

159. Predicting the Benefit of Bracing for Adolescent Idiopathic Scoliosis Using Sanders Maturity Stages

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Hypothesis

Treatment outcome is a function of SMS, Cobb angle and hours of brace wear

Design

Prognostic model derivation and validation

Introduction

Research suggests the Sanders' maturity stages (SMS) precisely reflect the current and future growth of patients with adolescent idiopathic scoliosis (AIS), hence a prognostic model including SMS would be clinically relevant and potentially useful. We sought the first model using the SMS to reliably and accurately estimate the benefit of bracing relative to patient, curve and wear time characteristics.

Methods

The model was derived and internally validated using patients treated within a multicenter trial and in routine clinical practice at four different locations. 585 subjects (Trial n=262; Clinical n=323) were included; 337 (58%) were braced. All were followed to either skeletal maturity (Risser 4), or Cobb angle $\geq 45^\circ$ or surgery. Candidate variables included the SMS, sex, age, BMI, Cobb, presence of a thoracic curve, in-brace correction and estimated average hours of wear (per temperature monitoring). Multivariate logistic regression estimated the probability of success (maturity with a Cobb angle $< 45^\circ$). Calibration (prediction accuracy) and discrimination (reliability) were estimated in the derivation sample, and then in the Trial, Clinical, Braced and Untreated patient subsets.

Results

53% were at SMS < 4 , average Cobb angle was 29° , and brace wear averaged 10 hrs/day (range 0-23). 72% had a successful outcome. The final model included the baseline age, SMS (1-2, 3, 4-7), Cobb angle, presence of a thoracic curve, BMI, and average hours of brace wear (model c-statistic = 0.885, Brier score = 0.135). The model showed minimal loss of discrimination or calibration in the subsets (see table). The figure summarizes the relationship between the baseline Cobb angle, SMS and hours of brace wear with success: increasing hours of brace wear had the largest effect for patients at SMS < 4 and those with larger curves.

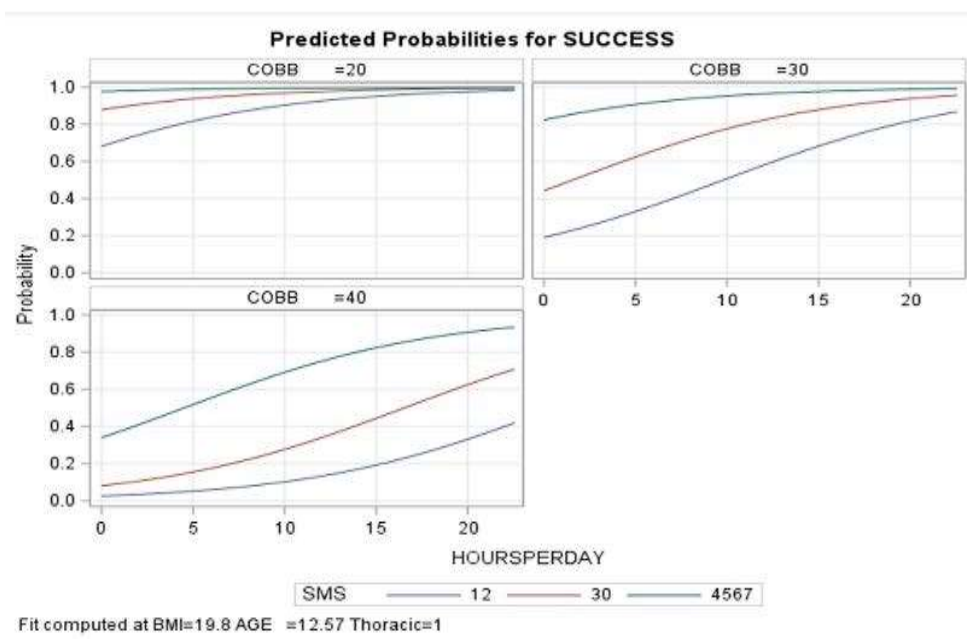
Conclusion

This model produced accurate and reliable predictions of the benefits of bracing in routine clinical practice. This work adds to the available models providing prognostic evidence families and providers can use to jointly weigh individualized, risk-based treatment options. We welcome additional testing of this model and its potential impact on patient outcomes.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

Summary of SMS Model Performance

Performance Statistics by Subset	c-statistic	Brier score	Calibration in the Large (Difference In Success: %Observed vs %Predicted)	Calibration Intercept	Calibration Slope
Entire Sample	0.876	0.135	0%	-0.0002	1.02
Trial	0.884	0.134	-3%	-0.25	0.97
Clinical	0.857	0.112	3%	0.25	1.03
Braced	0.831	0.119	1%	0.17	0.87
Untreated	0.891	0.124	0%	-0.05	1.11



Model Performance and Influence of Cobb Angle, Hours of Brace Wear and SMS on Probability of Success

160. In-brace Correction May Gate the Effect of Wear Time on Curve Regression in AIS Bracing

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Hypothesis

Curve regression in AIS bracing is associated with early IBCR, daily wear time, wear regularity, and night-time wear proportion.

Design

Retrospective cohort study of a prospectively maintained bracing registry

Introduction

Brace treatment in AIS aims to prevent progression, and curve regression has been observed in patients with high adherence. However, how brace wear time, IBCR, and wear patterns (regularity and night-time wear) are associated with curve regression remains unclear.

Methods

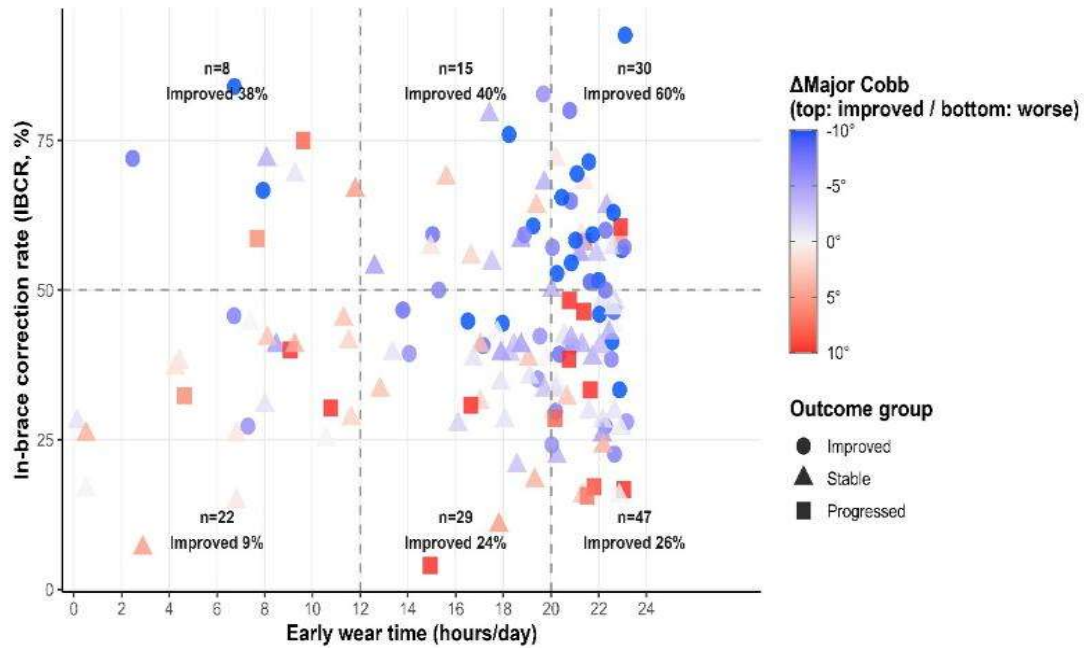
We included AIS patients with major Cobb angle (25–40°) treated with Boston brace. IBCR was defined as the correction rate on the first in-brace radiograph. The primary outcome was curve regression, defined as Improved (<−5°), Stable (±5°), or Progressed (>+5°). Wear time was categorized as <12, 12–<18, 18–<20, and ≥20 h/day. Wear consistency was the interquartile range of daily wear hours (higher IQR indicates greater day-to-day variability). Night-time wear proportion was the proportion of total wear occurring during 10 PM–6 AM. Multivariable logistic regression modeled improvement (Improved vs Stable/Progressed) with wear-time category and IBCR (per 10% increase), adjusting for age, sex, Sanders stage, and baseline major Cobb angle.

