Scores Superior in Assessing Outcomes of Primary versus Revision Surgery in ASD patients?

Tsung-Cheng Yin, MD; Wenbing Wan, MD, PhD; Jichao Ye, MD; Brenda A. Sides, MA; Munish C. Gupta, MD

Summary
PROMIS has better outcome assessment at post-op, 1 yr and 2 yrs between patients who had primary or revision surgery. For ASD patients, we suggest the use of PROMIS with SRS and ODI to achieve better outcome assessment.

Hypothesis
PROMIS scores are superior in the assessment of differences between primary and revision surgery in ASD than SRS and ODI.

Design
Retrospective comparative case series

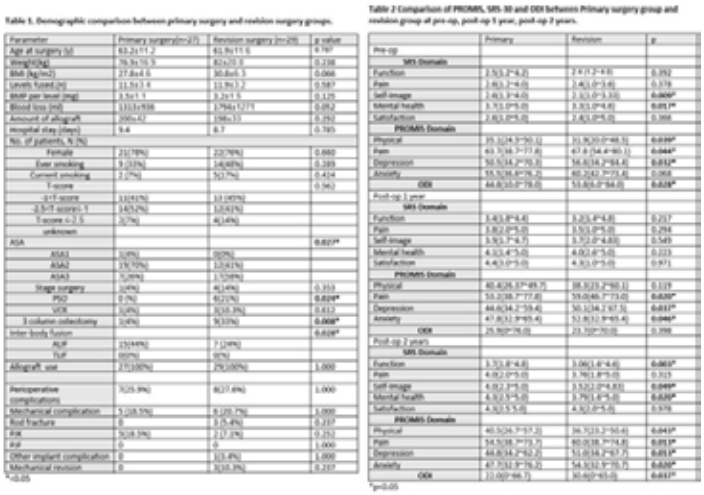
Introduction
Patient-reported outcome measures are increasingly important in determining the impact of disease states as well as in determining the effectiveness of treatments. PROMIS has shorter completion time and greater research flexibility for the ASD population versus the ODI and SRS-30. The purpose of the study is to evaluate the outcome assessment of different HRQOL questionnaires between primary and revision surgery in ASD.

Methods
This is a retrospective cohort study of 56 ASD patients undergoing ≥5 vertebra posterior spinal fusion to the sacrum performed from 2016 to 2017 at a single institution with over 2 years f/u.. PROMIS, SRS-30 and ODI were obtained at pre-op, post-op 1 year and 2 years. Patients' demographic data and x-ray parameters including the GAP score were studied along with PROMIS, SRS and ODI results obtained at pre-op, post-op, 1yr and 2 yrs.

Results
The mean age of surgery was 62.5(range: 34 to 80); BMI: 29.3. 27(48%) cases were PG; 29(52%) were RG. The median number of fusion levels was 13. The mean BMP use was 29.3mg/patient and 3.3mg/level. Primary group (PG) had better ASA grades, better sagittal alignment and less PI/LL mismatch preoperatively. PG had more inter-body fusion procedure, less 3-column osteotomy and no PSO. There was no significant difference in age, BMI, fusion levels, BMP use, blood loss and hospital stay. Both groups had significant HRQOL improvement from pre-op to post-op, 1 yr and 2 yrs. PROMIS, SRS and ODI could detect improvement of the score in (PG) and (RG) from pre-op to post-op, 1 and 2 years. However, only PROMIS could detect difference in improvement of outcomes between primary surgery and revision surgery at post-op, 1 yr (PROMIS PI:53.2 vs 59.0; PROMIS Depression: 44.6 vs 52.8; PROMIS Anxiety: 47.8 vs 52.8)

Conclusion
PROMIS has better outcome assessment at pre-op, post-op 1 yr and 2 yrs compared to SRS-30 and ODI.

Take Home Message
PROMIS has better outcome assessment at all intervals of primary versus revision surgery. For ASD patients, PROMIS offers alternative outcome instrument compared to SRS and ODI except for self image.



Comparison of Primary and Revision Group

252. Correction of Apical Vertical Translation may Prevent Unfused Lumbar Intervertebral Disc Degeneration after Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

Satoshi Suzuki, MD, PhD; Eijiro Okada, MD, PhD; Satoshi Nori, MD, PhD; Osahiko Tsuji, MD, PhD; Narihito Nagoshi, MD, PhD; Nobuyuki Fujita, MD, PhD; Mitsuru Yagi, MD, PhD; Masaya Nakamura, MD, PhD; Morio Matsumoto, MD, PhD; Kota Watanabe, MD, PhD

Summary
We conducted longitudinal MRI analysis of 130 unfused lumbar discs in patients with adolescent idiopathic scoliosis treated when their age was over twenty, and found that deteriorated intervertebral disc degeneration was observed in 15 discs (11.5%). Correction rate of apical vertical translation of the main curvature was significantly greater in patients without degenerated lumbar discs than those with, suggesting that unfused lumbar intervertebral disc degeneration (IVDD) could be prevented by maximum correction of apical translation of the main curvature

Hypothesis
Successful correction of apical vertical translation for adolescent idiopathic scoliosis (AIS) was associated with prevented progression of the caudal unfused intervertebral disc degeneration (IVDD) in adulthood.

Design
Longitudinal radiographic analysis with evidence level 4

Introduction
Although numerous studies have examined unfused lumbar IVDD after posterior spinal fusion for AIS, risk factors of uninstrumented IVDD after surgery is not fully elucidated.

Methods
Thirty-two AIS patients (6 male, 26 female, mean age 31.5 years) who underwent posterior collection surgery when their age was over twenty and were followed more than 5 years were included. We evaluated lumbar MRI and standing X-ray at preoperatively and 5 years postoperatively. Unfused lumbar disc was assessed by one radiologist and one spine surgeon using modified Pfirrmann classification. We divided the patients into two groups depends on the progression of IVDD on MRI, that is degenerated group (group D) consisted of patients with deteriorated IVDD, and non-degenerated group (group ND) consisted of those without.

Results
A total of 130 discs were evaluated. Of nine patients in group D, deteriorated IVDD was observed in 15 discs (11.5%) consisting of at L2-3 in 1 disc, L3-4 in two discs, L4-5 in six, and L5-S1 in six. No significant differences were observed between the groups in age, sex, BMI (P=0.71, 0.65, 0.10, respectively). In radiographic analysis, there were no significances in curve type (P=0.64), Cobb angle of the main curve (P=0.65), flexibility of the main curvature (P=0.51), number of fusion (P=0.46), correction rate of the main curvature (P=0.38) , level of lowest instrumented vertebra (LIV) (P=0.06), LIV tilt (P=0.68), LIV inclination (P=0.90). The correction rate of the apical vertical translation of the main curvature was significantly greater in group ND than that in group D (69.7% vs 56.8%, P=0.03).

Conclusion
The results of the study indicated that greater correction of apical vertical translation could be associated with reduced unfused caudal lumbar IVDD in adulthood.

Take Home Message
Maximum correction of apical translation could minimize the influence of long fusion on unfused lumbar disc in patients with AIS in adulthood.

253. Is Adjacent Segment Disease Inevitable in Instrumented Fusion from L2 to the Sacrum?

Amit Parekh, DO; Jeremy Smith, MD; Edward Quilligan, BS

Summary
Long term revision rate following L2-S1 fusion is high.

Hypothesis
The authors believe there is an increased risk of long term adjacent level degeneration in patients with spinal fusions from L2-S1.

Design
Retrospective case review

Introduction
Lumbar adjacent segment disease (ASD) is associated with lumbar instrumented fusion. Surgery involving 3 or more levels, sagittal imbalance, cephalad facet compromise, or pre-existing cephalad disc degeneration are known risk factors for developing ASD. To preserve motion segments and limit extending constructs to the thoracic spine, many surgeons attempt to limit cephalad extension of instrumentation to L2, however the benefits of preserving motion about the T12-L2 levels may be short lived.

Methods
A multi-center, multi-surgeon retrospective review of all patients undergoing an L2 to sacrum interbody and/or posterolateral fusion with or without pelvic fixation between 2010-2018 was performed. Long term follow up ranged from 1 year to 8 years post index surgery. Patient demographics, surgical technique, and radiographic variables including sagittal parameters were recorded.

Results
Preliminary data shows patients with L2-S1 fusions develop ASD at the L1-2 level, although not all are symptomatic. This finding is irrespective of patient factors including age, BMI, tobacco use, osteoporosis, cardiovascular disease, and others. Of patients who developed ASD, over 50% met criteria for PJK. Over 58% of L2-S1 fusions were revised within 8 years, the majority of which was for ASD or PJK. Over 29% of patients with L2-S1 fusions had two or more revisions within 8 years. Over 40% of patients had pelvic screws removed.

Conclusion
The rate of ASD and revision surgery at L1 - L2 is high in patients with lumbar spondylosis who undergo L2-S1 fusions. This is irrespective of surgical technique, patient factors, and sagittal alignment. Data collection is ongoing to meet power analysis and statistical significance. This is a multi-center, multi-surgeon study in a heterogenous patient population. These findings suggest a greater understanding of load transmission through the remaining L1-2 and T12-L1 discs is needed in patients undergoing L2-S1 fusions.

Take Home Message
L2-S1 fusions have a high rate of long term revision, weigh surgical risks and benefits carefully if deciding not to span across thoracolumbar junction.

255. Efficacy, Safety & Reliability of High Versus Low Dosages Form of Tranexamic Acid Used in Adolescent Idiopathic Scoliosis Surgery

Sharif A. Jonayed, FCPS; Mohammed Shah Alam, FCPS; Shubhendu Chakraborty, MRCS

Summary
Routine use of tranexamic acid is documented now a days. However, the whether high or low dose is more effective -is still a controversy. Our study determines that the high dose tranexamic acid is more effective than low dose in adolescent idiopathic scoliosis surgery.

