# Session 8B | Kyphosis & Basic Science Abstracts

*Papers are listed in presentation order*

## Paper #119. Flexible Posterior Vertebral Tethering for the Management of Scheuermann's Kyphosis(SK): Correction by Using Growth Modulation

*Mehmet Aydogan, MD*; *Tuna Pehlivanoglu, MD*; Yigit Erdag, MD; Umut D. Akturk, MD; Abdulhalim Akar, MD

### Hypothesis

Gradual correction of the kyphotic deformity together with vertebral wedging could be acquired as a result of posterior vertebral tethering (PVT),which induces a growth arrest on posterior portion of vertebral growth plates by compression,while accelerating growth on anterior portion of growth plates by distraction.

### Design

Prospective Case series

### Introduction

The present study was intended to present the minimum 3 years' results of flexible posterior vertebral tethering(PVT) applied to 10 skeletally immature patients with SK to question,if it could be an alternative to fusion, similar to VBT, which was proposed as an alternative to fusion in AIS patients.

### Methods

Ten skeletally immature patients with radiographically confirmed SK, who had flexible (minimum 35%) kyphotic curves (T2-T12), were included. A decision to proceed with PVT was based on curve progression within the brace, and/or persistent pain, and/or unacceptable cosmetic concerns of the patient/caregivers, and/or non-compliance within the brace. It was discussed with the patients and their families, that PVT may yield to additional future surgeries.

### Results

Patients had an average age of 13.1 (11-15) and an average follow-up duration of 47.6 months (36-60). Posterior vertebral tethering (PVT) was undertaken to all patients by utilizing Wiltse approach and placing monoaxial pedicle screws intermittently. At the final follow-up: mean pre-operative thoracic kyphosis and lumbar lordosis improved from 73.6 – 45.7 to 34.7 - 32.1($p<0.001$). A gradual correction was noted.Mean sagittal vertical axis (-15 to -3.2), vertebral wedge angle (14.1 to 6.1) and total SRS-22 scores (3.6 to 4.8) improved significantly ($p<0.001$). A fulcrum lateral X-ray obtained at the latest follow-up, showed that the tethered levels remained mobile as confirmed clinically.

### Conclusion

This study, for the first time in the literature, concluded,that as a result of growth modulation applied to skeletally immature patients with SK,flexible PVT was detected to yield gradual correction of the thoracic kyphosis by reverting the pathological vertebral wedging process, while keeping the mobility of the tethered segments in addition to successful clinical-functional results.The successful results of the present study questioned the role of the PVT as a viable alternative to fusion in skeletally immature patients with SK.

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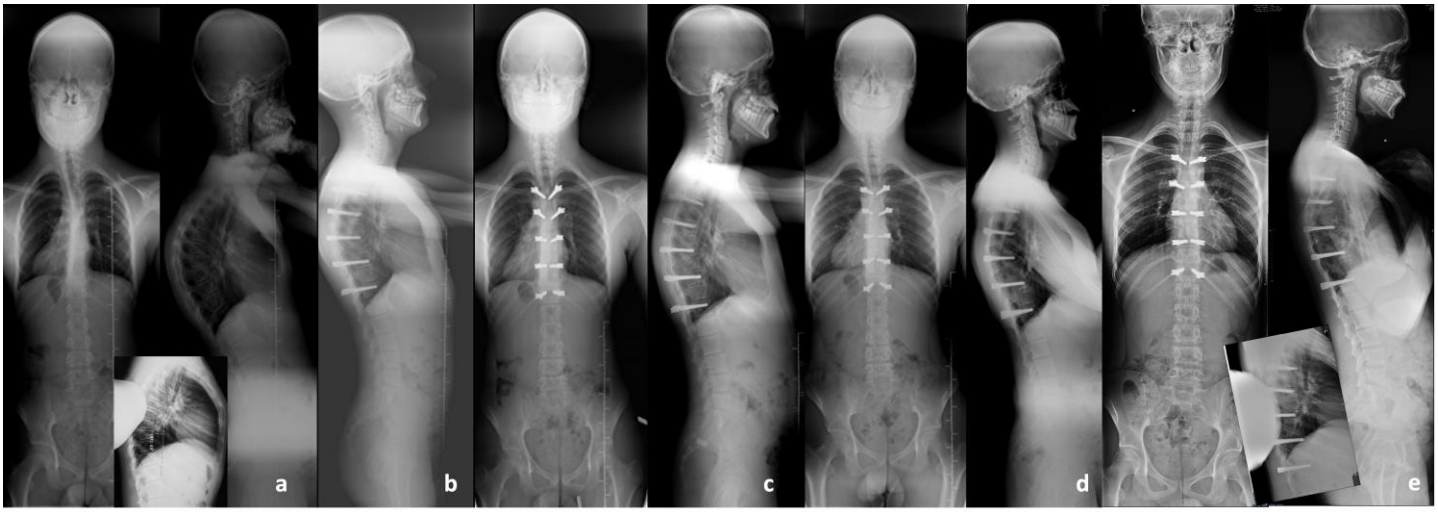



13yo M. TK:81-43-38-36-32. Flexibility:44%.

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #120. Outcomes of Pediatric and Young Adult Kyphotic Deformities Treated with Vertebral Column Resections at an Srs-Outreach Site in West Africa with 5-Year Follow-Up

*Kwadwo Poku Yankey, MD*; Derrick Owusu Nyantakyi, MPH; Arthur Sackeyfio, MD; Jessie Rapoza, MS; Irene A. Wulff, MD; Oheneba Boachie-Adjei, MD; Kushagra Verma, MD, MS; Liliane Luu, BS

### Hypothesis
VCR allows for excellent sagittal correction, but with known risks of intra and post-operative complications.

### Design
Retrospective analysis of prospectively collected data

### Introduction
Vertebral column resection (VCR) offers the potential for drastic improvements in sagittal balance but complication risks remain high and should be managed carefully. This study provides an updated outcome analysis of VCRs performed at an SRS-Outreach site in west Africa.

### Methods
Twenty patients with severe sagittal deformities underwent VCR at the FOCOS hospital in west Africa between 2013 and 2018. Follow-up included five-year outcomes. Sagittal radiographic parameters and SRS-22 scores were analyzed to compare preoperative and postoperative outcomes via paired t-tests.

### Results
39 patients (age 16 ± 3.7) underwent surgery with VCR and 20 returned for 5-year follow up (51%). Three patients underwent a 1-level VCR, seven 2-level VCRs, ten 3-level VCRs, and one 4-level VCR. Comparison of mean radiographic parameters depict a significant improvement in T2-T5 kyphosis (–4.3˚ to 6.7˚, P=0.016), T5-T12 kyphosis (68.9˚ to 37.8˚, P=0.02), and L1-S1 lordosis (69.5˚ to 43.2˚, P=0.003). Mean SRS-22 scores depicted significant improvement in all categories: pain (3.1 to 4.6, P=1.5E-6), self-image (2.3 to 3.8, P=2.3E-4), general function (3.1 to 4.5, P=1.04E-6), mental health (3.3 to 4.4, P=6.7E-5), satisfaction (3.3 to 4.5, P=0.028), and total (3.0 to 4.4, P=2.1E-6). Mean estimated blood loss was 1918 ± 859 mL and mean operating time was 337 ± 100 minutes. 12 patients had intraoperative complications, including 1 dural tear, 1 pleural tear, and 12 neuromonitoring changes that improved with corrective maneuvers. One patient experienced a postoperative neurologic complication. Re-operation rate was 20%.

### Conclusion
Here, VCRs performed on pediatric populations with severe sagittal deformities in an outreach setting produced generally favorable outcomes in both sagittal radiographic parameters and SRS-22 scores. Although a 60% complication rate was observed, a majority were intra-operative neuromonitoring changes and resolved without lasting neurological affects.

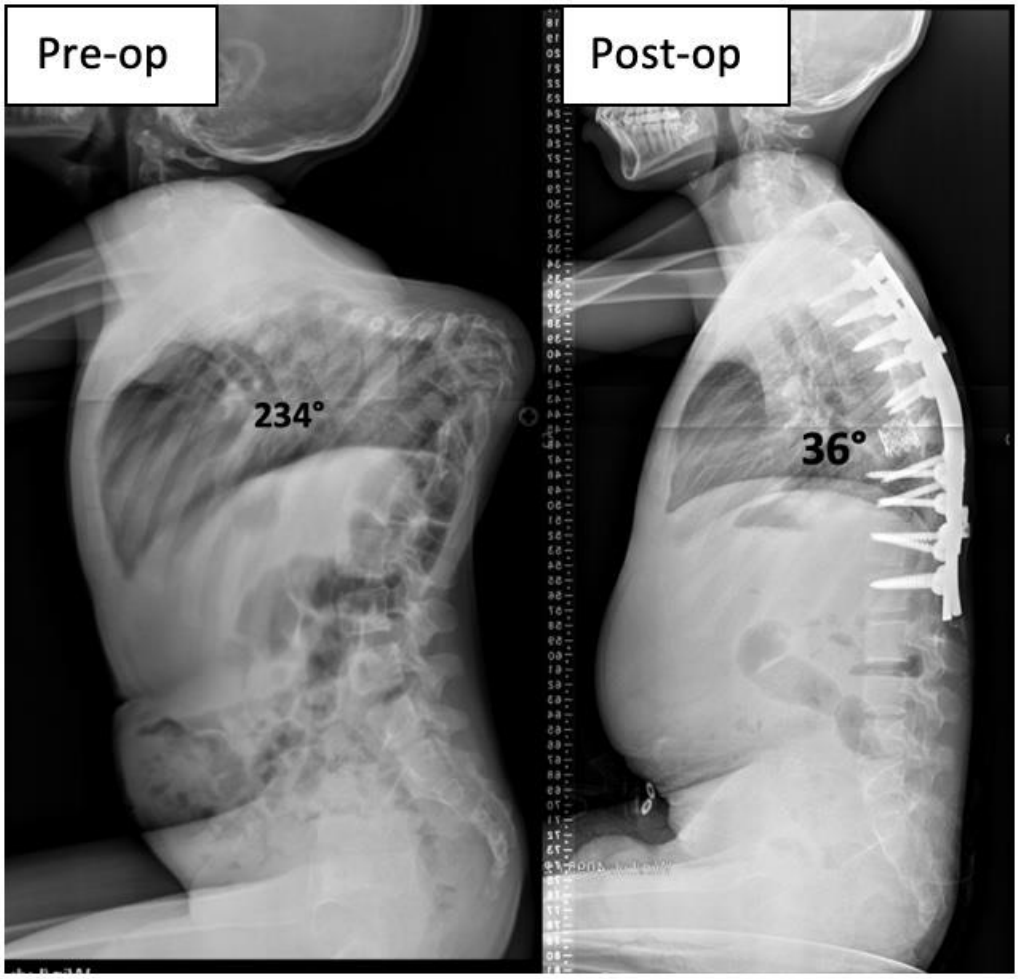



Figure 1: Radiographic images of case example.

