Session 5B | Adolescent Idiopathic Scoliosis II Abstracts

Papers are listed in presentation order

Paper #70. A Multipurpose Adolescent Idiopathic Scoliosis Specific Short MRI Protocol: Feasibility Study in Volunteers

Yulia Shcherbakova, PhD; *Peter Lafranca, MD*; Wouter Foppen, MD, PhD; Tijl van der Velden, PhD; René M. Castelein, MD, PhD; Keita Ito, MD, PhD; Tom Schlosser, MD, PhD; Peter R. Seevinck, PhD

Hypothesis
With a scoliosis-specific short MRI protocol, it is possible to visualize landmarks needed to detect early 3D anatomical changes, screen for neural axis abnormalities and perform surgical planning.

Design
Diagnostic validation study

Introduction
Scoliosis imaging requires ionizing radiation, especially when CT is required for 3D visualisation. Additional MRI is often obtained for neuraxial anatomy. Currently, MRI is not very suitable for visualizing 3D bony anatomy, but when combined with MRI-based synthetic CT (sCT), it has the potential to combine osseous and non-osseous information in one examination. We assess a scoliosis-specific, 14-min MRI protocol for its ability to detect early 3D patho-anatomical changes, screen for neural axis abnormalities, and perform surgical planning and navigation.

Methods
18 adult volunteers (mean 26 years-old) were scanned on 1.5T MR-scanner (3D T2wTSE and BoneMRI sequences) and based on the MRI, synthetic CT images were AI-generated. A predefined checklist of 8 questions on landmark identification (using lines and dots) and 10 Likert-based questions were used for assessment by three readers in an online tool for e-testing with 3D radiological images. Parameters included Cobb angles, rotation, torsion, segmental height, area and centroids of nucleus pulposus (NP) and discs (IVD). Precision (mean error of individual answers compared to group mean) and intra-class correlation coefficient (ICC) with 95% confidence interval (CI) were calculated.

Results
91% of Likert-based questions scored ≥4, indicating moderate to high confidence. Precision of line positioning was 0.6° (ICC=0.98, CI 0.98-0.99). Precision of 3D dot positioning was 1.0 mm (ICC=1.00, 1.00-1.00). Precision of vertebral and IVD height measurements was 0.4 mm (ICC=0.99, 0.99-1.00). Precision of sagittal area measurement was 8 mm2 (ICC = 0.55) for NP and 18 mm2 (ICC = 0.62) for IVD. Precision of centroid measurements for NP was 1.3 mm (ICC = 0.88-0.92) and for IVD 1.1 mm (ICC = 0.88-91).

Conclusion
This study shows that the short MRI protocol with synthetic CT reconstructions, has high precision and reliability for multiple scoliosis-specific purposes. It can be used for studies on scoliosis etiopathogenesis and for 3D assessments of spinal morphology. Future studies should explore the value of this radiation-free technique in children with severe scoliosis.

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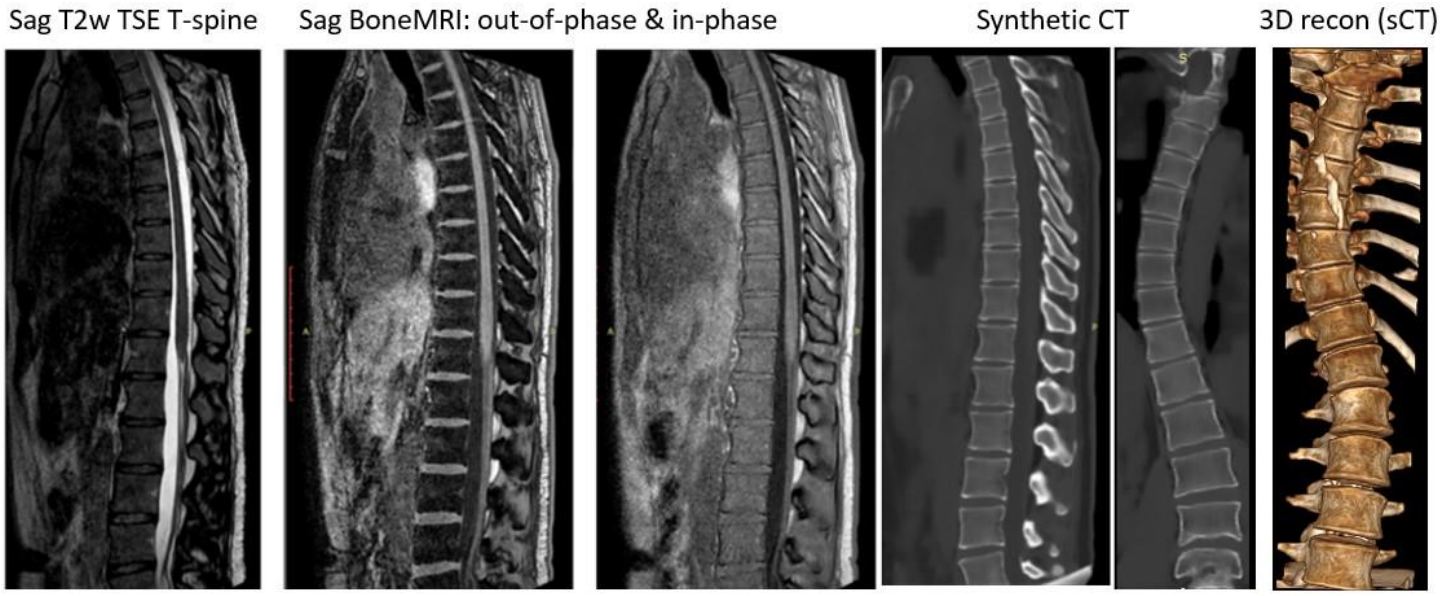

Examples of T2, BoneMRI and sCT reconstructions

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Paper #71. Intraoperative CT Based Pedicle Screw Navigation in Pediatric Spine Deformity Has Minimal Impact on Screw Accuracy for an Experienced Surgeon

Vishal Sarwahi, MD; Sayyida Hasan, BS; Keshin Visahan, BS; Katherine Eigo, BS; Aravind Patil, MD, BS; Anuj Gupta, MD; Effat Rahman, BS; David Essig, MD; Yungtai Lo, PhD; Jon-Paul P. DiMauro, MD; *Terry D. Amaral, MD*

Hypothesis
Intraoperative CT based navigation improves accuracy in pediatric spinal deformity surgeries.

Design
Retrospective case review

Introduction
Pedicle screw accuracy is an important safety goal in pediatric spine deformity surgery. Intraoperative CT guided navigation has a two-fold advantage of allowing screw insertion under navigation guidance and assessing accuracy after screw insertion. However, this entails modification of surgical workflow, which has potentially harmful effects such as increased surgical time, blood loss, and radiation exposure. This raises the question of the extent to which intraoperative CT navigation enhances accuracy and its impact on surgical efficiency and outcomes.

Methods
533 pediatric patients with spine deformity undergoing surgery were reviewed. Patients whose surgeries utilized intraoperative CT navigation were compared to patients who underwent deformity surgery utilizing free hand technique. Borderline screws were screws that appeared to be breaching but were ultimately deemed acceptable. Demographic, radiographic, radiation exposure, and perioperative data was collected. Kruskal-Wallis and Fisher's exact test were performed.

Results
112 navigation patients (2218 screws) were compared to 421 patients (8269 screws) with pedicle screws placed freehand and confirmed on fluoroscopy. Demographic and radiographic variables were similar in both groups. Blood loss was similar between the groups, however, navigation patients had significantly longer surgical time ($p=0.01$) and higher radiation exposure ($p<0.001$). In the fluoroscopy group, 0 (0.0%) screws needed to be revised, 5 (0.2%) screws needed revision in the navigation group ($p<0.001$). In the fluoroscopy group, 20 (0.2%) screws were borderline, and 6 (1.4%) patients experienced transient signal loss. In the navigation group, 6 (0.3%) screws were borderline, and 4 (3.6%) patients experienced a transient signal loss. Length of stay and complication rates were similar between the groups.

Conclusion
Patients operated on using navigation for pedicle screw placement do not see an increase in safety or screw accuracy. However, the availability of navigation offers a potential to avoid screw misplacement and, for younger surgeons, could have significant benefits in terms of accuracy and time. Regardless of surgeon experience, it is still an additional mechanism for confirmation.

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Paper #72. Radiographic Adaptation Between Standing and Sitting Positions of Subjects with Adolescent Idiopathic Scoliosis

Maria Karam; Emmanuelle Wakim; Maria Asmar; Abir Massaad, PhD; Mohammad I. Karam, PhD; Aren Joe Bizdikian, MD, MS; Georges El Haddad; Marc Boutros, BS; Marc Mrad; Gilles Prince, MD; Ibrahim Hamati; Guy Awad; Moustapha Rteil; Joe Azar; Nadim Freiha; Claudio Vergari, PhD; *Ismat Ghanem, MD, MS*; *Rami Rachkidi, MD, MS*; Ayman Assi, PhD

Hypothesis
Subjects with AIS utilize varied spinopelvic adaptation mechanisms between standing and sitting positions.

