Papers are listed in presentation order

Paper #13. Factors Associated with Construct Failures in Adult Spine Deformity Patients Matching Ideal Roussouly Type

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Hypothesis
To investigate factors associated with mechanical complications in patients with restored ideal Roussouly type.

Design
Retrospective cohort

Introduction
Restoring ASD patients' ideal Roussouly type is reported to prevent mechanical complications. There remain patients with restored ideal Roussouly type who still suffer these complications. The associated factors are incompletely understood.

Methods
ASD patients with complete data from baseline (BL) to 2 years (2Y) were stratified by matching ideal Roussouly (R) types as described by Latouissat: type 1 & 2 corresponding to pelvic incidence (PI) < 45°, type 3 to PI 45°–60°, & type 4 to PI >60°. Patients matching ideal R types postop and sustaining mechanical complications (Rouss+Mech+) were further isolated. Means comparison tests and logistic regressions were used to analyze differences and associations between groups.

Results
464 patients were included (Age:60.4 ± 14.9 years, BMI:27.5 ± 5.8 kg/m2, CCI:1.67 ± 1.66). 74% of patients were female. At BL, 8.2% of patients were R type 1, 51.8% type 2, 26.6% type 3 and 13.2% type 4. 41.5% of patients matched ideal R type (43.1% type 1, 30.4% type 2, 40.6% type 3 and 84.9% type 4, p<0.001). Post-op, 50.7% of patients matched ideal R type (40.3% type 1, 43.4% type 2, 55.8% type 3 and 74.6% type 4, p<0.001). At 2 years post-op, patients matching ideal R type experienced lower mechanical complications [MCs] (13% vs 86%, p<0.001). MC rates by R type in patients matching ideal R type (Rouss+Mech+) were 11.1% in type 1, 13.9% type 2, 12.7% type 3 and 15.3% type 4, p=0.930). Factors associated with MC in Rouss+Mech+ were under-correction by persistent pelvic incidence-lumbar lordosis mismatch (OR 1.1, 95% CI 1.1-1.2, p<0.001) and lower limb arthritis (OR 2.4, 1.2-4.9, p=0.024). Rouss+Mech+ had lower rates of matching in sagittal age-adjusted score compared to Rouss+Mech- at BL (27.3 vs 33.8%, p<0.001), postop (27.3 vs 31.4%, p<0.001), and at all timepoints up to 2 years. Rouss+Mech+ also had higher rates of reoperation at 2 years (58.3% vs 16.7%, p<0.001).

Conclusion
Although uncommon, patients matched to ideal Roussouly shape post-op may still experience mechanical complications. Inadequate realignment and lower limb arthritis are associated with increased risk within two years, and thus warrant consideration during ASD surgery planning.

Paper #14. Optimizing Lower Instrumented Vertebra Selection in Adult Idiopathic Scoliosis Using Preoperative Upright and Supine Last Touched Vertebra

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Hypothesis
Selecting the supine last touched vertebra (LTV) as the lower instrumented vertebra (LIV) in Adult Idiopathic Scoliosis (AdIS) yields alignment outcomes similar to upright LTV.

Design
Retrospective Cohort

Introduction
LIV selection in AdIS presents challenges in achieving optimal alignment while minimizing fused motion segments. Traditionally in adolescent scoliosis, the LTV on upright films is selected, however recent literature supports using the supine LTV. This study compared LTV as LIV on upright and supine radiographs.

Methods
AdIS patients fused proximal to the sacrum and ≥2-year follow-up were included. Radiographic measurements occurred pre/post surgery, at 6 months, and 1 and 2 years. 6 groups were formed based on LTV/LIV: 1)upright LTV=supine LTV=LIV; 2)upright LTV=LIV; 3)supine LTV=LIV. Modifiers A/B indicated if LTV was crossed at/medial versus lateral to the pedicle.

Results
55 AdIS patients were identified with 2.6year follow-up (R=2-6), significant coronal deformity (ave. curve 57°, R=34°-136°), and LIV between T12-L5. Trunk shift decreased from 18mm preop to 7mm at 2 years(F=10.33,p<0.01). C7-SVA improved from 23mm preop to 11mm in 2 years(F=9.58,p<0.01). Distal disc angle decreased from 2.8° to 0.7° in 2 years(F=8.18,p<0.01). No distal adding on, junctional kyphosis, or revision surgery occurred. The most notable differences were observed between groups A(n=36) and B(n=17). At 6 months and 2 years, the distance from CSVL to LIV was lower in groups 1A(n=6), 2A(n=18), 3A(n=13) versus 1B(n=3), 2B(n=6), 3B(n=9)(3.7vs7.5,F=9.0,p=0.004; 3.2vs6.9,F=6.7,p=0.01). This distinction was seen immediately postop and at 2 years in trunk shift(10.8vs18.4,F=4.03,p=0.05; 5.2vs9.3,F=5.3,p=0.03) and at 2 years in C7-SVA(7.6vs16.5,F=14.9,p=0.003). Group 3B had a larger distance from CSVL to LIV at 6 months compared to 1A/2A(8.0vs2.3/2.8,F=2.7,p<0.03). Trunk shift was lower in 2A vs 3B immediately and at 6 months(7.4vs23.3,F=2.6,p=0.07; 5.22vs18.7,F=2.2,p=0.01). C7-SVA was lower immediately and at 2 years in 2A vs 3B(11.0vs 26.0,F=2.85,p=0.03; 7.2vs18.3,F=3.38,p=0.01). No other differences were found.

Conclusion
Supine LTV touching the pedicle is a viable LIV strategy in AdIS. Preoperative CSVL lateral to the LIV pedicle correlates with residual trunk shift and CSVL-LIV distance.
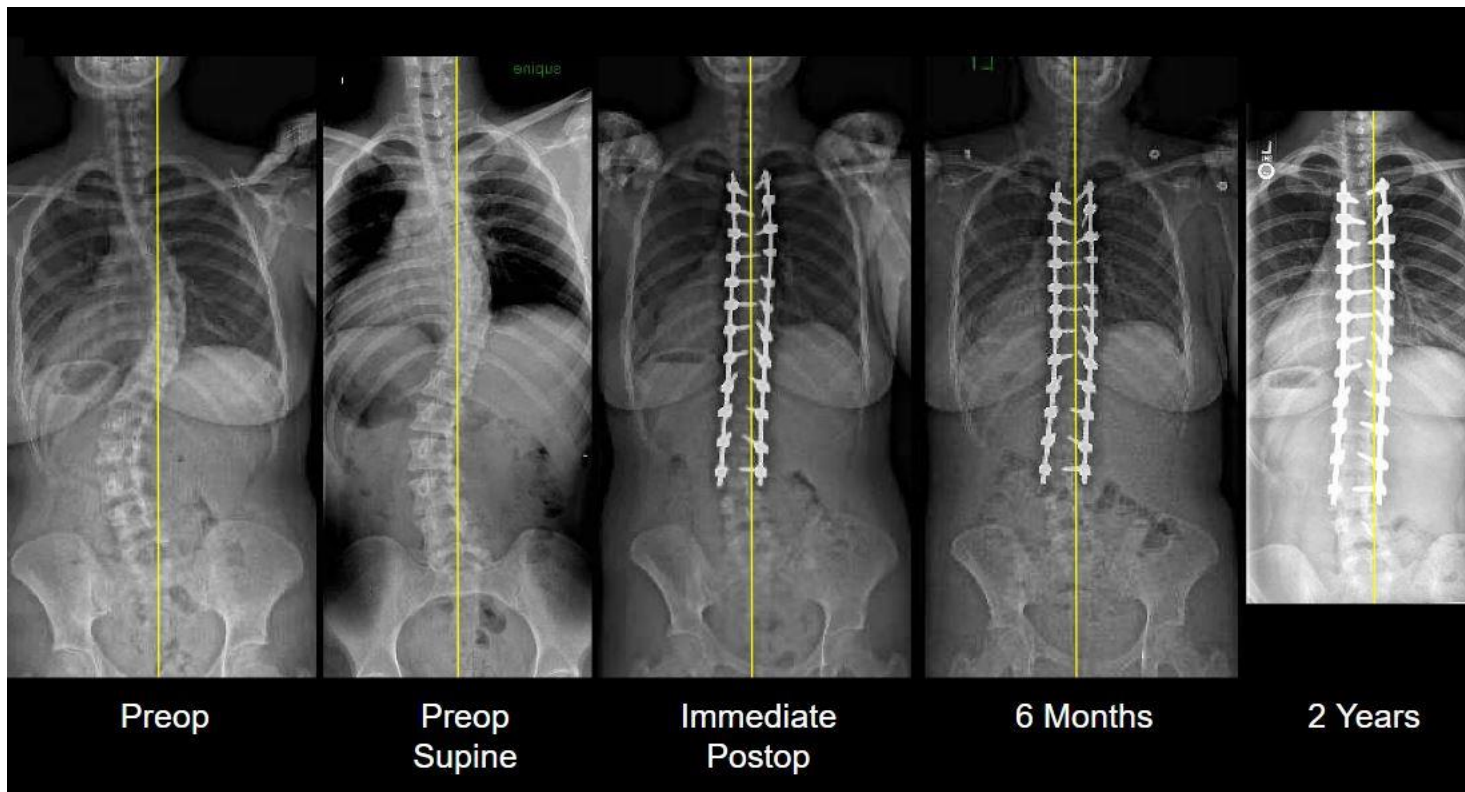
24F Grade 3A (upright LTV=L5, supine LTV=L3) fused to L3 with minimal residual deformity