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #121. Diagnostic Challenges and Consequences of Neonatal Vertebral Osteomyelitis: A Case Series

Talissa O. Generoso, MD; Rubens Furlan Neto, MD; Luca E. Cordeiro, MD; Luiz Müller Avila, MD; Carlos A. Aguiar, MD; *Luis E. Munhoz da Rocha, MD*

### Hypothesis

Patients with neonatal vertebral osteomyelitis often present in late childhood with acute-angle kyphosis, which may be mistakenly identified as congenital, thereby perpetuating the undiagnosed vertebral infection.

### Design

Retrospective case series.

### Introduction

Neonatal vertebral osteomyelitis is a rare condition, with limited descriptions in the literature primarily comprising case reports. Diagnosis within this age group proves challenging due to subtle clinical and laboratory findings, such as axial pain during breastfeeding, leading to a heightened risk of diagnostic errors, including misdiagnoses as meningitis, and subsequent treatment delays. This context fosters disease progression, resulting in the development of severe spinal deformities characterized by the destruction and collapse of affected vertebrae, posing a significant risk of neurological compromise. This study aims to enhance awareness of this challenging diagnosis, empowering healthcare professionals to recognize early signs and symptoms and provide optimal treatment for affected children.

### Methods

A retrospective case series was conducted by analyzing medical records and images within the past 15 years at a tertiary pediatric hospital in Brazil.

### Results

This study comprised 10 cases of neonatal osteomyelitis initially undiagnosed, presenting late for orthopedic evaluation due to severe kyphosis. All were either premature or had experienced a prolonged hospital stay as newborns, with at least 20 days spent in the ICU. Upon initial assessment, all patients had involvement of at least two vertebral bodies, acute angle kyphosis in the thoracic spine, spinal canal stenosis, and varying degrees of spinal cord compression. Four patients displayed signs of neurological compromise. Surgical intervention was required for all patients, with only one receiving treatment during the acute phase while hospitalized for sepsis.

### Conclusion

Early diagnosis of vertebral osteomyelitis in neonates can alter the course of the disease and patient outcomes. Awareness of this diagnosis is essential, especially in cases with a history of bacteremia and ICU admission, providing swift and aggressive treatment, preventing extensive bone destruction and neurological compromise. Surgical treatment with decompression and spinal stabilization should be considered early in cases with signs of vertebral instability.

Severe acute kyphosis with neurological compromise in a 2yo patient.

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #122. Posterior Corrective Surgery for Type Ii Congenital Kyphosis: SRS-Schwab Grade 4 Osteotomy or Vertebral Column Resection?

Yong Qiu, PhD; *Hongru Ma, MD*; Benlong Shi, PhD; *Zezhang Zhu, PhD*

### Hypothesis

Both SRS-Schwab Grade 4 osteotomy and vertebral column resection (VCR) are effective in surgical correction of congenital kyphosis if selected based on proper indications.

### Design

Retrospective comparative study.

### Introduction

The rigid nature of anterior or circumferential failure of segmentation in type II CK rendered indispensably radical and risky corrective surgery, raising the question on how to trade-off between safety and effectivity regarding the selection of surgical techniques. Bothe VCR and SRS-Schwab Grade 4 osteotomy were reported to be effective in surgical correction of CK, the optimal strategy in selection of the two techniques were not proposed.

### Methods

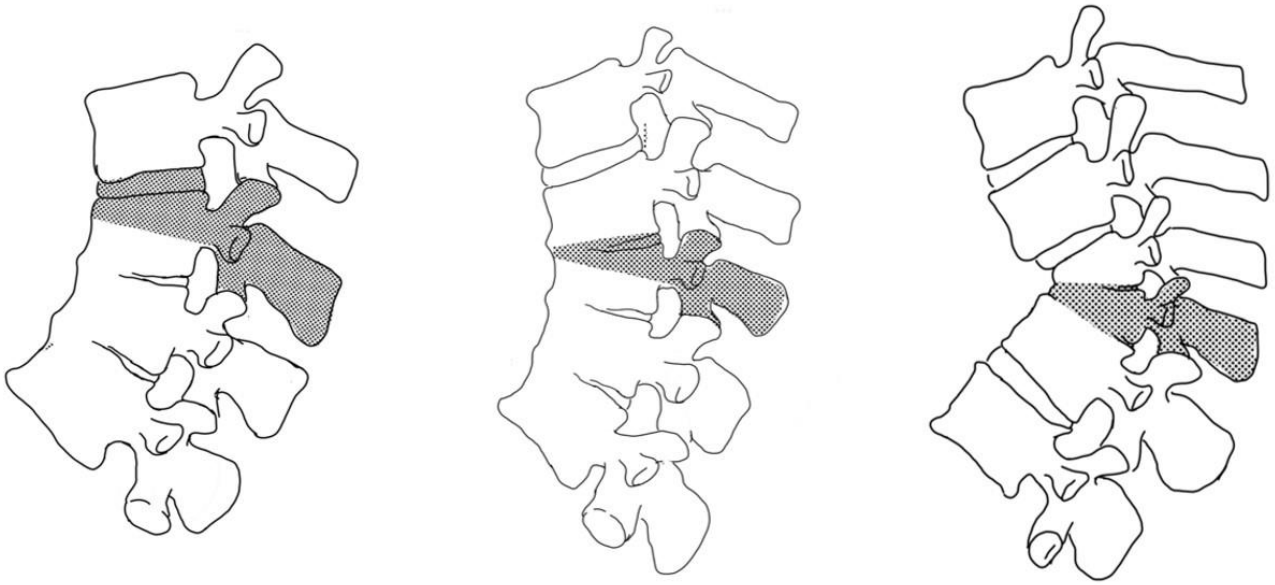
Type II CK patients undergoing vertebral column resection (VCR) in our center from January 2015 to January 2020 were included in Group 1, and those undergoing SRS-Schwab Grade 4 osteotomy during the same period were enrolled in Group 2. The radiographic parameters, clinical outcomes, and quality-of-life measures at pre-operation, post-operation and follow-up were compared between groups.

### Results

A total of 31 patients (19 patients in Group 1 and 12 patients in Group 2) with an average age of 16.3±10.4 years were recruited. Similar correction of segmental kyphosis was observed between groups (51.1±17.6º in Group 1 and 48.4±19.8º in Group 2, p=0.694). Group 1 had significantly longer operation time (365.9±81.2 vs.221.4±78.9, p<0.001) and more estimated blood loss (975.2±275.8 ml vs. 725.9±204.3 ml, p=0.011) as compared to Group 2. Significant improvement of SRS-22 Self Image, Function and Satisfaction domains was observed in both groups during follow-up. The SRS-22 measurements were similar between groups at the latest follow-up. Alert event of intraoperative sensory and motor evoked potential (SEP and MEP) monitoring was observed in 1 patient of Group 2. Both groups had 1 transient post operative neurological deficit respectively. The incidence of peri- and post-operative complications was higher in Group 1 but not statistically different.

### Conclusion

Both VCR and SRS-Schwab Grade 4 osteotomy, if selected properly, could provide satisfying radiographic and clinical outcome in type II CK patients during a minimum of 2 years follow-up. Compared to SRS-Schwab Grade 4 osteotomy, patients undergoing VCR procedure might have longer operation time, more blood loss and higher incidence of peri- and post-operative complications.



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# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #123. Decision of Pedicle Subtraction Osteotomy Vertebra in Surgical Correction for Ankylosing Spondylitis with Thoracolumbar Kyphosis

Yong-Chan Kim, MD, PhD; Tae-Hoon Kim, MD, PhD; *Young-Jik Lee, MD;* Sung-Min Kim, MD; *XiongJie Li, MD*; Romeo II G. Galapon, MD; Min-Gyu Kim, MD

### Hypothesis

'Kim's apex' is useful when determining the apex in Ankylosing spondylitis (AS) patients with thoracolumbar kyphosis, and performing pedicle subtraction osteotomy (PSO) using it can achieve better surgical outcomes.

### Design

A retrospective study

### Introduction

PSO can effectively correct AS patients with thoracolumbar kyphosis, but the choice of location remains controversial. This study aims to provide a method for the decision of the apical vertebra as the site for PSO in corrective surgery for AS with thoracolumbar kyphosis.

