

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

Papers are listed in presentation order

### Paper #1. The Effect of Night-Time Versus Full-Time Bracing on the Sagittal Profile in Adolescent Idiopathic Scoliosis: A Propensity Score-Matched Study

Martin Heegaard, MD; Lærke C. Ragborg, MD; Amy L. McIntosh, MD; Megan E. Johnson, MD; Martin Gehrchen, MD, PhD; Daniel J. Sucato, MD, MS; Benny T. Dahl, MD, PhD, DMSc; Soren Ohrt-Nissen, MD, PhD

#### Hypothesis

The sagittal profile is similar post bracing, irrespective of the bracing regimen.

#### Design

Retrospective consecutive cohort study.

#### Introduction

Recent research indicates that brace treatment in adolescent idiopathic scoliosis (AIS) may induce hypokyphosis or even flat back deformity. Whether this effect differs between night-time bracing (NTB) and full-time bracing (FTB) is unknown. The current study aims to investigate the impact of NTB and FTB on the sagittal profile in AIS patients.

#### Methods

We included skeletally immature AIS patients with main curves ranging from 25-45° treated with either NTB or FTB. The two cohorts were propensity-score matched on Risser stage, age, major curve size, and global kyphosis at brace initiation. Coronal and sagittal radiographic parameters were gathered at the initiation and completion of brace treatment.

#### Results

Two-hundred seventy patients were eligible for inclusion. The matched cohorts included 73 patients in each group. The groups were well-matched although, in the NTB group, 85% were females compared with 69% in the FTB group ( $p=0.019$ ). In the coronal plane, curve progression  $>5^\circ$  was seen in 63% in the NTB group and 43% in FTB ( $p=0.012$ ). Progression to  $>50^\circ$  was seen in 45% vs. 29% ( $p=0.040$ ), respectively. The global kyphosis increased during bracing from  $33\pm 12^\circ$  to  $37\pm 13^\circ$  in the NTB group compared to a decrease from  $32\pm 12^\circ$  to  $30\pm 12^\circ$  in the FTB group ( $p=0.001$ ). Ten percent ( $n=7$ ) were hypokyphotic (global kyphosis  $<20^\circ$ ) post bracing in the NTB group compared with 25% ( $n=18$ ) in the FTB group ( $p=0.016$ ). Pelvic incidence (PI) and sacral slope (SS) were similar post bracing between the two groups, with pelvic tilt (PT) being slightly different (PI: NTB  $46^\circ \pm 10$ , FTB  $44^\circ \pm 9$ ,  $p=0.270$ ; SS: NTB  $39^\circ \pm 8$ , FTB  $40^\circ \pm 9$ ,  $p=0.530$ ; PT: NTB  $7^\circ \pm 7$ , FTB  $4^\circ \pm 7$ ,  $p=0.022$ ).

#### Conclusion

Patients treated with a NTB were statistically more likely to experience frontal plane curve progression  $>5^\circ$  (63%) and progression to a surgical magnitude (45%) when compared to FTB patients. Despite the frontal plane curve progression, the NTB group had more normal sagittal alignment, with fewer patients exhibiting global hypokyphosis ( $<20^\circ$ ) than the FTB at the completion of bracing.

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #2. Effectiveness of Nighttime Bracing or Fulltime Bracing in Moderate-Grade Adolescent Idiopathic Scoliosis (AIS)

Anastasios Charalampidis, MD; Elias Diarbakerli, PhD; Hans Möller, PhD; Allan Abbott, PhD; Paul Gerdhem, PhD

#### Hypothesis

Fulltime bracing would demonstrate superior effectiveness compared to nighttime bracing in the treatment of patients with AIS.

#### Design

Prospective clinical trial.

#### Introduction

Effectiveness of nighttime bracing or fulltime bracing in patients with moderate-grade AIS is controversial.

#### Methods

We compared individuals 9-17 years with moderate-grade AIS (25° to 40°) and at least one year of remaining growth and treated with a nighttime bracing as part of a randomized controlled trial to non-participants treated with a fulltime bracing. Patients were included in the study from January 10, 2013, through October 23, 2018. 45 individuals were treated with nighttime bracing and 44 individuals with fulltime bracing. All were followed minimum until skeletal maturity unless surgery occurred before maturity. In case of curve progression of more than 6 degrees in the nighttime brace group individuals were offered transition to a fulltime bracing. Surgery was offered if curve sizes were 45 degrees or larger. Information about any operations was recorded until 31st December 2023 from the patient's medical charts, corresponding to a range of 5-10 years from brace treatment start.

#### Results

The median age for the entire population was 12.8 (IQR;1.8) Age, gender, BMI, menarche for girls and Risser grade did not differ significantly between the two groups (all  $p \geq 0.1$ ). The median radiographic follow-up time after brace start and until the last available radiograph did not differ significantly between the night-time and the full-time brace group (33 (24) vs 33 (27);  $p=0.9$ ). At the last available follow-up, no significant differences were observed between the two groups with regards to the magnitude of the major curve ( $p=0.7$ ). Female gender (odds ratio [OR] 6.5; 95% confidence interval [CI] 1.12 to 37.38), lower Risser grade (OR 1.6; 95% CI 1.01 to 2.67) and larger curve size at the beginning of brace treatment (OR 0.7; 95% CI 0.65 to 0.87) increased odds for curve progression  $\geq 45$  degrees. 11 patients in the nighttime brace group and 6 in the fulltime brace group underwent surgery (OR 2.0; 95% CI 0.7 to 6.1). The mean time from brace start to surgery did not differ significantly between the two groups (33 (18) vs 31(13);  $p=0.2$ ).

#### Conclusion

Night-time bracing including a possibility to transition to full-time brace in case of progression demonstrated comparable effectiveness in the treatment of moderate-grade AIS.

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #3. Natural Course of Moderate Adolescent Idiopathic Scoliosis: A Mean 25-Year Follow-Up Study

Masayuki Ohashi, MD, PhD; Kei Watanabe, MD, PhD; Kazuhiro Hasegawa, MD, PhD; Toru Hirano, MD, PhD; Hideki Tashi, MD; Keitaro Minato, MD, PhD; Tatsuo Makino, MD; Masayuki Sato, MD

#### Hypothesis

Moderate adolescent idiopathic scoliosis (AIS) curves might continue to progress after skeletal maturity (SM) and negatively affect health-related quality of life (HRQOL) in middle age.

#### Design

A long-term follow-up study

#### Introduction

Previous studies for AIS indicate that curves  $<30^\circ$  at SM rarely progress, while those  $>45^\circ$ – $50^\circ$  continue to progress in adulthood and require surgical treatment. However, whether intervention or long-term follow-up is necessary for moderate curves between  $30^\circ$  and  $40^\circ$  remains unclear.