Results

Of 154 patients, 48 (31%) experienced curve regression. Improvement increased with higher wear time (16% for <12 h/day; 26% for 12 to <18; 32% for 18 to <20; 39% for ≥20). Improved patients had higher IBCR (52.3% vs 39.9%, $p<0.001$) and higher early wear time (18.9 vs 16.7 h/day, $p=0.033$). In adjusted analysis, IBCR remained strongly associated with improvement (OR 1.83, $p<0.001$) and ≥20 h/day wear independently increased odds of improvement versus <12 h/day (OR 3.43, $p=0.044$). Wear consistency and night-time wear proportion were not independently associated with regression. In a spline model, the predicted probability of improvement crossed 50% at IBCR ≈52%. When stratified by both early wear time and IBCR, improvement was the most frequent with IBCR ≥50% and ≥20 h/day wear (60%) versus IBCR <50% (9–26%).

Conclusion

IBCR near 50% may gate the benefit of high wear time. Optimizing brace fit and correction quality at initiation, with adherence support to achieve ≥20 h/day, may maximize probability of curve regression, while wear regularity and night-time proportion were not independently associated with improvement.



Scatterplot of brace wear time (hours/day) vs in-brace correction rate (IBCR, %).

161. In-Brace Correction, Wear-time Compliance, and Outcomes in TLSO Bracing for Adolescent Idiopathic Scoliosis

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Hypothesis

In patients with AIS treated with TLSO braces, initial in-brace correction depends on patient and curve factors, but brace wear-time drives treatment success.

Design

Retrospective observational case review

Introduction

TLSO bracing in AIS aims to prevent curve progression and surgery. Treatment failure has been associated with inadequate IBC and poor wear compliance, yet factors influencing %IBC and its relationship to objectively measured wear-time compliance remain unclear. This study evaluated predictors of %IBC, its association with brace wear-time, and their impact on treatment outcomes.

Methods

Patients ≥ 10 years with AIS initiating TLSO bracing between January 2015 and April 2024 were included. Objective brace-wear compliance (iButtons), radiographic measures (curve magnitude, IBC, skeletal maturity), BMI%, and brace data were collected. Percentage curve correction at brace discontinuation was calculated. Analyses: descriptive statistics, ANOVAs, and linear regression (significance $p < 0.01$).

Results

334 patients (77% Female; age 12.7 ± 1.4 ; BMI% 60.2 ± 31.3 @BracePrescribed) Mean IBC = $55.1\% \pm 27.3$ ($\geq 50\%$ correction achieved in 57.5%). Higher %IBC was associated with lower BMI percentile and curve type, with lumbar curves resulting in greater correction than thoracic curves (67.8% vs 47.7%). Normal-weight patients achieved higher %IBC than overweight/obese patients (67.7% vs 31.7%). Curve magnitude weakly correlated with %IBC ($r = -.319$). Among patients who discontinued bracing ($N = 110$), mean %IBC was 53.2 ± 29.0 and mean wear-time was 8.5 ± 5.8 hours/day. Mean curve change at discontinuation was 1.9° (range: 84% correction to 118% progression). %IBC was not associated with wear-time compliance. Brace wear-time was the strongest predictor of curve progression, while %IBC showed only weak correlation ($r = -0.276$). Patients with curve improvement averaged 10.7 ± 5.5 hours/day of brace wear compared to 6.6 ± 5.1 hours/day among those without improvement.

Conclusion

Achieving $\geq 50\%$ initial in-brace correction was most strongly associated with BMI percentile and curve type and was not related to brace wear-time compliance. Brace-wear compliance emerged as the strongest predictor of successful TLSO treatment, underscoring adherence as the key determinant of curve outcomes. Ongoing analyses are evaluating psychosocial factors and their association with compliance.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

162. Radiographic and Pulmonary Function Outcomes in Lenke 4-6 (TL/L-Dominant) Adolescent Idiopathic Scoliosis: Relationship to Diaphragm Intrusion

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Hypothesis

TL/L-dominant AIS is associated with diaphragmatic intrusion and impaired pulmonary function, and posterior spinal fusion (PSF) improves diaphragm positioning and pulmonary outcomes.

Design

Retrospective cohort study.

Introduction

Pulmonary dysfunction in adolescent idiopathic scoliosis (AIS) is typically attributed to thoracic deformity. However, thoracolumbar and lumbar-dominant (TL/L; Lenke 4–6) curves may impair respiration through diaphragmatic and abdominal displacement. The impact of this mechanism and its response to surgical correction remain incompletely defined.

Methods

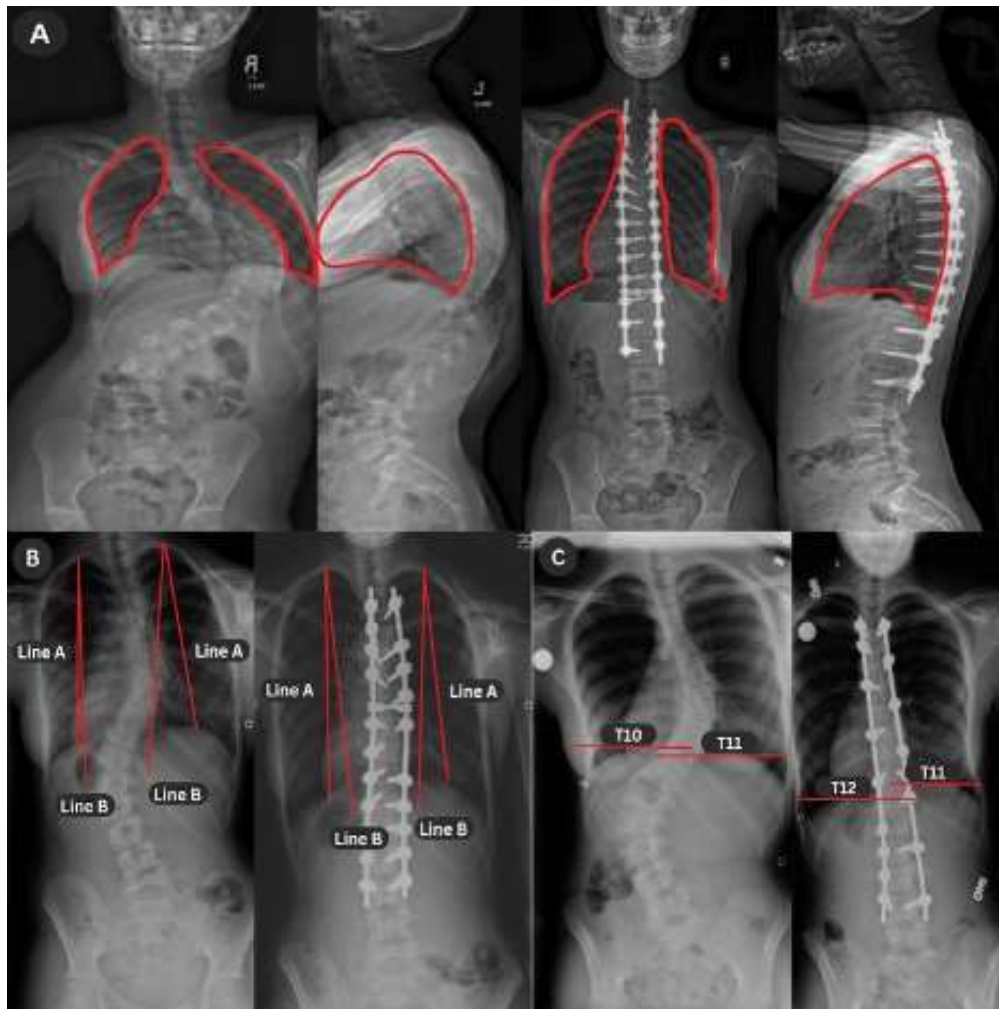
We retrospectively reviewed 540 AIS patients with Lenke 4 (n=130), 5 (n=209), or 6 (n=201) curves who underwent PSF with ≥2-year follow-up and available pulmonary function testing (PFT). Radiographic measures included Diaphragm Intrusion Index (DII), Diaphragm Vertebral Level (DVL), calculated lung volume (CLV), and T1–S1 height. PFT outcomes included forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and total lung capacity (TLC). Multivariable regression assessed associations between diaphragm metrics and pulmonary function.