### Methods

235 AS patients with thoracolumbar kyphosis who underwent PSO from 2009 to 2021 were retrospectively enrolled in this study. 'Kim's apex vertebra' was defined as the farthest vertebra from a line drawn from the center of the T10 vertebral body to the midpoint of the S1 upper endplate and 229 patients whose apex was located at each of T12, L1, or L2 were finally analyzed. We divided all patients into two groups. Group A (n=144) underwent PSO at the KA vertebra, while Group B (n=85) underwent PSO at a different level. Demographic and radiologic data, including sagittal spinopelvic parameters, were collected. An additional analysis was performed on patients with the same KA vertebra.

### Results

The distribution of patients based on KA were T12 (28,12.2%), L1 (119,51.9%), and L2 (82,35.9%), respectively. The correction of sagittal vertical axis (SVA, 101.0±48.5 mm vs 82.0±53.8 mm, p=0.010), global kyphosis (GK, 31.6±10.0° vs 26.4±10.5°, p=0.005), and thoracolumbar kyphosis (TLK, 29.4±10.2° vs 24.2±12.9°, p=0.012) in group A was significantly greater than in group B, and there was no difference in the correction of thoracic kyphosis (TK), lumbar lordosis (LL), and pelvic incidence (PI) between the two groups. On further analysis, Group A showed greater correction in TK (26.2±13.7° vs 4.5±20.1°, p=0.013) for patients with T12 as the KA, greater improvements in SVA (101.5±44.2° vs 73.4±48.7°, p=0.020), GK (30.6±11.0° vs 26.0±10.4°, p=0.046), and TLK (32.6±7.8° vs 26.7±9.9°, p=0.012) for those with L1 as the KA, and significant correction in TLK (30.0±6.3° vs 4.3±19.5°, p=0.008) for patients with L2 as the KA, compared to Group B.

### Conclusion

PSO at the apical vertebra provides a greater degree of correction of sagittal imbalance. Our proposed method, the KA is easily reproducible for determining the apex level in AS patients with thoracolumbar kyphosis.

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #124. Selection of Proximal Fusion Level in Osteoporotic Vertebral Compression Fracture with Spinal Kyphosis: the Guidence of Hounsfield Unit

*Junyu Li, MD*; Yiqiao Zhang, MD; Ben Wang, MD; Xueshi Tian, MD; Zhuoran Sun, MD; Yongqiang Wang, MD; Miao Yu, MD; Weishi Li, MD; Yan Zeng, MD

### Hypothesis

Upper maximal vertebra (UMV) and upper sagittal reverse vertebra (USRV) can help to select the fusion level and decrease the incidence of adjacent segment degeneration (ASD) and proximal junctional kyphosis (PJK).

### Design

Retrospective analysis

### Introduction

The selection of the upper instrumented vertebra (UIV) in Osteoporotic Vertebral Compression Fracture (OVCF) has been proven to be related to postoperative complications. For the first time, we defined the upper maximal vertebra (UMV) as the vertebra above the compressed section that had a higher Hounsfield Unit (HU) value than two vertebrae proximal to the fracture level. The upper sagittal reverse vertebra (USRV) was defined as the first vertebra that presented opposite HU value distribution from the anterior to posterior part of the vertebra compared to proximal vertebrae. In accordance with previous studies, we believe that the UMV and USRV might play an important role in the biomechanical stability of the spine.

### Methods

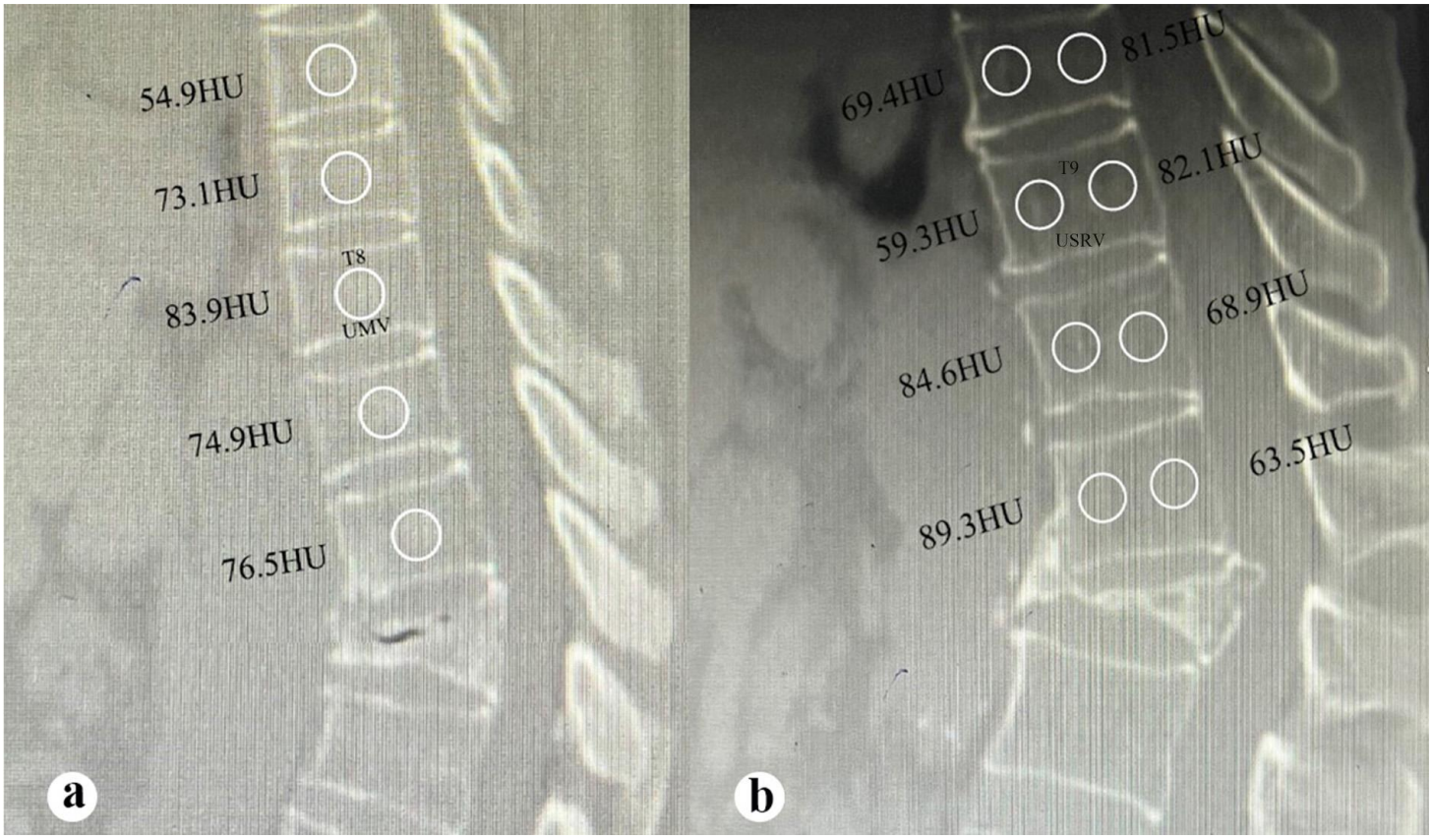
This clinical research included 70 continuous OVCF patients (14 males and 56 females) with a mean age of 63.24 ± 7.83 years and mean follow-up of 48.13 ± 20.22 months. Whole spine CT were performed for each patient. The patients were divided into groups according to whether their UIV was below the UMV or USRV. The incidence of ASD and PJK was evaluated in each subgroup.

### Results

The average HU value of all patients was 80.88 ± 39.84. All sagittal parameters improved significantly after operation and at follow-up. For UMV, the UIV of 25 OVCF patients was located on the UMV, while that of 45 patients was not. There was a significant difference in the rates of ASD ($p=0.003$) and PJK ($p=0.010$) between the 2 groups. 55 patients (78.57%) were identified to have USRV. The UIV of 16 patients was located on the USRV while that of 39 patients was not. There was a significant difference in the rate of ASD between the two groups ($p=0.010$).

### Conclusion

HU values should be considered in the selection of UIV. Locating UIV on UMV decreases the incidence of PJK and ASD, and taking USRV into the fusion level reduces the occurrence of ASD.




The definition of the UMV and the USRV

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #125. Opportunistic Monitoring of Bone Mineral Density Using a Stereoradiography Dual Energy System

Saba Pasha, PhD; Russell Chow; Darryl Lau, MD; *Christopher I. Shaffrey, MD*; *Tyler Koski, MD*

### Hypothesis

Bone mineral density (BMD) of lumbar, calculated with a stereoradiography dual energy system and DXA, are significantly correlated.

### Design

Cadaveric study

### Introduction

While the role of several spinal radiographic measurements on patients' spinal health, surgical planning, and outcome prediction has been investigated, the role of BMD values in treatment of spinal condition is not well documented. A hindering factor in systematically including BMD in patients' clinical care is additional imaging requirements, increasing operational burden and insurance policies associated with increased costs. A BMD measurement technology integrated in clinical a radiography system can alleviate this shortcoming.

### Methods

A total of 36 adult cadaveric torsos were scanned twice with a low dose stereoradiography system and once with DXA. An automated segmentation method identified vertebral bodies in the radiography system, while a technician manually adjusted the pre-determined boundary of the vertebrae in DXA. Stereoradiography frontal (L1-L4) BMD value in mono (only PA view) and bi-plane images (both PA and lateral images) and DXA images were calculated for both systems and compared statistically. The repeatability of the BMD measured in the stereoradiography system was evaluated.