Hypothesis
High dose tranexamic acid is more effective, safe and reliable than low dose in adolescent idiopathic scoliosis surgery

Design
Comparative study

Introduction
Tranexamic acid is a synthetic lysine-analogue antifibrinolytic agent that is used for reduction of intraoperative blood loss. It's routine use in adolescent idiopathic scoliosis (AIS) surgery has already been documented. However, the dosing regimens vary widely, and the optimal dose has not been yet established.

Methods
It was a quasi-experimental study in which of 78 patients' of AIS from June 2015 to July 2019 were included. Patients were selected by purposive sampling & allocated into two equal groups (n=39). Group A (high does) received 50 mg/ kg of tranexamic acid administered over 30 min before skin incision and continued at the rate of 5 mg/kg/h until the end of the procedure and group B (low does) received 10 mg/ kg of tranexamic acid over 30 min before skin incision and continued at the rate of 1 mg/ kg/h until the end of the procedure. Estimated blood loss and transfusion requirements were compared between the two-dosing group.

Results
Patient characteristics were nearly identical between the 2 groups. Compared with the low-dose TXA group, the high-dose TXA group had decreased estimated blood loss (545 vs. 870 mL, P=0.01), and a decrease in both intraoperative (0.2 vs. 0.8 units, P=0.01) and whole hospitalization (0.3 vs. 1.0 units, P=0.04) red blood cell transfusion requirements. The higher-dose TXA was associated with decreased intraoperative (P=0.01), and whole hospital transfusion (P=0.01) requirements, even after risk-adjustment for potential confounding variables. No complications or side effects from tranexamic acid use were noted

Conclusion
High-dose TXA is more effective than low-dose TXA in reducing blood loss and transfusion requirements in idiopathic scoliosis patients undergoing surgery. Further investigation is required regarding the safety of TXA before it can be generalized in the use of idiopathic scoliosis surgery.

Take Home Message
Despite lack of evidence, high dose TXA seems to be more effective in respect of bleeding, possibilities of transfusion in AIS surgery

256. Fusion Rate in Minimally Invasive Transforaminal Lumbar Interbody Fusion (MI-TLIF): Autograft outperforms rhBMP-2 and Mesenchymal Stem Cells

Avani S. Vaishnav, MBBS; Hikari Urakawa, MD; Kosuke Sato, MD; Steven J. Mcanany, MD; Sravisht Iyer, MD; Todd J. Albert, MD; (Catherine) Himo Gang, MPH; Sheeraz Qureshi, MD

Summary
This study retrospectively compares the fusion rate achieved by autograft (iliac crest), rhBMP-2 and mesenchymal stem cells in patients undergoing MI-TLIF. CT scans obtained at >1 year were evaluated by attending orthopedic surgeons blinded to the type of graft or fusion adjunct used. Autograft demonstrated a radiologic fusion rate of 92.5%, which was significantly higher than rhBMP-2 (78%) and CBM containing MSCs (68%), but there was no difference in reoperation rates for pseudoarthrosis.

Hypothesis
Autograft will result in higher fusion rate than artificial fusion adjuncts

Design
Retrospective cohort

Introduction
Various graft materials and fusion adjuncts are available to promote fusion. However, superiority of one substrate over others has not been established. Thus, the purpose was to compare fusion rate of MI-TLIF performed using autograft (ICBG), rhBMP-2 and cellular bone matrix (CBM) containing mesenchymal stem cells.

Methods
A retrospective review of a single-surgeon series of consecutive MI-TLIFs was performed. Each fusion substrate was used in consecutive patients before switching to a different substrate, thus minimizing selection bias. Fusion was assessed on 1-year CT scans by an independent blinded neuroradiologist or attending spine surgeon not involved in patient care. Demographics, operative factors and fusion rates of autograft, rhBMP-2 and CBM were compared.

Results
160 fusion levels (autograft:67; rhBMP2: 46; CBM:47) in 135 patients were reviewed. There were no significant differences in demographics or operative factors, except that the rhBMP-2 cohort was older than the CBM cohort (p=0.028). Over 80% of patients had 1-level surgery, and L4L5 and L5S1 were the most common levels. Although there was a significant difference in mean follow-up, all patients had a minimum follow-up of 12 months, at which time fusion was assessed on CT. Autograft demonstrated a higher fusion rate(92.5%) compared to rhBMP-2 (78.0%,p=0.042) and CBM(68.0%,p=0.002), with no difference

between the latter two(p=0.351). Despite significant differences in radiologic fusion rate, there was no significant difference in re-operation rate for pseudoarthrosis.

Conclusion

Autograft outperformed rhBMP-2 and CBM in terms of achieving solid arthrodesis on imaging studies, but rhBMP-2 and CBM show similar results. Although no significant differences were seen in re-operation rates for pseudoarthrosis, this analysis may not have been adequately powered due to the low incidence. Overall, these findings suggest superiority of autograft over other fusion adjuncts for MI-TLIF.

Take Home Message

In patients undergoing minimally invasive TLIF, autograft, specifically Iliac Crest Bone Graft resulted in higher rate of radiologic fusion than rHBMP-2 or cellularized bone matrix containing mesenchymal stem cells.

	CBM	rhBMP-2	Autograft	p-value		
				CBM vs rhBMP-2	CBM vs autograft	rhBMP-2 vs autograft
Number of cases (n=135)	39	39	57			
Total number of levels (n=160)	47	46	67			
DEMOGRAPHICS						
Age (in years)	55.6 ± 11.7	61.4 ± 11.1	59.81 ± 11.6	**0.028**	0.085	0.504
Gender				0.173	0.598	0.234
• Male	17 (43.6%)	24 (61.5%)	28 (49.1%)			
• Female	22 (56.4%)	15 (38.5%)	29 (50.9%)			
Body Mass Index (BMI, kg/m^2)	28.0 ± 7.4	27.4 ± 5.7	25.8 ± 3.3	0.660	0.051	0.086
OPERATIVE FACTORS						
Number of levels				1.000	0.960	0.960
• 1-level	32 (82.1%)	32 (82.1%)	47 (82.5%)			
• 2-level	6 (15.4%)	7 (17.9%)	10 (17.5%)			
• 3-level	1 (2.5%)	0 (0.0%)	0 (0.0%)			
Level of surgery						
• L3L4	2 (4.3%)	4 (8.7%)	0 (0.0%)	0.435	-	-
• L4L5	23 (48.9%)	28 (60.9%)	40 (59.7%)	0.300	0.298	0.907
• L5S1	22 (46.8%)	14 (30.4%)	27 (40.3%)	0.137	0.530	0.324
Graft type						
• CBM	39 (100.0%)	-	-			
• rhBMP-2	-	39 (100.0%)	-			
• Local autograft	-	-	25 (43.9%)			
• Iliac crest bone graft	-	-	55 (96.5%)			
OUTCOMES						
Fusion rate	32 (68.0%)	36 (78.0%)	62 (92.5%)	0.351	**0.002**	**0.042**
Revision surgery for pseudoarthrosis	3 (7.7%)	1 (2.6%)	1 (1.8%)	0.615	0.159	0.791
Mean follow-up (months)	18.4 ± 7.9	13.7 ± 4.1	12.3 ± 2.5	**0.001**	**<0.0001**	**0.041**

257. Worse Preoperative Health-Related Quality of Life Scores (HRQOL) are Predictive of Achieving Minimum Clinically Important Differences (MCID) in Oswestry Disability Index (ODI) at 1- and 2- Years After Complex Adult Spinal Deformity (ASD) Surgery

Joseph M. Lombardi, MD; Nathan J. Lee, MD; Andrew C. Vivas, MD; Jun Kim, MD; Jay S. Reidler, MD; Meghan Cerpa, MPH; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

Summary

Few studies have examined the relationship between preoperative patient characteristics and achieving a minimum clinically important difference (MCID) for ODI scores after ASD surgery. We found that patients with worse preoperative ODI scores were more likely to achieve MCID in ODI at 1 and 2 years following surgery for complex ASD.

Hypothesis

We hypothesize that patients who have preoperative HRQOL scores will reach statistically significant MCID in ODI following ASD surgery.

Design

Retrospective Review

Introduction

To date, few studies have examined the relationship between perioperative patient characteristics, especially how adversely affected patients are from their deformity, as they relate to postoperative MCID for ODI scores.

Methods

This was a retrospective review of a prospectively enrolled consecutive series of adult (≥18years old) patients with complex ASD surgery (defined as minimum 6 Fusion levels, range 6-23) at a single institution from 2015 to 2018 with 2 year follow up. Bivariate analysis was performed on perioperative patient variables. Independent risk factors for reaching MCID for ODI questionnaires were identified using multivariate logistic regression.

Results

A total of 104 patients met inclusion criteria with a mean age of 47.2 and 71% female. Compared to preoperative baseline values, 62.5% and 66.7% reached MCID for ODI at 1 and 2 years respectively. Likewise 74% and 86.7% reached MCID for SRS scores at 1 and 2 years respectively. Bivariate analysis demonstrated > 50th percentile preoperative ODI score (>36), cardiac comorbidity, use of TLIF, PSO and pelvic fixation as statistically significant for ODI MCID up to 2 years after surgery. Conversely, >50th percentile preoperative SRS score and use of VCR were significant predictors for not reaching ODI MCID. Multivariate logistic regression demonstrated that a worse preoperative ODI (>50th percentile, ODI >36) was an independent variable for predicting ODI MCID at 1 and 2 years after surgery (p< 0.001).

Conclusion

A majority of patients achieved MCID in both ODI and SRS scores following surgery for ASD. While bivariate analysis demonstrated multiple predictors for achieving MCID in ODI following surgery, when controlling for independent risk factors, a preoperative ODI score > 36 was statistically predictive in achieving a postoperative MCID in ODI.

Take Home Message

This study showed a worse preoperative ODI is an independent predictor for achieving ODI MCID following ASD surgery, demonstrating benefit with surgery for those most adversely affected by their deformity.