Results

The cohort was 83% female with mean 5-year follow-up. Across curve types, PSF significantly improved diaphragmatic positioning, lung volume, and spinal height (all $p < 0.001$). DII and DVL increased significantly, CLV increased by ~12%, and T1–S1 height increased by ~3 cm. Pulmonary function improved primarily through increased lung volumes, including FVC and TLC. Among patients with severe baseline impairment (FVC <60% predicted), mean FVC improved by ~15–19 percentage points at mid-/long-term follow-up, with 67–86% improving to ≥60% predicted. Diaphragm dome height decreased by ~0.6 cm following surgery. Both DII and DVL were independently associated with FVC and FEV1 (all $p < 0.02$). Despite improvement, Lenke 4 patients retained lower pulmonary function than Lenke 5 and 6 patients.

Conclusion

PSF improves diaphragmatic positioning and volume-based pulmonary function in TL/L-dominant AIS. Radiographic diaphragm metrics correlate with pulmonary function and may serve as useful adjunctive markers of respiratory impairment in this population.



Radiographic assessment of diaphragmatic positioning in AIS demonstrating measurement of Calculated Lung Volume, Diaphragm Intrusion Index (DII), and Diaphragm Vertebral Level (DVL).

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper,
‡SRS Funded Research Grant

163. Contextualizing Chest Radiograph–Based Pulmonary Function Estimation in Scoliosis Using Multimodal Deep Learning

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Hypothesis

Thoracic deformity associated with scoliosis can lead to impaired pulmonary function; however, the availability of pulmonary function testing (PFT) is often limited. We hypothesize that pulmonary function in scoliosis patients can be estimated using a multimodal deep learning framework incorporating chest radiographs and clinical information.

Design

Retrospective single-center study with multimodal deep learning model development.

Introduction

Scoliosis is a three-dimensional spinal deformity that can impair pulmonary function through thoracic cage deformation, while pulmonary function testing remains limited in clinical practice. This study proposes a multimodal deep learning framework to estimate pulmonary function in patients with scoliosis using routinely acquired chest radiographs and basic clinical data.

Methods

We retrospectively analyzed patients with scoliosis who underwent PFT and chest radiographs at a single institution between December 2013 and June 2025. After exclusions, 336 patients were included and divided into train-validation (80%) and independent test (20%) sets. Three model families were developed: S-Model using clinical data only; E-Model incorporating clinical and manual radiographic measurements; and M-Model integrating clinical data with raw chest radiograph images. Models predicted forced vital capacity (FVC) and forced expiratory volume in one second (FEV1). Restrictive ventilatory pattern was defined as FVC < 80% predicted.

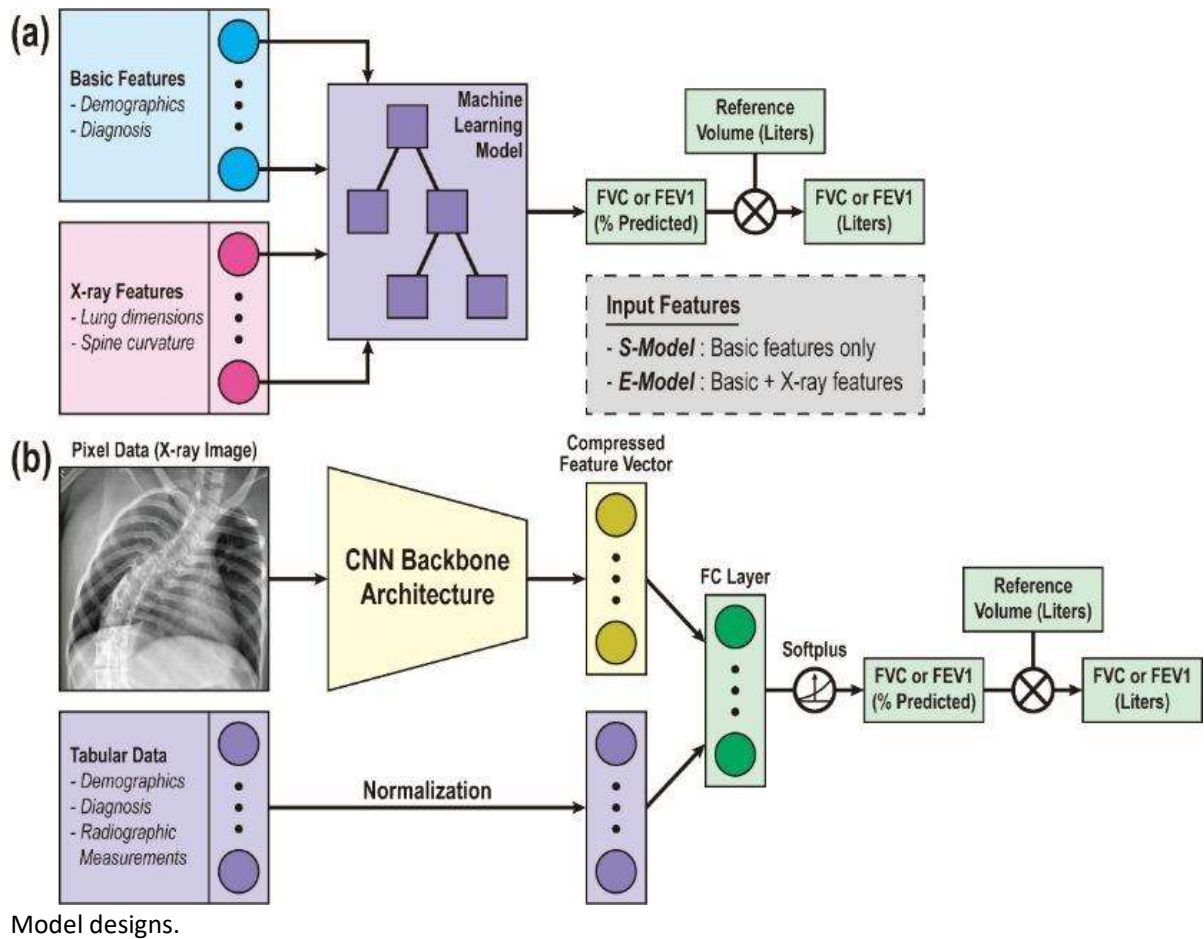
Results

The cohort included 336 patients (mean age 31.0 ± 24.1 years; 125 male). The EfficientNetV2-B3–based M-Model achieved the best performance for FVC prediction, with a test MAE of 0.31 L. For FEV1 estimation, the EfficientNetV2-B0–based M-Model achieved a test MAE of 0.37 L. Significant improvement in FVC prediction was observed with increasing model complexity (S-Model vs. E-Model, $p=0.04$; E-Model vs. M-Model, $p=0.002$). For restrictive ventilatory pattern classification, the ResNet-34–based M-Model achieved test accuracy, sensitivity, and specificity of 0.90, 0.85, and 0.93, respectively.