Paper #15. Anatomical Pelvic Parameters Using the Anterior Pelvic Plane in Healthy Volunteers: A Key for Natural Sagittal Alignment of Adult Spinal Deformity

Masayuki Ohashi, MD, PhD; Kazuhiro Hasegawa, MD, PhD; Shun Hatsushikano, BS; Kei Watanabe, MD, PhD; Hideki Tashi, MD; Keitaro Minato, MD, PhD; Tatsuo Makino, MD; Masayuki Sato, MD

Hypothesis
Anatomical pelvic parameters based on the anterior pelvic plane (APP) are correlated with sagittal spinal parameters in the standing position.

Design
A cross-sectional study

Introduction
We aimed to estimate the natural standing sagittal alignment in patients with adult spinal deformity (ASD), firstly investigating the normative values of anatomical pelvic parameters based on the APP in a healthy population and to clarify the relationships between the anatomical pelvic parameters and standing sagittal parameters.

Methods
We analyzed the images of biplanar slot-scanning full body stereoradiography in 140 healthy Japanese volunteers (mean age, 39.5 years; 59.3% female). Anatomical sacral slope (SS) and pelvic tilt (PT) (aSS and aPT, respectively) were calculated as the angles of the SS and PT in reference to the APP (Figure). We analyzed bivariate correlations between the anatomical pelvic parameters and standing sagittal parameters.

Results
The mean APPA was 0.7° ± 6.4° (range, −16.8° to 15.5°), indicating that the pelvis was tilted anteriorly by an average of 0.7°. Further, the mean values of the pelvic incidence (PI), aSS, and aPT were 50° (28.8°–74.2°), 36.8° (18.3°–64.9°), and 13.2° (−0.6° to 28.7°), respectively. Anatomical pelvic parameters were significantly correlated with standing sagittal parameters, except for cervical lordosis and T4–12 thoracic kyphosis (TK) (Table). aPT and aSS were significantly correlated with several sagittal parameters which were not correlated with PI. L4–S1 lumbar lordosis was significantly correlated with aPT ($r = -0.271$, $p = 0.001$) and aSS ($rs = 0.264$, $p = 0.002$) but not with PI. Moreover, the distance between the center of the acoustic meati and gravity line was significantly correlated with aPT ($r = -0.260$, $p = 0.002$), and T1–12 TK was significantly correlated with aSS ($rs = 0.172$, $p = 0.042$).

Conclusion
We found novel relationships between the anatomical characteristics of pelvis (aPT and aSS) and standing sagittal parameters, which were not represented by PI. Therefore, this novel measurement concept based on the APP, and our results from a healthy population, may aid the precise estimation of natural standing sagittal alignments using anatomical pelvic parameters in patients with ASD.
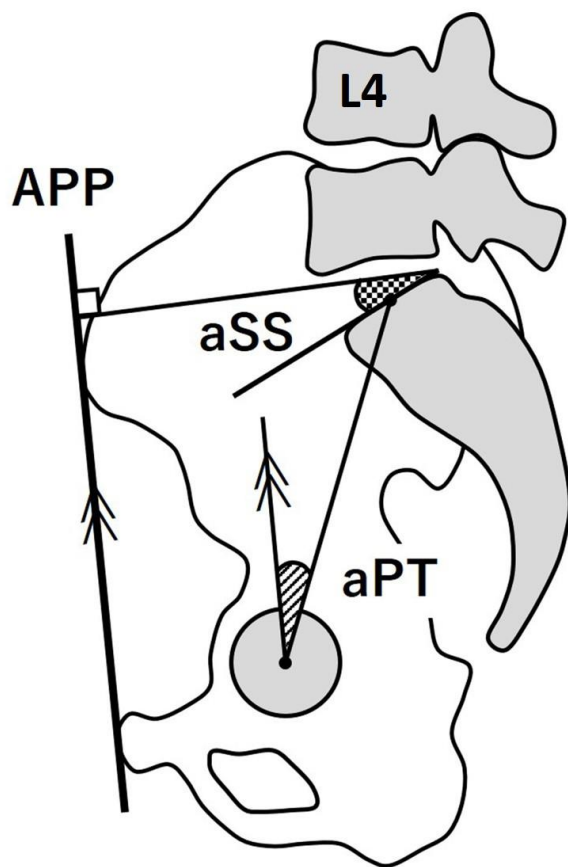
Table: Correlations between anatomical and standing sagittal parameters			
	PI	aPT	aSS
Age	0.05	-0.064	0.151
BMI	-0.153	-0.122	-0.037
CAM-GL	-0.105	-0.260**	0.052
SVA	0.205*	-0.006	0.244**
T1 pelvic angle	0.668***	0.507***	0.343***
Cervical lordosis	0.022	-0.048	0.133
T1-12 TK	0.067	-0.122	0.172*
T4-12 TK	0.028	-0.131	0.128
L1-S1 LL	0.475***	0.036	0.514***
L4-S1 LL	0.051	-0.271**	0.264**
PT	0.657***	0.571***	0.294***
SS	0.628***	0.046	0.641***

CAM-GL, distance between the center of the acoustic meati and gravity line.
*p <0.05, **p <0.01, ***p<0.001

Anatomical pelvic parameters based on anterior pelvic plane (PI, aSS, and aPT) and correlations with standing sagittal parameters

Paper #16. Predictive Role of Frax in Postoperative Proximal Junctional Kyphosis with Vertebral Fracture After Adult Spinal Deformity Surgery

Junya Katayanagi, MD, PhD

Hypothesis
FRAX, an osteoporosis assessment tool, can predict the occurrence of postoperative proximal junctional kyphosis (PJK) with vertebral fracture (VF) in adult spinal deformity (ASD) surgery patients.

Design
Retrospective cohort study

Introduction
A retrospective study included 127 ASD surgery patients (mean age 67.7 years, mean follow-up 7.7 years). Inclusion criteria were ASD patients aged ≥50, abnormal radiographic variables, and corrective spinal fusion of six or more segments. FRAX, BMD, and various surgical intervention factors were assessed. PJK with VF was defined according to Yagi-Boachie classification. Statistical analyses included Mann-Whitney test, Fisher's exact test, Kaplan-Meier analysis, and Cox proportional hazards regression.

Methods
This retrospective study included 127 ASD patients who underwent corrective surgery. Inclusion criteria comprised patients aged ≥ 50 years, abnormal radiographic variables, corrective long spinal fusion of six or more segments, and a postoperative follow-up of 2 years or more. FRAX scores, BMD measurements, surgical intervention factors, and outcomes related to PJK with VF were analyzed. Statistical analyses included Kaplan-Meier survivorship analysis, and Cox proportional hazards regression.