#### Methods

Of 155 nonoperatively treated patients with AIS who had major curve between  $30^\circ$  and  $40^\circ$  at SM (Risser 4), 58 patients (55 women) aged  $\geq 30$  years at the final follow-up were included (follow-up rate=37.4%). Curve type at SM was thoracic curve type in 24 patients, thoracolumbar/lumbar (TL/L) in 16, and double curve in 18. HRQOL questionnaires included SF-12, SRS-22, Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), and ODI. HRQOL scores were compared to age- and sex-matched healthy participants (Control, n=58).

#### Results

The mean age was 14.2 years at SM and 39.9 years at the survey, with a mean follow-up duration of 25.7 years. The mean Cobb angles of major curve [SM (n=58)/around 18 years of age (n=37)/final (n=47)] were  $35.6^\circ/40.1^\circ/48.3^\circ$  with annual increases of  $1.5^\circ$  from SM to the age of 18 years (n=37),  $0.2^\circ$  from the age of 18 years to the final follow-up (n=37), and  $0.5^\circ$  from SM to the final follow-up (n=47). At the final follow-up, major curves progressed to  $>50^\circ$  in 45.9% of patients, 82.4% of whom had already had major curves  $\geq 40^\circ$  at the age of 18 years. Conversely, patients demonstrated generally favorable HRQOL scores, including mental health, which were comparable with the control group, excluding SRS-22 self-image (AIS 2.8 vs. Control 3.5,  $p < 0.001$ ). Four patients (curve types; thoracic in 1 patient, TL/L in 2, and double in 1) underwent spinal fusion after this survey.

#### Conclusion

Although the curve progression declined with age,  $>40\%$  of moderate curves at SM were  $>50^\circ$  during mean 25-year follow-up. Therefore, moderate curves, especially those with  $\geq 40^\circ$  at the age approximately 18 years, are warranted for further follow-up. Additionally, the patients should be informed that the curves were associated with negative self-image, although it did not always cause significant psychosocial issues.

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #4. Does VBT Cause Disc and Facet Joint Degeneration? An MRI Study with Minimum 5-Years Follow-Up

Altug Yucekul, MD; Feyzi Kilic, MD; Atahan Durbas; Tais Zulemyan, MSc; Elif Gizem Carus, MS; Aynur Kaval; Gokhan Ergene, MD; Sahin Senay, MD; Pinar Yalinay Dikmen, MD; Sule Turgut Balci, MD; Ercan Karaarslan, MD; Yasemin Yavuz, PhD; Caqlar Yilgor, MD; Ahmet Alanay, MD

#### Hypothesis

VBT may cause degeneration at both intermediate and adjacent levels.

#### Design

Retrospective analysis of a prospectively collected data

#### Introduction

VBT is believed to prevent disc and facet degeneration due to its less rigid nature. While VBT's flexibility may be advantageous, the potential for compression-induced degeneration needs further research. The aim was to analyze the changes in the intermediate and adjacent levels, at least 5 years after surgery.

#### Methods

Demographic, perioperative, clinical and radiographic data were collected. Skeletal maturity and height were assessed at each follow-up. Curve behavior and mechanical complications were recorded. Whole spine MRI was obtained preoperatively on a routine basis. Follow-up MRI (between T2-S1) was obtained at a minimum of 5 years post-op. Disc and facet scores were compared using McNemar's Test and Related Samples Marginal Homogeneity Test.

#### Results

Out of the first 49 consecutive patients operated between 2014-2018, 35 (71.4%) were included. 34 (97%) were female. Mean age was 12.6 (9.5–16). Median Sanders was 4 (1-7). Mean preop major curve was 49 (40-73) degrees. 28 had a thoracic VBT, while 4 had thoracolumbar and 3 had bilateral. A median of 7 (5-11) levels were tethered. Preop mean height of 155.1 (130-178) was increased to 162.7 (147-189) at the latest f-up. At the time of the MRI (mean 72.5±14.8 (60–119) months), the median Sanders was 8 (7-8). Analyses of changes in thoracic disc and facet scores revealed no differences ( $p>0.05$ ). For the lumbar levels, 23 patients were graded as normal both at preop and postop. 3 patients that already had multilevel facet degeneration did not show any deterioration. However, 2 patients that had single level disc degeneration had a 1-point increase. Of the remaining 7 patients that were graded normal at preop, 2 experienced disc, 2 experienced facet, while 3 experienced both disc and facet degeneration, all of which were mild and located at the lower adjacent segments.

#### Conclusion

Intermediate discs and facet joints were preserved after growth modulation with VBT surgery at a mean of 72.5 months of follow-up. 6% of the patients experienced deterioration of previously degenerated discs, while lower adjacent facets had a mild degeneration in 20% of the patients. Studies in larger cohorts with longer follow-up are warranted to have more in-depth analyses of the effects of relative stabilization and altered biomechanical loads.

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #5. Changing Complication Trends After Anterior Vertebral Body Tethering (AVBT): 10-Year Experience

Taemin Oh, MD; Cleopatra Nehme, BS; Amer F. Samdani, MD; Joshua M. Pahys, MD; Jessica Steindler, BA; Sarah Nice, BS; Kaitlin Kirk, BS; Amanda Stutman, BS; Camille Brown, BS; Natalie Williams, BS; Emily Nice, BS; Steven W. Hwang, MD

#### Hypothesis

Overall complication rates have decreased over time but also transitioned from early overcorrection to more undercorrection and breakages.

#### Design

Single center retrospective study

#### Introduction

aVBT is an alternative surgery to treat scoliosis but is associated with unique complications such as overcorrection, breakage, and adding-on. We reviewed our series of complications from over a decade.

#### Methods

We reviewed all patients who underwent aVBT between 2011-2020 with 2-year follow-up (f/u) and identified those who had complications. We divided patients into 3 groups due to case volume: 2011-2015, 2016-2017, and 2018-2020.

Complications were categorized as follows: tether breakage (n=133), overcorrection (n=41), adding-on (n=11), curve progression (n=10), and miscellaneous (n=4). Breakage was defined as  $>5^\circ$  interscrew angle change between any f/u or largest Cobb  $>35^\circ$  at last f/u +  $>5^\circ$  change in Cobb between f/u intervals. Baseline demographics, radiographic parameters, and complication rates were compared across the groups.