Design
Retrospective analysis of prospectively collected data.

Introduction
Routine evaluation of the spinal deformity of subjects with Adolescent Idiopathic Scoliosis (AIS) is based on standing radiographs. Assessing how subjects cope with different functional positions of daily life, such as the sitting position, is essential to better understand the underlying pathological processes. A better understanding of such adaptation mechanisms would provide insight on spinal flexibility.

Methods
43 primary AIS (40F) and 22 controls (12F) underwent bi-planar radiographs in both standing and sitting positions from which 3D spino-pelvic and global postural parameters were calculated. AIS subjects were grouped according to the Lenke classification. Skeletal changes between the 2 positions were compared between Lenke groups and controls.

Results
Subjects with AIS were divided into 2 groups: 29 Lenke 1 (Cobb=35±16º, 27F) and 14 Lenke 5 (Cobb=22±9º, 13F). The severity of the scoliotic deformity remained unchanged in both AIS groups between the standing and sitting positions. Adaptation strategies used by AIS subjects when transitioning from standing to sitting were similar to controls, notably increase in pelvic retroversion (PT: standing=9° vs. sitting=29°), reduction of lumbar lordosis (L1S1: 58 vs. 30°) and thoracic kyphosis (T4T12: 31 vs. 24°) while preserving their head over the pelvis (Sagittal ODHA: -2° vs. -4°). Although control subjects preserved T10L2 values when transitioning from standing to sitting (4°), the thoracolumbar junction of Lenke 1 and Lenke 5 subjects tended to increase in kyphosis (Lenke 1: -1 to 2°, Lenke 5: -4 to -1°; $p<0.001$ for both).

Conclusion
This study showed that both AIS Lenke 1 and Lenke 5 patients were able to acquire a normal sitting position similar to controls. The overall flattening of the spine in AIS subjects required a slight recruitment of the thoracolumbar junction for optimal adaptation to the seated position, without significantly affecting their sitting posture. Future work should investigate how adaptation strategies vary when transitioning from standing to sitting in subjects with AIS after spinal fusion.

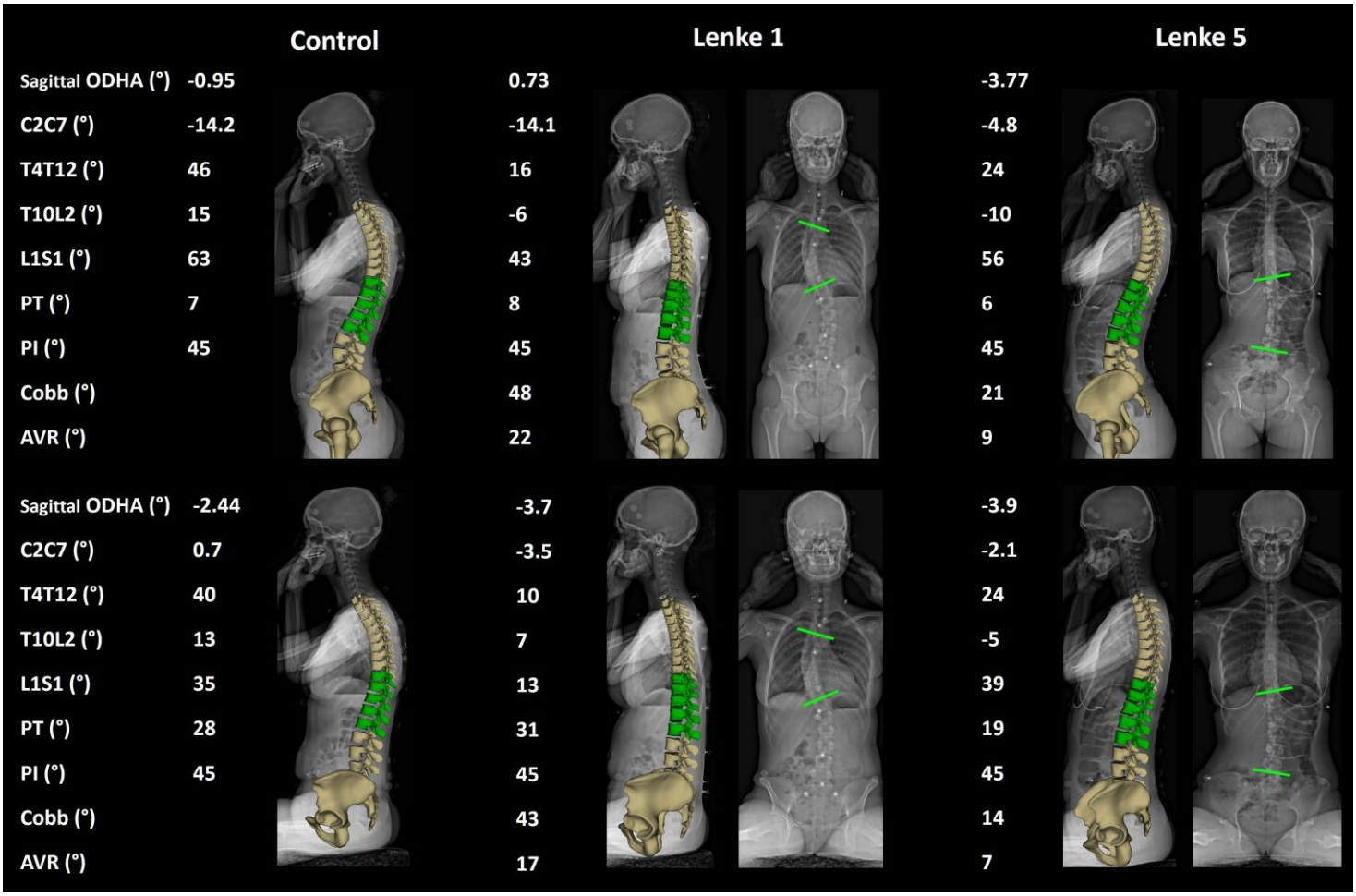

Figure 1: Examples of standing and sitting postures in controls, AIS Lenke 1 & 5.

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Paper #73. Prevalence and Prognosis of Right Scapular Pain Following Surgical Treatment of Adolescent Idiopathic Scoliosis: A Prospective Study to Guide Preoperative Counselling

Antoine Dionne, BS; Julie Joncas, RN; Soraya Barchi, BSc; *Stefan Parent, MD, PhD*; Jean-Marc Mac-Thiong, MD, PhD

Hypothesis

The prevalence of right scapular pain is high following surgical treatment of adolescent idiopathic scoliosis (AIS), but it tends to resolve during follow-up 2 years after surgery.

Design

Prospective cohort study of 106 consecutive patients treated surgically for AIS at a single institution.

Introduction

Developing pain after surgical treatment of AIS can be devastating for some patients, particularly when they had no pain prior to surgery. Unfortunately, the prevalence and localization of postoperative pain has been poorly studied in this population, which complexifies the preoperative counselling by surgeons. The objective of this study is to report the prevalence, predictors and evolution of scapular pain pre- and postoperatively.

Methods

This prospective study included 106 patients undergoing posterior instrumentation and fusion for AIS. They were instructed to localize (drawing with a pen) the presence of pain anywhere on a human body pictogram preoperatively, as well as postoperatively 6 and 12 months after surgery. The presence of pain between the medial border of the scapula to the shoulder was defined as scapular pain. In addition to descriptive statistics pertaining to the incidence and evolution of post-operative scapular pain, inferential statistics were performed to identify factors associated with persisting de novo scapular pain 2 years after surgery.

Results

Of the 106 patients included in this study, 21 (19.8%) had right scapular pain pre-operatively. This improved at 2 years post-operatively with only 9 (8.5%) having persisting pain. Out of the 85 patients without pre-operative pain, 37 (43.5%) developed de novo post-operative pain, among which 29 (34.1%) had persisting pain 2 years post-operatively. Curve type and severity, pre-operative angle of trunk rotation, and fusion levels were not associated with the outcome.

Conclusion

AIS patients should be advised about the high risk (50%) of de novo right scapular pain after surgery, and nearly 80% of these patients will remain with persisting pain in the long term. Since there are no apparent predictive factors of this outcome, clinicians should carefully discuss this potential complication with patients before surgery. However, more than 50% of patients with pre-operative scapular pain will be pain-free post-operatively.

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Paper #74. Increased Main Thoracic Curve Correction is Associated with Worse Postop Radiographic Shoulder Balance, Especially in Lenke 1A Curves with Balanced Shoulders Preop

Matan Malka, BA; Ritt Givens, BS; Kevin Lu, MS; Emma Berube, MD; Thomas M. Zervos, MD; Stefan Parent, MD, PhD; Michael P. Kelly, MD; Lawrence G. Lenke, MD; Michael G. Vitale, MD, MPH; Harms Study Group; *Benjamin D. Roye, MD, MPH*

Hypothesis
Increased correction of main thoracic (MT) Cobb angle is associated with worse postop shoulder balance measured by radiographic shoulder height (RSH) in Lenke 1 AIS patients.