Conclusion

Pulmonary function in patients with scoliosis can be estimated using routinely acquired chest radiographs and clinical data. This multimodal deep learning framework provides noninvasive, opportunistic FVC estimation and may serve as a complementary screening tool to prioritize confirmatory PFT when formal spirometry is unavailable.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant



Model designs.

164. Postoperative Anemia Predisposes to Serious Complications Following Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

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Hypothesis

In contemporary AIS surgery with low transfusion rates, postop anemia, rather than transfusion exposure, may be associated with increased postop complications and impaired early recovery.

Design

Retrospective cohort

Introduction

Contemporary blood conservation strategies have reduced blood transfusions (BT) in AIS surgery, but leave patients variably anemic postop. While BT has been previously seen as a risk factor, the impact of postop anemia on complications and recovery remains unclear. We evaluated the relationships between BT, hematocrit (HCT), complications, and early functional recovery after AIS surgery.

Methods

AIS pts undergoing primary PSIF from 2020–2023 with max Cobb $<75^\circ$ were included. Early functional recovery was measured by PT-documented ambulation documentation. Associations between ambulation and HCT, BT, and covariates were analyzed using mixed-effects models with piecewise modeling to assess HCT thresholds. Secondary analyses evaluated postop complications among pts with ≥ 2 -year follow-up.

Results

Among 225 AIS pts with ≥ 2 -year f/u 27 received BT, with rates declining from 13% (2020) to 5% (2023). Mean HCT decreased from 36.5 ± 5 preop to 31.1 ± 4 postop. 6 pts had postop wound complications, with 4 infections requiring I&D, postop HCT was lower (25.9 vs 31.2 , $p=0.03$), while BT rates were similar ($1/6$ vs $26/218$, $p=0.83$). 2 pts developed postop neurologic deficits despite normal intraop monitoring (1 sensory, 1 motor deficit requiring urgent revision) and had lower postop HCT comparatively (24.8 vs 31 , $p=0.01$). LOS did not differ in BT vs non-BT pts (3.7 vs 3.2 days, $p=0.06$). For early functional recovery, postop day was the strongest predictor of ambulation ($\beta=105.5$ ft/day, $p<0.0001$). Higher postop HCT independently predicted greater ambulation ($\beta=2.33$ ft per unit, $p=0.003$), while BT, demographics, and surgery magnitude did not. A threshold was seen at HCT 28, below which HCT was significantly associated with ambulation ($p=0.038$), with attenuation above this level.

Conclusion

In AIS surgery, BT rates are low and not independently linked with postop complications or delayed recovery. In contrast, postop anemia was related to increased wound complications, delayed neurologic deficits, and reduced early ambulation, with a threshold at HCT 28. These findings suggest anemia, rather than transfusion exposure, may be a modifiable risk factor for postop safety and recovery.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡ SRS Funded Research Grant

Table 1. Linear Mixed-Effects Model of Factors Associated with Postoperative Ambulation Distance

Variable/Effect	Estimate (β)	Standard Error	p-value
Intercept	-89.67	43.04	0.0380
Hematocrit (HCT)	2.33	0.78	0.0030
Postoperative Day (POD)	105.51	4.53	<0.0001
Age	-0.40	1.54	0.7946
BMI	-0.13	0.77	0.8647
Female gender	8.53	8.84	0.3348
Total Instrumented Levels	-0.77	2.03	0.7050
Number of PCOs (Levels)	1.99	2.06	0.3343
Estimated Blood Loss (cc)	0.005	0.02	0.8345
Cell Saver Transfused (cc)	-0.04	0.05	0.4423
Intraoperative pRRBC transfused	10.07	17.03	0.5544
Perioperative pRBC Transfused	6.24	13.87	0.6531

Table 1

165. Biomechanical analysis of Ponte-osteotomies vs No Osteotomies in Adolescent Idiopathic Scoliosis (AIS) – Radiographic Analysis from Randomized Clinical Trial

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Hypothesis

Use of Ponte-osteotomies results in superior sagittal and coronal correction in AIS.

Design

Randomized clinical trial.

Introduction

Ponte osteotomies (PO) are routinely used to facilitate curve correction in surgical treatment of adolescent idiopathic scoliosis (AIS). To date, the role of PO in AIS surgery has not been evaluated in a randomized clinical trial.

Methods

A randomized, multicenter clinical trial on 107 consecutive AIS patients scheduled for segmental pedicle screw instrumentation were prospectively randomized to PO (n=53) and non-PO (n=54) groups. PO group received minimum two and maximum four Ponte-osteotomies in the apical area of deformity. Radiographs were analyzed after the surgery

Results

Mean (SD) preoperative major curve was 50° (9.5°) in the non-PO and 50° (12°) in the PO group and preoperative thoracic kyphosis (T5-T12) was 19° (11°) in non-PO group and 15° (18°) in PO group. Postoperative major curve was in non-PO group 19° (8.4°) and PO group 18° (5.5°) mean difference (MD) -0.86 (95%CI -3.00 to 1.29). Postoperative kyphosis was 20° (7.5°) in non-PO group and 22° (7.8°) in PO group, MD 1.62 (95% CI -0.59 to 3.83). Thoracic kyphosis increased by 1.3° in non-PO group and by 4.0° in PO group MD -2.64 (95% CI -6.1 to 0.8). In subgroup analysis of AIS patients with preoperative kyphosis of less than 20°, postoperative kyphosis was 16° (4.3°) in non-PO group and 17° (5.1°) in PO group MD -1.44 (95% CI -4.22 to 1.33).

Conclusion

Ponte osteotomies do not provide superior sagittal or coronal radiographic correction in AIS.

	Non-Ponte osteotomy (n=54)	Ponte osteotomy (n=53)	Mean difference (95%CI)
Postoperative Major Curve	18.7° (8.4°)	18.3° (5.5°)	- 0.86 (95%CI -3.00 to 1.29)
Postoperative Main Thoracic Curve	17.7 (8.6)	17.2 (5.4)	- 0.7 (95% CI -2.71 to 1.30)
Postoperative Proximal Thoracic Curve	13.2° (9.6°)	14.9° (8.3°)	0.20 (95% CI -2.86 to 3.26)
Postoperative Lumbar Curve	13.4° (6.3°)	13.6° (7.0°)	-0.26 (95% CI -2.65 to 2.14)
Postoperative Thoracic Kyphosis	20.0° (7.47°)	21.9° (7.8°)	1.62 (95% CI -0.59 to 3.83)
Postoperative Lumbar Lordosis	49.0° (12.4°)	47.0° (12.4°)	0.34 (95% CI -3.66 to 4.33)
Fused vertebrae	11.3 (1.7)	11.2 (1.7)	0.09 (95% CI -0.55 to 0.73)
Screw density	1.96 (0.03)	1.92 (0.14)	-0.038 (95% CI -0.076 to -0.000)
Number of Ponte osteotomies	N/A	2.4 (0.6)	N/A

Table 1. Comparison of Non-Ponte osteotomy and Ponte osteotomys groups.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper,
‡SRS Funded Research Grant

166. Determining the Optimal Extent of Rib Resection during Thoracoplasty With Respect To Pulmonary Function in Adolescent Idiopathic Scoliosis

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Hypothesis

A dose-response relationship exists between the number of resected ribs and pulmonary function changes in adolescent idiopathic scoliosis (AIS), and that a specific threshold for rib resection can be identified to optimize the balance between airflow improvement and lung volume preservation.