### Results

22 male and 14 female specimens were included. A total of 222 vertebral bodies were segmented. A significant correlation was observed for both mono- and bi-plane acquisition modes compared to DXA scans, $R2=0.92$ and $R2=0.90$, $p<0.05$, respectively (Fig. 1). ANOVA analysis for repeatability assessment resulted in $F=0.001$ and $p=0.977$, showing no statistically significant differences between the repeated measurements. The mean and standard deviation of the differences between repeated BMD values measured in the stereoradiography system were 0.001 (g/cm2) and 0.058 (g/cm2) respectively.

### Conclusion

The dual energy stereoradiography system offers opportunistic monitoring of BMD as part of routine clinical evaluation of spine. The BMD measurements of the stereoradiography system were strongly comparable to the DXA BMD measurements. The repeatability of the stereoradiography system showed minimal differences between multiple measurements of the same dataset.

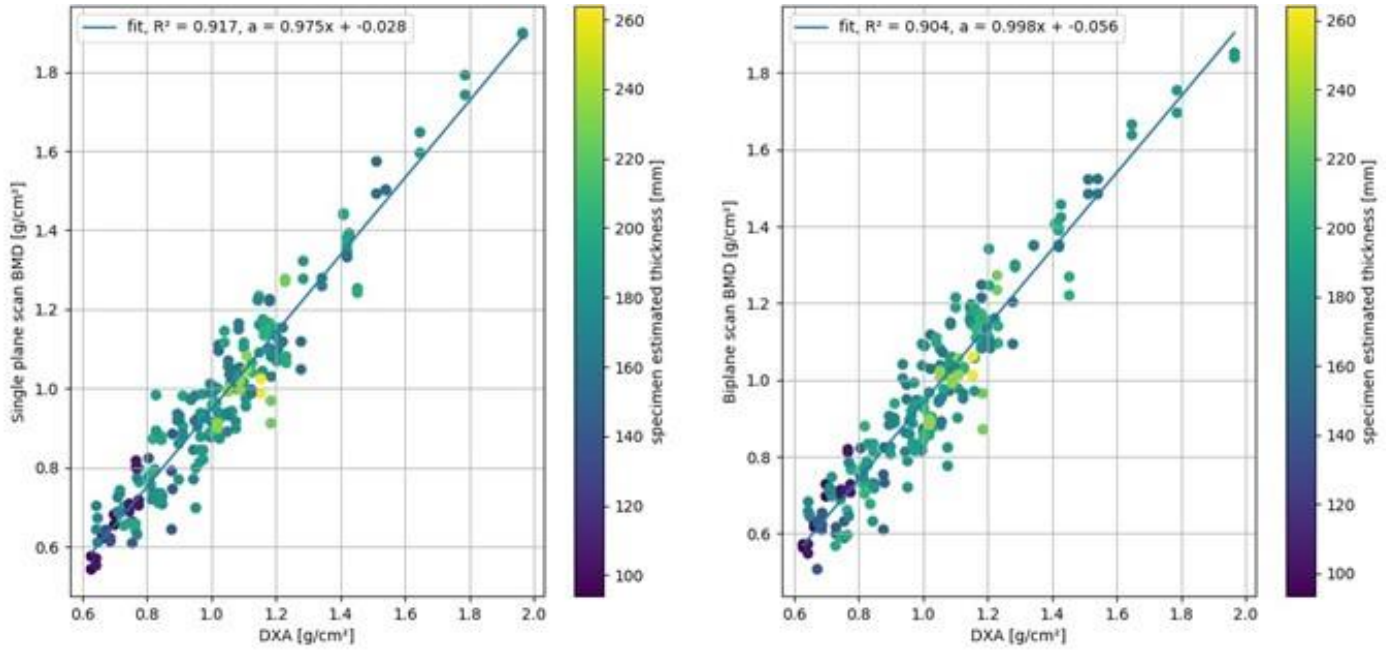



Fig. 1- The correlation between the BMD measured at all levels between DXA and stereoradiography mono- and bi-plane scans.

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #126. AI-Powered 3D Reconstructions from Stereo-Radiographs: is 3D Ready for Primetime

Justin Dufresne; Rachelle Imbeault; Lulu Zhou, PhD; Marjolaine Roy-Beaudry, MSc; Thierry Cresson, PhD; *Stefan Parent, MD, PhD*

### Hypothesis

Our hypothesis is that the newly developed AI-powered software can generate accurate 3D spine reconstructions with significantly improved efficiency compared to the previous generation semi-automatic software.

### Design

Retrospective cohort data

### Introduction

3D reconstructions of the spine have been used for over 30 years mainly in a research environment. The main limitation to their clinical use has been access to rapid and accurate 3D reconstructions. This study assesses the accuracy and reliability of a newly developed AI-powered software for generating 3D spine reconstructions from 2D X-ray images, focusing on idiopathic scoliosis.

### Methods

The study initially focuses on validating the accuracy of the AI-powered software by comparing 85 automatic reconstructions with those performed using a semi-automatic tool, which has undergone third-party verification for reliability and accuracy. Clinical parameters, including Cobb angle, thoracic kyphosis, lumbar lordosis, pelvic tilt, and plane of maximal deformity, are assessed. Following validation, the study shifts to creating a robust database by generating 1000 reconstructions using the validated automatic software. Exclusion criteria involve patients who have undergone surgery for scoliosis. Radiographs were sourced from a specialized center's research image database spanning the years 2014 to 2018.

### Results

Mean differences were observed for thoracic kyphosis (3.86°±3.6), lumbar lordosis (3.85°± 3.8), pelvic tilt (1.74°±2.1), plane of maximal deformity (6.14°±6.1) and Cobb angle (4.77°±5.2). Strong positive correlation coefficients were found (r = 0.93 for thoracic kyphosis, 0.91 for lordosis, 0.93 for pelvic tilt, 0.89 for max plan and 0.71 for Cobb angle). Notably, the AI-powered software reduced the time required for a single 3D reconstruction to 2.13 minutes, demonstrating significant efficiency gains compared to the semi-automatic software, which took approximately 75 minutes per reconstruction.

### Conclusion

This study confirms the precision of 3D spine reconstructions produced by the AI software for database creation, highlighting the successful automation of a large-scale dataset. The implementation of this AI-powered software for rapid database generation provides a unique opportunity to systematically investigate and provides an efficient method to make 3D reconstruction available in the clinical setting.

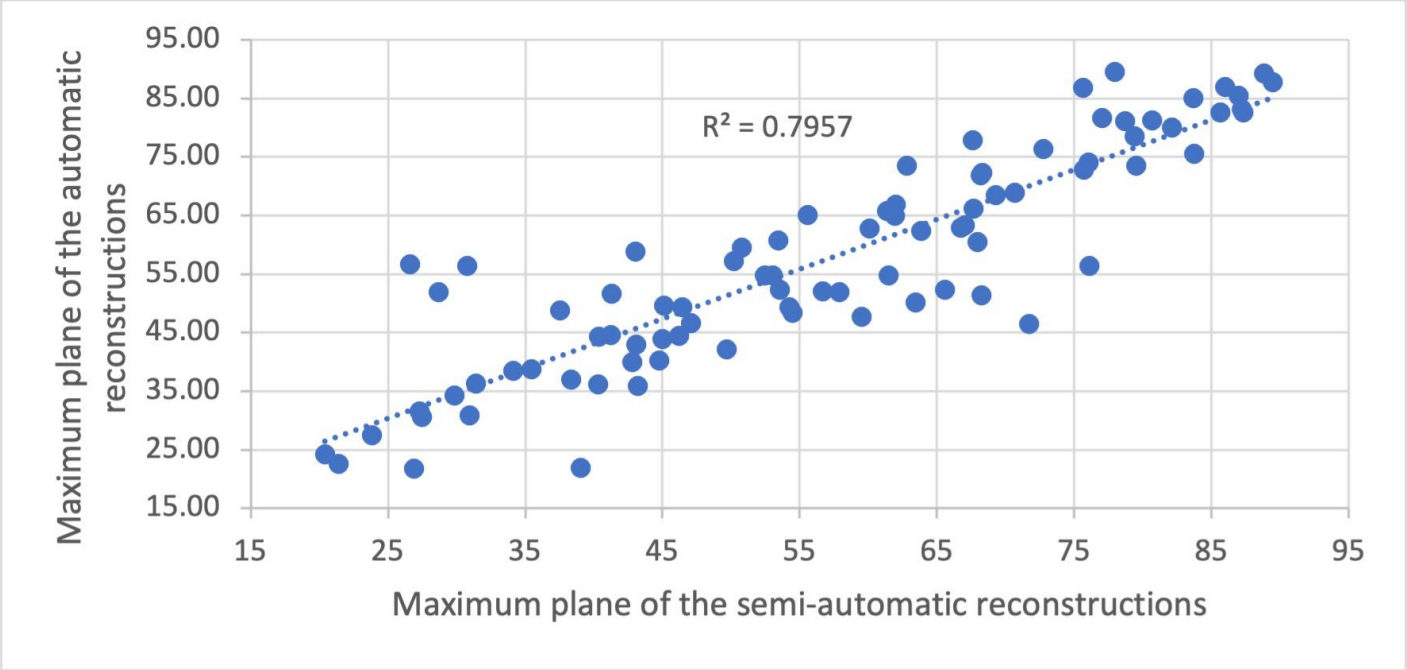



Figure 1 : Distribution of the different maximum plane angles

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #127. Novel Trizonal Membrane for Bone Generation in a Rabbit Posterolateral Spine Fusion Model

Takashi Hirase, MPH; Ava Brozovich, MD; Austin Q. Nguyen, MD; Enrica De Rosa, MS; *Comron Saifi, MD*; Francesca Taraballi, PhD; Weiner K. Bradley, MD

### Hypothesis

The biomimetic osteoinductive/osteoconductive collagen-based 3ZM is an effective scaffold for bone generation in a rabbit orthotopic posterolateral spine fusion model. We hypothesize this scaffold may have the potential to be utilized as an effective tool for spinal fusion.