Design
Multicenter retrospective cohort

Introduction
Previous research associated significant correction of the main thoracic (MT) curve in AIS as a cause of post-operative left shoulder elevation, and recommended MT undercorrection. We reevaluated this relationship in a large registry-based cohort.

Methods
Inclusion criteria were Lenke 1 AIS patients (10-18yrs) undergoing primary fusion with 2-year follow-up. Pre and postop radiographic variables and SRS scores were collected. We categorized patients into three groups based on RSH change pre to postop: 1)RSH improvement>1cm 2)RSH stable(<1cm change) 3)RSH worse>1cm. Mean and standard deviations are reported for continuous variables, Kruskal-Wallis test assessed significant differences. Chi-square tests were used for categorical ones.

Results
775 patients met inclusion criteria and groups showed no difference in age or sex. At preop, Group 1 had worse RSH (2.3 vs 0.4cm p<0.001), larger MT (54° vs 51° p=0.001) and lumbar curves (36.5o vs 31.4o p<0.001), smaller upper thoracic (UT) curves (24.6° vs 27.1° p=0.005), and fewer lumbar A modifiers (45% vs 71% p <0.001) than Group 3. 2 years post-op, Group 3 had smaller MT curves (17.3° vs 20.7° p<0.001) and greater %correction of MT curves (66.3% vs 61.4% p<0.001) than Group 1. SRS-22 scores did not vary between groups at 2-years and did not correlate with RSH. Linear regression revealed no correlation between SRS-22 self-image and RSH or MT curve magnitude at two years in any group. For all patients, worse post-op RSH was predicted by lower pre-op RSH (ß= -0.08, p<0.002) and Lenke A modifiers (ß= -0.15, p<0.01).

Conclusion
Like previous work, Group 3 patients (worse postop shoulder balance) had more correction of their MT curves and larger UT curves. Yet it is difficult to apply the small magnitudes of these differences (3-5°) to clinical surgical decision making. However, our novel finding that Lenke 1A curves with low preop RSH (better balanced shoulders) are at highest risk for postop shoulder imbalance suggests modulating MT correction in this group may be most crucial. Continued work on finding a clinically relevant definition of shoulder imbalance is an important next step.

Table 1: Comparison between groups at preoperative and two-year timepoints.

		Group 1 (n=230)	Group 2 (n=415)	Group 3 (n=130)	P value
Preop:	Age	14.58±2.13	14.76±2.06	14.56±1.92	0.46
	Female n (%)	199 (86.5%)	350 (84.3%)	117 (90.0%)	0.53
	Lenke A n (%)	103 (44.8%)	227 (54.7%)	93 (71.5%)	**<0.001**
	Lenke B n (%)	55 (23.9%)	86 (20.7%)	20 (15.4%)	
	Lenke C n (%)	72 (31.3%)	101 (24.3%)	17 (13.1%)	
	Upper Thoracic Cobb (°)	24.62±8.10	25.68±6.50	27.13±6.51	**0.005**
	Main Thoracic Cobb (°)	54.23±9.37	51.77±8.64	51.46±8.38	**0.001**
	Lumbar Cobb (°)	36.53±9.68	34.09±9.38	31.42±8.38	**<0.001**
	RSH (cm)	2.28±0.90	0.83±0.60	0.40±0.55	**<0.001**
	SRS Pain	4.03±0.72	4.05±0.73	4.07±0.73	0.87
	SRS Self Image	3.30±0.72	3.41±0.68	3.48±0.59	**0.04**
	SRS Total	3.86±0.50	3.93±0.49	3.98±0.44	0.06
2 years	Upper Thoracic Cobb (°)	13.81±6.60	14.73±5.75	16.08±6.02	**0.003**
	Main Thoracic Cobb (°)	20.70±7.10	19.64±6.74	17.32±7.15	**<0.001**
	Lumbar Cobb (°)	16.19±8.06	14.36±8.36	10.86±7.85	**<0.001**
	% Correction Upper Thoracic Cobb	37.83±37.48	38.60±29.65	40.98±17.64	0.63
	% Correction Main Thoracic Cobb	61.41±13.06	61.36±13.28	66.31±13.03	**<0.001**
	% Correction Lumbar Cobb	55.69±29.31	55.41±29.88	66.17±22.88	**<0.001**
	RSH (cm)	0.41±0.45	0.81±0.58	2.08±1.43	**<0.001**
	SRS Pain	4.36±0.65	4.43±0.59	4.42±0.59	0.36
	SRS Self Image	4.44±0.54	4.46±0.54	4.44±0.53	0.92
	SRS Total	4.39±0.45	4.43±0.42	4.46±0.40	0.39

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Paper #75. Do Postoperative Medial Shoulder, Lateral Shoulder and Neck Imbalance Improve over Time? An Analysis of 120 Lenke 1 and 2 Adolescent Idiopathic Scoliosis (AIS) Patients with a Minimum of 5-Year Follow-Up

Chris Yin Wei Chan, MD, MSOrth; Weng Hong Chung, MD, MSOrth; Yuki Mihara, MD, PhD; Siti Mariam Mohamad, BSc; Chee Kidd Chiu, MBBS, MSOrth; Mun Keong Kwan, MBBS, MSOrth

Hypothesis
Postoperative lateral shoulder imbalance in Lenke 1 and 2 AIS would improve over time but not medial shoulder and neck imbalance.

Design
Retrospective study

Introduction
Shoulder and neck imbalance following AIS surgery is a cause of patients' dissatisfaction. However, the postoperative evolution of shoulder and neck imbalance over time is unclear.

Methods
We retrospectively reviewed 120 Lenke 1 and 2 AIS patients. "Medial shoulder balance (MSB)" was represented by T1 tilt and was defined as "balanced" (MB) when -3º≤T1 tilt≤3º. T1 tilt>3º was defined as Medial Shoulder Imbalanced Positive (MI+ve). T1 tilt<-3º was defined as MI-ve. "Lateral shoulder balance (LSB)" was represented by Clavicle angle (Cla-A) and was defined as "balanced" (LB) when -2º≤Cla-A≤2º. LI+ve was Cla-A>2º; LI-ve was Cla-A<-2º. Cervical axis (CA) represented "Neck Balance" and defined as "balanced" (NB) if -3º≤CA≤3º. NI+ve was CA>3º and NI-ve was CA<-3º. Shoulder and neck balance were compared at 6-month follow-up (FU) and at 5-year FU.

Results
At 6-month FU, 51.7% achieved MB, 35.8% had MI+ve and 12.5% reported MI-ve. Among the MB group, 87.1% remained MB at 5-year FU. 65.1% of patients with MI+ve remained MI+ve at 5-year FU. 86.7% MI-ve patients remained MI-ve at 5-year FU. For LSB, 68.3% achieved LB, 24.2% had LI+ve and 7.5% had LI-ve at 6-month FU. 72.4% of LI+ve patients achieved LB at 5-year FU. At 6-month FU, 65.8% achieved NB, 28.3% had NI+ve and 5.9% had NI-ve. 89.9% of patients who had NB remained NB at 5-year FU. However, 50% of those with NI+ve remained as NI+ve while the other half achieved NB at 5-year FU. Among patients with MI+ve and LI+ve who achieved good balance at final follow-up, there was a significant change in the distal disc angulation but not the T1-UIV angle.

Conclusion
At 5-year FU, most patients with MI+ve and MI-ve remained imbalanced. The majority of patients achieved LB regardless of the LSB pattern at 6-month FU. 50% of NI+ve patients remained NI+ve. Distal disc angulation led to improvement in the MSB/LSB. However, the T1-UIV angle remained relatively stable at 5 years follow-up.

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Paper #76. Anterior Release is Not Needed to Restore Kyphosis in Moderate AIS with Hypokyphosis

Craig R. Louer, MD; Jacquelyn S. Pennings, PhD; Maty Petcharaporn, BS; Arun R. Hariharan, MD; John S. Vorhies, MD; Michael P. Kelly, MD; Suken A. Shah, MD; Peter O. Newton, MD; Harms Study Group; *Burt Yaszay, MD*

Hypothesis

Posterior spine fusion (PSF) and PSF with Anterior Release (PSF+AR) have similar ability to correct most hypokyphosis deformities, but PSF+AR offers improved correction in the most severe cases.

Design

Retrospective review of prospective database

Introduction

Thoracic hypokyphosis is a common component of the typical three-dimensional deformity in AIS. In severe cases of hypokyphosis, the deformity can lead to pulmonary restriction as well as pathologic compensatory changes in the lumbar spine. While PSF alone is the most common approach to AIS, the addition of an anterior release (AR) can shorten the anterior column and potentially enable more kyphosis restoration.