Design

Retrospective cohort study

Introduction

Thoracoplasty is often performed concomitantly with spinal fusion in AIS to correct rib hump deformity. However, concerns persist regarding its potential negative impact on pulmonary function. While extensive resection may maximize cosmetic outcomes, the optimal extent of resection to preserve pulmonary function remains unclear.

Methods

A total of 178 patients with AIS who underwent deformity correction with concomitant thoracoplasty were retrospectively reviewed. Patients were grouped according to the number of ribs resected. Pulmonary function test parameters, including forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), and peak expiratory flow (PEF), were analyzed preoperatively and at final follow-up. Clinically relevant outcomes were defined as FVC loss >10% and PEF gain >12%. Nonparametric smoothing splines were used to model continuous dose-response relationships, and multivariate logistic regression was performed to identify factors associated with significant FVC loss.

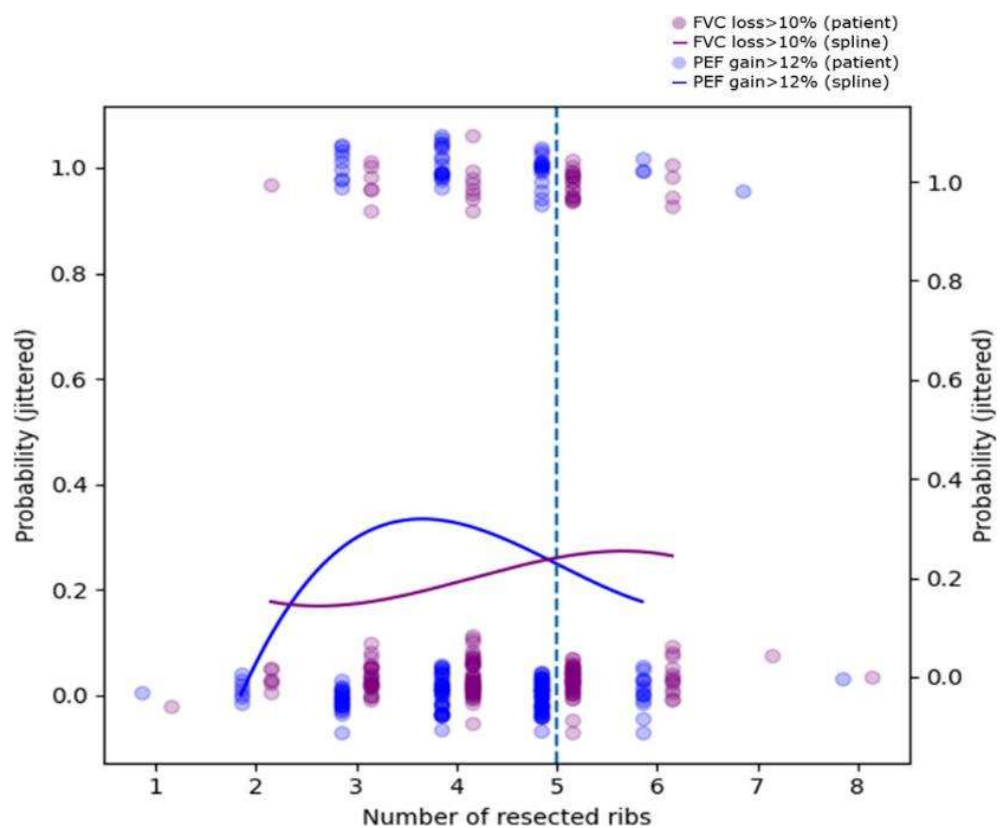
Results

At final follow-up (mean, 42.3 months), predicted FEV₁ and PEF increased, whereas predicted FVC showed no significant overall change. Among patients with normal-to-mild preoperative FVC, 84.3% maintained their functional grade, while 40.4% of those with moderate-to-severe restriction improved. Dose-response modeling demonstrated increasing PEF gains up to 4–5 rib resections and an increased probability of FVC loss >10% beyond 5 ribs. In multivariate logistic regression analysis, age and preoperative predicted FVC were independently associated with FVC loss > 10%.

Conclusion

Pulmonary function after thoracoplasty reached optimized balance point between airflow and lung volume capacity. Resection of up to four ribs was associated with preservation of FVC while providing meaningful airflow improvement. However, the extent of rib resection should be individualized, taking into account, preoperative pulmonary function, age, and rib hump severity.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant



A dose dependent model between pulmonary function and rib resection

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper,
‡SRS Funded Research Grant

167. Effectiveness of Dual Rod Translation in Thoracic Kyphosis Restoration for AIS: A Comparison with the Conventional Technique

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Hypothesis

Dual rod translation (DRT) provides superior restoration of thoracic kyphosis compared with traditional rod rotation (RR) while achieving equivalent coronal curve correction in thoracic adolescent idiopathic scoliosis (AIS).

Design

Retrospective cohort study.

Introduction

Thoracic hypokyphosis is common in thoracic AIS and has been associated with adverse reciprocal changes in cervical and lumbar alignment as well as compromised thoracic morphology and pulmonary function. Although RR remains widely used, translation-based correction strategies have been developed to improve sagittal plane control. This study compared radiographic and clinical outcomes between DRT and RR techniques.