### Design

The osteoinductive and osteoconductive potential of the 3ZM was evaluated using a preclinical rabbit posterolateral fusion model. Suturability was also assessed.

### Introduction

This study aimed to investigate a new biomimetic osteoinductive collagen-based trizonal membrane (3ZM) that exhibits molecular mimicry with human periosteum to be used alone as a scaffold for bone generation in a rabbit spinal fusion model. This first phase was aimed at (a) demonstrating the ability to form bone in this milieu and (b) to verify suturability of the material for use in fusions.

### Methods

3ZM was fabricated using type I collagen from bovine tendon in GMP-like condition. A rabbit posterolateral spine fusion model was used to evaluate the osteoinductive and osteoconductive potential of the 3ZM. 3ZM was implanted within the bilateral lumbar paraspinal musculature of eight New Zealand white rabbits. The suturability of the 3ZM was investigated using 3-0 PDS sutures. Bone formation was assessed at 3, 6, and 9 weeks using computer tomography (CT) bone quantification analysis. The implanted 3ZM was explanted at 9 weeks and histological analysis was performed to evaluate for de novo bone formation.

### Results

The 3ZM demonstrated excellent suturability affording fixation in the intertransverse process interval. Successful de novo trabecular bone formation was observed at 3, 6, and 9 weeks via CT bone quantification. The mean de novo trabecular bone formation at 3, 6, and 9 weeks were 6140.6 ± 636.6 mm3, 2236.0 ± 1149.5 mm3, and 2913.2 ± 910.0 mm3 respectively. The mean de novo cortical bone formation at 3, 6, and 9 weeks were 3892.1 ± 423.0 mm3, 3753.3 ± 725.4 mm3, and 3776.4 ± 836.3 mm3 respectively.

### Conclusion

The biomimetic osteoinductive/osteoconductive collagen-based 3ZM is an effective material for bone generation in a rabbit orthotopic posterolateral spine fusion model. Additional in vivo and clinical trials will be required to further determine the efficacy and safety of this product in the clinical setting.

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #128. A Transcriptomic Assessments of Pulmonary Development Based on Porcine Model of Early-Onset Scoliosis Combined with Thoracic Insufficiency Syndrome Treated by a Novel Growth-Friendly Device

*Ying Zhang, MD*; Jingming Xie, MD; Yingsong Wang, MD; Zhiyue Shi, MD; Quan Li, MD; Tao Li, MD; Ni Bi, MD; Zhi Zhao, MD; Jin Zhou, MD

### Hypothesis

There were differentially expressed mRNAs (DE-mRNAs) that may be key regulatory genes of pulmonary hypoplasia treated with NGFD in EOS + TIS.

### Design

A comparative study with large animal model of EOS+TIS treated with NGFD and transcriptome analysis.

### Introduction

EOS+TIS demonstrated with pulmonary hypoplasia. However, there is little study on the outcomes based on large animal models for evaluating pulmonary development of EOS+TIS treated with NGFD in therapeutic studies and basic research at the transcriptomic level.

### Methods

Two groups (treatment and model groups) were set up in this study (6 Yorkshire pigs in each group). Imaging studies, pathological analysis, RNA sequencing, bioinformatics analysis of lung tissue were performed.

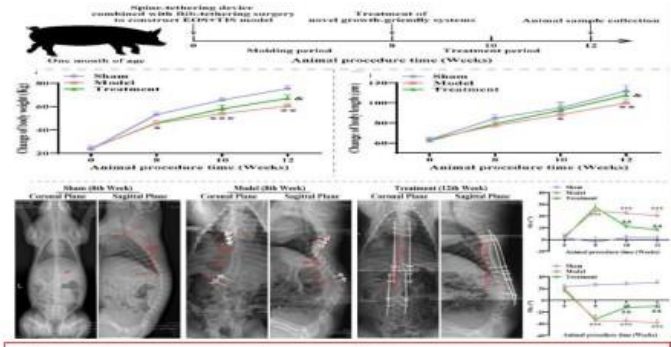
### Results

Implantation of NGFD increased body weight, body length, and TLV and decreased the θs and θk for EOS+TIS model. It also ameliorated the EOS+TIS-induced thickening of the alveolar wall, increase in alveolar spaces, and decrease in alveolar number and diameter. In lung tissue, a total of 790 novel growth-friendly system-associated DEGs were identified, and they were mainly involved in the regulation of immune, inflammatory, calcium transport and vascular development. Among these DEGs, BDKRB1, THBS1, DUSP1, IDO1, and SPINK5 were hub genes, and their differential expression was consistent with RNA-seq results in lung tissues.

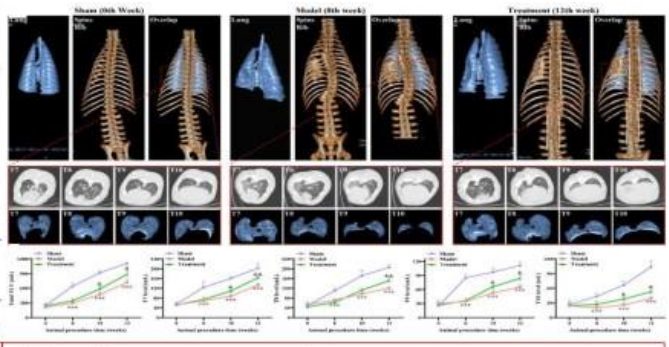
### Conclusion

Scoliosis and pulmonary hypoplasia of EOS+TIS model treated by NGFD have been alleviated. We also reveal the molecular mechanism of improvement of pulmonary hypoplasia. These findings will provide a solid theoretical foundation for future applications of novel growth-friendly system in clinical therapy.

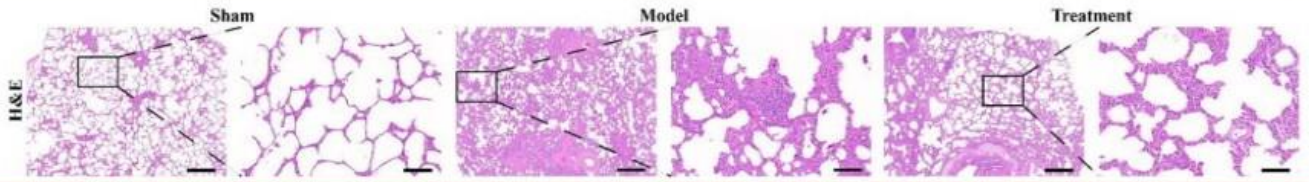
## Session 8B | Kyphosis & Basic Science Abstracts



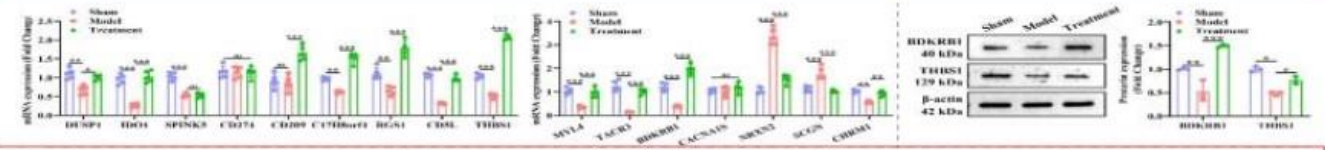
Effect of NGFD on scoliosis in the EOS+TIS.



Effect of NGFD on TLV in the EOS+TIS.




Effect of NGFD on lung histopathology in EOS+TIS.




Expression validation of NGFD-associated DEGs.

porcine model of early-onset scoliosis combined with thoracic insufficiency syndrome treated by a novel growth-friendly device

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #129. Tethering of Kyphotic Deformities in the Hyperkyphotic Porcine Model: Insights for All Vertebral Growth Modulation

*Matthew A. Halanski, MD*; Cameron Jeffers, BS; David M. Bennett, MD; Brittney Kokinos, MS; Susan Hamman, MD; Ellen Leiferman, DVM; Max Twedt, BS; James Sypherd; Thomas Crenshaw, PhD

### Hypothesis
Posterior vertebral tethering can be used to correct deformities through growth modulation in the hyperkyphotic porcine model.

### Design
Prospective Cohort

### Introduction
Growth modulation has been used in coronal plane deformities, this study evaluates vertebral tethering to correct kyphotic deformities.

### Methods
70 piglets were divided into non-operative (N=23) and operative cohorts (N=47). Piglets underwent vertebral periosteal resection (N=6), Disc pressure testing (N=21), Distraction-based (N=4) or High (N=4) and Low (N=4) tension single level posterior tethering, and multi-level High (N=4) or Low (N=4) tension posterior tethering. Digital radiographs were used to measure Cobb angles and regional vertebral growth rates were measured using pulsed fluorochrome labeling using a custom Matlab image analysis program used to measure distance between the labels.

### Results
Apical disc pressures decreased with increasing tether load and this was significant in the control spines (99+25 vs 61+39 kPa, p=0.02). Periosteal resection of the vertebra did not accelerate vertebral growth. At two-weeks, distraction-based and high-tension single level tethering resulted in significantly greater growth modulation (28+14%, 53+43%) than lower tether tension (-1+15% p=0.03). Higher tension resulted in increased (241+54 vs 157+12um/d, p=0.04) anterior and decreased (141+43, 198+ 38 um/d, p=0.001) posterior growth rates compared to internal physeal controls. No differences between the initial (17+10°, 18+/-4°, p=0.9) or final (15+6°, 12+8°, p=0.7) apical Cobb angles were found. Growth modulation was normalized at 2-4 weeks (p=0.6) between the low (14+11%) and high (10+10%) tensioned tethers. Serial Cobb measurements paralleled growth rate findings in the multi-tether cohorts. A significantly lower instrumented Cobb angle was found in the high-tension cohort (11.3+14° vs. 32+6° p=0.04) at week one, however after the initial 2 weeks, mean slopes (degree kyphosis/week) normalized becoming very similar between cohorts (-9.7 vs -10.4).