MCID ODI			
	No	Yes	P-value
Preoperative ODI >36 (50th Percentile)	18	67.7	**<0.001**
Preoperative SRS >=62 (50th Percentile)	74.4	50.8	**0.018**
Perioperative Factors			
Female	69.2	72.1	0.737
BMI>=30	33.3	43.1	0.325
ASA>=3	20.5	23.1	0.76
Anxiety	18	15.4	0.732
Anemia	2.6	3.1	0.88
Cardiac Comorbidity	18	36.9	**0.041**
Depression	18	21.5	0.659
Diabetes	5.1	4.6	0.906
GI Comorbidity	2.6	10.8	0.129
Hx of Cancer	5.1	6.2	0.828
Hx of DVTPE	0	4.6	0.173
Hypothyroidism	10.3	12.3	0.751
Pulmonary Comorbidity	18	12.3	0.428
Osteoporosis	15.4	27.7	0.149
Stroke/TIA	2.6	0	0.195
Operative Time>7 hours	46.2	53.9	0.447
PCO	87.2	93.9	0.242
Pelvic Fixation	48.7	78.5	**0.002**
PSO	0	10.8	**0.034**
TLIF	41	69.2	**0.0047**
ALIF/OLIF	0	1.5	0.436
VCR	20.5	4.6	**0.011**
Postop Transfusion	53.9	69.2	0.115
Any Inpatient Postop Complication	20.5	18.5	0.797
LOS >=8 (75th Percentile)	28.2	30.8	0.782
Readmission within 90 Days of DC	2.6	6.2	0.407

Multivariate Analyses for MCID in Patient Reported Outcomes				
1 Year ODI; C-stat=0.82	Odds Ratio	95% CI		P-value
Preoperative ODI > 36 (50th Percentile)	6.649	2.409	18.353	<0.001
2 Year ODI; C-stat=0.77				
Preoperative ODI > 36 (50th Percentile)	11	2.45	49.387	0.0018

258. The Increased Fatty Atrophy and Decreased Lumbar Muscle Cross Sectional Area Throughout the Lumbar Spine Associated with Spondylolisthesis

Sohrab Virk, MD; Milan Sandhu, BS; Avani S. Vaishnav, MBBS; Steven J. Mcanany, MD; Sravisht Iyer, MD; Todd J. Albert, MD; (Catherine) Himo Gang, MPH; Sheeraz Qureshi, MD

Summary
There is significant data underlining the relationship between muscle health and spine related pathology. We have determined the changes related to spondylolisthesis and muscle health on a cohort of patients undergoing spine surgery. There was significantly worse cross sectional area and goutallier classification for those patients with spondylolisthesis.

Hypothesis
There is worse muscle health associated with spondylolisthesis.

Design
Retrospective coho

Introduction
We wanted to determine whether spondylolisthesis was associated with detrimental changes in muscle health for patients suffering from lumbar spine pathology.

Methods
A retrospective review was performed on a consecutive series of patients presenting to spine clinic with lumbar spine pathology. A pre-operative lumbar MRI was analyzed for various muscle health measurements including lumbar indentation value (LIV), paralumbar cross sectional area divided by body mass index (PL-CSA/BMI), and goutallier classification of fatty atrophy. All measurements were taken from an axial slice of a T2 weighted image at L1-L2, L2-L3, L3-L4 and L4-L5 disc spaces. The presence of spondylolisthesis was determined on standing lumbar radiographs. We performed a one-way ANOVA analysis and student's t test to determine statistically significant results.

Results
There were 248 patients (average age 56.1 +/- 16.7 years old, 125 females) included within our analysis. Of these patients, 108 patients had at least some degree of spondylolisthesis. There was significantly worse goutallier classification at L1-L2 ($p < 0.001$), L2-L3 ($p < 0.001$), L3-L4 ($p < 0.001$) and at L4-L5 ($p < 0.001$) for patients with spondylolisthesis. There was significantly worse PL-CSA/BMI for patients in the spondylolisthesis cohort at L1-L2 (139.7 +/- 40.0 vs 152.7 +/- 40.1, $p = 0.013$), L2-L3 (147.4 +/- 40.6 vs 161.1 +/- 40.7, $p = 0.01$), L3-L4 (147.0 +/- 39.4 vs. 160.2 +/- 43.3, $p = 0.016$) and at L4-L5 (132.1 +/- 39.7 vs 145.8 +/- 37.5, $p = 0.007$). There was also worse lumbar indentation value for the spondylolisthesis cohort at L1-L2 (10.3 +/- 6.5 vs 11.9 +/- 5.6, $p = 0.045$), L2-L3 (10.8 +/- 5.8 vs 12.6 +/- 5.5, $p = 0.016$), L3-L4 (12.0 +/- 6.5 vs 14.4 +/- 5.8, $p = 0.004$) and L4-L5 (13.7 +/- 6.1 vs 15.9 +/- 6.1, $p = 0.006$).

Conclusion
There is significant detrimental changes to paralumbar muscle health throughout the lumbar spine associated with spondylolisthesis.

Take Home Message
There is worse muscle health associated with spondylolisthesis associated with lumbar spine pathology.

259. One and Done: A Comparison of Definitive Fusion to Growth-Sparing Surgery for Early Onset Scoliosis (EOS)

Robert C. Palmer, MD; David C. Thornberg, BS; James O. Sanders, MD; Lukas Keil, MD; Charles E. Johnston, MD

Summary
We compared the outcomes of 14 EOS patients treated by index definitive fusion to 18 treated by growth-sparing surgery between age 6-10.9 yr. At 2 yr followup, PFTs and EOSQ scores were equivalent for the 2 groups, suggesting definitive spinal fusion offers equivalent patient outcomes to growth-sparing methods.

Hypothesis
Children who have definitive fusion vs growth sparing surgery demonstrate equivalent outcomes

Design
Retrospective, single institution cohort study in patients with

EOS ages 6-10.99 treated with definitive fusion (DF) versus a growth sparing (GS) construct with minimum 2 year follow-up after last surgery.

Introduction
GS treatment outcomes for EOS are uncertain, requiring multiple surgeries for lengthening, revisions and complications. A single definitive spine fusion may be superior if the eventual outcome compared to GS surgery is equivalent. The purpose of this study is to compare the outcomes of patients that underwent definitive fusion with those having growth sparing techniques.

Methods
We compared outcomes for patients age 6-10.9 y with index spine surgery from 2011-18, minimum 2-yr follow-up after last surgery. Neuromuscular cases were exluded. Outcomes measures included major cobb, T1-12 height, T1-S1 length, max kyphosis, pulmonary function test, early onset scoliosis questionnaire and complications.

Results
32 patients were studied, 14 having index definitive fusion and 18 having growth sparing strategies (9 magnetically-controlled growing rods, 8 traditional growing rods, 2 tether constructs). There were 9 congenital (DF 4, GS 5), 10 idiopathic (DF 5, GS 5) and 13 syndromic (DF 5, GS 8) patients. Preoperative patient height (p=0.026) and age at index surgery (p=0.000) were greater in the DF group. Curve size (DF 31 vs GS 45) was significantly decreased (p=0.008) in the DF group compared to GS, while spine length (T1-S1) at final follow-up was greater in the GS group (p=0.018). No significant differences between the EOSQ and PFTs (Final FVC DF 1.54, GS 1.80; FEV1 DF 1.28, GS 1.26) were noted among the 2 groups and there were no correlations between the EOSQ and radiographic outcomes. There were 6 complications in the DF group and 8 in GS; 5 complications in the GS group resulted in conversion to DF.

Conclusion
Aside from the final cobb angle and change in T1-S1 length, there are no differences in outcomes between definitive fusion and growth sparing surgery for early onset scoliosis between age 6-10.9 y.

Take Home Message
Treating EOS between ages 6-10.9 y. with index definitive fusion provides similar outcomes to growth sparing surgery.

260. Perioperative Complications in 199 Cases of Anterior Vertebral Body Tethering

James Meyers, BA; Lily Q. Eaker, BA; Theodor Di Pauli von Treuheim, BEng; Sergei Dolgopolov, MD; Baron Lonner, MD

Summary
Anterior Vertebral Body Tethering (AVBT) is a motion-sparing alternative to spinal fusion, the current standard of surgical treatment for Adolescent Idiopathic Scoliosis (AIS). 199 patients underwent AVBT to correct AIS. We report major and minor perioperative complication rates of 3.0% and 3.0%, respectively. These rates are within clinically acceptable ranges and are comparable to those reported for spinal fusion.

Hypothesis
The rate of perioperative complications following AVBT to correct AIS is within a clinically acceptable range.

Design
Retrospective chart review

Introduction
Spinal fusion is the current standard of care for AIS. Anterior vertebral body tethering (AVBT) is a motion-sparing alternative to posterior fusion (PF) gaining clinical interest. As a novel procedure, there is a paucity of literature on safety and efficacy. Here, we report 90-day complication rates in 199 patients who underwent AVBT, by a single surgeon, the largest series to date.

Methods
199 adolescent patients underwent AVBT. Approaches included 77 thoracic, 52 thoracolumbar, and 70 double. Major complications were defined as those that either required readmittance or reoperation, prolonged the use of invasive materials such as chest tubes, or those that resulted in spinal cord or nerve root injury. Minor complications were those that resolved without the need of invasive intervention.

Results
Mean operative time and blood loss were 235.6± 56.9 minutes and 192.3±108.3 ml, respectively. No patient received an allogenic blood transfusion. 6 patients experienced major (3.0%), and 6 had minor complications (3.0%). Major complications included 3 chylothoracies (1-R T and L TL; 1- R T; 1- L TL approaches), 2 hemothoracies (2- R T and L TL), and 1 lumbar radiculopathy secondary to screw placement requiring re-operation. Minor complications included 1 patient with respiratory distress requiring supplementary oxygen, 1 superficial wound infection, 2 cases of prolonged nausea, and 1 Raynaud phenomenon. There was a notable difference in major complication rates between patients who had a tether placed on both thoracic and thoracolumbar curves (5.7%), and those who had a single approach, although not statistically significant (1.6%, p = 0.19).

Conclusion
We report on complications observed in 199 patients who underwent AVBT for correction of AIS. The major and minor complication rates were both 3.0%.