Methods

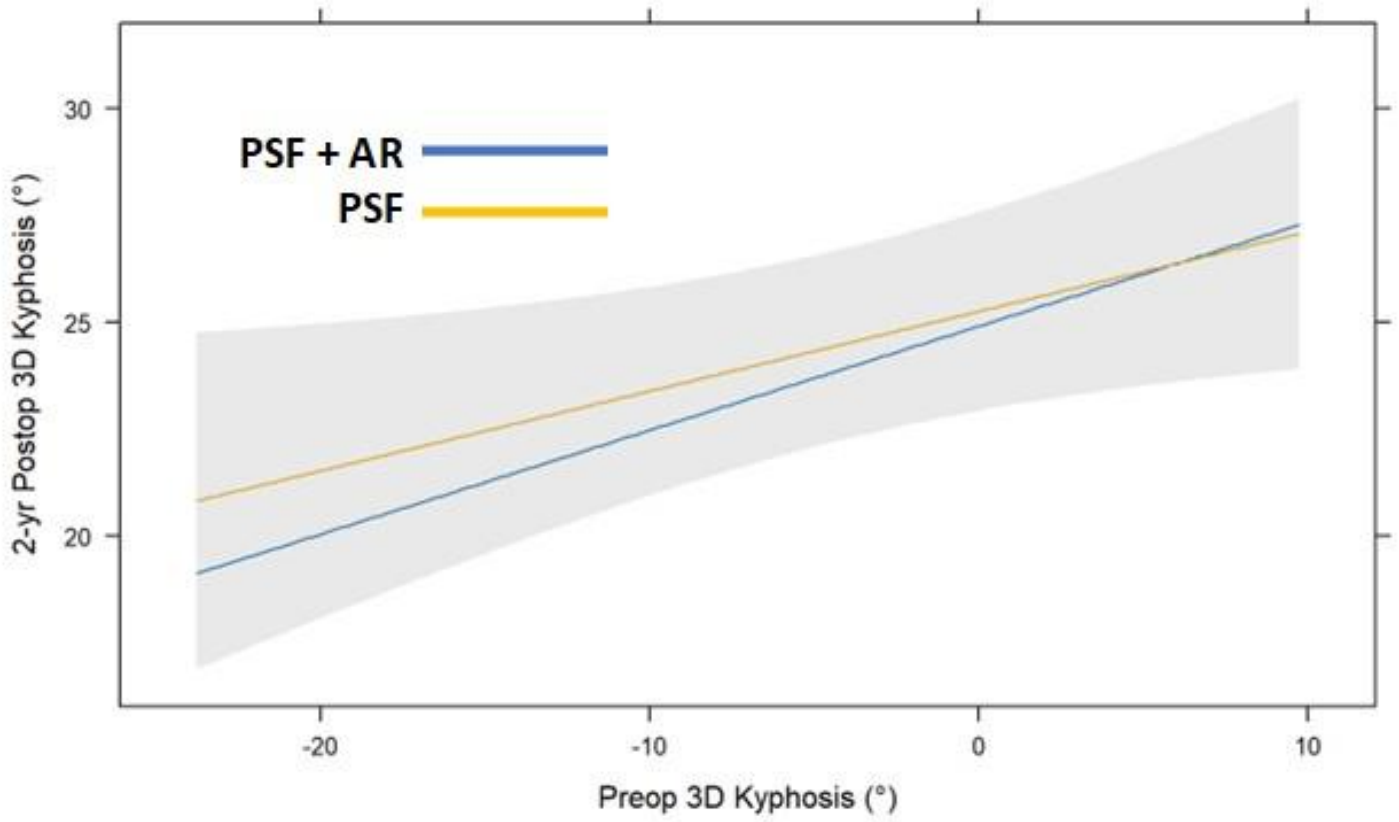
A multicenter pediatric spine registry was queried for hypokyphotic (<10°) Lenke 1-4 AIS patients aged <20 years with >2-year surgical follow-up. Coronal curves were limited to <70°. Sagittal measures were converted to estimated 3D kyphosis by previously validated formula. Patients were grouped by treatment with PSF or PSF+AR. A linear mixed model was created to predict 2-year 3D kyphosis by treatment, while controlling for age, sex, pre-op 3D kyphosis, thoracic coronal deformity and flexibility, posterior column osteotomy use, rod size, rod material, surgery recency, and surgeon.

Results

1384 patients were included with 53 (3.8%) undergoing PSF+AR. PSF+AR group was younger (13.9 vs. 14.8yrs) with 36.5% open tri-radiates (vs. 7.2% in PSF). Groups had similar mean preop 3D kyphosis (-3.7° vs. -0.5°) and thoracic coronal deformity (54.6° vs. 55.0°). PSF-AR had similar 2-year 3D kyphosis (23.0° [95%CI 20.5-25.4°] vs. 23.3° [22.9-23.6°]) and correction (26.7° [23.3-29.9°] vs. 23.7° [23.3-24.2°]) to PSF. 71.7% of PSF+AR and 66.4% of PSF had restoration of TK above 20° at 2-years (p=0.42). When controlling for covariates, the model demonstrated no difference between approach (p=0.74) or interaction of approach and preop 3D kyphosis (Figure 1, p=0.51). Post-hoc power analysis showed adequate sample size to detect a difference of 5° between approaches. PSF+AR had longer surgical times (324 vs. 266 min, p<0.001) and a higher rate of 2-year complications (30.2% vs. 18.5%, p=0.033).

Conclusion

In AIS patients with coronal curve <70° and 3D hypokyphosis of 10° to -40°, treatment with PSF+AR did not improve 2-year sagittal correction more than PSF alone. Larger deformities in immature patients may still benefit from AR, but it is likely not warranted at this range.


PSF + AR
PSF
2-yr Postop 3D Kyphosis (°)
30
25
20
-20
-10
0
10
Preop 3D Kyphosis (°)

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Paper #77. A Large Comparison Study Demonstrates Little to No Difference in Deformity Correction when Using Ponte Osteotomies for Lenke 1 and 2 AIS Curves

Daniel J. Sucato, MD, MS; Suken A. Shah, MD; Michael G. Vitale, MD, MPH; Amer FSamdani,MD; Peter O. Newton, MD; A. Noelle Larson, MD; Harms Study Group

Hypothesis

Ponte osteotomies do not provide clinically important improvement in deformity correction for patients with primary thoracic adolescent idiopathic scoliosis.

Design

Prospective multi-center

Introduction

The routine use of Ponte osteotomies in adolescent idiopathic scoliosis (AIS) surgery is controversial with conflicting data for deformity correction using 2D X-rays in small studies. Ultra-low dose slot scanning radiographs provide an opportunity to assess deformities in 3D. The objective of this study was to analyze the effectiveness of Ponte osteotomies to achieve improved deformity correction in AIS.

Methods

A prospectively-collected multicenter cohort evaluated consecutive patients treated for Lenke 1A and 2A AIS with pedicle screws with minimum 2-year follow-up. Patients with Ponte osteotomies (P group) were compared to patients without Ponte (NP group) for both 2D and 3D correction.

Results

There were 1403 (984 P, 419 NP) patients with 2D analysis, of which 328 (234 P, 94NP) had 3D data. There were no differences in age (13.7 vs 12.4 years) or gender between P and NP groups. Blood loss was greater (787.1 vs 678.4 cc, $p<0.0001$), surgical time was longer (286.9 vs 264.8 min, $p=0.001$) and the incidence of intraoperative neuromonitoring events was higher (7.9 vs 3.9%, $p=0.02$) in the P group. 2D Analysis: Preoperatively, the P group had larger thoracic coronal curves (56.4 vs 54.5°, $p=0.001$) but thoracic kyphosis was similar (20.9 vs 22.2°, $p=0.06$). At 2 years, there was no difference in thoracic coronal curve magnitude (18.8 vs 19.4°, $p=0.5$) or thoracic kyphosis (21.2 vs. 20.6°, $p=0.2$) between the P and NP groups. 3D Analysis: Preoperatively, the thoracic coronal curves were the same (55.7 vs. 55.0°, $p=0.5$), thoracic kyphosis was smaller in the P group (19.5 vs 22.9°, $p=0.02$) without differences in thoracic axial rotation (16.5 vs 15.8°, $p=0.5$). At 2 years there were smaller thoracic coronal curves for the P group (15.2 vs 17.9°, $p=0.02$) but similar thoracic kyphosis (25.0 vs 23.8°,$p=0.3$) and thoracic axial rotation (8.6 vs 8.8°, $p=0.8$).

Conclusion

There were no advantages identified to support the routine use of Ponte osteotomies in Lenke 1A and 2A curves for deformity correction, however limitations in understanding the specific indications for each patient may mask potential benefit in some cases.

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Paper #78. Importance of Thoracic Kyphosis and Global Sagittal Plane Restoration in the Surgical Treatment of AIS Patients with Preoperative Cervical Sagittal Malalignment

Baris Peker, MD; Onur Levent Ulusoy, MD; Hamisi M. Mraja, MD; Ugur Yuzuguldu, MD; Bilge K. Yilmaz, MD; Halil Gok, MD; Emre Kurt, MD; Sepehr Asadollahmonfared, MD; Tunay Sanli, BE, MA; *Meric Enercan, MD*; Selhan Karadereler, MD; Azmi Hamzaoglu, MD

Hypothesis
The restoration of physiologic thoracic kyphosis and sagittal alignment in the thoracolumbar and lumbar spine will improve postoperative cervical sagittal alignment in AIS pts with preoperative cervical malalignment.