Results
Postoperative PJK occurred in 31.5% of patients, with 65% being PJK with VF. FRAX (MOF > 15%) and lower instrumented vertebra (LIV) level were independent risk factors for PJK with VF, and the hazard ratio was 2.52 and 9.03 respectively. The median time to PJK with VF occurrence was 2.0 months, with 73% occurring within 6 months postoperatively.

Conclusion
FRAX (MOF > 15%) and LIV (caudal to S1) are identified as independent risk factors for postoperative PJK with VF in ASD surgery patients. Early intervention for osteoporosis, guided by FRAX, may reduce the risk of PJK with VF. Surgeons should consider FRAX in preoperative evaluations for ASD surgery to enhance patient outcomes and reduce complications.

Paper #17. Enhancing Spinal Deformity Surgery Outcomes: A Novel Approach Using Intraoperative Extended Pelvic Tilt Line Parameters to Predict Mechanical Failure

Jae-Koo Lee, MD; Seung-Jae Hyun, MD, PhD; Sunho Kim, MD; Seung-Ho Seo, MD; Kwang-Ui Hong, MD

Hypothesis
This study hypothesizes that intraoperative extended pelvic tilt (ePT) line parameters can be a reliable predictor of postoperative mechanical failure (MF) in spinal deformity surgeries, thereby aiding in improving surgical planning and patient outcomes.

Design
A retrospective single-center study.

Introduction
Spinal deformity surgery relies heavily on preoperative planning using angular parameters. However, accurately predicting patient alignment in an erect position intraoperatively is a significant challenge. This study introduces an innovative approach, utilizing intraoperative parameters based on an ePT line to predict postoperative outcomes and alignments.

Methods
The study involved 46 patients who underwent surgery for degenerative sagittal imbalance with sacropelvic fixation and UIV from T8 to 11 from 2014 to 2019, ensuring a minimum follow-up of two years. Patients were stratified into two groups based on the occurrence of mechanical failure. A detailed analysis encompassed demographic, surgical, and radiographic parameters, with a focus on the novel ePT line, delineated as a line intersecting both bifemoral head points and the sacral endplate center. Intraoperative parameters such as the T10/L1ePT metric, L1 pelvic angle (L1PA), and UIVPTA were introduced and analyzed. The cut-off values for each parameter were established using Youden's index to maximize sensitivity and specificity.

Results
Out of the 46 patients, 25 suffered from mechanical failure. Significant differences were observed between the MF and non-MF groups in terms of T10ePT (12.7 ± 45.0mm vs. 46.5 ± 51.3mm, p=0.02), L1ePT (24.2 ± 31.3mm vs. 45.7 ± 35.1mm, p=0.04), L1PA (5.1 ± 6.4° vs. 9.1 ± 6.9°, p=0.048), and UIVPTA (1.6 ± 6.8° vs. 7.0 ± 7.7°, p=0.017). Binary logistic regression revealed significant odds ratios for T10ePT (5.41, CI: 1.41-20.77), L1PA (5.54, CI: 1.30-23.67), and UIVPTA (5.69, CI: 1.56-20.76), highlighting their predictive value for MF.

Conclusion
This first-of-its-kind study demonstrates that incorporating linear measurements with angular parameters in intraoperative ePT line assessments can predict MF in spinal deformity surgeries. Achieving targeted values intraoperatively could reduce MF risks, suggesting a novel approach for surgical planning. These findings have potential implications for improving patient outcomes in spinal deformity surgeries.
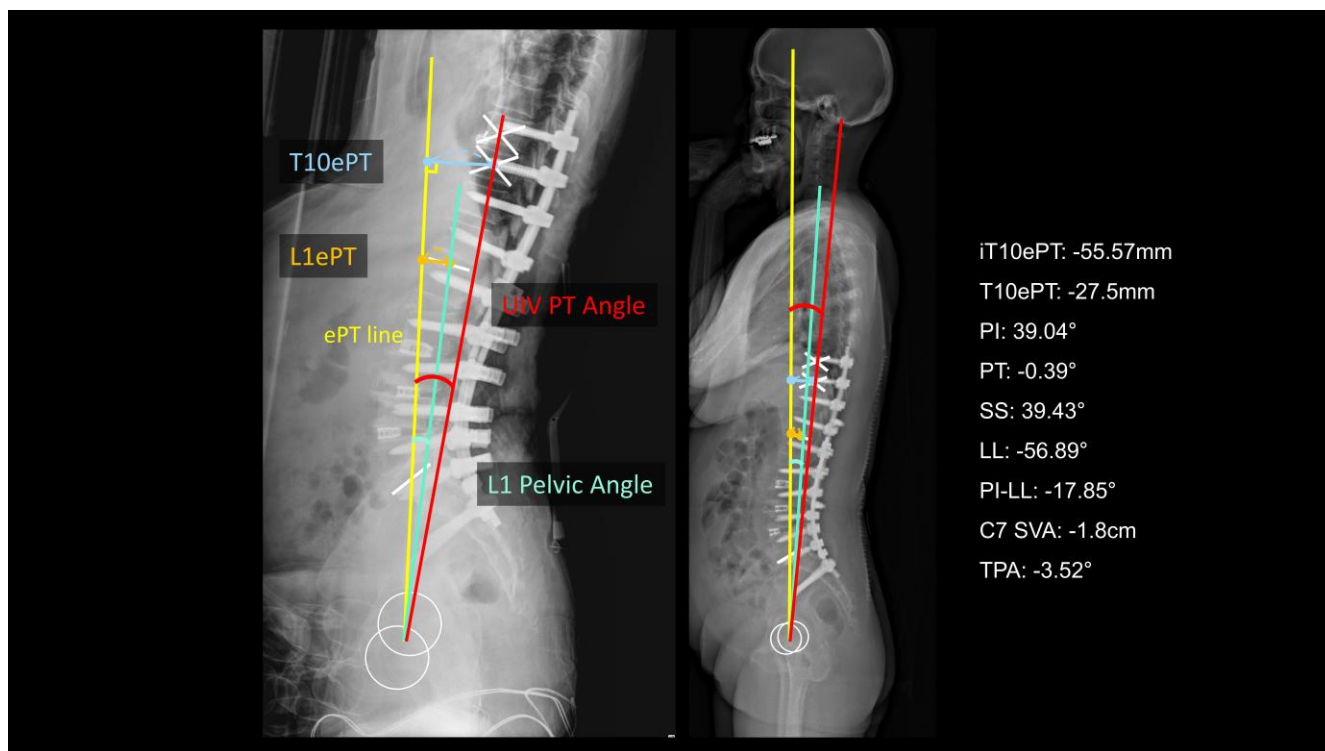
ePT line parameter

Paper #18. Health Utility Outcomes Following Surgery for Adult Thoracolumbar Spinal Deformity

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Hypothesis
Health utility significantly improves following surgery for thoracolumbar ASD.

Design
Retrospective analysis of prospectively collected multicenter registry data

Introduction
Health utility is a fundamental patient reported outcome which assesses the impact of a disease or treatment on a patient's quality of life and is critical in performing cost-effectiveness analyses. This is particularly relevant in ASD which portends high treatment risks and costs. Currently there is a paucity of published data detailing the expected change in utility following surgery.

Methods
Patients within a surgical prospective multicentered ASD registry with SF-36 data and ≥2 years follow-up were included. SF-6D utility was calculated using US health preferences. ΔUtility was defined as the difference between ≥2 year and preoperative SF-6D, and was dichotomized into < 0 (bad) and ≥ MCID=0.033 (good). Linear and logistic regression were used to explore factors associated with ΔUtility and probability of good outcome, respectively.