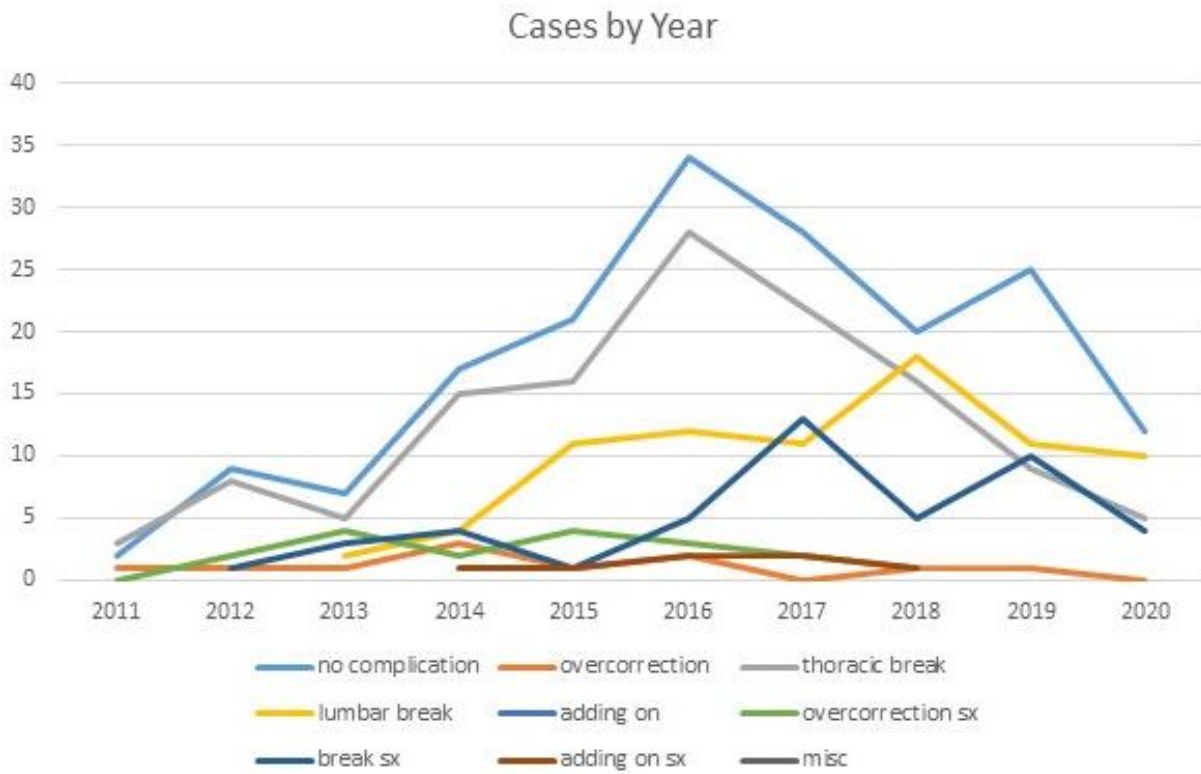
#### Results

200/388 patients (52%) developed complications and 75 (19%) required additional surgery with a mean f/u of  $55.9 \pm 22.3$  months. Mean age was  $12.6 \pm 1.4$  years, with F:M ratio of 9:1, and the vast majority were skeletally immature. 65% of patients underwent single thoracic tethers. Over time, there has been an increase in age at surgery ( $p < 0.05$ ), curve magnitude ( $p < 0.05$ ), more patients with closed triradiate cartilages ( $p < 0.05$ ) and a trend towards more double or lumbar curves ( $p = 0.09$ ). Type of complications have changed significantly over time ( $p < 0.05$ ) with overcorrection occurring in 13% of cases [2011-2015] then decreasing to 4% and 2% subsequently ( $p < 0.05$ ). The incidence of breakage was 49% [2011-2016] then 55% [2016-2017] then 59% [2018-2020], with respective revision surgery rates of 6% to 11% to 13% ( $p > 0.05$ ). There has been a significant increase in number of lumbar breakage and decrease in thoracic breakage ( $p < 0.05$ ) likely related to more double and lumbar aVBTs. The mean thoracic Cobb of the entire cohort was  $24 \pm 14^\circ$  at last f/u. However the mean f/u was shorter (38 vs. 56 vs. 79 months,  $p < 0.05$ ) in the more recent group.

#### Conclusion

Our 10-year experience with aVBT reflects the lessons learned where overcorrection and associated revision surgery have diminished over time with a subsequent increase in breakages and surgery.

Session 1 | Adolescent Idiopathic Scoliosis Abstracts



## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #6. What Predicts a Successful Result in Vertebral Body Tethering?

Julia Todderud, BA; Todd A. Milbrandt, MD, MS; *D. Dean Potter, MD; A. Noelle Larson, MD*

#### Hypothesis

We hypothesize that lower preoperative curve magnitude and greater intraoperative correction correlate with VBT success.

#### Design

Retrospective review of 87 patients aged 9 to 16 treated with VBT surgery at a single institution with 2-year surgical outcomes.

#### Introduction

Vertebral body tethering (VBT) is a non-fusion alternative for management of pediatric scoliosis that allows for growth and flexibility of the spine. However, current rates of revision for VBT range 14%-25%. Current indications for VBT are skeletally immature AIS patients with a flexible major curve of 30-65 degrees and failure of bracing. This study aims to evaluate perioperative factors influencing the success of VBT.

#### Methods

Success of VBT was defined as a major Cobb <35 degrees and no re-operation at the two-years. 70 patients were considered successful (80%), 17 patients were considered unsuccessful (20%). The peri-operative factors associated with these patient populations were stratified and compared to evaluate potential characteristics for predicting VBT outcomes. Evaluations of significance were performed via two-sample t-tests.