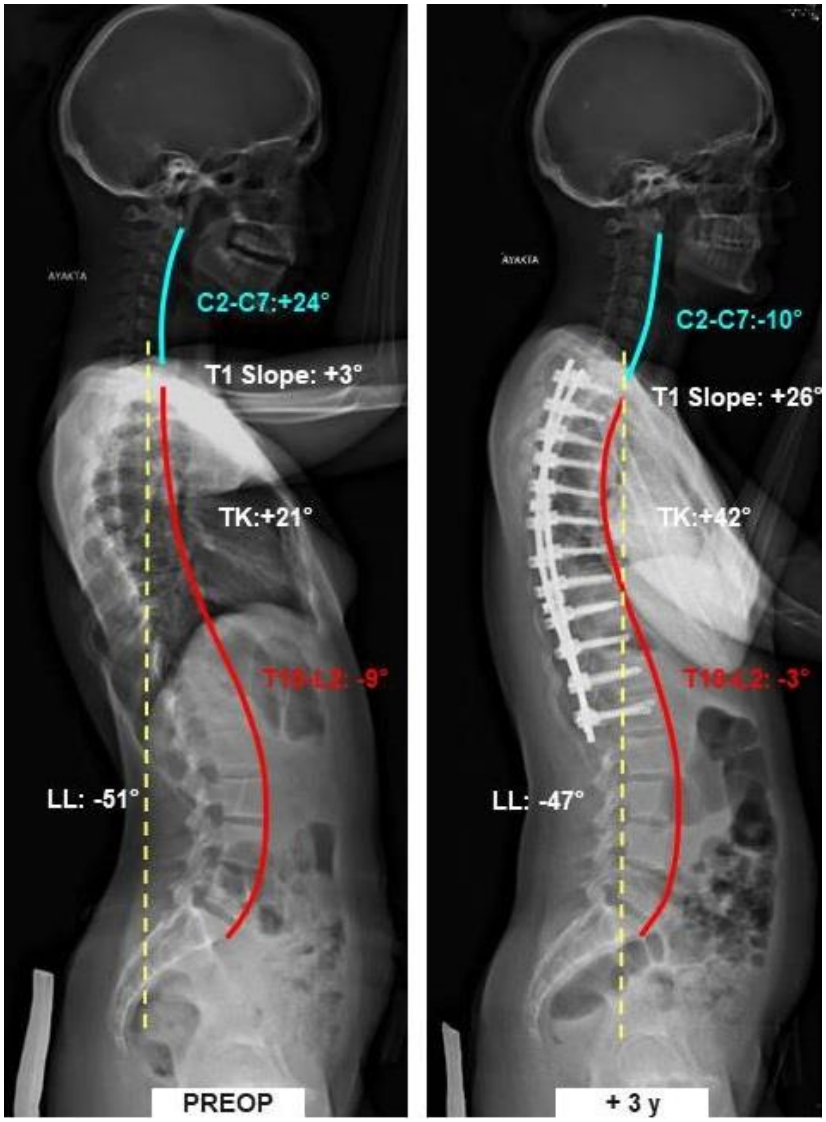
Design
Retrospective

Introduction
Restoration of the ideal sagittal alignment is essential in AIS deformity correction. Postop cervical sagittal alignment has been reported to be related to TK and global sagittal plane restoration following AIS surgery. The aim of the study is to evaluate the possible factors influencing the postop cervical sagittal alignment.

Methods
Among 253 AIS pts who underwent posterior-only surgery with all pedicle screw construct and had UIV between T2-T4 levels, 195(77%)pts with preop cervical sagittal malignment (sigmoid and kyphotic type) were included. Coronal and sagittal parameters were measured on preop and f/up x-rays. Cervical alignment was classified according to the Roussouly class.

Results
195 AIS pts with a mean age was 14.7 yrs and f/up was 6.3(2-9) yrs. Preop 89 pts had thoracic hypokyphosis(mean TK:11°). Preop 55 pts had thoracolumbar kyphosis and 29 pts had thoracolumbar lordosis. MT curve of 51° was corrected to 9.2°(82%) and TL/L of 43° was corrected to 9.7°(76%). Mean preop TK was improved from 25.4° to 35.5°. Mean T10-L2 kyphosis of 15° restored to 2.3°. Mean T10-L2 hyperlordosis of -12° restored to 2°. Mean preop C2-C7 was +12.2° was corrected to -5.1° and preop T1 slope improved from 11° to 21°. Cervical malignment improved in 155(79%). Among 155 pts, cervical alignment was completely restored to lordosis in 68(35%) pts and to a straight alignment in 87(65%)pts. ROC analysis showed that the restoration of TK >39.5° and T1 slope >23.5° correlated with postop cervical lordotic alignment(area=0.743). Additionally, changes in T10-L2 sagittal alignment were correlated with improvements in cervical lordotic alignment($r=0.531, p<0.01$).

Conclusion
In AIS pts with preop cervical malalignment, the ideal cervical alignment restoration can be achieved by correcting abnormal thoracic hypokyphosis, thoracic lordosis, thoracolumbar kyphosis, thoracolumbar hyperlordosis, and restoring sagittal lumbar parameters. According to the study, among 253 AIS pts of 195(77%) pts who had preop cervical malalignment, cervical lordosis improved significantly when TK was restored to >39.5°, T1 slope was restored to >23.5°


C2-C7:+24°
T1 Slope: +3°
TK:+21°
T10-L2: -9°
LL: -51°
PREOP
C2-C7:-10°
T1 Slope: +26°
TK:+42°
T10-L2: -3°
LL: -47°
+ 3 y

Session 5B | Adolescent Idiopathic Scoliosis II Abstracts

Paper #79. Thirty Years Later: The Lingering Effects of Adolescent Idiopathic Scoliosis Surgery with Third Generation Implants on Quality of Life ‡

Antonia Matamalas, MD, PhD; Juan Bago, MD, PhD; Francisco Javier S. Perez-Grueso, MD; Lucía Moreno-Manzanaro, BS; Javier Pizones, MD, PhD; Carlos Villanueva Leal, MD, PhD; Susana Núñez Pereira, MD; Sleiman Haddad, MD, PhD, FRCS; Ferran Pellisé, MD, PhD

Hypothesis
Three decades post-surgery, patients treated with 3rd-generation implants for adolescent idiopathic scoliosis (AIS) report lower quality of life (QOL) than peers.

Design
Multicentric cross-sectional observational study.

Introduction
Surgery for AIS aims to eliminate traces of scoliosis, restoring normalcy. Long-term success with 3rd-gen implants is inadequately documented

Methods
We included AIS patients, operated during adolescence with CD or ISOLA instrumentation and ≥25 years of follow-up (FU). The clinical condition (status?) was assessed using the following self-perceived health-related instruments: numerical pain scale (NRS), ODI, SRS-22r, SF-36, and EQ-5D-5L questionnaires. For the NRS and SRS-22r, the reported “Patient Acceptable Symptom State” (PASS+) was used as the reference for normality. For the SF-36 and EQ-5D-5L, the patient cohort was compared with adjusted normative data. The standardized mean difference (SMD) was calculated as a measure of effect size (relevant if >0.7).

Results
Out of 226 eligible patients, 152 (67%) (87% female) participated in the study, after a mean FU of 29.6 (SD2.8; range 25-35) years. The mean age at surgery was 15 (1.9; 11-21) years and 45.1 (3.4; 36-55) years at FU. PASS+ status was achieved by 56.1%, 56.7%, and 55.5% of patients, on NRS, SRS-22 subtotal, and SRS-22-Self image scores, respectively. Mean NRS score was 3.3±2.9 with 56% of patients scoring ≤3. Mean ODI was 22.6± 16.9, with 56.8% of patients scoring ≤20. Significant differences were found between the patient cohort and normative values for the SF-36 physical component score (SF36-PC) (42.8 vs 50; p=0.0001), with a moderate effect size (SMD=0.6). No differences were observed for the SF-36 mental health score (SF36-MH). Patients’ EQ-5D-5L score was significantly lower (0.8vs0.9; p=0.0001). The primary difference was observed in the pain question; 26.8% of patients compared with 82.5% of general population answered "I have no pain or disability" (p=0.0001).

Conclusion
Thirty years after surgery, individuals treated for AIS using 3rd-generation implants exhibit physical and mental health similar to the general population. Yet, the operated scoliotic group, on average, reports lower quality of life and increased pain. Surgery during adolescence has not fully restored normalcy in adulthood.