### Conclusion
(1) The hyperkyphotic pig model can be used to study vertebral growth modulation. (2) Sagittal deformities can be corrected by growth modulation. (3) Vertebral growth modulation, in the flexible spine, appears to be biphasic with an initial phase that is tether load dependent that later transitions into a tether load independent phase.

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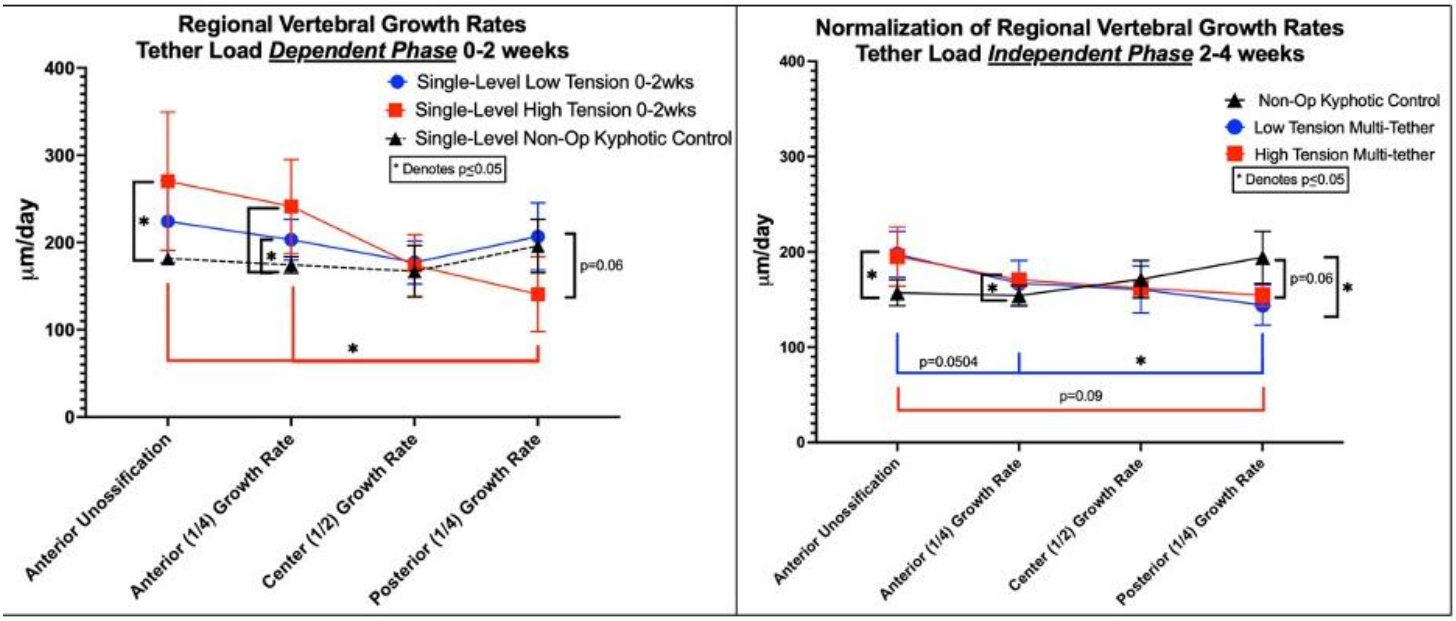

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #130. Zebrafish Pre-Clinical Models Implicate Oxidative Stress-Induced Intervertebral Extracellular Matrix Defects in Adolescent Idiopathic Scoliosis, and Identify Elevated Spine Stiffness as a Prognostic Biomarker

Josh Gopaul, BS; Patrick Pumputis; Ran Xu; Jenica VanGennip, PhD; Nikan Fakhari, PhD; Jerome Baranger, PhD; David E. Lebel, MD, PhD; Olivier Villemain, MD, PhD; *Brian Ciruna, PhD*

### Hypothesis
Increased spine stiffness drives AIS

### Design
prospective interventional

### Introduction
Patient exome/genome sequencing and mouse functional studies have associated genetic variants in musculoskeletal collagen and cartilaginous extracellular matrix (ECM) defects with a fraction of adolescent idiopathic scoliosis (AIS) cases. However, GWAS meta-analyses estimate that >95% of total genetic variance underlying AIS remains to be discovered. As the biology of AIS remains poorly understood, there are no prognostic biomarkers and treatment options remain limited to restrictive bracing and corrective surgery. Using zebrafish models of AIS, we discovered that oxidative stress and pro-inflammatory signals in the spinal cord, which develop because of cerebrospinal fluid homeostasis defects, are necessary and sufficient to drive spine curvature. Indeed, antioxidant and immunomodulating drugs can efficiently block scoliosis onset and severe progression in fish models. Although this provides proof-of-principle that AIS might be managed therapeutically, uncertainties regarding downstream mechanism and their link to human disease pose a barrier to clinical translation.

### Methods
Zebrafish genetics, electron microscopy, shear wave elastography, pharmacological intervention

### Results
Here, we demonstrate that oxidative stress in fish AIS models induces an unfolded protein response that is associated with collagenous ECM defects within developing intervertebral spine segments. Using shear wave elastography (SWE), we show that zebrafish scoliotic spines are consequently stiffer than healthy controls - a property also reported for intervertebral discs in human AIS patients. Remarkably, animals are significantly stiffer prior to scoliosis onset and increasing axial stiffness positively correlates with curve severity, suggesting a causal role for elevated stiffness in AIS. Finally, we demonstrate that antioxidant drugs known to suppress scoliosis also reduce spine stiffness to normal levels, providing a possible mechanistic link between oxidative stress and connective tissue/intervertebral defects identified in both fish and human AIS studies.

### Conclusion
As SWE is non-invasive and widely applied in the clinic, tissue stiffness may translate into a valuable prognostic biomarker and therapeutic target for AIS.

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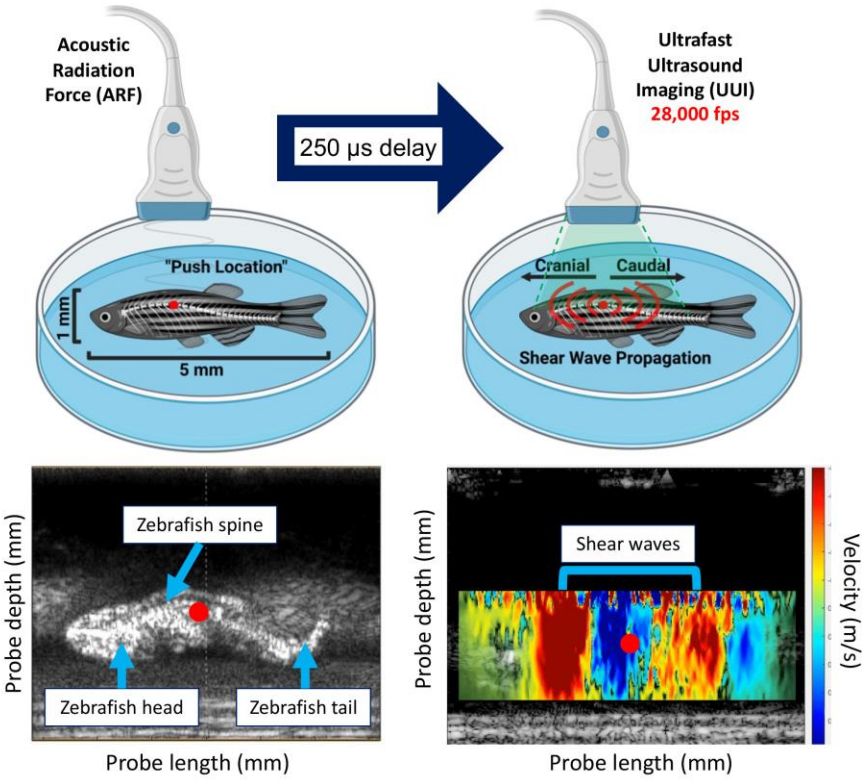


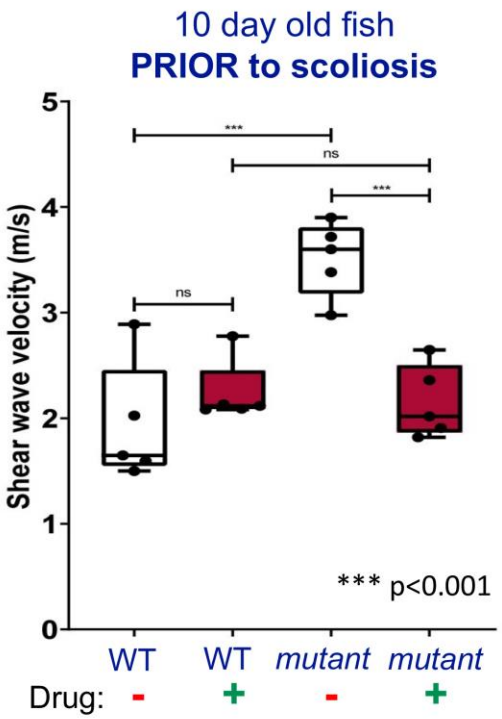

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #131. Machine Learning Clustering of Preoperative Fitness and Its Prognostic Value Following Deformity Correction

*Sarthak Mohanty, BS*; *Fthimnir Hassan, MPH*; Larae Klarenbeek-Mitchell, PT, DPT, OCS; David Ruderman, PT, DPT; Eric Schaum, PT, DPT; Erik Lewerenz, BS; Zeeshan M. Sardar, MD; Joseph M. Lombardi, MD; Ronald A. Lehman, MD; Lawrence G. Lenke, MD

### Hypothesis
Phenotypes based on functional fitness assessment preoperatively prognosticate medical complications following ASD correction.