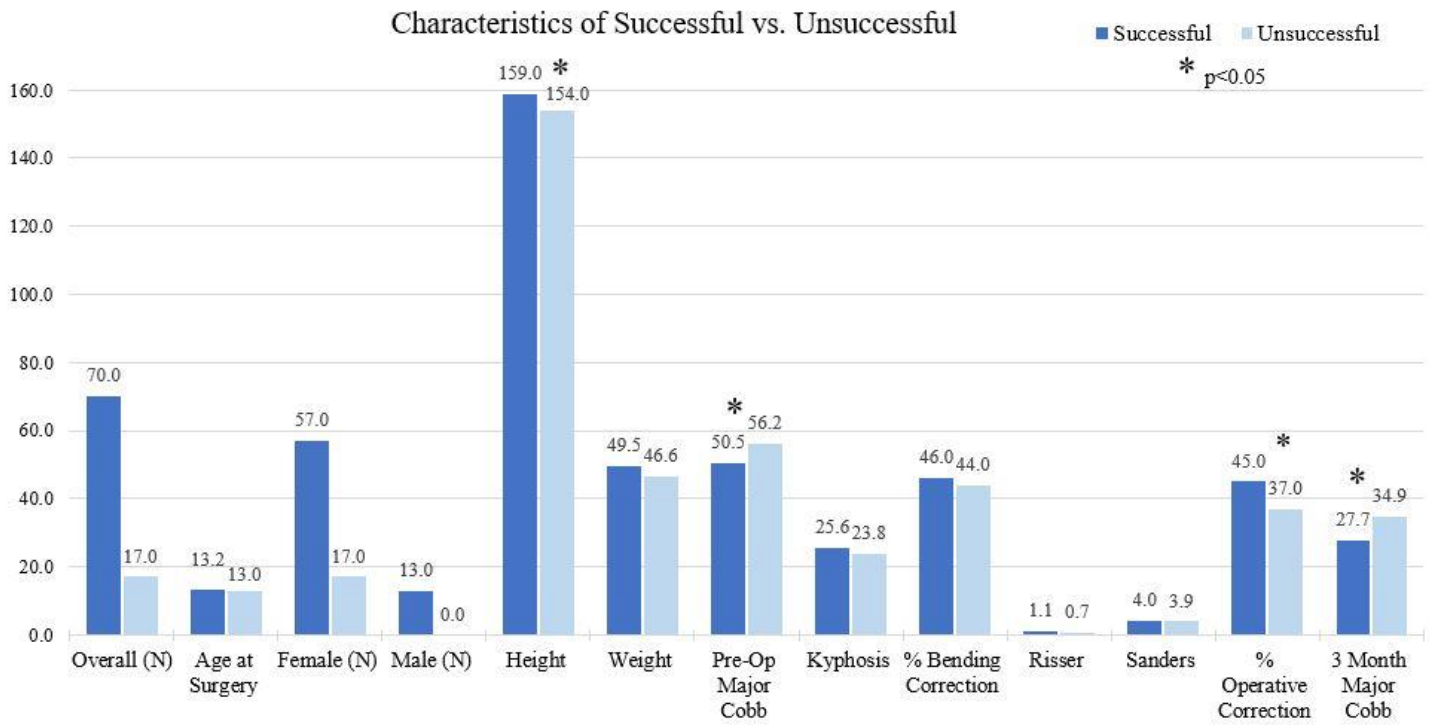
#### Results

Perioperative factors such as BMI, age, Risser/Sanders score, pre-operative major Cobb, percent correction on bending films, and percent correction at 3 months post-operative visit were considered in evaluation of contributors to tethering outcomes. Of the 17 patients not considered successful 4 had suspected cord breakage and 8 (9%) underwent reoperation, with 3 of the reoperations due to overcorrection. The VBT patients who were successful showed significantly higher percent correction at first erect (45% compared to 37%,  $p < 0.01$ ), lower preoperative major Cobb angles (50.5 compared to 56.2,  $p < 0.01$ ), and preoperative greater height (159 cm compared to 154 cm,  $p = 0.02$ ). They also demonstrated significantly better correction with lower Cobb angles at 3 months compared to the unsuccessful group (27.7 compared to 34.9,  $p < 0.01$ ). Values for pre-operative kyphosis, correction with bending, weight, Risser score, and Sanders score did show differences between the patient groups but did not reach significance.

#### Conclusion

Patients with smaller curve magnitudes, greater standing height, and with greater pre-operative correction tended toward better outcomes at 2-year follow-up. These results indicate a need for maximizing intraoperative correction and careful patient selection.

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts



Perioperative metrics of successful and unsuccessful VBT patients.



## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #7. Early Detection of Progressive Adolescent Idiopathic Scoliosis by Unsupervised Machine Learning Clustered Bone Microarchitecture Phenotypes: A 3-Year Prospective Longitudinal Study

Kenneth Guangpu Yang, PhD, MBBS; Adam Yiu-chung Lau, MBBS, FRCS; Wayne Yuk-wai Lee, PhD; Alec Lik-hang Hung, MBBS, MS, FRCS; Tsz-Ping Lam, MBBS, FRCS; Jack Chun-yiu Cheng, MD, FRCS

#### Hypothesis

Bone microarchitecture phenotype is an important early detectable prognostic factor for progressive AIS.

#### Design

A longitudinal cohort study

#### Introduction

Abnormal bone qualities are known prognostic factors of curve progression in AIS. Recent unsupervised machine learning study from 11 high-resolution peripheral QCT (HRpQCT) generated parameters have identified 3 bone microarchitecture phenotype clusters in AIS of prognostic values on curve progression to surgical threshold from the first visit. This study aimed to investigate whether bone microarchitecture phenotype could predict risk of curve progression in early AIS girls (Cobb:10-20°).

#### Methods

AIS girls at Thumb Ossification Composite Index (TOCI) 4-6 (Sanders SSMS 2-5) corresponding to peak height velocity were recruited. Femoral neck was scanned by DXA and distal radius by HRpQCT at their first visit. Bone phenotypes were clustered by our established unsupervised machine learning model. Patients were followed up longitudinally at 6-month interval for 3 years.

#### Results

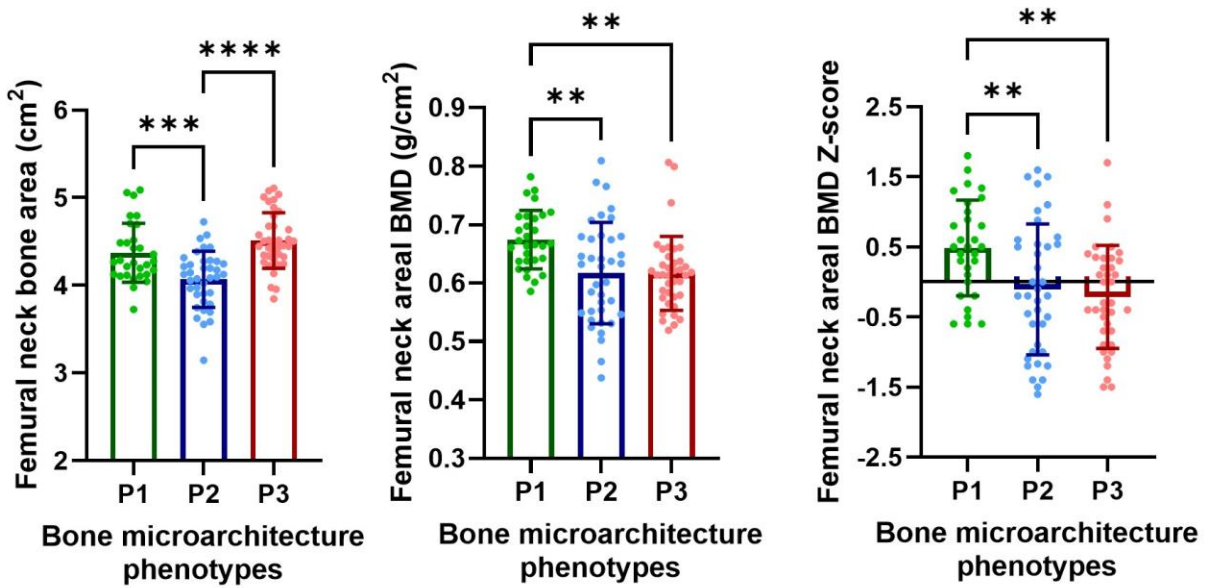
106 AIS girls (11.8±0.9y/o; Cobb:14.7±3.2°) without prior bracing were recruited at their first visit. Features of their bone phenotype clusters were in line with our previous reports. Phenotype-1 had normal bone qualities. Phenotype-2 had smaller bone volume and lower DXA Z-score. Phenotype-3 had lower cortical BMD and deranged trabecular microarchitecture with accompanying lower DXA Z-score. (Fig. 1A) No significant differences of spinal profile were found between the 3 bone phenotype clusters at baseline. During the 3-year follow-up, 15 girls in Phenotype-2 (adjOR=5.39) and 15 girls in Phenotype-3 (adjOR=3.67) had curve progression ≥ 6° (comparing with 7 girls in Phenotype-1) with their predictive values being significantly higher than DXA Z-score. (Fig. 1B)