Take Home Message
Perioperative complication rates associated with AVBT are within a clinically acceptable range, and comparable to those reported for the treatment of AIS using PF.

Demographic and Clinical Features	All Patients N = 199	Complications, split		All Complications N = 12	No Complications N = 187	Significance
		Major N = 6	Minor N = 6			
Age	16.3 ± 6.1	14.7 ± 3.6	15.5 ± 3.8	15.1 ± 3.6	15.8 ± 6.3	p = 0.83
Female Sex	155 (77.9%)	5 (2.5%)	6 (3.0%)	11 (5.5%)	144 (72.4%)	p = 0.41
EBL	192.3 ± 108.3	180.0 ± 75.8	204.2 ± 120.8	154.2 ± 64.1	197.4 ± 119.1	p = 0.56
Thoracoplasty	51 (25.6%)	1 (0.5%)	0 (0.0%)	1 (0.5%)	50 (25.1%)	p = 0.28
Pre-Op Cobb	54.4 ± 10.5	51 ± 12.7	54.3 ± 10.7	52.1 ± 10.9	54.6 ± 10.5	p = 0.69
Thoracic Tether	**77 (38.7%)**	**1 (0.5%)**	**1 (0.5%)**	**2 (2.6%)**	**75 (37.7%)**	p = 0.13
Right	75 (97.4%)	1 (0.5%)	1 (0.5%)	2 (2.6%)	73 (36.7%)	
Left	2 (2.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (2.6%)	
TL Tether	**52 (26.1%)**	**1 (0.5%)**	**2 (2.6%)**	**3 (1.5%)**	**49 (24.6%)**	p = 0.80
Right	14 (26.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	14 (7.0%)	
Left	38 (73.1%)	1 (0.5%)	2 (2.6%)	3 (1.5%)	35 (17.6%)	
Th and TL Tether (bilateral)	**70 (35.2%)**	**4 (2.0%)**	**3 (1.5%)**	**7 (3.5%)**	**63 (31.7%)**	p = 0.12

All values represent means ± standard deviation or number of patients (percentage of total)

Table. Complications in 199 VBT patients.

261. Predictive Model for Selection of Upper Treated Vertebra using a Machine Learning Approach

Renaud Lafage, MS; Basel Sheikh Alshabab, MD; Jonathan Elysee, MS; Francis C. Lovecchio, MD; Karen A. Weissmann, MD; Han Jo Kim, MD; Frank J. Schwab, MD; Virginie Lafage, PhD

Summary
There is no consensus on the optimal upper instrumented vertebra (UIV) in surgical correction of thoracolumbar adult spinal deformity (ASD). Using a retrospective cohort of ASD patients with complete fusion of the lumbar spine and a UIV between T1 and T12, a Neural Network model was trained to mimic surgeon decision making regarding the selection between Upper Thoracic versus Lower Thoracic UIV. This deployable model had an accuracy above 80% during the cross-validation phase

Hypothesis
Selection of the Upper Instrumented Vertebra can accurately be predicted using a combination of pre-operative information and surgical objectives

Design
Single Center Retrospective review

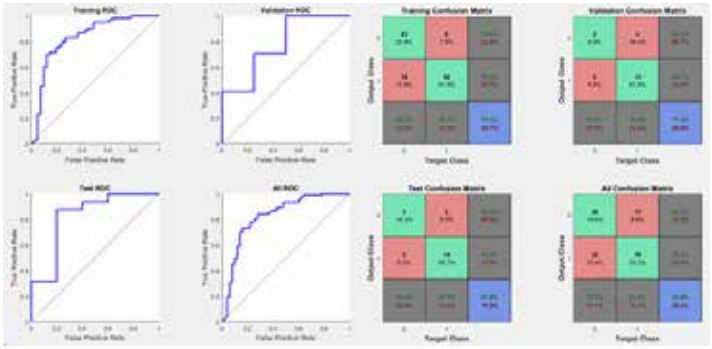
Introduction
There is no consensus on the optimal upper instrumented vertebra (UIV) in surgical correction of thoracolumbar adult spinal deformity (ASD). The purpose of the current study is to train and validate an algorithm mimicking experienced surgeons' decision making regarding UIV selection.

Methods
This study is a retrospective review of a single center database of ASD patients who underwent fusion of the lumbar spine (UIV>L1 to pelvis) from 2013-2018. Data collection included demographic and radiographic information. The sample was stratified into 3 groups, 70% for model training, 15% for validation and 15% for performance testing. Using a deep learning algorithm, a neural network model was trained to select between upper thoracic (UT: T1-T6) and lower thoracic (LT: T7-T12) UIV. Parameters used in the deep learning algorithm included demographic, coronal and sagittal pre-operative alignment and post-op PI-LL (objective).

Results
143 patients (mean age: 63.3yo±10.6, 81.8% F) with moderate to severe deformity (MaxCobb: 43°±22; TPA: 27°±14 ; PI-LL: 22°±21) were included. Patients underwent a significant change in lumbar alignment (ΔPI-LL: 21°±16 p<0.001); 35.0% had a UIV in the UT region, and 65.0% in the LT region. At 1Y, revision rate was 11.9% (pseudo/ hardware failure: 5.6%, PJF: 4.2%) and rate of radiographic PJK was 29.4%. 101 patients were used for model training and 21 for validation and testing. Neural network was composed of 8 inputs, 10 hidden neurons and 1 output (UT or LT). After training, results demonstrated an accuracy of 81.0%, precision of 87.5% and recall of 87.5% on testing set

Conclusion
Using advanced predictive analytics, a model simulating surgeons' decision making in the selection of UIV was developed. This model was able to accurately predict the surgical strategy for ASD correction. Future models integrating surgical outcomes should be developed

Take Home Message
A deployable predictive model mimicking surgeons' decision making regarding selection of upper treated vertebra was developed using neural network machine learning with an accuracy of selection of 81.0%.



262. Determination of Thresholds for the Magnitude of Osteotomy Required in Adult Cervical Deformity Surgery with Incorporation of Radiographic Determinants

Peter G. Passias, MD; Katherine E. Pierce, BS; Sara Naessig, BS; Waleed Ahmad, BS; Bassel G. Diebo, MD; Aaron J. Buckland, MBBS, FRCSA; Han Jo Kim, MD; Renaud Lafage, MS; Themistocles S. Protopsaltis, MD; Virginie Lafage, PhD

Summary
Osteotomy protocols for cervical deformity have yet to be identified. Certain preoperative radiographic thresholds were identified for utilizing Three-column, Ponte and Facet osteotomies in patients undergoing spinal realignment for cervical deformity.

Hypothesis
Certain preoperative radiographic parameters affect the surgeon choice of osteotomy for correction of severe cervical deformity.

Design
Retrospective cohort study of single-surgeon database

Introduction
There are no guidelines to direct how to determine the appropriate osteotomy protocols for correcting severe cervical deformity(CD).

Methods
Included: surgical adult CD patients with baseline radiographic data. Excluded: anterior-only approach with<3 levels. Patients were grouped by isolated osteotomy type: (1)Three column osteotomy(PSO or VCR)[3CO] (2)Ponte osteotomy[PO] (3)Facet osteotomy[FO]. Sagittal cervical deformity angular ratio(DAR):-maximum C2-C7 Cobb angle divided by the number of vertebrae involved(negative values=kyphosis in the cervical spine at BL). Flexibility=(C2-C7 Cobb angle–Bending C2-C7 Cobb angle)/Cobb angle. Tukey's test identified significant variables between paired groups and Receiver Operating Characteristic(ROC) analysis showed the AUC for the variables identified. Cut-offs were deter-

mined via decision-tree analysis for significant variables within osteotomy type.

Results

55 CD patients included(56.5yrs, 52.7%F, 29.2kg/m2). Average levels fused for the cohort was 6.8. 8 patients underwent a 3CO, 23 patients Ponte Osteotomy, 24 Facet Osteotomy. Tukey's test identified 5 significant radiographic variables between osteotomy groups and are listed in Table 1. ROC analysis showed AUC for the 5 variables that ranged from 0.539-0.868(max as cSVA). Flexibility >0.5(0.25[0.02-3.3], p=0.080) and DAR >0.54(7[0.7-20.0], p=0.098) predicted 3CO patients (Total model: 0.445, p=0.049). An L1-S1 angle ≤-32.5°(64[9.6-426.9], p<0.001), T4-T12 angle >-17.2°(128[12.2-1342],p<0.001) and a DAR of ≤-0.168(7.5[1.7-33],p=0.008) predicted a PO(R2 =0.757, p<0.001).). Lastly, patients who presented with baseline cSVA>18mm (4.8[1.1-20.3], p=0.034) and T4-T12 ≤-28.3° (133[12.7-139], p<0.001(R2 =0.717, p<0.001).

Conclusion

This study defined radiographic thresholds of utilizing Three-column, Ponte and Facet osteotomies in patients undergoing spinal realignment for cervical deformity.

Take Home Message

Analysis of the use of these higher risk procedures and the optimal candidates may help guide surgeons in their pre-operative assessment of appropriate invasiveness required to optimize outcomes.

Tukey's 5 Significant Variables

	Facet Osteotomy	Ponte Osteotomy	Three Column Osteotomy	p-value
DAR	0.16	-0.31	0.90	0.010
C2-C7 SVA	23.4mm	-28.7mm	9.9mm	<0.001
Flexibility	-5.24	-14.4	1.7	0.049
T4-T12 Angle	-36°	33.3°	-8.1°	<0.001
L1-S1 Angle	51.1°	-38.4°	20.5°	0.013

263. Osteoporosis is a Predictor for Two-Year Adverse Outcomes in Patients Undergoing Long Cervical Fusion

Alexander Rompala, BS; Ryne J. Veenema, MS; Neil V. Shah, MD, MS; George A. Beyer, MS; Pelin Celiker, BS; Hallie A. Tiburzi, BS; Vincent Challier, MD; Peter G. Passias, MD; Frank J. Schwab, MD; Virginie Lafage, PhD; Carl B. Paulino, MD; Bassel G. Diebo, MD

Summary

Osteoporosis (OP) is highly prevalent, globally, but there is a paucity of literature exploring the complications arising for osteoporotic patients undergoing cervical fusion (CF). Osteoporosis significantly associated with all 2Y adverse postoperative outcomes in patients undergoing multilevel CF. This data indicates that preoperative screening and management of osteoporosis may be important in optimization of patient undergoing these types of procedures.