‡ = SRS Funded Research Grant

Session 5B | Adolescent Idiopathic Scoliosis II Abstracts

Paper #80. Enhanced Care Delivery and Patient Experiences for Kids with Scoliosis: Smart Digital Strategies to Link Patients and Care Services ‡

J Paige Little, PhD; Sinduja Suresh, PhD; Maree T. Izatt, BPhy; Annabelle Stubbs, BEng; Addison Suhr, BSc; Simon Gatehouse, MD, FRCS; Robert D. Labrom, MD, FRCS; Geoffrey N. Askin, MD, FRCS

Hypothesis
Clinical measures of scoliosis trunk rotation show excellent agreement with digitally measured values from 3D models.

Design
Prospective cohort study

Introduction
We are developing new eHealth technology that will enable surgeons to undertake a 'virtual point-of-care' spinal healthcare appointment for paediatric spinal deformity patients located in rural and remote geographic regions. It uses interactive 3D virtual models of scoliosis patient anatomy captured by the parent with their smartphone at home. A critical step is validation of the predicted spinal deformity measurements.

Methods
Using our custom photogrammetry methodology we create 3D virtual models of the full body, while standing and in forward bend positions (Figure 1). The models are analysed using custom-code to evaluate torso deformity and measure angle of torso rotation (ATR), and then embedded within a new digital interface for use by the surgeon during eHealth appointments (Figure 1). ATR measured in forward bending is a key clinical deformity measurement for adolescent idiopathic scoliosis (AIS). To validate ATR measured from 3D models, 20 AIS patients were recruited (Ethics:LNR/21/QCHQ/75249) from our spinal orthopaedic clinic. Patients received their standard spinal healthcare appointment and in parallel, 3D models were created using photos captured on a smartphone. ATR was digitally measured from the bending models and compared with the clinically measured values (Spearman correlation, Mann-Whitney U test).

Results
ATR showed excellent positive correlation between clinically measured and 3D model-derived measurements ($r=0.937$, $p<<0.05$), with no significant difference between the two measures. Intra-rater variability (one user, three occasions) and inter-rater variability (three users, one occasion) showed mean ATR difference of 0.67 ± 0.6 degrees, and 0.49 ± 0.2 degrees.

Conclusion
Despite the abundance of smartphone-applications relating to paediatric scoliosis, there is currently no existing application that allows rural families to receive equitable access to healthcare from tertiary orthopaedic spine clinics in Australia. This technology will be pivotal in reducing departmental costs associated in facilitating orthopaedic surgeons to provide remote spine clinics.

‡ = SRS Funded Research Grant

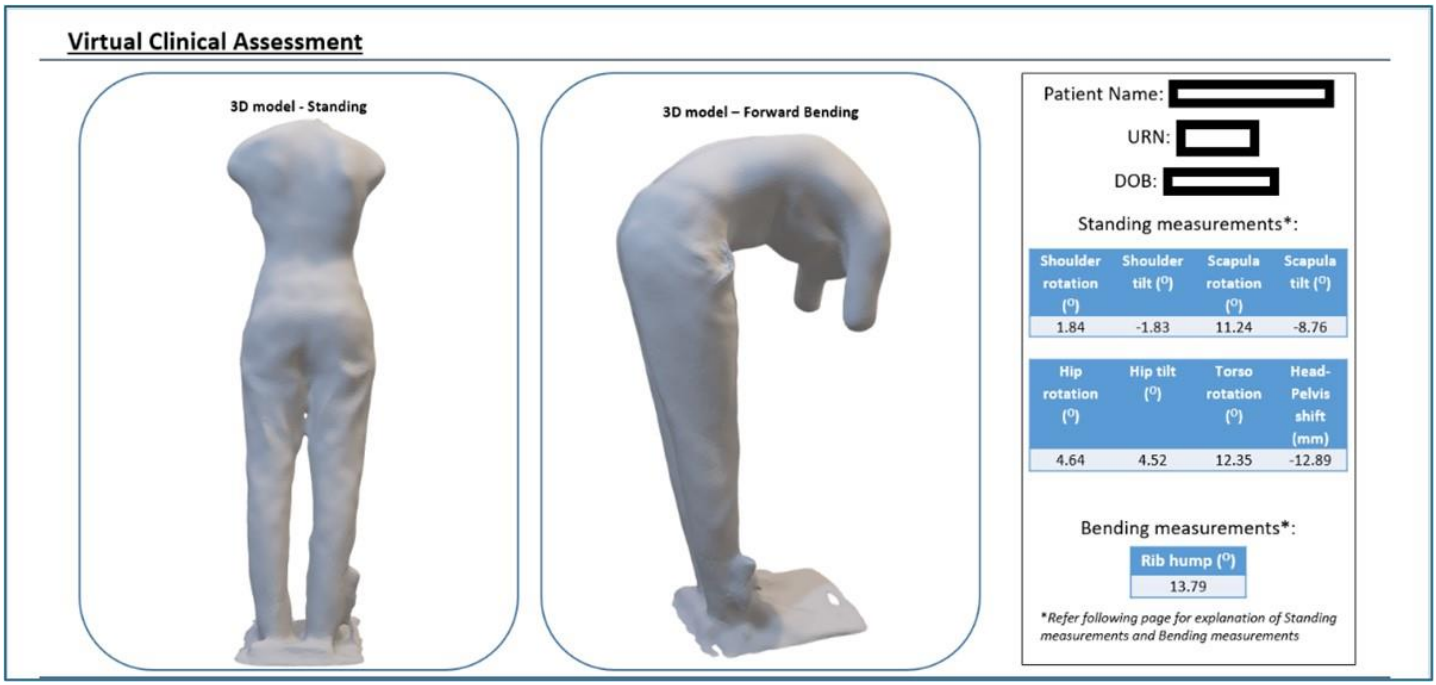


Figure-1: eHealth surgeon user interface. ATR shown as 'Bending measurement'

Session 5B | Adolescent Idiopathic Scoliosis II Abstracts

Paper #81. Serum Titanium Levels Remain Elevated 6 Years and Beyond from Spinal Instrumentation in Children

Peter J. Cundy, MBBS; William J. Cundy, FRACS; Georgia Antoniou, BS

Hypothesis

That metal ion serum levels will persist in children following instrumented spinal fusion for adolescent idiopathic scoliosis

Design

34 of 56 participants from an earlier study returned for repeat testing for circulating metal ions at a minimum of 6 years from surgery.

Introduction

Publications on metal ion levels after paediatric spine surgery have shown an immediate initial peak of most serum metal ion levels following surgery. Cobalt and chromium levels trend to baseline by 1 year post surgery, however titanium levels have been shown to remain elevated to 5 times baseline at a minimum 2 years. This persistence in raised titanium levels prompted a repeat study beyond 6 years from surgery.

Methods

34 of 56 participants from an earlier study returned for repeat testing for circulating metal ions, using high-resolution inductively coupled plasma mass spectrometry. To analyse differences in serum ion levels, linear regression models were used, with Generalised Estimating Equations (GEEs) to account for correlation due to repeated measurements. The use of GEEs also allowed the incorporation of incomplete data, so all participants were included in the models rather than only those who participated at 6 years.

Results

Median titanium levels at 6 years decreased significantly to 0.46 times that of 2-year levels (95% CI: 0.32-0.67, $p<0.001$) however they remained 2.40 times higher compared to the pre-surgery control levels (95% CI: 1.47-3.92, $p<0.001$). In comparison, median chromium levels at 6 years were significantly increased from 2 years (1.45 times, 95% CI: 1.05-2.01, $p = 0.024$), but were not significantly different to baseline (1.13 times, 95% CI 0.79-1.61, $p=0.509$). Cobalt levels at 6 years remained significantly higher than baseline (1.32 times, 95% CI 1.06-1.66, $p = 0.015$), but also decreased significantly compared to 2-year levels (0.76, 95% CI 0.64, 0.92, $p = 0.004$). Nickel levels at 6 years did not differ significantly from baseline or from 2-year levels.

Conclusion

Titanium remains elevated at beyond 6 years from spinal instrumentation in children. The effects on a person's health via deposition in solid organs including the brain, or on the offspring of persons with spinal instrumentation, remain unclear. Curiously, chromium levels increased at 6-year sampling in "all titanium" constructs which may be explained by metallurgical irregularities.