#### Conclusion

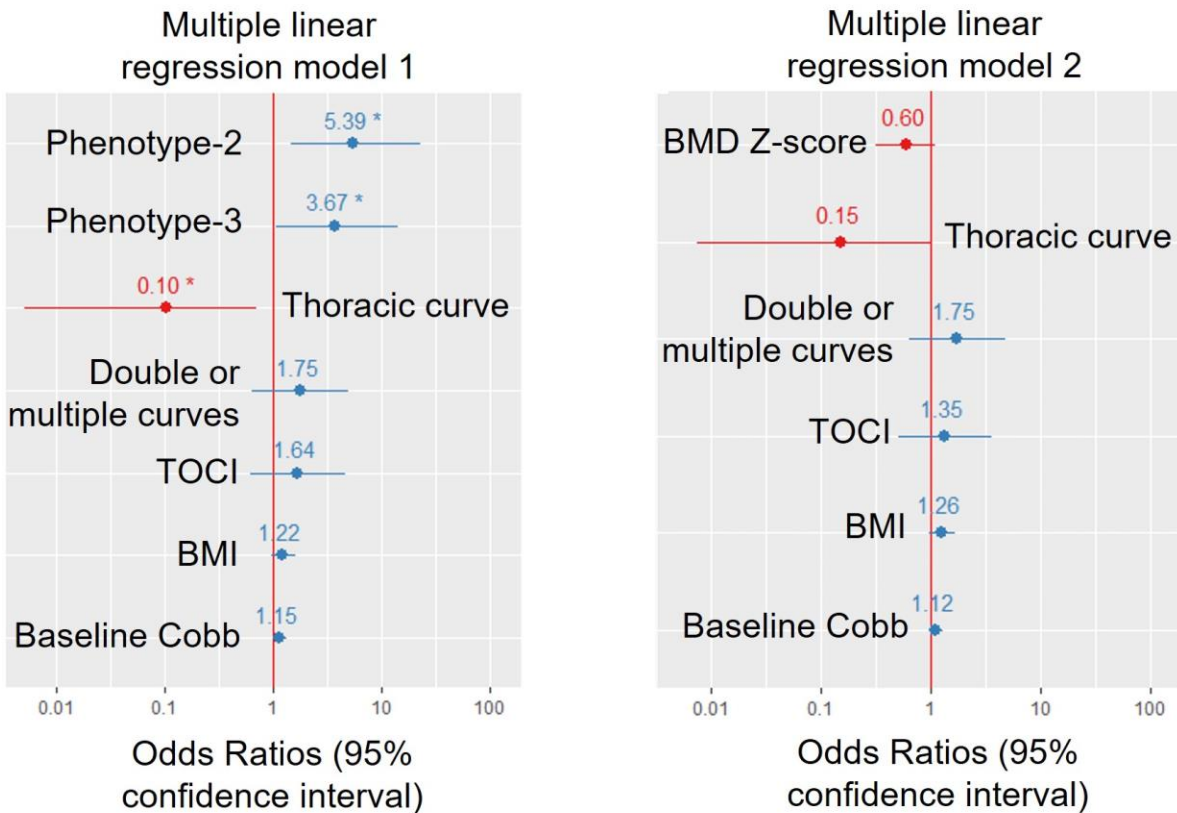
Bone Microarchitecture Phenotype 2 and 3 were found to have significantly higher prognostic value for curve progression in early AIS (Cobb:10-20°) at their first visit reflecting the importance of bone qualities in the etiopathogenesis of AIS. This together with our previous report on prediction of curve progression to surgical threshold could have important clinical implications. We might consider starting early bracing, PSSE and nutritional intervention for the high-risk group with curve less than the current recommended bracing threshold.

Session 1 | Adolescent Idiopathic Scoliosis Abstracts

A



B



## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #8. Feasibility of Using Artificial Intelligence to Predict Postoperative Health-Related Quality of Life for Adolescent Idiopathic Scoliosis

Dusan Kovacevic, MD; Aazad Abbas, MD; Gurjovan Sahi, MD; Johnathan Lex, MD; Jay Toor, MD; Suken A. Shah, MD; Amer F. Samdani, MD; Peter O. Newton, MD; Michael P. Kelly, MD; Harms Study Group; Firoz Miyanji, MD

#### Hypothesis

Machine learning models will not accurately predict Health-Related Quality of Life (HRQoL) outcomes for AIS surgery at 2 yrs post-op.

#### Design

Prospective, multicenter

#### Introduction

The impact on Health-Related Quality of Life (HRQoL) following scoliosis surgery is well-documented, however, there is limited consensus on preoperative and intraoperative strategies to optimize HRQoL outcomes following surgery. Accurate prediction of postoperative outcomes can guide operative planning, ultimately leading to better HRQoL. This feasibility study aimed to generate machine learning models (MLMs) using preoperative and intraoperative variables to accurately predict postoperative HRQoL outcomes following AIS surgery.

#### Methods

A prospective, longitudinal, multicenter database was queried to identify Lenke 1 or 5 curves with minimum 2yr f/u. MLMs were generated using various preoperative and intraoperative factors to predict the difference in SRS-22 scores from preoperative assessment to 2 yr f/u. MLMs were compared to a model that estimates the mean score by evaluating the coefficient of determination ( $R^2$ ) and the number of times the prediction was within a predesignated value of the actual score (i.e. buffer accuracy).

#### Results

A total of 1,417 patients were included. The stochastic gradient descent (SGD) model had the highest  $R^2$  for all SRS-22 scores (0.31–0.64). For 0.5-buffer accuracy, the linear regression model performed best for the satisfaction (66.2%), self-image (70.1%), pain (65.7%), and total SRS-22 scores (80.9%), while the SGD model performed best for the mental health (54.9%) and general function SRS-22 scores (79.9%). The SGD model had the highest 1-buffer accuracy across all SRS-22 scores (87.4%–97.2%). All MLMs, except for the AdaBoost model, outperformed the mean estimates on all accuracy metrics across each outcome.

#### Conclusion

MLMs accurately predicted the difference in HRQoL outcomes for AIS patients using preoperative and intraoperative factors. Findings provide key insights into the feasibility of implementing MLMs to guide operative planning and counsel patients on expected outcomes of surgical management. Future work should aim to optimize these factors to ultimately maximize patient outcomes.

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

Table 1. Training and testing results for the machine learning models predicting differences in total Scoliosis Research Society-22 scores.