Hypothesis

Patients with osteoporosis undergoing long cervical fusion have comparable rates of post-op complications.

Design

Retrospective cohort

Introduction

There is limited data regarding long-term outcomes in osteoporotic patients in the setting of ≥4-level cervical fusion.

Methods

Patients undergoing posterior/anterior-posterior, ≥4-level CF for cervical radiculopathy of myelopathy (CR, CM) were selected from the New York State Statewide Planning and Research Cooperative System data. Patients with and without OP were identified. Demographics, 2Y medical/surgical complications, 2Y readmissions, and 2Y revisions were compared between groups. Logistic regression identified predictors of 2Y outcomes.

Results

2,604 patients were included (OP, n=136 (5.2%); No-OP, n=2468). OP pts were older (66.9 vs. 60.0 years), more often female (75.7% vs. 36.2%) and white (80.0% vs. 65.3%), all p≤0.007. OP and No-OP pts had similar Deyo scores (1.1 vs. 1.0), total hospital charges ($100,953 vs. $91,618), length of stay (9.7 vs. 8.4 days), and posterior vs. anterior-posterior approach distribution (83%, 17% vs. 86%, 14%), all p>0.05. OP pts had higher overall medical complication rates (41.9% vs. 29.4%, p≤0.002). OP pts had higher rates of surgical complications, including implant-related complications (8.1% vs. 2.9%) and CNS complications (1.5% vs. 0.2%), though overall surgical complications (14.0% vs. 9.2%) were comparable, p>0.05. OP was associated with 2Y revisions (OR=2.80), 2Y readmissions (OR=1.86), 2Y medical complications (OR=1.57), and 2Y surgical complications (OR=1.52), all p≤0.03. Combined anterior-posterior approach was also an independent predictor for 2Y surgical (OR=1.60) and medical (OR=1.52) complications, both p≤0.001 (Table a).

Conclusion

Osteoporosis was associated with 2Y adverse postoperative outcomes in patients undergoing multilevel CF. Combined approach was associated with increased 2Y complications.

Take Home Message

Osteoporosis is independently associated with medical, surgical, revisions, and readmissions. These data highlight the need for pre-operative osteoporosis optimization.

	Odds Ratio	Lower Bound (95% CI)	Upper Bound (95% CI)	p-value
Medical Complications	1.57	1.07	2.32	**0.021**
Surgical Complications	1.52	1.04	2.22	**0.030**
Revisions	2.80	1.73	4.53	**<0.001**
Readmissions	1.86	1.24	2.80	**0.003**

Table a. Multivariate regression models evaluating baseline osteoporosis as a predictor for 2-year adverse outcomes following long cervical fusion (≥4-level) in patients with cervical radiculopathy or myelopathy.

264. Late Spinal Infections Are Five Times More Common in Pediatric vs. Adult Deformity Patients

Graham Beutler, BS; Brian T. Sullivan, MD; Amit Jain, MD; Khaled M. Kebaish, MD; Paul D. Sponseller, MD

Summary
We reviewed 838 pediatric AIS patients and 321 adult deformity patients who underwent primary surgery for thoracolumbar deformity at a single institution. Incidence of late infection (≥6 months after operation) was 3.1% in the AIS group and 0.62% in the adult group and the difference between groups was significant. Late spinal infections are five times more common in pediatric AIS patients vs. adult spinal deformity patients, with skin and indolent organisms being the primary identifiable causative agents in both cohorts.

Hypothesis
Late spinal infection, defined as ≥6 months after index operation, is more common in pediatric AIS patients vs. adult spinal deformity patients.

Design
Retrospective, single institution

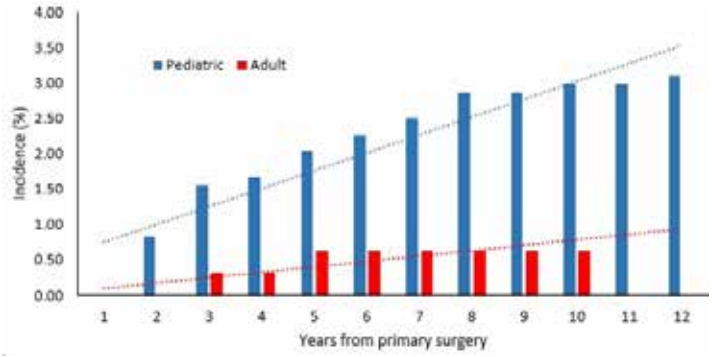
Introduction
The incidence of late infection following PSF in pediatric AIS patients has been reported in the literature to be approximately 2-3%. However, there is limited prior literature on late spinal infections in adult deformity patients, suggesting that this phenomenon may be less frequent in adults.

Methods
We queried a prospective pediatric deformity registry (age <21) from 2000 to 2015, and an adult deformity registry (age ≥21) from 2010 to 2017, to identify patients who underwent primary surgery for thoracolumbar deformity at a single institution. The same implant system was used in all patients. We excluded patients with prior deformity surgeries and those with neuromuscular or syndromic deformities. The individual charts of all patients were personally reviewed by study team members to identify those who went on to have late spinal infections.

Results
A total of 1,159 patients met criteria, 838 pediatric AIS patients and 321 adult deformity patients. Incidence of late infection was 3.1% (26/838) in the AIS group and 0.62% (2/321) in the adult group and the difference between groups was significant (Fisher's exact test p=0.010). Average onset of infection was 4.2 years (1.0-11.6) in the AIS group and 3.3 years (2.6-4.0) in the adult group. Cutibacterium acnes was the most common microorganism identified in the AIS group (19%, 5/26). The microorganism identified in the two adult cases was coagulase-negative Staphylococci. Management involved implant removal in all cases, with concurrent reinstrumentation only in the two adult cases.

Conclusion
Late spinal infections are five times more common in pediatric AIS patients vs. adult spinal deformity patients. Differences in skin colonization density may be one possible explanation. Skin and indolent organisms are the primary identifiable causative agents in both cohorts.

Take Home Message
Late spinal infections are five times more common in pediatric AIS patients vs. adult spinal deformity patients. Skin and indolent organisms are the primary identifiable causative agents in both cohorts.



Late spinal infections are five times more common in pediatric AIS patients vs. adult spinal deformity patients.

265. Soft Landing: Can it Prevent Proximal Junctional Kyphosis and Proximal Junctional Failure in Adult Spinal Deformity?

Alejandro Cazzulino, BA; Rikesh A. Gandhi, MD; Thaddeus Woodard, BS; Nissim Ackshota, MD; M. Burhan Janjua, MD; Vincent Arlet, MD; *Comron Saifi, MD*

Summary
"Soft Landing" creates a gradual transition from a rigid segmental construct to the native spine at the top of the construct while reducing junctional stress at those levels by keeping the soft tissue attachment on one side. This retrospective case series found an overall lower rate of Proximal Junctional Failure (PJF) in 39 patients who underwent the new technique when compared to published rates of PJF.

Hypothesis
"Soft Landing" is a novel technique to reduce proximal junctional kyphosis (PJK) and PJF.

Design
Retrospective case series

Introduction
PJK and PJF are a well-recognized, yet incompletely defined, complications of adult spinal deformity surgery. There is no standardized definition for PJK, but most studies describe PJK as an increase in the proximal junctional angle (PJA) of greater than 10°–20°.

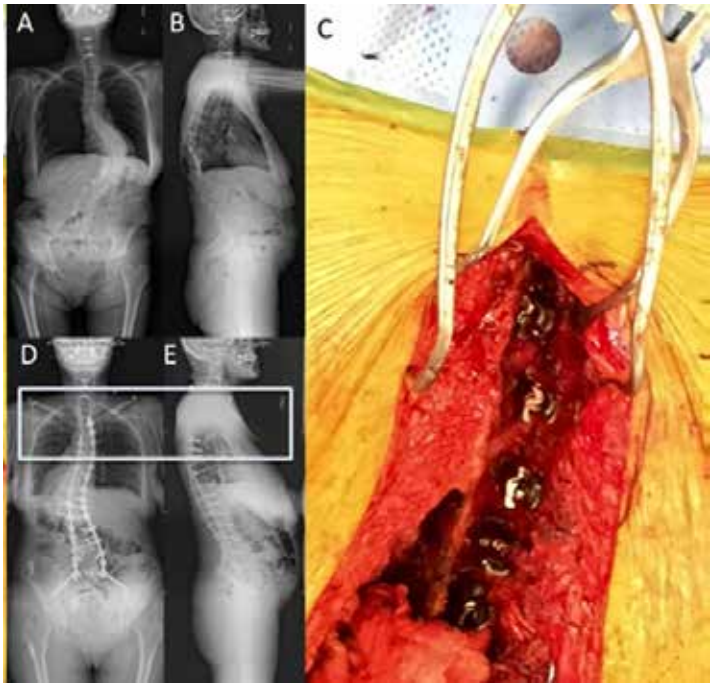
Methods
"Soft Landing" was used in a series of 39 consecutive adult spinal deformity patients at a single institution. Patient demographics, including age, sex, indication for surgery, revision surgery, surgical approach, use of osteotomies, and vertebroplasty were collected. The PJA was measured preoperatively and at last follow-up using 36-inch radiographs. Data on change in PJA and need for revision surgery were collected. Univariate and multivariate analyses were performed to identify factors associated with change in PJA and proximal junctional failure (PJF), defined

as PJK requiring surgical correction. Our results were compared to the rate of PJK and PJF available in the literature.