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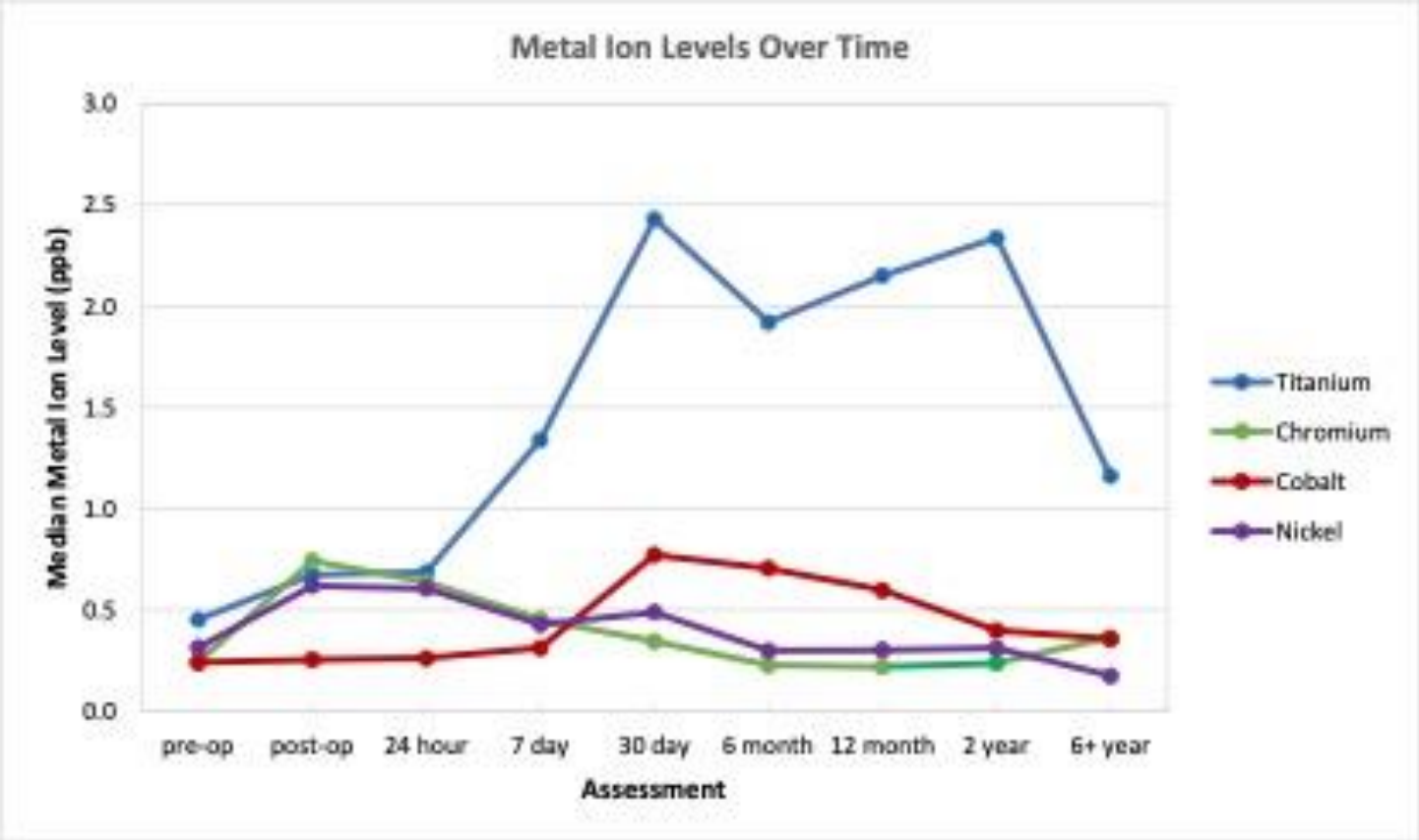

Session 5B | Adolescent Idiopathic Scoliosis II Abstracts

Paper #82. How Does Posterior Fusion Affects Muscle Activation Pattern in Adolescent Idiopathic Scoliosis: A Walking EMG Analysis

Bhavuk Garg, MS

Hypothesis
AIS and subsequent spinal fusion surgery changes the trunk and lower extremity muscle activity.

Design
prospective case control experimental

Introduction
This study assesses the impact of AIS and spinal fusion surgery on muscle activity during gait.

Methods
Five AIS patients (14.8 ± 1.7 years) and three age-matched healthy controls (15.1 ± 1.2 years) were recruited. Participants underwent 3D gait analysis using a BTS SMART DX-7000 motion capture system, AMTI force plates, and SMART DX100 EMG system . Surface EMG electrodes were bilaterally placed on the following muscles: Erector Spinae (ES), Iliocostalis, Gluteus Medius (GM), Biceps femoris (BF), Semimembranosus (SM), Gastrocnemius Lateralis (GL), Rectus Femoris (RF), Tibialis anterior (TA). EMG data were recorded during five overground walking trials at self-selected pace. The raw EMG data was filtered using a fourth-order Butterworth filter of 20 to 450 Hz with zero phase lag. Subsequently, the data was fully wave rectified. A double threshold method was used to detect muscle activation when the filtered TKEO-treated EMG signal exceeded 3% of its maximum amplitude and when the muscle was active for a period of at least 50 ms (Figure 1).

Results
Preop, AIS patients exhibited a significant increase ($p<0.05$) in muscle activity duration in the ES (52%), RF (56%), GM (59%) and SM (52%) compared to healthy subjects (31%; 34%; 40%; 36%, respectively). Ipsilateral side ES and RF were more activated than the contralateral side(15% and 18%, respectively). Postop, there was a significant reduction ($p < 0.05$) in muscle activity duration in ES (11%), RF (9%), and GM (12%) muscles compared to the preop.

Conclusion
AIS patients had prolonged and abnormal muscle activity, leading to inefficient gait patterns with higher energy demands. Spinal fusion surgery corrected the scoliotic deformity and reduced excessive electrical activity in lower extremity muscles. Future research should study the impact of surgical technique and rehabilitation on muscle activity in AIS patients.

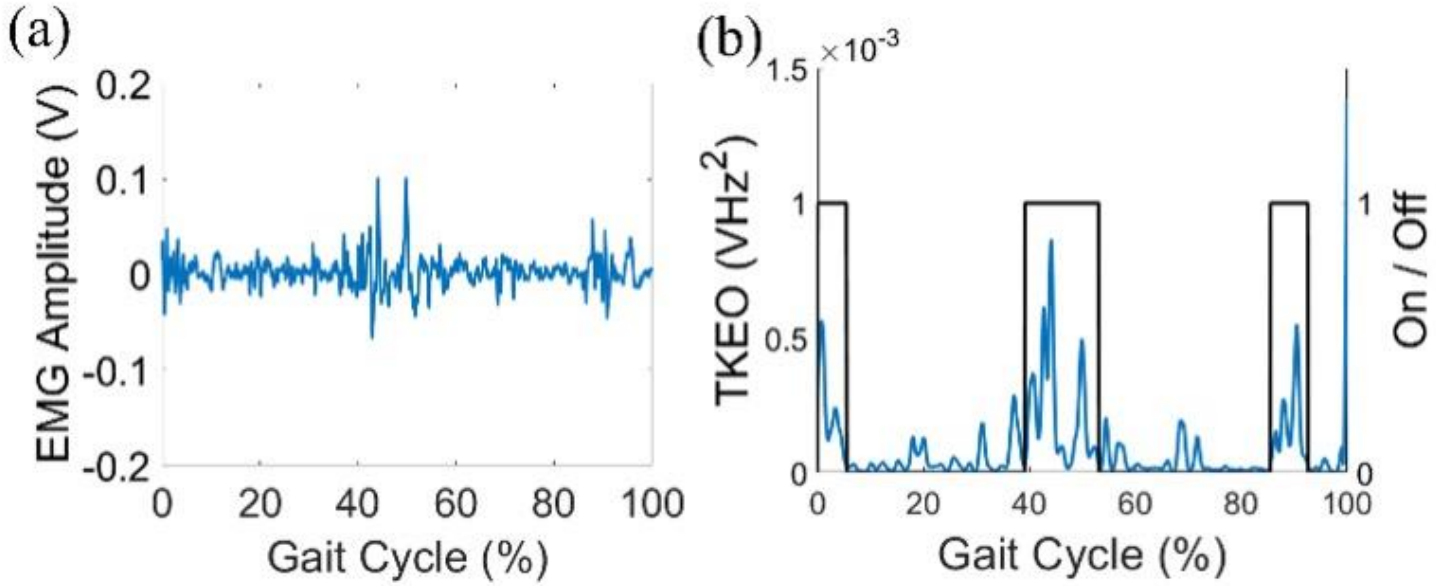

Figure 1: Processing of the EMG signal of the left Erector Spinae muscle recorded from a single participant (a) raw signal (b) detection of muscle activation from TKEO treated signal

Session 5B | Adolescent Idiopathic Scoliosis II Abstracts

Paper #83.AIS Patients with Distinct Lenke Types Adopt Different Kinematic Strategies During Walking

Maria Asmar; Maria Karam; Emmanuelle Wakim; Abir Massaad, PhD; Mohammad I. Karam, PhD; Aren Joe Bizdikian, MD, MS; Georges El Haddad; Marc Boutros, BS; Marc Mrad; Gilles Prince, MD; Ibrahim Hamati; Guy Awad; Joe Azar; Moustapha Rteil; Nadim Freiha Claudio Vergari, PhD; Helene Pillet, PhD; Ismat Ghanem, MD, MS; *Rami Rachkidi, MD, MS*; Ayman Assi, PhD

Hypothesis

AIS Lenke 1 and Lenke 5 patients use different strategies and compensation mechanisms during walking.