Results
Of the 1487 included patients, 1073 (72.3%) were female, with a preoperative median [IQR] age of 64.4 [55.5, 70.4], ODI of 46 [34, 58], and SRS-22r of 2.8 [2.3, 3.2]. Surgery involved a median of 10 [8, 14] fused levels, with 256 (17.2%) having a 3-column osteotomy. Median preoperative SF-6D, ≥2 year SF-6D, and ΔUtility were 0.556 [0.485, 0.616], 0.649 [0.579, 0.757], and 0.0840 [0.016, 0.166] respectively. The 696 (70.6%) patients with good outcome had a median ΔUtility of 0.130 [0.077, 0.202], which is similar to that seen following total hip arthroplasty. In multivariate linear regression, higher preoperative NRS back and leg pain were both associated with greater ΔUtility (β = 0.00380, p = 0.041 and β = 0.00258, p = 0.048 respectively) while PJK leading to revision surgery was associated with decreased ΔUtility (β = -0.0539, p = 0.0023). Multivariate logistic regression revealed that a 3-column osteotomy was associated with lower likelihood of a good outcome (OR=0.549, p=0.0052).

Conclusion
Surgery for thoracolumbar ASD imparts significant improvement in SF-6D utility, with a median increase of 0.0840. This represents the highest quality available evidence for predicting the expected postoperative utility in ASD. Significant factors on multivariate analyses included NRS back and leg pain, 3-column osteotomy, and PJK requiring revision surgery, all of which represent pertinent areas of future research.
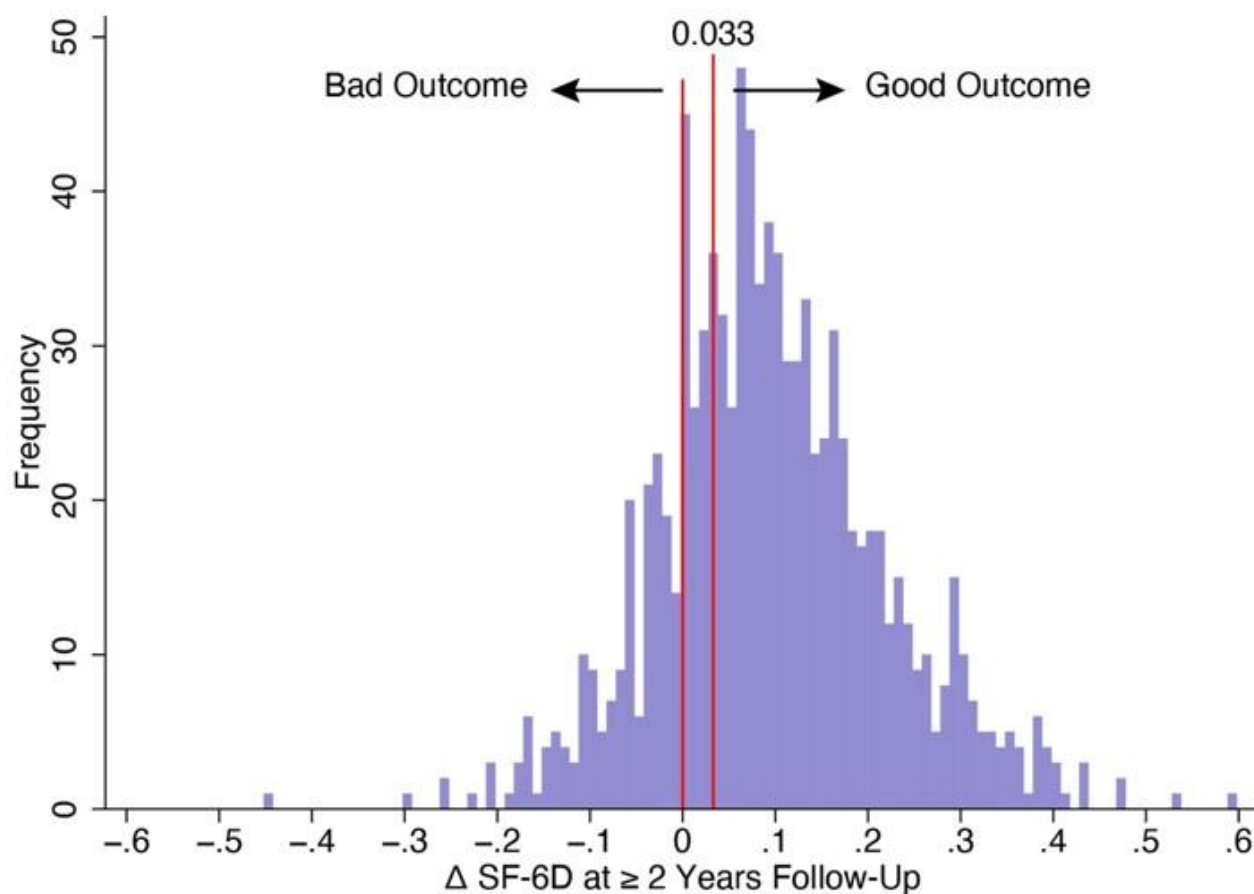
Figure 1: Distrubtion of the difference between ≥ 2 year follow-up and preoperative SF-6D Utility following surgery for thoracolumbar ASD

Paper #19. Comparative Study Between Teriparatide and Denosumab on the Prevention of Proximal Junctional Kyphosis: Prospective, Randomized Controlled Trial

Ho-Joong Kim, MD

Hypothesis
Teriparatide treatment is effective in preventing PJK (Proximal Junctional Kyphosis) in patients with osteoporosis undergoing ASD (Adult Spinal Deformity) surgery.

Design
Prospective, randomized controlled trial

Introduction
The purpose of this ramdomized controlled trial was to compare the incidence of Proximal Junctional Kyphosis(PJK) in patients with osteoporosis receiving teriparatide or denosumab after adult spinal deformity (ASD) surgery.

Methods
Each 32 ASD patients were randomly assigned to parathyroid hormone group and denosumab group. The treatment with teriparatide or denosumab for both groups was conducted from three months before surgery to three months after surgery, based on the standard regimen for each medication. The primary outcome of this trial was the occurrence of PJK or PJF within one year post adult spinal deformity surgery. Secondary outcomes included Patient-reported outcomes (PROs), Bone Mineral Density (BMD), and Dual-energy X-ray Absorptiometry (DEXA) t-score.

Results
In the primary outcome, regarding PJK (Proximal Junctional Kyphosis) incidence, the teriparatide group had a lower rate of 16.7%, compared to 30.8% in the denosumab group, but this difference was not statistically significant ($p=0.243$ in a modified intention to treat analysis). However, for PJF (Proximal Junctional Failure) incidence, the teriparatide group exhibited a significantly lower rate of 0.0%, as opposed to 19.2% in the denosumab group. In the secondary outcome, at the 1-year follow-up, there were no significant differences in hip Bone Mineral Density (BMD) and DEXA t-score between the two groups. Postoperatively, the teriparatide group showed a significantly lower score in the Visual Analog Scale (VAS) for back pain and a significantly higher score in EQ-5D and SRS-22 pain score. There were no significant differences in other patient-reported outcome measures.

Conclusion
In patients with osteoporosis undergoing ASD surgery, the rate of PJF was lower in those receiving teriparatide treatment compared to those receiving denosumab treatment. In terms of patient-reported outcomes related to pain, patients who received teriparatide treatment showed better results compared to those who received denosumab treatment.

Paper #20. Perioperative Change in Bone Quality Following Thoracolumbar Fusion and Its Effects on Postoperative Outcomes

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Hypothesis
In long-construct thoracolumbar fusions, there will be a postoperative decrease in CT vertebral Hounsfield Units (HUs) inside the fusion mass and an increase in HUs at the proximal instrumented and adjacent vertebral level that is more pronounced if junctional complications occur.

Design
Retrospective Cohort Analysis

Introduction
Preoperative CT HUs have been previously associated with adverse outcomes after spinal fusion including pseudoarthrosis, screw loosening, and reoperation. No existing studies have investigated the preoperative to postoperative change in vertebral HUs after spinal fusion.