Results
A total of 39 consecutive patients were included. The mean age of the cohort was 61.4 years, and 90% of patients were women. Over half of these cases (59%) were revision surgeries, with 72% involving a combined anterior or lateral and posterior approach. The mean change in PJA was 9°; 23 patients had a change of less than 10°. Thirteen patients had a change in PJA of 10°–20°, and 3 patients had a change in PJA of greater than 20°. Twelve patients had to return to the OR for various indications including prominent hardware and traumatic construct damage; however, only 3 (7.7%) were for PJF. Compared to the available literature, the Soft Landing technique is associated with far less PJF than constructs with bilateral pedicle screws at the upper instrumented level.

Conclusion
Soft landing should be considered as a novel technique for PJF prevention given the apparent decreased need for revision surgery.

Take Home Message
Soft Landing requires more evaluation but may provide surgeons with a method to reduce rates of PJF in ASD.



A/B: AP and lat XRs C: Intraop image of 3 Supra laminar hooks on R, and intact soft tissue on L. D/E: Postoperative AP and Lat XR with boxed area showing fig 3C.

266. Should Selective Thoracic Fusion Be Reserved for Non-Structural Compensatory Lumbar Curves? Radiographic and Clinical Results from Propensity Score Matched Patients at Minimum 5 Year Follow Up

Jay S. Reidler, MD; Scott Zuckerman, MD; Andrew C. Vivas, MD; Joseph M. Lombardi, MD; Jun Kim, MD; Meghan Cerpa, MPH; Peter O. Newton, MD; Lawrence G. Lenke, MD; Harms Study Group

Summary
In this multicenter study with minimum 5-year follow-up, we performed propensity score matching to compare patients treated with selective thoracic fusion and non-selective fusion for Lenke 1-2C curves vs. 3-4C curves. We found that selective thoracic fusion resulted in slightly less radiographic improvement compared to non-selective fusion for all curves. While STF led to similar patient-reported outcome scores as NSF for Lenke 1-2C curves, NSF led to better scores for Lenke 3-4C curves.

Hypothesis
Selective thoracic fusion results in worse radiographic outcomes compared to non-selective fusion for Lenke 1-4C curves, but similar patient reported outcomes for Lenke 1-2C curves.

Design
Retrospective analysis of multicenter, prospectively collected data.

Introduction
For adolescent idiopathic scoliosis (AIS) Lenke Type 1-4C curves, controversy exists whether selective thoracic fusion (STF) is sufficient or non-selective fusion (NSF) should be used to treat the associated lumbar curves.

Methods
A prospective, multicenter database was queried for Lenke 1-4C curves (min 5-yr follow up). Patients were dichotomized to STF (fusion L1 or above) vs. NSF (fusion below L1). We analyzed two subgroups: 1) non-structural lumbar curves (1-2C), and 2) structural lumbar curves (3-4C). After propensity score matching within each subgroup for age and preop thoracic and lumbar Cobb angles, we conducted within and between group comparisons of radiographic data and SRS-22 scores.

Results
Of 124 patients with 1-2C curves, 74 matched (37 STF, 37 NSF). At 5 years postop, both STF and NSF led to improvement in main thoracic (MT) and compensatory lumbar (CL) Cobb angles as well as coronal balance (C7-CSVL), but NSF values were better than STF ($p<0.05$). While SRS total and self-image scores improved for each procedure ($p<0.05$), there were no significant differences in STF and NSF patient reported outcomes (PROs). Of 95 patients with 3-4C curves, 36 matched (18 STF, 18 NSF). At 5 years postop, both STF and NSF led to improvement in MT and CL cobb angles, but again NSF values were better than STF ($p<0.05$). NSF reported better total SRS ($p<0.02$) and self-image ($p=0.05$) scores when compared to STF.

Conclusion
In propensity score matched patients treated for Lenke Type 1-2C curves, STF results in slightly less radiographic correction

but similar patient reported outcomes as NSF at 5 years. In contrast, matched patients treated for Lenke Type 3-4C curves with NSF have both better radiographic and patient reported outcomes when compared to STF.

Take Home Message

Non-selective fusion results in slightly better radiographic improvement compared to selective thoracic fusion for AIS Lenke 1-4C curves, but only significantly improves patient-reported outcomes for structural lumbar (Lenke 3-4C) curves.

	Lenke Type 1-2C			Lenke Type 3-4C			
Radiographic Outcomes	STF N=37	NSF N=37	p-value		STF N=18	NSF N=18	p-value
MT cobb angle (°), mean±SD							
Preop (N=37/37)	53.9±8.9	52.8±8.9	0.601	N=18/18	63.6±12.8	64.2±11.8	0.883
5-year (N=37/37)	24.6±6.6	18.3±5.4	<0.001*	N=18/18	27.9±8.3	21.8±7.7	0.029*
p-value	<0.001*	<0.001*			<0.001*	<0.001*	
Lumbar cobb angle (°) (n=80)							
Preop (N=37/37)	42.8±5.6	44.1±6.0	0.337	N=18/18	49.3±6.8	49.9±8.0	0.806
5-year (N=37/37)	23.5±7.0	16.0±7.8	<0.001*	N=18/18	27.4±7.8	16.2±5.2	<0.001*
p-value	<0.001*	<0.001*			<0.001*	<0.001*	
Fusion Length	8.4±1.3	11.6±1.3	<0.001*	N=18/18	8.9±1.1	12.5±1.3	<0.001*
Lumbar apical vertebral translation (cm) (AVT)							
5-year (N=34/37)	-2.1±1.1	-1.4±1.1	0.016*	N=17/16	-2.6±1.4	-1.2±1.1	0.005*
Coronal balance (C7-CSVL)							
5-year (N=34/36)	-1.3±1.2	-0.6±1.1	0.021*	N=17/16	-1.6±1.8	-0.7±1.2	0.110
SRS-22 Reported Outcomes							
Total							
5-year (N=32/36)	4.30±0.48	4.22±0.48	0.510	N=17/15	4.07±0.52	4.45±0.33	0.020*
Function/Activity							
5-year (N=32/36)	4.58±0.55	4.46±0.47	0.313	N=17/15	4.41±0.46	4.56±0.35	0.329
Pain							
5-year (N=32/36)	4.11±0.66	4.14±0.79	0.863	N=17/15	4.04±0.62	4.43±0.51	0.060
Self-image							
5-year (N=32/36)	4.25±0.66	4.13±0.68	0.447	N=17/15	4.01±0.75	4.47±0.45	0.051
Mental health,							
5-year (N=32/36)	4.26±0.65	4.08±0.64	0.242	N=17/15	3.80±0.87	4.31±0.55	0.063
Satisfaction							
5-year (N=31/36)	4.39±0.77	4.51±0.62	0.457	N=16/11	3.66±1.35	3.73±1.21	0.890

Comparison of STF and NSF Outcomes Stratified by Curve Type

267. Spinal Hounsfield Units Predict Proximal Junctional Angle Changes and Kyphosis Following Adult Spinal Deformity Surgery

Amer Aboubakr, MD; Amy Minnema, MS; William F. Lavelle, MD; *H Francis Farhadi, MD, PhD, FRCS(C)*

Summary

DEXA is a standard BMD screening tool for the diagnosis of osteoporosis, which is a risk factor for proximal junctional kyphosis and failure (PJK/F). In this study, we compared pre-operative CT Hounsfield Unit (HU) vs DEXA in terms of their ability to predict PJ compression fractures (PJCF) and PJK/F. In our cohort, only spinal HU is significantly associated with the occurrence of PJCF and PJK. Spinal HU is also a fair predictor of PJ Cobb angle (PJCA) on final follow-up.

Hypothesis

Pre-operative spinal HU and DEXA assessments of BMD are predictive of PJCF and PJK/F

Design

Single-center retrospective study of consecutive ASD patients who underwent instrumented surgery of at least seven intervertebral levels between August 2015 and December 2018

Introduction

As compared to DEXA scans, CT-based BMD measures have been posited as potentially more accurate measures of osteoporosis, not confounded by regional sclerosis

Methods

All patients underwent hybrid thoracolumbar spinal deformity surgery supplemented with PJ sublaminar bands during the study period. Baseline clinical status as well as peri-operative and final follow-up radiographic parameters were measured. Mean axial CT HU were calculated using measurements from each of the three proximal upper instrumented vertebral levels (UIV+1, UIV, and UIV-1). Using binary logistic regression, HU and BMD were evaluated as potential predictors of PJCF and PJK/F, defined as an absolute and relative change in the UIV+2 to UIV PJCA from preoperative to final follow-up radiographs.

Results

All 85 subjects had a minimum of 1.0 year follow-up with an average follow up of 2.0 years. An overall PJK incidence of 19.3% was noted. There were no cases of PJF in this cohort. Independent samples t-tests confirmed significant differences in spinal HU (124.5 +/- 38.9 vs 164.9 +/- 53.8, p=0.015; 134 +/- 42.2 vs 169 +/- 53.5, p = 0.015) but not in average BMD hip (-0.93 +/- 1.4 vs -0.52 +/- 1.1, p=0.290; -0.78 +/- 1.33 vs -0.50 +/- 1.15, p=0.389) in the PJCF vs non-fracture and PJK vs non-PJK groups, respectively. Logistic ordinal regression analysis confirmed that spinal HU (p = 0.041; p = 0.039), but not average BMD hip (p = 0.096; p = 0.146), was predictive of PJCF and PJK, respectively, while controlling for upper vs lower thoracic surgeries. Linear regression analysis further confirmed that both variables were predictive of final PJCA [average BMD hip AUC 0.58 (poor) and spinal HU AUC 0.70 (fair)].

Conclusion

Spinal HU is significantly associated with the occurrence of PJCF and PJK and is a fair predictor of PJCA on final follow-up

Take Home Message

Taken together, spinal HU may allow surgeons to better predict and counsel their patients regarding the development of PJCF and PJK following ASD surgery

268. Long Term Radiographic Outcomes Following Adult Spinal Deformity Surgery

Amit Parekh, DO; Jeremy Smith, MD; Edward Quilligan, BS

Summary

The T1-pelvic angle and the preoperative pelvic incidence may be predictive of continued pain, proximal junctional kyphosis (PJK), and revision surgery following thoracolumbar fusions for adult spinal deformity.