Design

Retrospective analysis of prospectively collected data.

Introduction

Gait function requires meticulous coordination between the spine and adjacent segments. This can be affected in the setting of Adolescent Idiopathic Scoliosis (AIS) or after posterior spinal fusion, a procedure known to limit spine mobility and therefore affect movement. This study aims to investigate pre-operative kinematic strategies and compensation mechanisms in AIS during walking.

Methods

33 AIS: 10 AIS Lenke-5 (major Cobb: 26±7°), 23 AIS Lenke-1 patients (major Cobb: 40±13°) and 24 controls underwent biplanar X-rays with calculation of 3D radiographic spinopelvic parameters. 3D gait analysis was then performed, with the calculation of kinematic parameters of the head, trunk, pelvis, lower limbs, and spinal segments. Kinematic parameters were compared between groups.

Results

AIS Lenke 5 patients had a lumbar segment bending while walking: T12L3-L3L5 (5±8° vs. -2±7°) to the concave -right- side of the scoliotic curve. They walked with an increased pelvic axial mobility (18±7° vs. 13±4°) and internal rotation of the right foot (-2±7° vs. -11±8°; all $p<0.05$). In relation to their primary thoracic deformity, AIS Lenke 1 patients increased their thoracic & lumbar segment bending while walking: T3T6-T6T9 (-6±8° vs. 0±6° in controls) to the concave (left) side of the scoliosis and T12L3-L3L5 (9±13° vs. -2±7°) to the opposite side. However, they tend to reduce their lumbo-pelvic mobility (L3L5-Pelvis bending ROM=8±5° vs. 12±5°; all $p<0.05$; Fig.1).

Conclusion

AIS Lenke 5 patients seem to compensate at the lower limbs level due to the inherent stiffness in their scoliotic lumbar segment. In response to their lumbar bending, they tended to increase their pelvic axial mobility and to develop a homolateral internal foot rotation, ensuring a dynamic alignment during forward gait progression. AIS Lenke 1, by producing opposite bending movement at the thoracic and lumbar segments, tended to reduce lumbo-pelvic mobility and ensure coronal dynamic alignment. This further emphasizes the role of selective fusion in Lenke 1 patients in order to preserve adaptation mechanisms in the lumbar segment during gait.

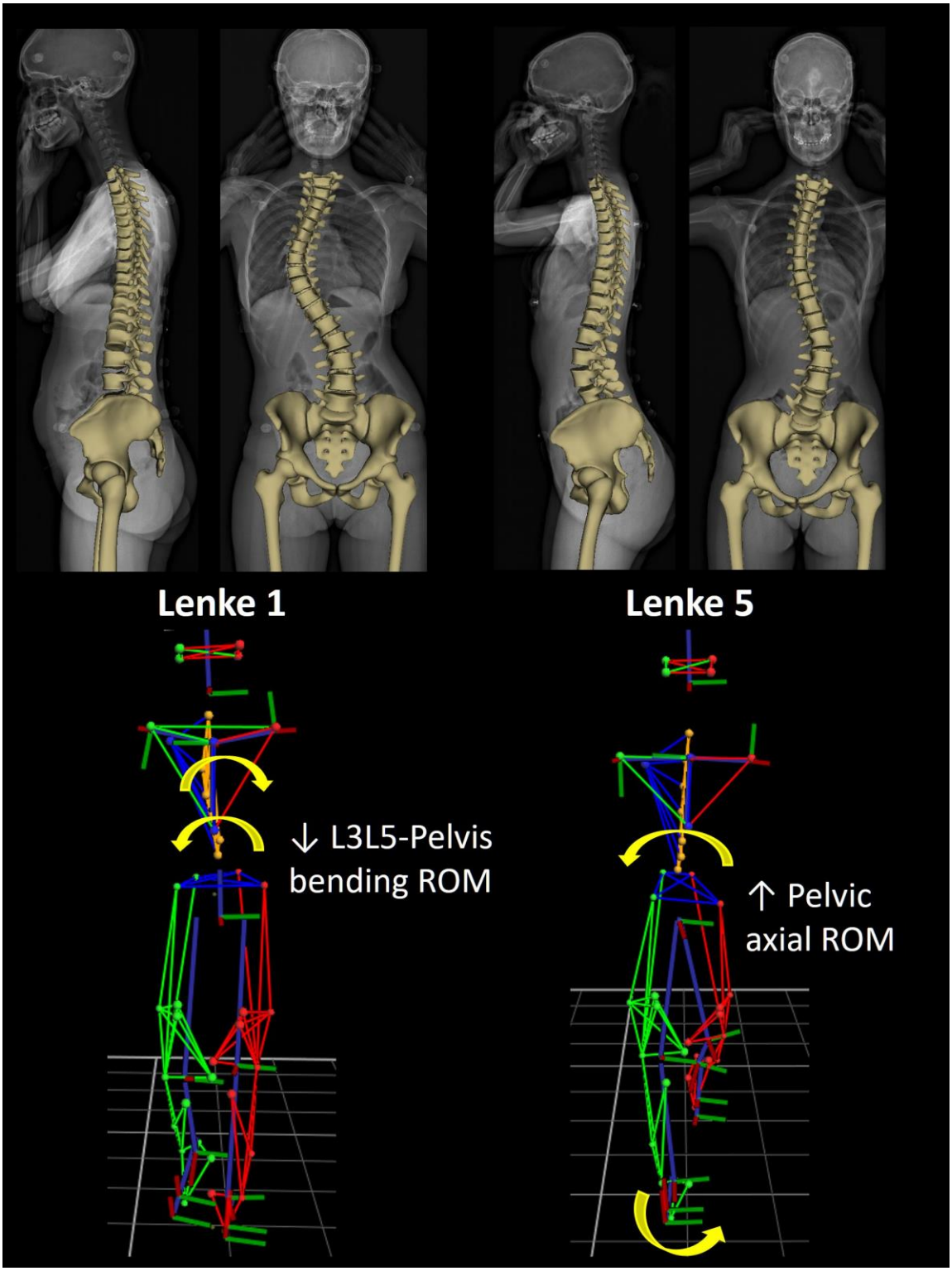

Fig.1: Illustration of kinematic strategies during walking in Lenke 1 and 5 AIS patients.

Session 5B | Adolescent Idiopathic Scoliosis II Abstracts

Paper #84. Patient's Perceived Flexibility After a Spinal Fusion

Vishal Sarwahi, MD; Katherine Eigo, BS; Sayyida Hasan, BS; Himanshu Rao, BS; Brittney Moncrieffe, BS; Kiara Thompson, BS; Hannah Travers, BS; Effat Rahman, BS; Sanjeev Suratwala, MD; Yungtai Lo, PhD; Terry D. Amaral, MD; Keshin Visahan, BS

Hypothesis

Fusion level does not affect one's postop flexibility.

Design

Retrospective Cohort Study with Survey

Introduction

Spinal fusion has been associated with loss of functional flexibility in patients postoperatively. Furthermore, it is believed the more distal a fusion, the less flexible you become. However, recent literature is challenging this belief. The aim of this study is to assess a patient's perceived flexibility after a spinal fusion and determine if there is a correlation between level fused and flexibility.

Methods

This study included 311 participants, 287 AIS patients who underwent PSF between 2016-2022, and 24 non-operative control patients. Data was collected retrospectively through radiographic and chart review, as well as via phone or email. Out of 287 patients who were contacted, 253 had a working phone or email listed in the EHR. Among those, 159 patients responded to the survey (62.8% response rate). The survey asked various questions on flexibility such as toe-touch, trunk rotation, activity levels etc. Likert scale ranging from 1 (indicating severely limited flexibility and sedentary lifestyles) to 10 (representing high flexibility and activity levels).

Results

159 patients underwent PSF. 131 patients were fused to L3/L4, 28 were fused to T12/L1. Demographic data was similar between the two groups. Both L3/L4 patients and T12/L1 patients had an average 3.0-day LOS ($p = 0.90$). Preop self-assessed flexibility (L3/4: 7.0 vs T12/L1: 7.5 $p = 0.76$) and activity levels Likert scale results (7.0 vs 7.0, $p = 0.80$) were similar between groups. Postop, both groups had similar flexibility (6.0 vs 7.0, $p = 0.11$) and activity levels (6.5 vs 8.0, $p = 0.08$). Flexibility levels did not change between pre- and postop visit for L3/L4 ($p = 0.32$) or T12/L1 ($p = 0.87$) patients. L1+ patients were significantly less likely to be able to touch their toes both pre- and post-surgery and neither significantly changed after surgery. These groups were similar to the control group before and after surgery. L3/L4 patients returned to unrestricted gym and competitive sports at an average of 6.8 months and 7.0 months versus 6.3 months and 7.1 months for T12/L1 ($p = 0.48$, $p=0.35$).

Conclusion

Our study's findings suggest that adolescent's flexibility levels postop returned to the same level as they were preop and that fusion level did not affect flexibility. This is contrary to the common conception that fusion to L3/L4 restricts patients' flexibility.