Model Name	Coefficient of Determination (R <sup>2</sup> )	0.25-Buffer Accuracy (%)	0.5-Buffer Accuracy (%)	1-Buffer Accuracy (%)
Training				
Mean Estimates	0	43.0	75.0	95.1
Linear Regression	0.36	51.3	84.7	97.9
Stochastic Gradient Descent	0.35	51.4	84.3	97.8
K-Nearest Neighbour	0.46	54.5	84.9	98.7
Random Forest	0.89	90.0	98.9	99.9
AdaBoost	0.28	38.7	73.7	99.9
Neural Network	0.75	74.0	95.1	99.8
Testing				
Mean Estimates	0	39.5	70.1	93.2
Linear Regression	0.35	51.9	80.9	96.9
Stochastic Gradient Descent	0.35	52.2	80.3	97.2
K-Nearest Neighbour	0.29	44.4	78.4	96.3
Random Forest	0.34	47.8	79.6	96.9
AdaBoost	0.20	40.7	71.9	96.3
Neural Network	0.24	45.1	75.9	96.3

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #9. Machine Learning Algorithms for Predicting Future Curve in Female Adolescent Idiopathic Scoliosis Patients Based on the Data from the Minimal Visits

Shuhei Ohyama, MD; Satoshi Maki, MD, PhD; Toshiaki Kotani, MD, PhD; Yosuke Ogata, MD; Yasushi Iijima, MD, PhD; Tsutomu Akazawa, MD, PhD; Tsuyoshi Sakuma, MD, PhD; Kazuhide Inage, MD, PhD; Shohei Minami, MD, PhD; Seiji Ohtori, MD

#### Hypothesis

The machine learning (ML)-based model using items commonly evaluated based on minimal visits accurately predicts future curves in female patients with adolescent idiopathic scoliosis (AIS).

#### Design

Retrospective cohort study.

#### Introduction

Identifying the risk of AIS progression is important in determining treatment strategies. Previous models predicting future curves for patients with AIS had difficulty adapting to the routine practice because these models required numerous visits and detailed radiographically features. Several studies have investigated ML-based models for AIS prediction. However, those utilizing an ML approach to predict the progression of AIS from data of minimal visits have shown limited accuracy.

#### Methods

We studied 887 girls with AIS. Patient data, including demographic and radiographic data were collected at the first, second, and last visits. Angular progression was defined as a Cobb angle greater than 25 degrees for each of the proximal thoracic (PT), main thoracic (MT), and thoracolumbar/lumbar (TLL) curves at the last visit. ML algorithms were employed to develop individual binary classification models and individual regression models for each type of curve (PT, MT, and TLL) using PyCaret in Python. Multiple models were explored and analyzed, with the selection of optimal models based on the area under the curve (AUC) and Recall scores for binary classification models and coefficient of determination (R<sup>2</sup>) and median absolute error (MAE) for regression models. For all models, we evaluated Shapley Additive Explanations (SHAP) values.

#### Results

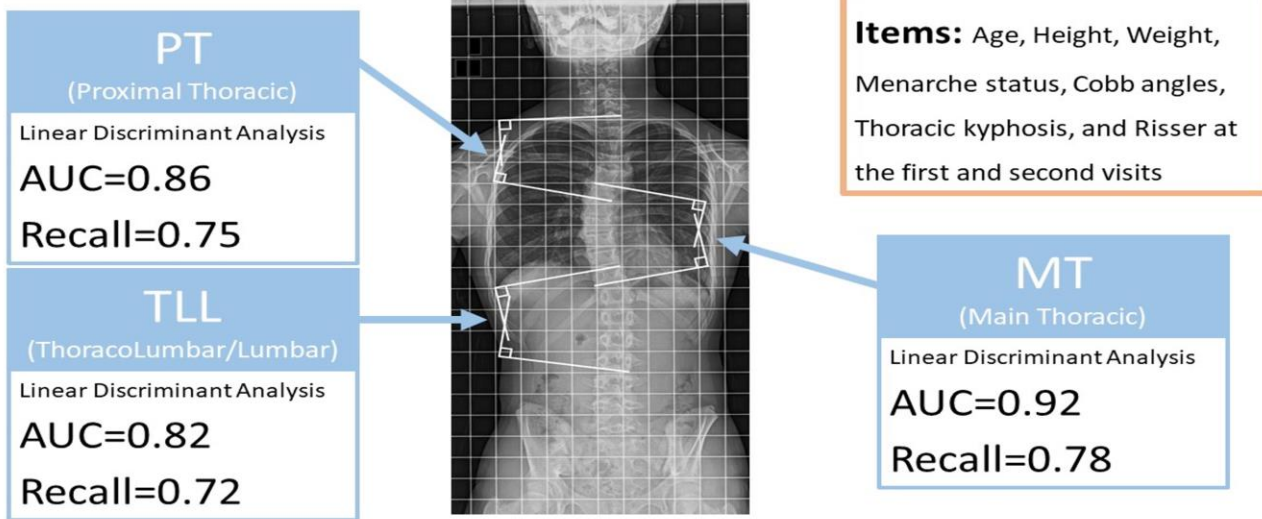
Regarding binary classification models, the best-performing models for PT, MT, and TLL progression had AUCs of 0.86, 0.92, and 0.82 and recall values of 0.75, 0.78, and 0.72, respectively. Regarding regression models, the best-performing models for Cobb angles of PT, MT, and TLL at the last visits had R<sup>2</sup> of 0.73, 0.63, and 0.61 and MAE values of 2.3, 4.0, and 4.2, respectively. The most significant factors predicting progression varied for each model.

#### Conclusion

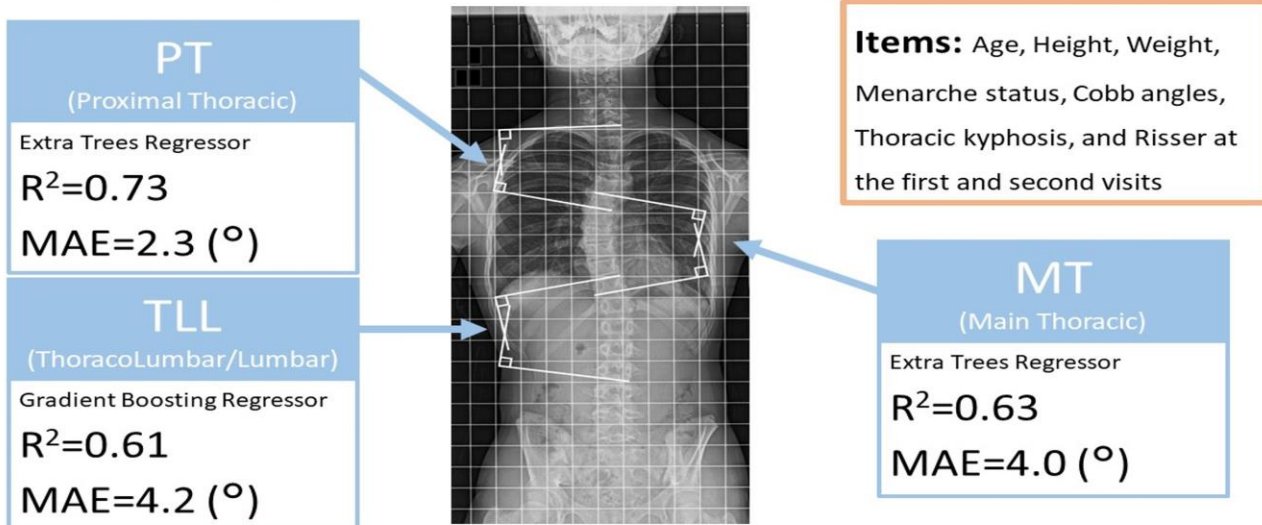
The ML-based model using items commonly evaluated at the first and second visit accurately predicted angle and progression at the last visit in female patients with AIS.