Hypothesis

The purpose of the study is to evaluate whether a high preoperative pelvic incidence, postoperative pelvic incidence-lumbar lordosis (PI-LL) mismatch, or postoperative T1-pelvic angle (T1PA) is predictive of proximal junctional kyphosis (PJK) or failure and subsequent revision or persistent pain at long term follow up.

Design
Multi-center, multi-surgeon retrospective cohort study

Introduction
Sagittal balance in adult spinal deformity is topic of ongoing exploration. PJK and PJF are challenging problems whose contributing factors are not entirely understood. A high native PI is a risk factor for adjacent segment disease (ASD). Recent developments in sagittal plane measures include the T1 pelvic angle (T1PA) which correlates with health related quality of life scores.

Methods
A multi-center, multi-surgeon retrospective cohort study of patients following a posterior thoracolumbar fusion with pelvic fixation, with or without interbody fusion or three column osteotomy between 2010-2019 was performed. Long term follow up was 1-8 years post index surgery. PI and LL, T1PA, and PJA were recorded at preoperative, short term (less than 3 months) and long term postoperative (over 1 year) follow up. At long term follow up the revision rate and patient symptoms were recorded. Patients were separated into cohorts of preoperative PI less than or equal to 55 degrees or greater than 55 degrees.

Results
Preliminary data suggests 60% of patients with a high native PI had evidence of PJK or PJF within long term follow up. No patients with a low PI had PJK at long term follow up. Of patients with a T1PA over 20 degrees, 55% had evidence of PJK or PJF. The rate of revision surgery, continued pain, or deformity was 87% in patients with a T1PA over 20 degrees. No patients with a T1PA less than 20 degrees had PJK or PJF.

Conclusion
A native PI over 55 degrees may be predictive of long term PJK and symptomatic ASD. A postoperative T1PA greater than 20 degrees is associated with continued back pain and revision surgery following thoracolumbar fusions at up to 8 years post surgery. Data collection is ongoing to meet power analysis and statistical significance criteria.

Take Home Message
A preoperative PI over 55 degrees is associated with symptomatic ASD, PJK, and revision surgery in the long term.

269. The Posterior Cranial Vertical Line (PCVL): A Novel Classification System for Defining Global Sagittal Alignment

Paul J. Park, MD; Cole Morrissette, BS; Nathan J. Lee, MD; Meghan Cerpa, MPH; Zeeshan M. Sardar, MD; Han Jo Kim, MD; Lawrence G. Lenke, MD

Summary
The PCVL grading system is a novel, comprehensive measurement of skull position relative to overall sagittal alignment. Only 4% of normal subjects had a PCVL anterior to the thoracic apex and PSVL, and only 6% of patients had a PCVL anterior to the tibial plafond. Further study is warranted of the PCVL in the adult spinal deformity population both preoperatively and postoperatively, as well as potential correlations with eventual proximal junctional kyphosis and failure of instrumentation.

Hypothesis
We propose a novel radiographic classification system to understand global sagittal alignment based on the posterior cranial vertical line (PCVL) relative to the thoracic apex and PSVL.

Design
Single center retrospective review of prospectively collected data

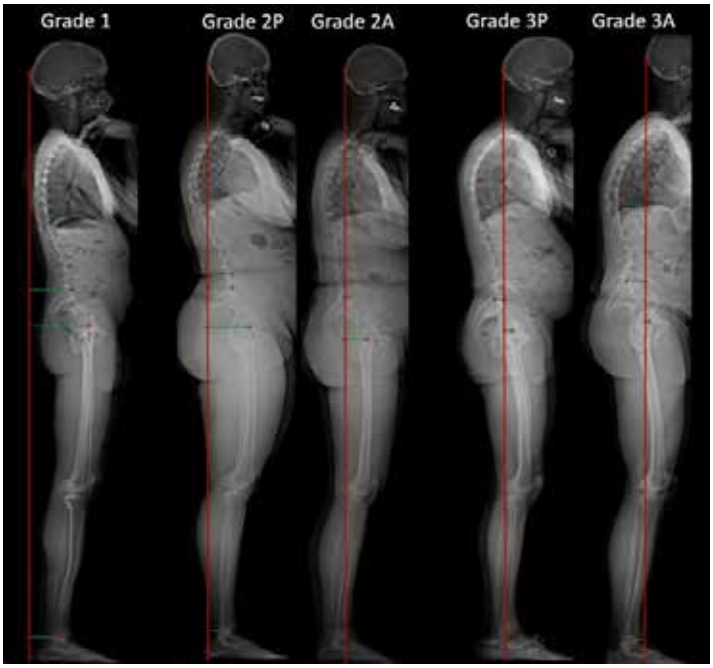
Introduction
Sagittal alignment is a well-established factor in patient outcomes following adult spinal deformity surgery. The long-used standard of the sagittal vertical axis (SVA) excludes critical factors such as the position of the skull and its relative position to the lower extremities. We define here a novel radiographic measurement in a normal population to better understand global sagittal alignment.

Methods
Standing, full-length radiographs were reviewed for 117 healthy volunteer subjects. The PCVL was defined as a vertical line from the posterior-most aspect of the occiput down to the floor. The distances of the PCVL to the thoracic apex, PSVL, femoral head center, and tibial plafond were measured. Subjects were either grade 1 (PCVL posterior to thoracic apex and PSVL), grade 2 (PCVL anterior to thoracic apex and posterior to PSVL), or grade 3 (PCVL anterior to thoracic apex and PSVL).

Results
In our normal population, 75% of subjects were grade 1, 21% were grade 2, and 4% were grade 3. Increasing PCVL grade was significantly correlated with increased age ($p=0.0015$), increased sacral slope ($p=0.04$), increased T1 slope ($p<0.001$), PI-LL mismatch ($p=0.027$), increased C7-S1 SVA ($p<0.001$), increased C2-C7 SVA ($p<0.001$), and decreased LL ($p=0.039$).

Conclusion
The PCVL grading system may be an accurate representation of a patient's global sagittal alignment. Increasing PCVL grade was significantly correlated with expected changes seen in adult scoliosis such as decreased SS, decreased LL, increased PI-LL mismatch and increased C7-S1 SVA. There was also a significant relationship with increasing PCVL grade and increased C2-C7 SVA. 6% of normal patients had a PCVL anterior to the tibial plafond center. This may be a powerful tool in defining the sagittal imbalance of patients and may have prognostic implications for postoperative proximal junctional kyphosis as well.

Take Home Message
The PCVL grading system is a novel method to define sagittal imbalance using a vertical line from posterior occiput to the thoracic apex, PSVL, hip center and tibial plafond.



270. Preoperative HRQoL scores predict Chronic Opioid use after Adult Spine Deformity Surgery

Rahul Sachdev, BS; *Brian J. Neuman, MD*; Khaled M. Kebaish, MD; Richard L. Skolasky, PhD

Summary
Given the potential negative health repercussions of chronic opioid use, there is a growing desire to understand risk factors for chronic dependence. We sough to understand the impact of preoperative HRQoL scores on 2-year opioid use, discovering that severe disability on ODI was an independent risk factor for chronic opioid dependence,

Hypothesis
Preoperative HRQoL will independently predict 2-year opioid use

Design
Retrospective review

Introduction
This study aims to better understand risk factors for chronic opioid use, with particular attention towards preoperative HRQoL.

Methods
We retrospectively reviewed a single-institution database of ASD patients. Inclusion criteria was ASD patients 18 and older undergoing 5 or more levels of arthrodesis with 2-year clinical follow-up. Primary outcome variable was chronic opioid use, defined as patients using opioids 2-years after surgery. Additional variables collected include patient demographics, smoking history, preoperative SRS-22 and ODI scores, surgical parameters (levels fused, three column osteotomy), CCI, and BMI. Preoperative ODI scores were used to stratify patients into those with and without severe disability, with ODI scores >40 indicating severe disability. Multivariate logistic regression analysis was used to determine risk factors for chronic opioid use. Additionally, we performed a sub-group analysis on a cohort of patients who achieved MCID for ODI at 2-years, to determine whether risk factors for chronic opioid use were different for this group.

Results
118 patients met the inclusion and exclusion criteria. At 2 years, 40 patients were using opioids and 78 were not. On multivariate logistic regression, risk factors for chronic opioid use included preoperative opioid use (OR: 15.4, P-value<0.01)., ODI >40 (OR: 4.39, P-value: 0.04). Preoperative SRS domains, including pain and function, were found to be insignificant predictors of chronic opioid use. In our sub-group analysis of patients achieving MCID for ODI at 2-years, we similarly found preoperative ODI and preoperative opioid use as risk factors for chronic opioid use.

Conclusion
We found that preoperative disability, as assessed using ODI, was a significant, independent risk factor for chronic opioid use. Clinically, surgeons can use this information to identify patients who may be at risk for chronic opioid dependence.

Take Home Message
Baseline ODI is an independent predictor of chronic opioid use.

271. Casting for Non-Idiopathic Scoliosis - Combined Results from Two Centers

Charles E. Johnston, MD; Dong-Phuong Tran, MS; Graham T. Fedorak, MD, FRCS(C)

Summary
Mehta casting for non-idiopathic scoliosis (NIS) successfully controlled (=surgical treatment avoided) 15/45 cases, compared to success in 57/74 early-onset (infantile) idiopathic scoliosis (EOIS) cases (p<.001) at mean f/u 7 yr. NIS patients were older (3.7 vs 2.1 y, p=.000) than EOIS at cast initiation and had larger deformities (62.5 vs 53.2o p<.002). Patients requiring surgery had larger RVAD (33.5 vs 23.7 p=.04) initially than patients managed non-operatively successfully.

Hypothesis
NIS curves (congenital, syndromic, or N-M) treated by casting may be controlled with similar efficacy as EOIS.

Design
To compare results of casting for NIS cases to EOIS cases with minimum 5 yr f/u from 2 centers with large Mehta experience.

Introduction
Mehta casts are widely accepted for treatment of early-onset idiopathic scoliosis (EOIS), ideally < age 3, intending to control or "cure" the deformity. At centers with extensive experience, casting indications have expanded to non-idiopathic scoliosis (NIS). We report results of casting a NIS cohort with minimum 5 years f/u from initial cast.