### Design
Retrospective

### Introduction
Preop rehabilitation preceding ASD correction is associated with less postop disability. The impact of preop fitness on patients' presentation and subsequent outcomes remains unclear.

### Methods
Included patients underwent PSF≥8 levels and had sagittal deformity[PI-LL≥20°, T1PA≥20°, or C7SVA ≥4 cm]. Preoperative fitness was prospectively assessed through 6-Minute Walk Test(6MWT) and the Timed Sit-to-Stand Test. Fuzzy K-means machine learning clustering algorithm categorized patients into three fitness-based clusters: Deconditioned, Intermediate, and Strongly Conditioned. Primary outcome was 90-day(90D) medical readmission. Secondary outcomes included the length of stay(LOS) and intra-op complications. Exploratory analysis compared ODI sub-domains in 75 patients with baseline and two-year ODI. Clusters were compared using Tukey's post-hoc test following ANOVA with data presented as: [worst vs intermediate vs best fitness, P-value(ANOVA or Chi-Square)].

### Results
108 patients, 32 Deconditioned, 40 Intermediate, 32 Strongly Conditioned, were included. Age(P=0.1923), gender (P=0.5543), instrumented levels(P=0.9714), pelvic fixation(P=0.1397), preop T1PA(P=0.9470), and C7 SVA(P=0.4893) were comparable across cohorts. Patients with the best conditioning had the shortest sit to stand time(12.7 vs 11.5 vs 8.9;P=0.0035), highest speed during 6MWT(1.23 vs 1.69 vs 2.15 m/s;P=0.0103) and walked the farthest(1331.1 vs 1659.95 vs 1771.22;P<0.0001). While LOS was similar(6.44 vs 6.95 vs 6.11 days;P=0.2697), intra-op complication rates decreased with increasing fitness levels(50% vs 25% vs 11.11%, p=0.0015). 90D medical readmissions were lowest among patients with the best preop conditioning(37.5% vs 18.18% vs 11.11%; p=0.0014). In the exploratory analysis, preop ODI was significantly better with improved fitness(43.83 vs 34.0 vs 26.0;P<0.0001) with significant differences in all ODI domains aside from sleeping and standing. Two-year ODI scores were superior in patients with best baseline fitness(23 vs 25.4 vs 12.5;P=0.0005).

### Conclusion
Baseline fitness profiling in ASD patients offers predictive value for perioperative complications. Better preop fitness is associated with lower intra-op complication rates, lower early readmissions, and better two-year ODI scores.

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| | Deconditioned *Worst Fitness* [N=32] | Intermediate *Medium Fitness* [N=40] | Strong *Best Fitness* [N=36] | Worst vs. Best Fitness | Best vs. Medium Fitness | Worst vs. Medium Fitness |
|---|---|---|---|---|---|---|
| **Demographics and Baseline Alignment** | | | | | | |
| **Demographics** | | | | | | |
| Age | 58.56 ( 1.44 ) | 55.45 ( 1.3 ) | 56.3 ( 0.85 ) | 0.1812 | 0.5826 | 0.1122 |
| Gender [Male] | 6 (18.75) | 8 (20) | 4 (11.11) | 0.5543 | | |
| ASA Score | 1.92 (0.1) | 1.88 (0.07) | 1.73 (0.16) | 0.3335 | 0.3943 | 0.766 |
| Total Instrumented Levels (TIL) | 13.69 (0.62) | 13.45 (0.7) | 13.56 (0.75) | 0.8927 | 0.9181 | 0.8004 |
| Pelvic Fixation [Pelvic] | 30 (93.75) | 36 (90) | 28 (77.78) | 0.1397 | | |
| **Baseline Alignment** | | | | | | |
| Pelvic Incidence [PI] | 55.53 (5.33) | 62.5 (4.87) | 64.93 (3.93) | 0.1644 | 0.6997 | 0.3401 |
| PI - LL | 28.67 (5.34) | 27.49 (4.11) | 26 (4.51) | 0.9241 | 0.934 | 0.8622 |
| T1 Pelvic Angle [T1PA] | 28.35 (3.91) | 27.78 (3.8) | 29.49 (3.67) | 0.8332 | 0.749 | 0.9178 |
| C7 Sagittal Vertical Axis | 5.9 (1.6) | 4.73 (0.9) | 3.82 (1.11) | 0.292 | 0.5307 | 0.5264 |
| **Baseline Functional Testing** | | | | | | |
| **6 Minute Walk Test** | | | | | | |
| Systolic Resting Blood Pressure(BP) | 130.63 (1.9) | 126 (1.88) | 119.78 (1.27) | <0.0001 | 0.0079 | 0.0881 |
| Diastolic Resting BP | 81.31 (1.2) | 80.35 (1.6) | 77.89 (1.11) | 0.0401 | 0.2104 | 0.632 |
| Sit to Stand Test - Seconds | 12.71 (0.82) | 11.5 (0.92) | 8.9 (0.5) | 0.0002 | 0.0159 | 0.3308 |
| Gait Speed During 6 Min Walk (m/s) | 1.23 (0.06) | 1.69 (0.2) | 2.15 (0.27) | 0.0019 | 0.1769 | 0.028 |
| 6 Min. Walk Test(6MWT) Distance | 1331.06 (65.59) | 1659.95 (36.39) | 1771.22 (35.34) | <0.0001 | 0.0363 | <0.0001 |
| 6 Min. Walk Test(6MWT) Heart Rate(HR) | 112.5 (2.91) | 102.18 (3.57) | 120.33 (3.22) | 0.0756 | 0.0003 | 0.0286 |
| 6 Min. Walk Test(6MWT) HR - 1min | 101 (2.5) | 98.95 (3.81) | 107.56 (3.06) | 0.1021 | 0.0824 | 0.6542 |
| 6 Min. Walk Test(6MWT) HR - 2min | 92.75 (2.6) | 91.9 (3.59) | 102.89 (2.72) | 0.0089 | 0.0171 | 0.8485 |
| **Primary Outcome** | | | | | | |
| **Perioperative Complications** | | | | | | |
| Length of Hospital Stay | 6.44 (0.34) | 6.95 (0.41) | 6.11 (0.36) | 0.5098 | 0.1285 | 0.3367 |
| Intraoperative Complication | 16 (50) | 10 (25) | 4 (11.11) | 0.0015 | | |
| 90-Day Readmission | 12 (37.5) | 4 (18.18) | 2 (11.11) | 0.0014 | | |
| **Exploratory Outcome** | | | | | | |
| **Baseline, Preoperative Functional Scores** | | | | | | |
| Pain Intensity | 2.67 (0.34) | 1.53 (0.22) | 1.75 (0.28) | 0.0443 | 0.5414 | 0.0084 |
| Personal Care (Washing, Dressing, etc.) | 1.42 (0.22) | 0.76 (0.15) | 0.38 (0.09) | <0.0001 | 0.0309 | 0.0178 |
| Lifting | 2.75 (0.27) | 2.71 (0.2) | 2 (0.2) | 0.0312 | 0.0144 | 0.8956 |
| Walking | 2.33 (0.13) | 1.35 (0.15) | 1 (0.22) | <0.0001 | 0.1664 | <0.0001 |
| Sitting | 1.75 (0.17) | 1.82 (0.16) | 1 (0.16) | 0.0022 | 0.0005 | 0.7566 |
| Standing | 2.75 (0.24) | 2.65 (0.19) | 2.5 (0.22) | 0.4488 | 0.6133 | 0.739 |
| Sleeping | 1.56 (0.3) | 0.94 (0.16) | 0.88 (0.17) | 0.0463 | 0.7904 | 0.0758 |
| Employment/Homemaking | 1.75 (0.19) | 1.82 (0.15) | 1.38 (0.09) | 0.0855 | 0.0121 | 0.7642 |
| Social life | 2.58 (0.28) | 2.06 (0.16) | 1.25 (0.17) | 0.0002 | 0.0012 | 0.1093 |
| Traveling | 2.33 (0.3) | 1.35 (0.12) | 0.88 (0.11) | <0.0001 | 0.004 | 0.0047 |
| ODI score | 43.83 (3.61) | 34 (2.13) | 26 (1.41) | <0.0001 | 0.0027 | 0.0243 |
| **Two-Year, Functional Scores** | | | | | | |
| Pain Intensity | 1.63 (0.32) | 1.7 (0.24) | 0.03 (0.03) | <0.0001 | <0.0001 | 0.8524 |
| Personal Care (Washing, Dressing, etc.) | 0.63 (0.18) | 0.6 (0.11) | 0.06 (0.04) | 0.0039 | <0.0001 | 0.9045 |
| Lifting | 2.25 (0.27) | 2.2 (0.21) | 1.75 (0.23) | 0.1624 | 0.1585 | 0.8836 |
| Walking | 1 (0.27) | 0.9 (0.15) | 0.25 (0.08) | 0.0112 | 0.0003 | 0.7475 |
| Sitting | 0.75 (0.12) | 1.2 (0.12) | 0.75 (0.15) | >0.9999 | 0.0217 | 0.0095 |
| Standing | 1.63 (0.22) | 1.5 (0.23) | 1.06 (0.04) | 0.0158 | 0.0652 | 0.6945 |
| Sleeping | 0.38 (0.18) | 0.7 (0.16) | 1 (0.13) | 0.006 | 0.1479 | 0.1804 |
| Employment/Homemaking | 1.38 (0.28) | 1.3 (0.22) | 0.5 (0.09) | 0.0055 | 0.0012 | 0.8337 |
| Social life | 1.25 (0.17) | 1.6 (0.19) | 0.5 (0.09) | 0.0004 | <0.0001 | 0.1812 |
| Traveling | 0.63 (0.09) | 1 (0.16) | 0.5 (0.09) | 0.3212 | 0.0085 | 0.044 |
| ODI score | 23 (3.06) | 25.4 (2.65) | 12.5 (1.2) | 0.0029 | <0.0001 | 0.5567 |

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #132. Insights from Wearable Biometrics After ASD Surgery: Does Wearable Biometric Data (WBD) Correlate to Complications and 30-Day Readmission Better than Traditional Pros?