Methods
All adult patients who underwent posterior thoracolumbar fusion (upper instrumented vertebrae [UIV]: T10-L2 to pelvis) for deformity at an academic center between 2010-2018 were retrospectively identified. Preoperative and postoperative HUs were assessed on axial CT images in the cranial, middle, and caudal cut of UIV+1, UIV, L3, L4, and L5 vertebral bodies, outside of the region of hardware and artifact in postoperative CTs, by two reviewers with interrater correlations. Primary outcomes included fusion status on CT (one-year) and proximal junctional kyphosis (PJK) and failure (PJF) on final XR (>2 years postoperatively). Paired t-tests compared pre- to post-operative changes in HUs. Logistic regressions determined if perioperative HU changes (Δ) predicted complications independent of preoperative HUs. Receiver operating curve (ROC) analyses determined the probability of PJK and PJF based on ΔHUs.

Results
A total of 136 patients were included. The average pre- to post-operative change in HUs in the UIV+1, UIV, L3, L4, and L5 vertebral bodies were 59.2 ($p<0.001$), 83.6 ($p<0.001$), 30.8 ($p=0.005$), 5.0 ($p=0.640$), and 2.5 ($p=0.912$) respectively, with all interrater correlations >85%. Decrease in L3 (OR=0.997, $p=0.008$) and L4 (OR=0.998, $p=0.017$) ΔHUs independently predicted fusion. On logistic regression UIV+1 ΔHUs (OR=1.01, $p<0.001$) independently predicted PJK and UIV ΔHUs (OR=1.002, $p=0.006$) independently predicted PJF. ROC identified an optimal UIV+1 ΔHUs cutoff of 73.9 (AUC=0.71) and UIV ΔHUs cutoff of 109.6 (AUC=0.73) to predict PJK and PJF, respectively.

Conclusion
Perioperative decreases in mid-construct HUs secondary to stress shielding predicted successful fusion. However, perioperative increases in upper construct and adjacent level HUs predicted proximal junctional complications.

Paper #21. Creating Sustainability in Centers Performing High Volume Adult Spinal Deformity Surgery: Evaluation of the Maryland All-Payer Model

Andrew Kim, BS; Micheal Raad, MD; Richard Hostin, MD; Shay Bess, MD; Jeffrey L. Gum, MD; Breton G. Line, BS; Pratibha Nayak, PhD, MBA, MPH; Virginie Lafage, PhD; Renaud Lafage, MS; Kojo D. Hamilton, MD, FAANS; Peter G. Passias, MD; Themistocles S. Protopsaltis, MD; Lawrence G. Lenke, MD; Alex Soroceanu, MD, FRCS(C), MPH; Justin S. Smith, MD, PhD; Christopher P. Ames, MD; Bassel G. Diebo, MD; Eric O. Klineberg, MD; Alan H. Daniels, MD; Han Jo Kim, MD; Robert K. Eastlack, MD; Michael P. Kelly, MD; Munish C. Gupta, MD; Frank J. Schwab, MD; Christopher I. Shaffrey, MD; Douglas C. Burton, MD; Khaled M. Kebaish, MD; International Spine Study Group

Hypothesis
Reimbursement for adult spinal deformity (ASD) surgery under the Maryland All-Payer Model (MAPM) will be higher than the Medicare Severity-Diagnosis Related Group (MS-DRG) model.

Design
Multicenter prospective study

Introduction
The MAPM is a healthcare payment system that ensures all payors pay the same rate for healthcare services. The MS-DRG model is used by all other states, where payments are influenced by factors such as geographic location and teaching hospital status. With Medicare allowable rates underestimating direct costs of ASD surgery by approximately $17,000, the MAPM ensures the sustainability of centers performing high volume ASD surgery on Medicare patients. The purpose of this study is to examine differences in reimbursement and inpatient length of stay (LOS) in ASD surgery between the MAPM and MS-DRG models.

Methods
A total of 416 ASD patients were examined. MS-DRG reimbursements were calculated using the CMS Pricer tool, while reimbursements for the MAPM were compiled from a single institution from 1,783 patient accounts. Payments for the most common ASD MS-DRG codes (453, 454, 455, 456, 457, 458, 460) were analyzed for fiscal years 2018-2023. Average inpatient LOS was calculated for each MS-DRG code and payer model. Univariate analysis was performed to assess for differences in mean reimbursements and LOS between models.

Results
From 2018-2023, overall mean reimbursements for ASD surgery were significantly lower under the MS-DRG model compared to the MAPM ($59,198.59 vs $77,246.28; $p<0.001$). Mean reimbursement payments for MS-DRG codes 453 ($144,730.73 vs $86,574.54), 454 ($95,316.99 vs $57,716.02), 455 ($55,409.23 vs $39,291.13), 456 ($127,043.70 vs $72,380.38), 457 ($98,011.94 vs $60,669.77), and 460 ($57,207.78 vs $38,856.31) were higher under the MAPM compared to the MS-DRG model ($p<0.001$). Mean LOS was lower in the MAPM for MS-DRG code 453 ($p=0.046$) and higher for code 457 ($p<0.001$). For all other codes, no significant difference in LOS was observed.

Conclusion
ASD surgery reimbursements are higher overall under the MAPM compared to the MS-DRG model with similar inpatient LOS. These results highlight how the MAPM can create financial sustainability in centers performing high volume ASD surgery on Medicare patients.

Table 1. Reimbursement and LOS by MS-DRG code between models

MS-DRG Code	MS-DRG Model Mean (SD)	Maryland All-Payer Model Mean (SD)	p-value
453 - Combined anterior/posterior spinal fusion with MCC			
Total (*n*)	46	85	
Reimbursement	86,574.54 (19,229.26)	144,730.73 (79,766.41)	**< 0.001**
LOS, *days*	9.31 (4.36)	7.50 (4.57)	**0.046**
454 - Combined anterior/posterior spinal fusion with CC			
Total (*n*)	181	332	
Reimbursement	57,716.02 (12,208.51)	95,316.99 (39,626.34)	**< 0.001**
LOS, *days*	7.23 (5.85)	7.50 (4.57)	0.599
455 - Combined anterior/posterior spinal fusion without CC/MCC			
Total (*n*)	25	146	
Reimbursement	39,291.13 (10,003.48)	55,409.23 (13,439.77)	**< 0.001**
LOS, *days*	4.04 ± (1.09)	4.03 (1.77)	0.977
456 - Spinal fusion except cervical with spinal curvature or malignancy or infection or extensive fusions with MCC			
Total (*n*)	21	65	
Reimbursement	72,380.38 (8,310.69)	127,043.70 (86,087.43)	**< 0.001**
LOS, *days*	13.79 (18.51)	16.77 (17.15)	0.515
457 - Spinal fusion except cervical with spinal curvature or malignancy or infection or extensive fusions with CC			
Total (*n*)	96	287	
Reimbursement	60,669.77 (12,213.56)	98,011.94 (42,487.77)	**< 0.001**
LOS, *days*	6.43 (2.95)	8.99 (7.10)	**< 0.001**
458 - Spinal fusion except cervical with spinal curvature or malignancy or infection or extensive fusions without CC/MCC			
Total (*n*)	29	65	
Reimbursement	45,158.86 (7,037.20)	51,813.92 (32,989.71)	0.125
LOS, *days*	4.06 (2.09)	3.94 (2.28)	0.793
460- Spinal fusion except cervical without MCC			
Total (*n*)	18	803	
Reimbursement	38,856.31 (8,865.15)	57,207.78 (26,530.69)	**< 0.001**
LOS, *days*	6.28 (3.95)	5.12 (3.86)	0.208
Overall			
Total (*n*)	416	1,783	
Reimbursement	59,198.59 (16,926.18)	77,246.28 (26,106.95)	**< 0.001**

MS-DRG: Medicare Severity Diagnosis-Related Group; *MCC*: major complicating or comorbid condition; *CC*: complicating or comorbid condition; *LOS*: length of stay

Paper #22. Influence of Implant Density on Mechanical Complications in Adult Spinal Deformity Surgery

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Hypothesis

In adult spinal deformity surgery, the use of double rods and interbody cages are intended to decrease rod strain and the risk for pseudarthrosis. Rigid instrumentation might increase stress at construct extremities and the risk for proximal junctional kyphosis/failure (PJK/PJF) or screw loosening.