Methods

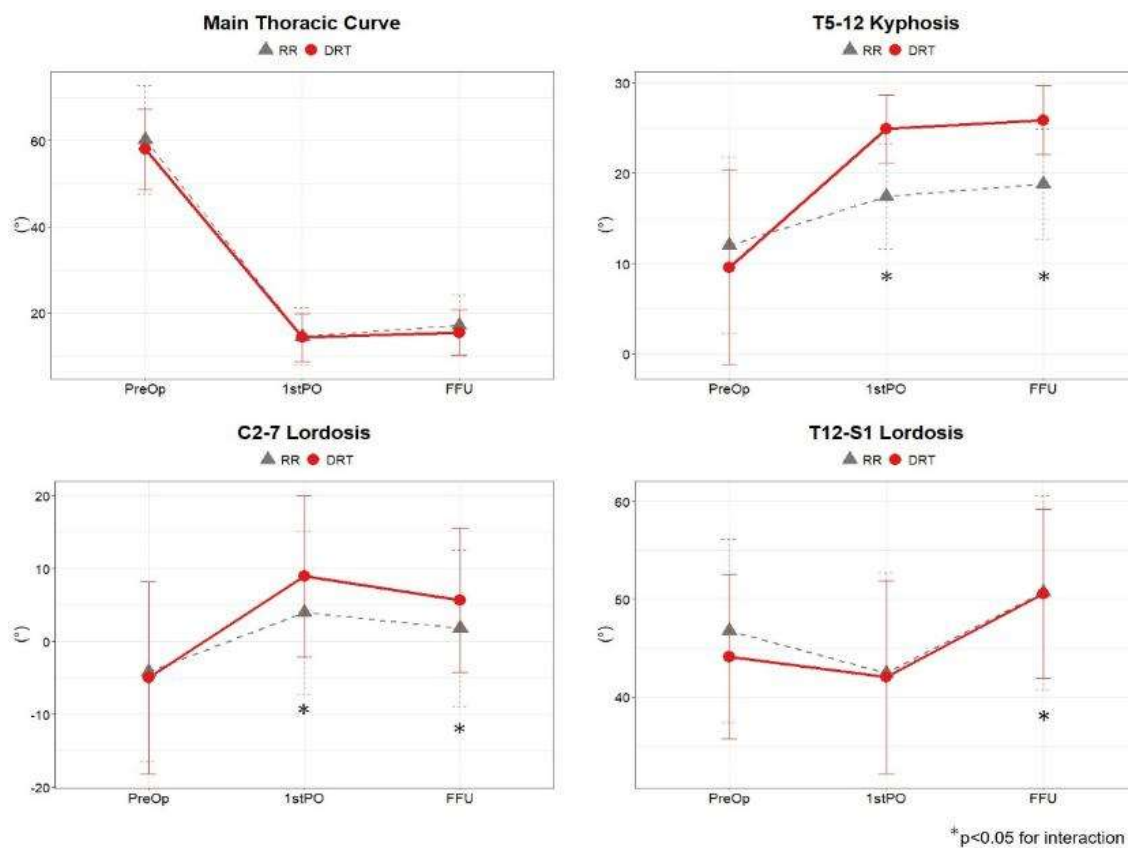
Patients with thoracic AIS (Lenke type 1 or 2) who underwent posterior spinal fusion between 2010 and 2023 were reviewed. RR was used in earlier cases, whereas DRT was adopted in later cases. Standing whole-spine radiographs were obtained preoperatively, at 1 week postoperatively, and at final follow-up. Changes in coronal and sagittal parameters were analyzed using mixed-effects models with group-by-time interaction terms. Patient-reported outcomes were assessed using the SRS-22 questionnaire.

Results

A total of 239 patients were included (DRT, n = 90; RR, n = 149). Preoperative characteristics and coronal curve magnitudes were comparable. Both techniques achieved equivalent correction of the main thoracic curve, improving from approximately 60° preoperatively to 16–17° at final follow-up. Thoracic kyphosis increased from 10° to 26° in the DRT group and from 12° to 19° in the RR group, resulting in a significantly greater kyphosis gain with DRT (+16° vs. +6°, $p < 0.001$). More favorable reciprocal changes in cervical and lumbar lordosis were observed with DRT, whereas global sagittal balance was similar between groups. Improvements in SRS-22 scores at 2 years were comparable.

Conclusion

DRT achieved coronal correction equivalent to RR while providing significantly greater restoration of thoracic kyphosis and more favorable reciprocal sagittal alignment changes. Although short-term patient-reported outcomes were similar, improved sagittal restoration with DRT may be important for long-term spinal and thoracic health in thoracic AIS.



Changes in main thoracic curve, TK, CL, and LL are shown. *p < 0.05 for group-by-time interaction.

168. Manual Rod Contouring is Non-Inferior to Patient-Specific Rods for Achieving Goal Alignment in Adolescent Idiopathic Scoliosis

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Hypothesis

Pre-fabricated patient-specific rod (PSR) technology will outperform manual rod (MR) contouring in adolescent idiopathic scoliosis (AIS)

Design

Retrospective cohort

Introduction

Patient-specific rod (PSR) technology uses preoperative planning and AI-aided design to pre-shape rods to individual anatomy. Prior literature suggests potential for improved restoration of sagittal alignment parameters, but evidence remains mixed and limited by a focus on adult deformity and lack of direct MR comparison. This study evaluates PSR performance compared to MR using comprehensive coronal and sagittal parameters.

Methods

We retrospectively reviewed AIS patients ≤ 21 years who underwent spinal fusion with either MR (10/2020-1/2023) or PSR (1/2023-2/2025) instrumentation. Preoperative and early postoperative upright radiographs were analyzed for coronal and sagittal parameters, including Cobb angle, 2D T5-T12 thoracic kyphosis (TK), 3D TK conversion, sagittal vertical axis (SVA), T4 pelvic angle (T4PA), L1 pelvic angle (L1PA), and sagittal balance, defined as $|T4PA-L1PA| \leq 4^\circ$. MR was compared to PR across the entire cohort, with subanalysis for selective thoracic fusions (STF) (Lenke 1, 2) and lumbar/thoracolumbar (TL) fusions (Lenke 3-6).

Results

A total of 129 patients were included (53 PSR, 76 MR). Groups were similar in age, sex, preop Cobb, 2D-TK, 3D-TK, and sagittal alignment (all $p > 0.2$). The MR group trended towards slightly better coronal correction index for STF (71% vs 66%, $p = 0.061$) and for TL fusions than PSR (63% vs 57%, $p = 0.026$). Sagittal correction measured by delta 2D and 3D-TK ($p = 0.770$, $p = 0.413$ respectively) did not differ between groups. Mean $|T4PA-L1PA|$ was similar for MR vs PR across the entire cohort (0.1 vs 0.3, $p = 0.643$), and after both STF (0.6 vs 0.4, $p = 0.512$) and TL fusions (0.2 vs 1.1, $p = 0.459$), but a higher percentage of MR patients achieved postop sagittal balance with $|T4PA-L1PA| \leq 4^\circ$ than PSR (71.6% vs 54.7%, $p = 0.05$).

Conclusion

While both techniques produce acceptable deformity correction, manual rod contouring achieved slightly better coronal correction, similar TK, similar mean $|T4PA-L1PA|$, and a higher rate of postoperative sagittal balance, thereby demonstrating noninferiority to PSR. These findings challenge the proposed advantage of PSR technology; further refinement of PSR design and performance is needed to reliably achieve ideal sagittal profiles.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡ SRS Funded Research Grant

169. Patient-specific Rod Planning is Often Too Optimistic in Hypokyphotic Adolescent Idiopathic Scoliosis Patients

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Hypothesis

The planned value for thoracic kyphosis is often not reached in hypokyphotic AIS patients treated with PSR, mainly due to intraoperative rod flattening

Design

Retrospective analysis of prospectively collected data

Introduction

Thoracic kyphosis (TK) restoration remains challenging in adolescent idiopathic scoliosis (AIS), especially in flattened or lordotic spines. Patient-specific rods (PSR) aim to enhance surgical execution, and the plan tries to restore a physiological sagittal alignment. However, there is still little knowledge regarding the sagittal flexibility of the scoliotic thoracic spine, and the intraoperative rod bending is difficult to anticipate. The purpose of this study was therefore to evaluate the difference between the planned and the postoperative TK in hypokyphotic AIS.

Methods

All consecutive patients operated with PSR were included, with a minimum 2-year follow-up. Planned and postoperative TK were compared, and the execution was considered excellent if the difference was $<5^\circ$, acceptable between 5 and 15° , and insufficient if $>15^\circ$. The reliability of the predictions was compared between hypokyphotic ($<20^\circ$) and normokyphotic (20 – 40°) patients.

Results

Among the 217 patients analyzed, 92 were hypokyphotic (mean preoperative TK $11 \pm 7^\circ$) and 125 were normokyphotic (mean TK $29 \pm 6^\circ$). Age and sex ratio were comparable between groups. The planned TK was significantly lower in the hypokyphotic group ($30 \pm 4^\circ$ vs $35 \pm 4^\circ$, $p < 0.001$), but the target was an average gain of 19° (vs 6° in the normokyphotic group). Despite a significant postoperative increase ($+10^\circ$, $p < 0.001$), TK remained significantly lower at follow-up in hypokyphotic patients ($21 \pm 7^\circ$ vs $28 \pm 7^\circ$, $p < 0.001$). TK correction remained significantly lower than expected in both groups ($-9 \pm 6^\circ$ and $-6 \pm 5^\circ$, $p = 0.001$), and the plan execution was considered insufficient in 20% of the hypokyphotic group (vs 12% in normokyphotic, $p = 0.004$). However, only 3% of the cohort remained hypokyphotic according to Lenke's criteria ($<10^\circ$).