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Classification models using machine-learning approach (Whether the Cobb angle $\geq 25^\circ$ or not at the last visit)



### Regression models using machine-learning approach (Future Cobb angle at the last visit)



Model performance for predicting the progression and future curves of each curve

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #10. Pulmonary Function at Minimum 10 Years After Segmental Pedicle Screw Instrumentation for Thoracic Adolescent Idiopathic Scoliosis

Linda Helenius, MD, PhD; Matti Ahonen, MD, PhD; Johanna Syvänen, MD, PhD; Ilkka J. Helenius, MD, PhD

#### Hypothesis

We hypothesized that pulmonary function would improve during the follow-up as more effective correction of AIS can be obtained using current standard treatment than with hook or hybrid constructs.

#### Design

A prospective cohort study.

#### Introduction

Adolescent idiopathic scoliosis with thoracic curves is associated with reduced pulmonary function preoperatively. It remains unclear how much pulmonary improvement can be obtained using pedicle screw instrumentation at long-term follow-up.

#### Methods

Out of 64 consecutively surgically treated patients with thoracic AIS (Lenke 1-4, 6) using pedicle screw instrumentation, 50 (mean age at surgery 14.7 years, 44 females) participated in a prospective 10-year follow-up study (mean FU 12.2 years). Preoperative major curve averaged 57° (SD 8.5°) with a remaining curve of 15° (SD 6.3°) at 10-year follow-up. They were evaluated using clinical examination, spinal radiographs, and spirometry preoperatively and at 10-year follow-up. The preoperative percentage predicted values were adjusted for the height loss caused by the scoliosis according to curve size.

#### Results

Preoperatively 49% (20/41) had forced vital capacity (FVC) or forced expiratory volume in one second (FEV1) below 80% of the predicted normal values representing pulmonary function impairment. FVC improved from preoperative 3.29 L (SD 0.78L) to 3.87 L (0.79L) at 10-year follow-up ( $p < 0.001$ ). This improvement averaged 510 mL (SD 560 mL) in patients having both preoperative and 10-year follow-up measurements available. The percentage predicted values for FVC showed an improvement from 83% preoperatively to 86% at 10-year follow-up ( $p = 0.048$ ). At 10-year follow-up 38% (19/50) of the patients had FVC or FEV1 below 80% of the predicted values.

#### Conclusion

FVC improved by a mean of 510 ml from preoperative to 10-year follow-up in patients undergoing pedicle screw instrumentation for thoracic AIS. Despite 75% scoliosis correction and significant improvement of absolute lung volume values, more than one-third of these surgically treated otherwise healthy young adults fulfilled the criteria for pulmonary function impairment at 10-year follow-up.

**Session 1 | Adolescent Idiopathic Scoliosis Abstracts**

**Table 1. Patient demographic data and pulmonary function**

	Mean ± SD	Range
Age at surgery	14.7 ± 1.9	10 to 18
Age at final follow-up	26.9 ± 2.1	21 to 31
<b>Preoperative</b>		
Major curve (°)	56.5 ± 8.5	45 to 78
Thoracic kyphosis (°)	21.6 ± 11.9	2 to 54
Lenke classification		
1	25	
2	11	
3	7	
4	3	
6	8	
<b>10-year FU</b>		
Major curve (°)	13.8 ± 5.9	4 to 31
Thoracic kyphosis (°)	21.7 ± 8.8	7 to 60
Correction (%)	75 ± 11	39 to 92
<b>Surgical data</b>		
Number of levels fused	11.6 ± 1.3	8 to 15
Surgical time (h)	4.2 ± 0.8	2.7 to 5.8
Intraoperative bloodloss (mL)	694 ± 377	230 to 1800
<b>Pulmonary function</b>		
	preoperative	10-year FU
FVC (L)	3.29 ± 0.78	3.80 ± 0.75
FVC (%)	83 ± 12	86 ± 11
FEV <sub>1</sub> (L)	2.86 ± 0.60	3.05 ± 0.63
FEV <sub>1</sub> (%)	81 ± 12	83 ± 10



## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #11. Bracing in Severe Skeletally Immature Adolescent Idiopathic Scoliosis – Does a Holding Strategy Change the Surgical Plan?

*Soren Ohrt-Nissen, MD, PhD*; Martin Heegaard, MD; Thomas B. Andersen, MD, PhD, DMSc; Martin Gehrchen, MD, PhD; Benny T. Dahl, MD, PhD, DMSc; Niklas Tøndevold, MD, PhD

#### Hypothesis

Curve flexibility is maintained during night-time bracing in skeletally immature adolescent idiopathic scoliosis (AIS) with curves in the surgical range.

#### Design

Retrospective consecutive cohort study

#### Introduction

Management of skeletally immature AIS patients with curves in the surgical range is challenging. Fusion surgery in AIS should ideally be carried out in skeletally mature patients to reduce the risk of adding-on or crankshaft. A few studies have shown an effect of bracing in AIS curves larger than 40°. In early-onset scoliosis, the principle of casting and bracing as a delay tactic prior to surgery is well known but is not well described in AIS patients.

#### Methods

We included a consecutive cohort of 89 AIS patients with curves  $\geq 45^\circ$ . All patients had an estimated growth potential but not deemed suitable for vertebral body tethering. All patients were eventually treated with fusion surgery and all patients had side-bending radiographs prior to both bracing and surgery. Curves were classified as structural or nonstructural according to Lenke at both timepoints.