Design

Retrospective register study.

Introduction

The purpose of this study was to analyze how rod characteristics, screw density and cages could influence the incidence of mechanical complications compared to patient-related factors and alignment.

Methods

Multi-center register data of patients with T9-T11 to pelvis instrumentation and follow-up ≥2 years was analyzed. Relative lumbar lordosis (RLL) and relative sagittal alignment (RSA) was measured. Surgical data included rod characteristics, pedicle screw density and interbody cages. Univariate logistic regression models analyzed the impact of patient- and implant-related factors on complications. Multivariable models were then used for clinically relevant and significant ($p<0.2$) variables.

Results

Among 302 patients, pseudarthrosis was evidenced in 24.1%. On univariate analysis Odds Ratio (OR) was 0.74 for ≥3 cages ($p=0.452$), 0.48 for double rods ($p=0.008$), 4.30 for high screw density 1.5-2 ($p=0.001$). Patient-related factors were non-significant. On multivariate analysis OR was 0.59 for double rods ($p=0.084$) and 4.67 for screw density 1.5-2 ($p=0.005$). PJK/PJF occurred in 19.2%. Age >60 had an OR 2.83 ($p=0.023$), postoperative RSA malaligned OR 2.84 ($p=0.030$), severely malaligned OR 6.54 ($p<0.001$). Implant characteristics were non-significant. On multivariate analysis OR was 1.25 for age >60 ($p=0672$), 2.56 for malaligned RSA ($p=0.068$), 6.37 for severely malaligned RSA ($p<0.001$). Screw loosening without PJF was present in 8.9%. On univariate analysis OR was 0.95 for ≥3 cages ($p=0.920$), 1.64 for double rods ($p=0.235$), 0.25 for screw density 1.5-2 ($p=0.011$). Patient-related factors were non-significant. On multivariate analysis OR for screw density 1.5-2 was 0.23 ($p=0.022$).

Conclusion

Double rods decrease the risk for pseudarthrosis. Cages seem to have a secondary role in load sharing. High screw density does not prevent from pseudarthrosis. Postoperative malalignment and age mainly influence the risk for PJK/PJF. Implant characteristics have a minor influence and rigid constructs don't increase the risk. High density screw constructs have a lower risk for screw loosening.

Paper #23. Achieving Correction and Mitigating Complications in Adult Spinal Deformity Through an Anterior-Posterior Combined Approach: 1 or 2-Level Apical Segment Interbody Fusion is Enough?

Dongkyu Kim, MD; Kyunghyun Kim, MD, PhD

Hypothesis
To assess the adequacy of 1 or 2-level apical segment interbody fusion for achieving correction and mitigating complications in adult spinal deformity through an anterior-posterior combined approach compared to posterior only approach.

Design
Retrospective study from prospective consecutively collected database from a single institution.

Introduction
Adult spinal deformity (ASD) can be effectively treated by posterior approach, but at the expense of invasive osteotomies and excessive blood loss. Addition of anterior approach in ASD correction surgery can reduce the invasiveness of the surgery, but major anterior-related complications are also reported. There is still debate regarding which approach is more favorable, and the optimal strategy of combining anterior approach is not yet established.

Methods
Between January 2014 and May 2021, a cohort of 150 ASD patients with a minimum follow-up period of 2 years was collected. Of the 150 ASD patients, 108 underwent a posterior-only surgical approach (P group), whereas 42 underwent a combined approach surgery (AP group). Comprehensive baseline demographic and surgery-related data were collected. Serial standing radiographs of radiological parameters were acquired at baseline, immediately postoperatively, and 2 years postoperatively. Various clinical outcomes were assessed and the incidents of complications were recorded.

Results
AP group showed significantly less invasive osteotomy (1.7 vs. 2.3, p=0.001), less total blood loss (1629.0 cc vs. 2202.8 cc, p=0.049), and a shorter duration of surgery during the posterior stage (301.4 min vs. 412.3 min, p<0.001). AP group achieved more significant correction in coronal imbalance, as measured by Cobb angle correction (17.5 vs. 7.3, p<0.001). Additionally, AP group demonstrated a statistically significant improvement in the Global Alignment and Proportion (GAP) score compared to P group, regarding sagittal imbalance correction. Both groups exhibited comparable clinical outcomes, complication rates, and fusion rates, with no statistically significant differences noted.

Conclusion
Apical one or two level anterior lumbar interbody fusion combined with posterior approach showed superior coronal correction and comparable sagittal correction with less invasive osteotomy and less blood loss without occurrence of major complications.
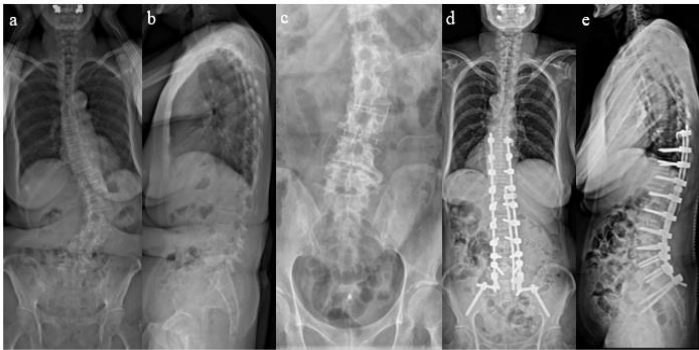
Figure 1. Representative case of ASD patient who received anterior to posterior combined approach surgery. **a,b**) 65-year-old female presented with severe coronal imbalance at thoraco-lumbar junction. **c**) We first performed oblique interbody fusion in L2/3/4 level for the anterior stage. **d,e**) 7 days later, we performed posterior stage, which included T9 to iliac screw fixation and additional transforaminal interbody fusion posteriorly at L4/5/S1.

Figure 2. Illustrative flowchart of data collection

Table 1. Basic Demographic and Surgical Data

Demographic variable	Combined (N=42)	Posterior (N=108)	*p*-value
Follow-up periods	42.1 ± 26.7	48.2 ± 27.5	0.124
Age	69.1 ± 5.5	69.0 ± 5.0	0.678
Female	38 (90.5)	97 (89.8)	1.000
Height (cm)	155.3 ± 7.1	153.7 ± 6.7	0.307
Weight (kg)	59.5 ± 9.4	59.5 ± 10.0	0.833
BMI (kg/m^2)	24.7 ± 3.7	25.1 ± 3.5	0.589
BMD	-1.9 ± 0.8	-2.0 ± 1.0	0.395
ASA classification	2.3 ± 0.7	2.4 ± 0.7	0.397
Fixated vertebral number	8.9 ± 2.5	9.0 ± 2.2	0.705
Interbody fusion number	3.2 ± 1.1	1.3 ± 1.3	0.000
Anterior interbody fusion number	2.2 ± 0.6		
Osteotomy grade	1.7 ± 0.8	2.3 ± 1.0	0.001
Total Surgery time (min)	445.7 ± 111.8	412.3 ± 110.2	0.045
Ant Surgery time (min)	117.3 ± 49.0		0.000
Post Surgery time (min)	301.4 ± 111.5	412.3 ± 110.2	0.000
Total blood loss (cc)	1629.0 ± 760.7	2202.8 ± 1391.9	0.049
Hospital stay day	30.0 ± 26.7	24.8 ± 17.5	0.013

Continuous variables are depicted as mean ± SD and categorical values as number (%)

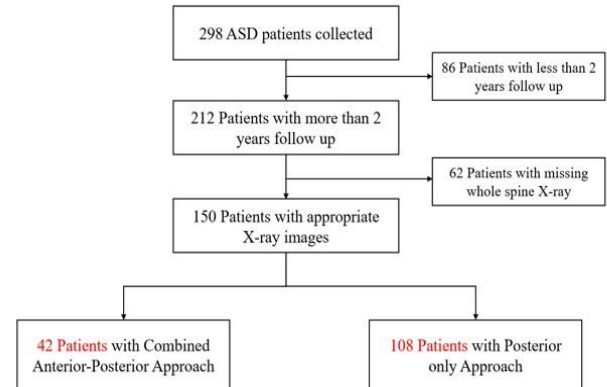BMI = body mass index; BMD = bone mineral density; ASA = american society of anethesiologists