Conclusion

PSR TK predictions are often too optimistic in hypokyphotic AIS patients. The plan should therefore be adapted to the surgeon's specific outcomes in order to optimize the execution accuracy.

170. Does Preoperative Pelvic Incidence Influence Postoperative Sagittal Balance? Evaluation of Standardized Rod Curvature in AIS Surgery.

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Hypothesis

In Lenke 1 adolescent idiopathic scoliosis (AIS) surgery using standardized anatomically bent rods, physiological thoracic kyphosis (TK) is consistently restored regardless of the preoperative pelvic incidence (PI). Furthermore, the postoperative lumbar and global sagittal balance naturally adapt to the individual's pelvic morphology, thereby maintaining spinopelvic harmony.

Design

Retrospective comparative study

Introduction

The goal of surgery for AIS is 3D correction including TK restoration. While contouring rods to a standardized anatomical shape provides a robust template for TK formation, it remains unclear how such a uniform rod shape interacts with the patient's unique pelvic morphology to achieve global sagittal balance.

Methods

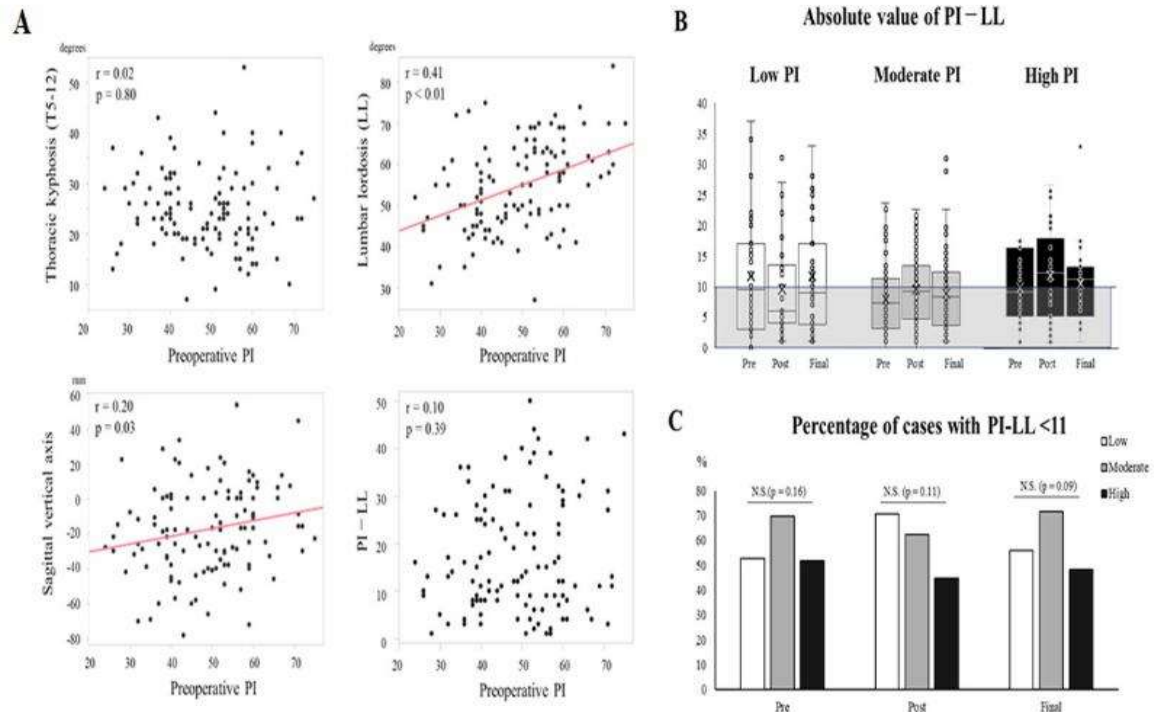
116 patients with Lenke1 AIS (mean: 14.4years) who underwent posterior corrective fusion (follow-up ≥ 2 years) were categorized into three groups based on preoperative PI: low (≤ 40), moderate (41-57), and high (≥ 58). Standardized anatomically bent rods (mean maximum angle: 43.2°) were utilized to restore physiological TK. Radiographic parameters were analyzed preoperatively, postoperatively, and at the final follow-up.

Results

Final TK was restored to physiological levels in all groups (mean: 24.7°), showing no correlation with preoperative PI ($r = 0.02$, $p = 0.80$) (Fig.A). In contrast, preoperative PI was significantly correlated with final lumbar lordosis (LL) ($r = 0.41$, $p < 0.01$) and final sagittal vertical axis ($r = 0.20$, $p = 0.03$). Although the low PI group exhibited a wider variability in outcomes, the mean absolute PI-LL mismatch remained comparable among the three groups through the final follow-up (Fig.B, C).

Conclusion

Standardized anatomically contoured rods provide consistent restoration of TK regardless of PI. Postoperative lumbar and global sagittal balance naturally adapt to the patient's pelvic morphology, maintaining spinopelvic harmony. These results validate the efficacy of standardized anatomical rod geometry in achieving individualized physiological alignment.



A. Correlation analysis between preoperative PI and final TK(T5-12), LL, absolute PI-LL mismatch, and SVA. B. Box-and-whisker plots showing absolute PI-LL mismatch for low, moderate, and high PI groups. C. Bar charts showing the percentage of cases achieving PI-LL < 11°

171. Utilizing Intrathecal Morphine in Rapid Recovery Pathway Protocol For Economic Benefit

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Hypothesis

The Rapid Recovery Pathway (RRP) protocol utilizing intrathecal morphine (ITM) contributes to economic benefits and simultaneously improves pain and minimizes opioid consumption.

Design

Retrospective Study

Introduction

The RRP protocol was introduced at our institution in 2018, utilizing ITM (ITM-RRP), and eliminated the standard Patient Controlled Analgesia (PCA) protocol. ITM-RRP decreases opioid consumption, LOS, narcotic refills, & provides adequate pain control. This study aims to examine cost outcomes of ITM-RRP in this large population.

Methods

Pts with AIS undergoing primary instrumentation and fusion between 2014-2023 were included. Pts operated on prior to 2014-2017 were in the PCA group (n=250). Pts operated on after 2018 were in the ITM-RRP group (n=400). Pt outcomes measured include op & anesthesia time, EBL, max VAS pain score (POD0-2), OOB, LOS, 90-day complications, narcotic refills, & morphine consumption at various timepoints. Cost outcomes measured included intraoperative anesthesia, postoperative morphine, ICU stay, non-ICU hospital room, operating room, implantation, & total cost. A contemporaneous cost analysis between 2017 PCA and 2018 RRP, & a matched analysis, controlling levels fused and fixation points were conducted. Wilcoxon rank-sum, Kruskal-Wallis, and Chi-Squared tests were used.

Results

Operative time ($p<0.001$), anesthesia time ($p=0.03$), EBL ($p<0.001$), LOS ($p<0.001$), time to OOB ($p<0.001$), and morphine consumption ($p<0.001$) were significantly lower in the ITM-RRP group. Max VAS scores were lower for the ITM-RRP group. Intraoperative ($p<0.001$) and postoperative morphine ($p<0.001$), operating room ($p<0.001$), and non-ICU hospital room costs ($p<0.001$) were significantly lower for ITM-RRP. Implantation costs were significantly higher in ITM-RRP ($p<0.001$). No difference in ICU stay cost ($p=0.36$). Total cost was lower in ITM-RRP by a median \$7,283 due to shorter hospital stay, lower anesthesia, & operating room costs.