Rohit Bhan, MD, MS; Salim Yakdan, MD, MSCI; Jacob Greenberg, MD; *Brian J. Neuman, MD*; Kristen E. Jones, MD, FAANS

### Hypothesis

Patients with greater mobility captured by wearable biometric data (WBD) will have a less complicated post-operative-course.

### Design

Prospective

### Introduction

ASD surgery has been shown to provide substantial long-term benefit to patients, however many patients ask about short-term recovery in the 4-6 weeks after surgery. Traditional PROs have failed to reliably predict post-operative course, with studies showing inconsistent results. This may reflect PROs capturing a single moment in time, whereas pain, function, and activity are dynamic processes. WBD, including motion trackers like Fitbit, provide a more comprehensive picture of physical activity. We evaluated the relationship between WBD, PROMIS Physical Function, and postoperative course after ASD surgery.

### Methods

ASD patients were enrolled at their preoperative visit. PROMIS scores were collected and patients were provided a Fitbit to wear prior to surgery. Preoperatively, various activity metrics were recorded for a minimum of 1 week. Perioperative course and complications were recorded for 30 days after discharge, such as reoperation, DVT, dehiscence, infection, and others. Parametric and non-parametric analyses were performed to assess significance.

### Results

23 ASD patients were enrolled. Average fusions levels were 10.4 (SD = 3.6), all patients were fused to pelvis. 8 received all-posterior surgery and 15 received anterior-posterior surgery. 8 patients (35%) experienced perioperative complications and 3 (13%) patients were readmitted within 30-days of discharge. Patients with greater activity measured by WBD were less likely to experience complications. Between complication and non-complication groups, number of steps per activity bout was 44.5 and 81.0 ($p=0.017$), active time per bout was 1.78 and 2.59 ($p=0.028$), and number of steps per minute of activity was 23.5 and 29.1 ($p=0.028$) respectively (Figure 1). No difference was found for Physical Function between complication groups ($p=0.104$).

### Conclusion

Increased preoperative activity determined by Wearable Biometric Data was associated with decreased complications, however no relationship was found with self-reported activity questionnaires. These preliminary findings suggests that WBD is superior to traditional PROs in assessing activity levels and may have utility in predicting perioperative course.

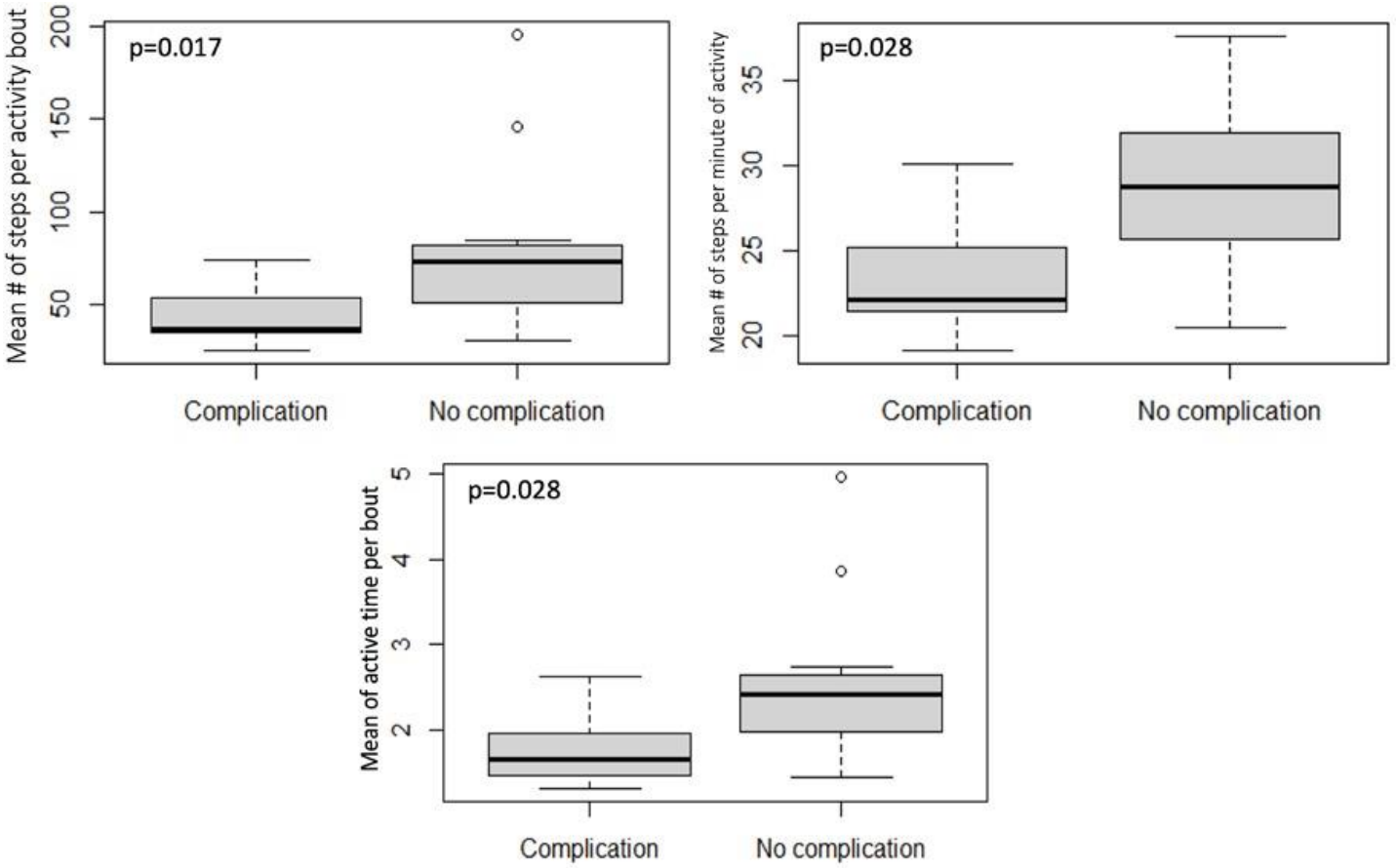


Figure 1: Box and whisker plots of activity measures in patients with and without complications

# Session 8B | Kyphosis & Basic Science Abstracts

## Paper #133. Computer-Aided Planning of Surgical Fusion Level for Adolescent Idiopathic Scoliosis Based on Deep Learning Models

*Zhong He, MD*; Wu-Jun Li, PhD; Neng Lu, MS; Xiaodong Qin, PhD; Yi Chen, MD; Zhen Liu, PhD; Xipu Chen, MD; Yong Qiu, PhD; *Zezhang Zhu, PhD*; Xiaodong Qin, PhD

### Hypothesis

Our advanced deep learning system will revolutionize surgical fusion level decisions in AIS treatment by accurately detecting and segmenting vertebrae in X-ray images. Its multi-module approach is expected to surpass current methods in precision, potentially improving surgical outcomes and minimizing complications.

### Design

Retrospective study.

### Introduction

This study aims to develop a deep learning system which achieves the target detection and instance segmentation of vertebrae in adolescent idiopathic scoliosis (AIS), assisting spine surgeons in choosing the optimal surgical fusion levels to improve the correction effect of scoliosis.

### Methods

This automatic system consists of the following modules: preprocessing module, deep learning network module, target detection module, instance segmentation module, and calculation module for surgical confidence. The system concatenates coarse-grained results of instance segmentation with the original X-ray image as input for the target detection network, recognizing whether the target vertebra needs to be fused by extracting multi-scale features from X-ray images. Surgical confidence is further refined with prior knowledge. A total of 1079 AIS patients who underwent posterior corrective surgery and were followed up for more than 2 years postoperatively were included for model training and internal testing.

### Results

According to internal test results, the accuracy of our proposed method for surgical levels prediction is 0.840, with a recall rate of 0.942. The mAP50 of the instance segmentation mask is 0.945, and mAP50-95 is 0.563. The mAP50 for the target detection box of our method is 0.951, and mAP50-95 is 0.690. We compared the performance of seven other mainstream algorithms: the mAP50 of instance segmentation masks ranged from 0.870 to 0.929, and mAP50-95 ranged from 0.485 to 0.569; the mAP50 for target detection boxes ranged from 0.885 to 0.935, and mAP50-95 ranged from 0.542 to 0.678.

### Conclusion

We propose an automatic method to determine AIS surgical fusion levels. Compared to current algorithms, it demonstrates SOTA (State-of-the-Art) performance. Our method is the first computer-assisted prediction system for AIS surgical fusion level based on instance segmentation and target detection. This proposed system can simultaneously extract semantic and instance features from spine X-ray images and effectively assess the correction range.