Table 3. Radiologic outcome by correction amount

	Combined (N=42)	Posterior (N=108)	*p*-value
Immediate Correction (IMM-Base Δ)			
Major Cobb's angle (°)	17.9 ± 10.5	8.1 ± 8.5	0.000
Coronal Balance (C7PL to CSVL) (mm)	3.3 ± 22.8	5.8 ± 18.7	0.197
Sagittal Balance (C7SVA) (mm)	63.2 ± 61.4	73.3 ± 72.1	0.504
Global tilt (°)	21.0 ± 14.6	18.2 ± 16.1	0.198
Pelvic tilt (°)	12.6 ± 9.0	9.1 ± 9.7	0.027
Pelvic incidence (°)	2.3 ± 7.7	1.5 ± 6.2	0.714
Sacral slope (°)	-10.5 ± 9.1	-7.2 ± 9.1	0.023
Lordosis L1-S1 (°)	-27.7 ± 23.7	-25.8 ± 18.3	0.171
Kyphosis T5-T12 (°)	11.2 ± 11.2	9.9 ± 13.6	0.540
T1_Slope (°)	3.4 ± 8.5	3.6 ± 10.7	0.854
T1 Pelvic angle (°)	17.2 ± 11.6	15.8 ± 12.6	0.355
PI-LL mismatch (°)	30.6 ± 17.0	27.9 ± 20.3	0.243
Total GAP score	4.4 ± 4.0	2.9 ± 3.6	0.043
2-year Correction (2yr-Base Δ) *			
Major Cobb's angle (°)	17.5 ± 10.7	7.3 ± 8.6	0.000
Coronal Balance (C7PL to CSVL) (mm)	5.7 ± 25.5	5.4 ± 19.3	0.542
Sagittal Balance (C7SVA) (mm)	47.1 ± 57.3	45.5 ± 76.9	0.379
Global tilt (°)	14.5 ± 10.6	11.7 ± 14.8	0.125
Pelvic tilt (°)	8.1 ± 7.9	5.0 ± 9.3	0.051
Pelvic incidence (°)	1.5 ± 7.5	0.3 ± 8.2	0.388
Sacral slope (°)	-6.7 ± 10.4	-4.2 ± 9.6	0.109
Lordosis L1-S1 (°)	-25.8 ± 16.4	-21.1 ± 21.4	0.198
Kyphosis T5-T12 (°)	16.0 ± 13.5	13.1 ± 15.9	0.264
T1_Slope (°)	0.3 ± 10.3	2.1 ± 11.8	0.787
T1 Pelvic angle (°)	12.2 ± 8.8	9.7 ± 12.6	0.127
PI-LL mismatch (°)	23.1 ± 15.0	20.2 ± 23.2	0.347
Total GAP score	3.2 ± 2.9	1.7 ± 3.0	0.016

* Patients who received revision surgery within 2 years of follow up were excluded from analysis

GAP = global alignment and proportion; PI-LL = pelvic incidence - lumbar lordosis

Paper #24. Spinal Deformity Surgery in Patients with Movement Disorders: Trade-Off Between Increased Complications and Improved Long-Term Quality of Life

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Hypothesis
Patients with movement disorders undergoing adult spinal deformity (ASD) surgery have a worse postoperative course compared to patients without movement disorders.

Design
Retrospective cohort study.

Introduction
Movement disorders have been associated with poor outcomes after ASD surgery. In a cohort of patients undergoing ASD surgery, we sought to: 1) describe the operations performed in patients with movement disorders, 2) determine the impact of movement disorders on mechanical complications, reoperations, and patient-reported outcome measures (PROMs).

Methods
A single-institution, retrospective cohort study was performed for patients with a movement disorder undergoing ASD surgery from 2009-21. Inclusion criteria were: ≥5-level fusion, spinal deformity, and 2-year follow-up. Postoperative outcomes included mechanical complications, reoperations, and patient-reported outcome measures. A 3-1 propensity matching was performed, based on age, sex, BMI, and prior surgery.
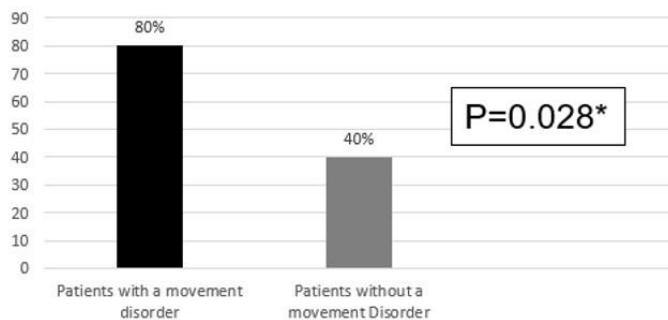
Results
Among 238 patients undergoing ASD surgery, 10 (4.2%) had a movement disorder. Five (50.0%) had Parkinson's Disease and 5 (50.0%) had Essential Tremor. No significant difference was found in the type of surgery performed between patients with and without movement disorders, including total instrumented levels (p=0.101), three-column osteotomy (p=0.361), and pelvic instrumentation (p=0.729). No significant difference was found in preoperative or postoperative radiographic variables. Patients with movement disorders developed a higher rate of proximal junctional kyphosis and failure (PJK/F) (80% vs. 40%, p=0.028) without a significant difference in other mechanical complications or reoperations. Patients with movement disorders had better 2-year ODI (20.1±12.5 vs. 36.7±14.3, p=0.015) and 2-year NRS-back pain (2.3±2.5 vs. 5.0±2.4, p=0.022) than patients without movement disorders.
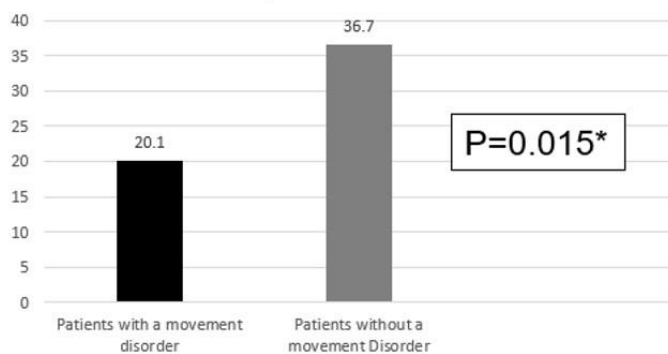
Conclusion
Patients with and without movement disorders ultimately undergo similar ASD operations. Despite a two-fold higher PJK/F rate, movement disorder patients reported better disability and pain at 2-years postoperative compared to non-movement disorder patients.

A — Rate of Proximal Junctional Kyphosis and Failure (PJK/F) (%). Patients with a movement disorder: 80%; Patients without a movement Disorder: 40%. P=0.028*

B — 2-year ODI Score. Patients with a movement disorder: 20.1; Patients without a movement Disorder: 36.7. P=0.015*

C — 2-year NRS-back pain score. Patients with a movement disorder: 2.3; Patients without a movement Disorder: 5. P=0.022*
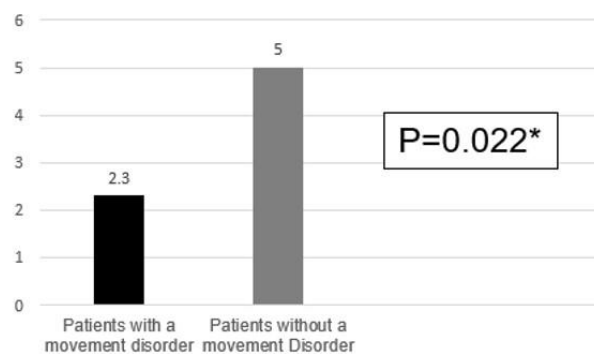
Paper #25. The Prioritized Correction of Deformity at Osteotomy Site: A Novel Technique for Preventing Sagittal Translation in 3CO of Adult Spinal Deformities

Chen Ling, MD, PhD; *Zhen Liu, PhD*; Jie Li, MD; Yanjie Xu, MD; Zezhang Zhu, PhD;
Yong Qiu, PhD

Hypothesis

The prioritized correction is a straight-forward technique to effectively avoid the massive blood loss and sagittal translation caused by 3-COs in ASD surgery.