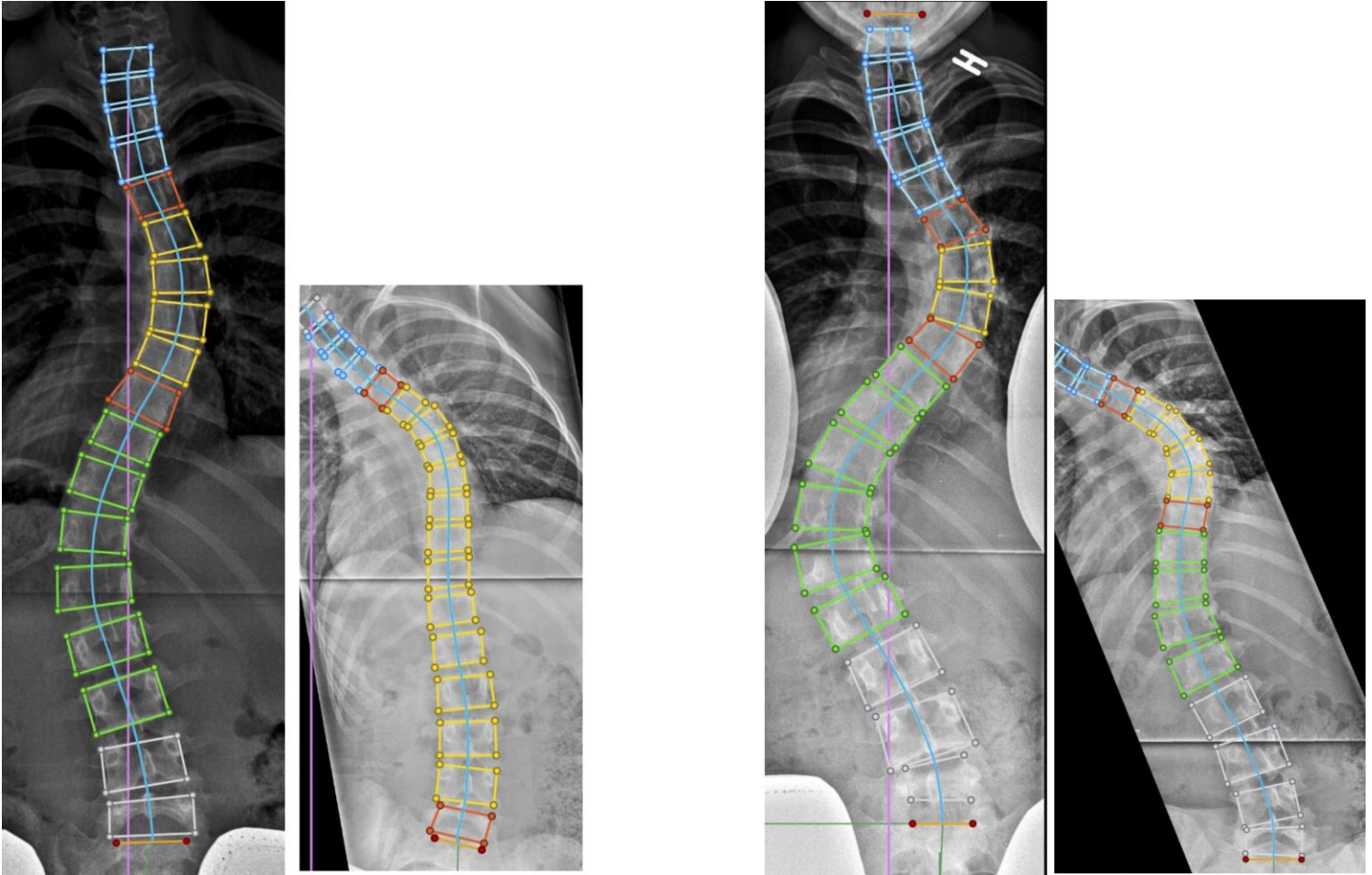
#### Results

The main curve progressed by a mean of  $12 \pm 10^\circ$  and the secondary curve by  $8 \pm 8^\circ$ . Flexibility of the main curve decreased from  $50 \pm 19\%$  to  $44 \pm 19\%$  ( $p=0.001$ ) and the lumbar curve from  $85 \pm 21\%$  to  $77 \pm 22\%$  ( $p=0.005$ ). In 69 patients (79%) the Lenke category did not progress during bracing. In 14 patients (15%), the progression in Lenke type occurred in the thoracic region (i.e. Lenke type 1 to type 2) while 6 patients (7%) progressed in the lumbar region (i.e., Type 1 to type 3). In the 69 patients that did not progress, we found that the last touched vertebra moved distally by one or two levels in 26 patients.

#### Conclusion

This is the first study to describe a decrease in curve flexibility during bracing in severe AIS. However, this had only a modest impact on the surgical strategy. Bracing as a holding strategy can be applied but the risk of losing flexibility in the lumbar spine should be outweighed against the risks of premature fusion surgery.

Session 1 | Adolescent Idiopathic Scoliosis Abstracts



A 45-degree Lenke 1A curve before bracing. At the time of surgery both curves have progressed, and the lumbar curve is now structural with a lumbar Cobb angle on bending films of 33 degrees.

## Session 1 | Adolescent Idiopathic Scoliosis Abstracts

### Paper #12. Proximal Femur Maturity Index at Brace Initiation for Adolescent Idiopathic Scoliosis Predicts Curve Progression Risk ‡

Jason Pui Yin Cheung, MD, MBBS, MS, FRCS; Prudence Wing Hang Cheung, PhD, BSc (Hons)

#### Hypothesis

The Proximal Femur Maturity Index (PFMI) at brace initiation for adolescent idiopathic scoliosis (AIS) can predict curve progression risk.

#### Design

Prospective study.

#### Introduction

The PFMI can be used to assess skeletal maturity on existing whole-spine radiographs without additional radiation. However, the relationship between the PFMI at the initiation of bracing for AIS and subsequent curve progression remains unknown. This study aimed to investigate the relationship between the PFMI and curve progression, and the predictability of risks to adulthood curve progression and surgical thresholds based on the PFMI grade at brace initiation.

#### Methods

202 patients with AIS who were prescribed underarm bracing according to the Scoliosis Research Society criteria and had good brace-wear compliance. The patients were followed from brace initiation until complete skeletal maturity. Longitudinal data on the coronal Cobb angle and skeletal maturity assessments using Risser staging, Sanders staging, the distal radius and ulna classification, and the PFMI were collected. Each patient was assessed on whether the major curve progressed to  $\geq 40^\circ$  (adulthood deterioration) and  $\geq 50^\circ$  (the surgical threshold). Logistic regressions were used to predict probabilities of curve progression to the 2 thresholds, adjusted for factors that were significant in univariate analyses.

#### Results

The PFMI correlated with the other skeletal maturity indices ( $r_s = 0.60$  to  $0.72$ ,  $p < 0.001$  for all). The pre-brace PFMI grade correlated with progression to  $\geq 40^\circ$  ( $rrb = -0.30$ ,  $p < 0.001$ ) and to  $\geq 50^\circ$  ( $rrb = -0.20$ ,  $p = 0.005$ ). Based on regression models ( $p < 0.001$ ) adjusted for the pre-brace major Cobb angle and curve type, brace initiation at PFMI grades 2 and 3 for a curve of  $\geq 30^\circ$  had predicted risks of 30% (95% confidence interval [CI], 4% to 55%) and 12% (95% CI, 7% to 17%), respectively, for progression to the surgical threshold. Brace initiation at PFMI grade 5 had 0% progression risk.

#### Conclusion

The PFMI can be used for predicting curve progression and prognosticating brace outcomes in AIS. Patients with brace initiation at PFMI grade 4 for a curve of  $< 30^\circ$  or at grade 5 were unlikely to progress to the adulthood deterioration or surgical threshold. In comparison, skeletally immature patients initiating bracing at a PFMI grade of  $\leq 3$  for a major curve of  $\geq 30^\circ$  had a higher risk of progression despite compliant brace wear.

‡ = SRS Funded Research Grant