Conclusion

ITM-RRP decreases total cost with savings of over \$7000 USD per case, despite implantation costs being \$8400 more in the ITM-RRP group. As an institution performing 100+ cases a year, this results in significant cost savings. This protocol decreases both opioids prescribed and consumed while improving pain scores, earlier ambulation, & earlier discharge. Better cost benefits due to shorter length of stay and reduction in anesthesia medications.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

172. Radiographic-Cosmetic Discrepancy in Adolescent Idiopathic Scoliosis: Impact of Extremely Low BMI

Zhen Liu, MD, PhD

Hypothesis

We hypothesized that AIS patients with extremely low BMI would demonstrate poorer postoperative cosmetic improvement and weaker correlations between radiographic and cosmetic parameters compared to those with higher BMI, due to insufficient soft tissue coverage and altered body composition.

Design

Retrospective matched cohort study.

Introduction

Postoperative cosmetic improvement is a primary concern in AIS surgery. Patients with AIS often exhibit lower BMI, which may influence soft tissue volume and cosmetic outcomes. However, the impact of BMI on cosmetic improvement remains underexplored. This study aimed to establish an AIS-specific BMI classification system and compare cosmetic outcomes between extremely low and non extremely low BMI groups.

Methods

We included 737 female AIS patients and established an AIS-specific BMI threshold (10th percentile: 15.57 kg/m²). Thirty-five matched pairs (extremely low vs. non extremely low BMI) of Lenke type 1 cases were analyzed. Radiographic parameters (Cobb, SHD, T1 tilt, FRA, CA, CRCI, CB) and cosmetic parameters (SAI1, SAI2, SA, AA, TLAI, RLWAD, PSIS angle) were measured pre- and postoperatively. SRS-22 scores were collected. Statistical analysis included paired t-tests and Pearson correlation.

Results

Radiographic correction was comparable between groups. However, the extremely low BMI group showed significantly less improvement in shoulder-related (Δ SAI1, Δ SAI2, Δ SA, Δ AA) and lumbar-related (Δ RLWAD, Δ PSIS) cosmetic parameters (all $P < 0.05$). SRS-22 self-image and mental health scores were lower in the extremely low BMI group ($P = 0.005$ and 0.010). Correlation between radiographic and cosmetic improvements was weaker in the extremely low BMI group.

Conclusion

AIS patients with extremely low BMI exhibit poorer cosmetic improvement and lower self-image despite comparable radiographic correction. Extremely low BMI weakens the correlation between radiographic and cosmetic outcomes, highlighting the need for BMI-specific cosmetic assessment and integrated nutritional and psychological support in surgical planning.

173. Revisions for Pseudoarthrosis in Adolescent Idiopathic Scoliosis: Strategies and Outcomes from a Multicenter Registry

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Hypothesis

Advanced techniques such as anterior interbody support, additional rods, and enhanced grafting strategies will be utilized frequently in pseudoarthrosis repair procedures for AIS.

Design

Multicenter retrospective cohort study using a prospectively collected registry

Introduction

Pseudoarthrosis is an uncommon but clinically relevant complication after PSF for AIS, often presenting with pain or implant failure. Due to its low incidence, evidence guiding revision strategy and graft selection is limited.

Methods

AIS patients undergoing PSF with more than two years of follow-up were screened for pseudoarthrosis using complication codes for “pseudoarthrosis” or “instrumentation failure.” Diagnosis was confirmed through review of radiographs, operative reports, and clinical records, defined as failed arthrodesis more than six months after index surgery. Presentation details, revision approach, implant strategy, graft utilization, and post-revision outcomes were summarized descriptively.

Results

Of 3,532 AIS patients, 22 had pseudoarthrosis treated with revision (prevalence 0.8%). Mean age at index surgery was 14.8 ± 1.9 years, and at revision was 17.9 ± 2.3 years. Median time from index to revision was 2.5 years [IQR 2.0], with post-revision follow-up of 1.2 years [IQR 2.6]. All revisions were posterior only. Most (77.3%) had revision at the same levels; 5 (22.7%) had extension due to junctional deformity. Only one patient underwent lumbar interbody fusion, and one patient had a three-rod construct. Allograft (68.2%) and local autograft (45.5%) were most commonly used grafts, while BMP-2 (22.7%) and distant autograft (4.5%) were used infrequently. Two patients (8.7%) experienced postoperative surgical site infections, one of which underwent re-operation. No recurrent pseudoarthrosis or implant failure was observed.

Conclusion

This study represents the largest multicenter analysis of revision surgery for pseudoarthrosis in AIS. Posterior-only, level-preserving strategies predominated, with targeted implant revision. Construct extension was performed only in the presence of associated junctional deformity. Outcomes were favorable, supporting posterior-only revision as a safe and effective approach that may inform future management guidelines.

§ Hibbs Award Nominee – Best Clinical Paper, † Hibbs Award Nominee – Best Basic Science/Translational Science Paper, ‡SRS Funded Research Grant

Presentation Details			
Pain, n (%)		12 (54.5%)	
Implant failure at presentation, n (%) (patients may present with >1 mode of failure)			
Broken Rods		7 (31.8%)	
Broken Screws		6 (27.3%)	
Loose Screws		9 (40.9 %)	
Screw Rod Dissociation		6 (27.3%)	
No Obvious Implant Failure (i.e. Subtle screw loosening confirmed with Computed Tomography)		1 (4.5%)	
Associated junctional deformity, n (%)			
Proximal Junctional Kyphosis		1 (4.5%)	
Distal Junctional Kyphosis		3 (13.6%)	
Coronal plane "Adding on"		1 (4.5%)	
Revision Surgery Details			
Operative Metrics	Mean $\pm$ SD	Min	Max
Surgical Time (minutes) <i>n=18; missing=4</i>	187.4 $\pm$ 109.3	77	480
Estimated Blood Loss (mL)	260.9 $\pm$ 212.3	10	800
Length of Hospital Stay (days)	3.2 $\pm$ 1.9	1	10
Revision Approach	N	%	
Posterior-only Approach	22	100%	
Anterior or Combined Approach	0	0%	
Thoracoplasty Performed	2	9.1%	
Interbody Fusion	1 (TLIF)	4.5%	
Revision Type	N	%	
Revised full rod	10	45.5%	
Revised partial rod (connector)	8	36.4%	
Supplemental rods (≥ 2 rods)	1	4.5%	
Revised screws	18	81.8%	
Added instrumented levels	5	22.7%	
Removed instrumented levels	1	4.5%	
Graft only	0	0%	
Bone Graft Use in Revision Surgery (patients may have >1 graft type used)			
Graft Type	# of patients	% of patients	
Allograft	15	68.2%	
Local Autograft	10	45.5%	
Cellular Allograft	5	22.7%	
BMP-2	5	22.7%	
No Graft	1	4.5%	
Distant Autograft	1 (Iliac crest)	4.5%	
BMA	0	0.0%	
Synthetics	0	0.0%	
TLIF = transforaminal lumbar interbody fusion; BMP-2 = bone morphogenetic protein-2; BMA = Bone Marrow Aspirate; Patients may have received more than one graft type. Missing data noted when unavailable; n=22 if not otherwise mentioned.			

Table 1: Presentation and Revision Surgery Details (N = 22)