Methods
Mehta cast retrospective study with minimum 5 yr f/u from 2 centers. Age at initiation, # casts, treatment following casting, and clinical outcome (observation, brace, surgery) were documented as well as curve magnitudes, T1-12/T1-S1 lengths. Cast "failure" was defined as progression to surgery, f/u defined as

time of last visit before surgery in failures; success = continued brace/observation at f/u w/o surgery.

Results
119 patients were reviewed at mean 7 yr from cast initiation: 45 NIS and 74 EOIS with 68 and 92 mo f/u respectively (p<.001), including treatment after cast d/c. Entire cohort NIS patients were older (3.7 yrs vs 2.1,p=.000) @ cast initiation with no difference in # casts (6.2). Initial curve was larger 6.25 vs 53.2o p<.002 in NIS cases, but no difference in initial RVAD. Curve @f/u = 73.1o for all NIS (range 13-126), 32.9 for EOIS (0-105), p=.000. There was no difference in T1-12 or T1-S1 length at f/u. NIS success achieved in 15 cases (3 under observ,11 still in brace, 1 cure), while 30 had surgery ; EOIS success in 57 cases (24 observ, 27 brace, 6 cures) and surgery 17 p<.001. Cases requiring surgery were older @ initial cast (3.8 vs 2.0 yr p=.000), had larger RVAD (33.5 vs 23.7 p=.04) and Cobb (65.2 vs 51.4 p<.001). There was no difference in #abnomal MRI between success and failed casting.

Conclusion
57/74 EOIS were successfully controlled with casts and continue non-operative rx vs 15/45 NIS controlled, p<.001. While non-idiopathic deformities were not controlled as effectively as EOIS cases, NIS curves were larger and patients older at initial cast.

Take Home Message
Non-idiopathic EOS can be controlled by Mehta casting, but with less success compared to infantile idiopathic curves. Older age and larger curve magnitude predict cast "failure" (surgery required).

272. Definitive Fusions are Better than Growth Friendly Procedures for Juvenile Patients with Cerebral Palsy and Scoliosis: A Prospective Comparative Cohort Study

Arun R. Hariharan, MD; *Suken A. Shah, MD*; Joseph Petfield, MD; Margaret Baldwin, MD; Carlos Pargas, MD; Paul D. Sponseller, MD; Burt Yaszay, MD; Michael P. Glotzbecker, MD; Patrick J. Cahill, MD; Tracey P. Bastrom, MA; Geraldine I. Neiss, PhD; Harms Study Group ; Pediatric Spine Study Group

Summary
In this prospective comparative cohort study of posterior spinal fusion versus growth friendly (GF) surgery with minimum 2 year follow up from "definitive" surgery for juvenile CP scoliosis, we have shown that radiographic results were better in the PSF group and the complication rate and number of unplanned reoperations were higher in the GF group. Caregiver reported outcomes also rated PSF surgery with greater satisfaction.

Hypothesis
Juvenile patients with cerebral palsy (CP) who undergo posterior fusion have better outcomes than those undergoing growth friendly surgery.

Design
Retrospective review of prospectively collected data from multicenter databases

Introduction
In juvenile patients with CP and scoliosis, there is controversy regarding surgical treatment with posterior fusion (PSF) versus allowing for potential truncal growth with growth friendly (GF) constructs. This study compared the outcomes of juvenile CP patients with scoliosis who underwent PSF versus GF.

Methods
Two prospective registries were queried for patients 8-10 yrs old with minimum 2 yrs follow-up who underwent PSF or GF surgery. Demographics, radiographs, complications and outcomes scores were recorded.

Results
There were 41 patients in the PSF group and 15 in the GF group. The mean age at initial surgery was 10 yrs (8.1-10.9) and 9.3 yrs (8-10.9) in the PSF and GF groups, respectively (p=0.1). In the PSF group, the mean preop curve was 86 deg (50-144) and 80 deg (30-133) in the GF group (p=0.20). "Definitive" surgery in the GF group consisted of PSF in 10, implant retention in 3, and implant removal in 2. At 2 yr follow-up after definitive surgery, the PSF group had 62% curve correction and the GF group had 40% correction (p=0.04). In the PSF group, 27% had major complications (n=11) and in the GF group, 73% had major complications (n=11) (p=0.02) (see Table). In the PSF group, 2 patients had re-operations for infection while 8 patients in the GF group had re-operations for infection and implant complications (p<0.01). In the PSF group, 26/35 parents (75%) noted that the child's life "improved a lot". In the GF group, 3/7 parents (43%) noted they were "neutral" about their child's ability to do things and 3/7 (43%) were "very dissatisfied."

Conclusion
This study demonstrates that PSF in juvenile CP patients with scoliosis resulted in fewer complications and reoperations and better radiographic outcomes compared to growth friendly strategies. Quality of life improvements were better in the PSF group.

Take Home Message
In juvenile patients with CP and NSM, PSF results in better radiographic results and quality of life outcomes with fewer complications and re-operations when compared to growth friendly surgery.

PSF Complications	Rate (n)
Infection	7% (n=3)
Respiratory	17% (n=7)
GI	7% (n=3)
Medical	2% (n=1)
GR Complications	**Rate (n)**
Infection	46% (n=7)
Hardware	13% (n=2)
PJK	13% (n=2)
Respiratory	20% (n=3)
Decubitus Ulcer	13% (n=2)

Comparison of Complications in the PSF and GR Groups

274. Predicted Life Expectancy in Patients with Cerebral Palsy and Neuromuscular Scoliosis Undergoing Spinal Fusion

Arun R. Hariharan, MD; Carlos Pargas, MD; *Margaret Baldwin, MD*; Joseph Petfield, MD; Julio Jauregui, MD; Kenneth J. Rogers, PhD; Suken A. Shah, MD; M. Wade Shrader, MD; Julieanne P. Sees, MD; Freeman Miller, MD

Summary
In children with CP, NMS is a common ailment that requires surgical management. Surgery is not free of complications and decision making on the utility of undergoing a major surgical intervention is a difficult one. This study has demonstrated that 68% of patients survive for approximately 12 years post spinal fusion. This information will be crucial in allowing shared decision making on treatment for these patients.

Hypothesis
In patients with cerebral palsy and neuromuscular scoliosis, the predicted life expectancy after spinal fusion is 50% at 10 years.

Design
Retrospective review of consecutive cases

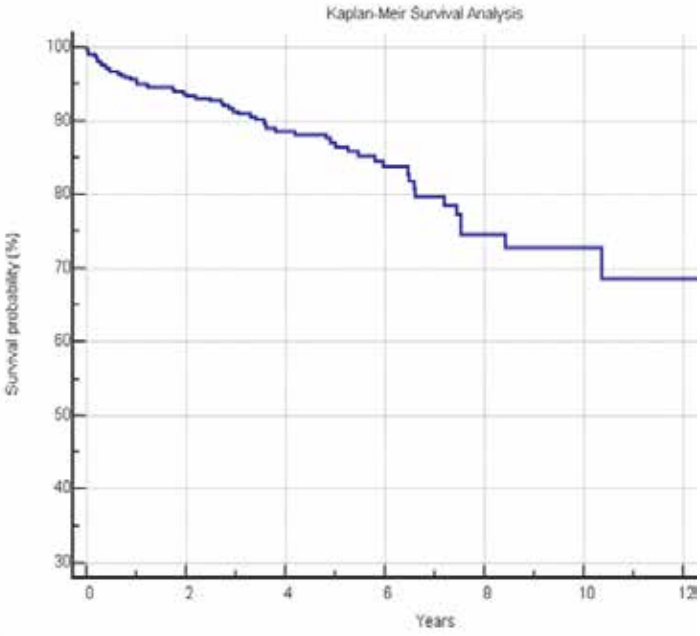
Introduction
The treatment of severe neuromuscular scoliosis (NMS) secondary to cerebral palsy (CP) can be life changing; but comes at significant cost and potential complications. The aim of this study was to document the rate of survival among patients with CP and NMS who underwent spinal fusion.

Methods
Retrospective review of patients with CP less than 21 years of age who underwent spinal fusion between 2004-2019 for NMS. Demographics, surgical details, length of stay, and dates and causes of death were recorded. A Kaplan-Meier survival analysis was completed with 95% confidence interval.

Results
A total of 425 patients were identified. The mean age at surgery was 14.3 years, 48% were female. 72.5% were GMFCS V (n=308) and 76.7% had spastic quadriplegia (n=326). The mean major coronal curve was 73 degrees and 63.6% patients (n=258) had a noted sagittal plane deformity. 90% of patients underwent posterior only surgery (n=383) and 90.3% had fixation from T1 or T2 to Pelvis (n=383). Mean estimated blood loss of 2.4 liters. All patients were taken to pediatric intensive care unit post-operatively with mean hospital stay of 16.2 days. 16.7% had at least one re-operation (n=71), 77.5% of which were for infection or implant complications (n=55). Mean follow up was 50.8 months post-operatively (0-161 months). There were 59 known deaths (13.9%). Causes of death remains unknown in most. Kaplan-Meier survival analysis demonstrated that the mean survival for this group of was 10.5 years with 95% CI ranging from 9.9 to 11.6 years.

Conclusion
This is the largest study to analyze the life expectancy of children with CP undergoing spinal fusion. These patients have an average predicted life expectancy of 10.5 years post-operatively. This will have a major impact in shared decision making for providers and caregivers when considering surgical intervention.

Take Home Message
In children with CP and NMS who undergo spinal fusion, the mean predicted survival is 10.5 years after surgery.



Kaplan-Meir Survival Analysis of Cerebral Palsy Patients Undergoing Spinal Fusion

E-Posters

E-Posters

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 1,300 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. Visit www.srs.org/professionals/membership for more information and to apply online.

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 Courses, a Global Outreach Program, the Research Education Outreach (REO) Fund which provides grants for spine deformity research, and development of patient education materials.

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