Design

A retrospective study.

Introduction

In the surgery for rigid adult spinal deformity (ASD), 3-column osteotomies (3-COs) enable substantial correction but the risk of sagittal translation (ST) is high. Here, we proposed "prioritized correction with multiple rod construct" to reduce the risk of ST in the 3-CO procedure for ASD.

Methods

Data of ASD patients who underwent 3‐column osteotomies with a minimum 2-year follow-up was collected. Patients were devided: prioritized correction with multiple rod constructs (PC-MRC) group and traditional multiple-rod constructs (M-RC) group. The PC-MRC technique was using one or two short rods to close the osteotomy site when the osteotomy was completed, then restoring the global alignment by the correction maneuver of two long rods. Radiographic and clinical parameters were evaluated preoperatively, postoperatively, and at final follow-up.

Results

A total of 101 patients (mean age: 45.5 years; mean follow-up time: 24.9 months; PC-MRC group: 65 cases; M-RC group: 36 cases; PSO: 64 cases; VCR: 37 cases) were included. The PC-MRC group had significantly shorter operation time and lower estimated blood loss (p=0.045 and 0.007, respectively). The mean correction rate for GK angle was 54.7%±17.0% and 58.3%±18.5%, with no statistical significance (p=0.828 and 0.546, respectively). No significant loss of correction was observed at the final follow-up. ST occurred in 1 case (1.5%) in PC-MRC group and 9 cases (25%) in M-RC group, showing statistical significance (X2=14.296, p<0.001). 5 of the 9 ST cases in M-RC group went through IONM events and developed new neurologic deficit. The total incidence of neurological injury were 5 (7.7%) vs 8 (22.2%) cases between PC-MRC and M-RC groups, respectively, showing statistical significance (X2=4.362, p<0.037).

Conclusion

The prioritized correction with multiple rod construct offers a versatile and rigid fixation for 3‐columns osteotomy in ASD Patients with significant correction of global deformity. This is a straight-forward technique can effectively avoid the massive blood loss and sagittal translation caused by 3-COs, and minimize the risk of neurological complication.
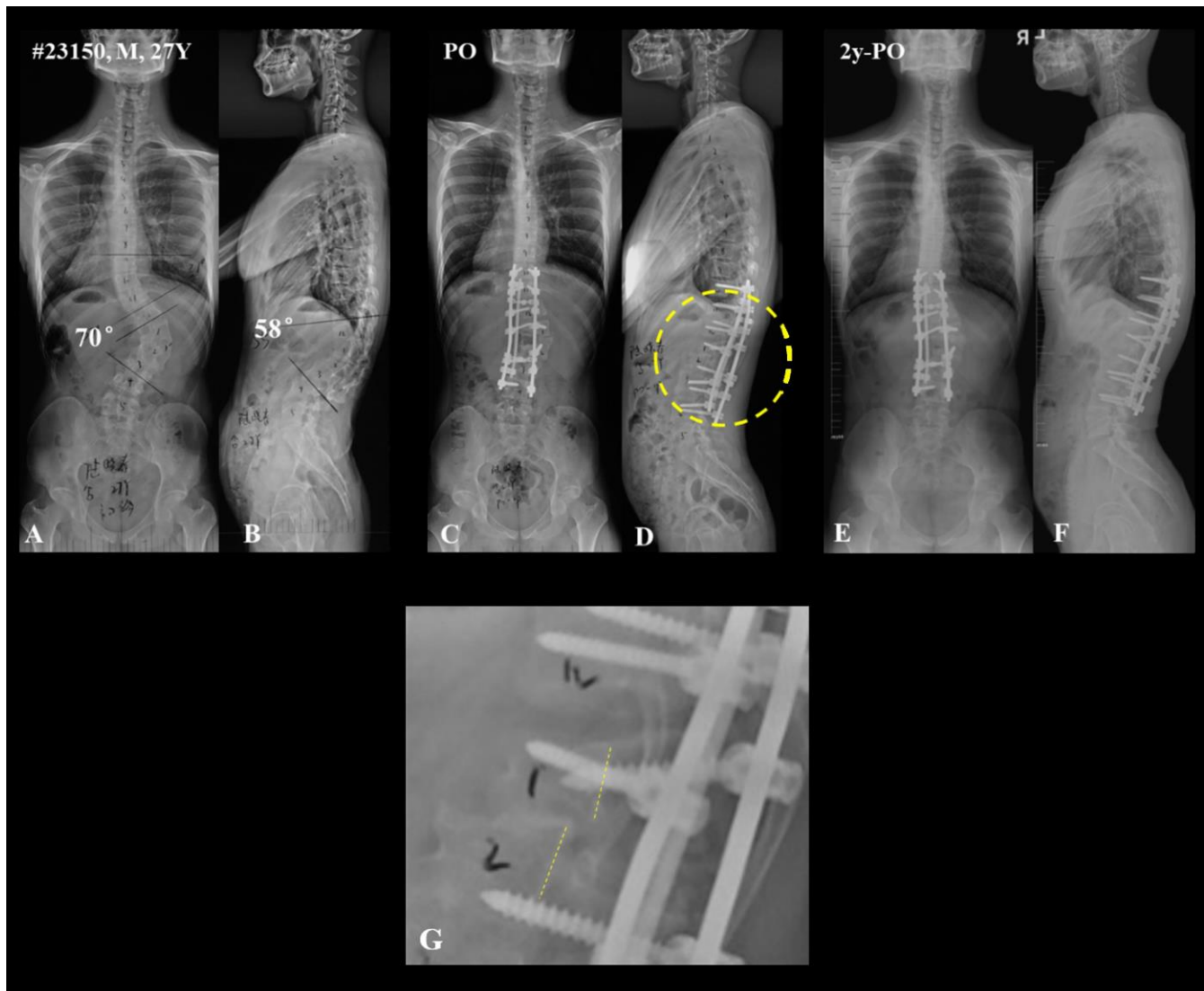
M-RC case of patient who developed sagittal translation

Paper #26. Pedicle Subtraction Osteotomies Vs Anterior Column Reconstruction: Examining the Rates of Pseudoarthrosis

Michael R. McDermott, DO; Kyle Barner, DO; Andre Jakoi, MD; Alfredo J. Guiroy, MD; Ashish Patel, MD; *Joshua Bunch, MD*

Hypothesis
Anterior Column reconstruction with a hyperlordotic implant will have a lower rate of pseudoarthrosis than a pedicle subtraction osteotomy.

Design
Retrospective Cohort

Introduction
Restoring physiologic sagittal and segmental alignment is crucial for improving postoperative outcomes and preventing adjacent segment disease in patients with symptomatic spinal pathologies. Larger sagittal corrections can be accomplished through an anterior column reconstruction (ACR) or a pedicle subtraction osteotomy (PSO). PSOs are maximally invasive and require substantial bony removal to achieve the desired correction. On the other hand, ACR is minimally invasive and achieves correction through the placement of a hyperlordotic implant. Due to the instability that is created through the techniques, fusion may be difficult to achieve. This study was designed to examine the rate of pseudoarthrosis and other surgical parameters of ACR compared to PSO.

Methods
A retrospective review was conducted on patients who underwent an ACR or PSO at two centers. Preoperative and first postoperative radiographic films were measured. Surgical characteristics were recorded and statistically analyzed. The presence or absence of Pseudoarthrosis was confirmed on CT imaging.

Results
Forty-four (44) patients were included in the study, eighteen (18) of which underwent correction with an ACR, and twenty-six (26) had a PSO. Each patient had a single ACR or PSO as part of a multilevel construct, with a total of 317 instrumented levels. The average EBL was significantly lower for the ACR group (287 ± 365 ml) vs the PSO group (1451.2 ± 661 ml, p = <0.0001). There was no difference in length of stay between ACR (4.2 ± 2.5 days) and PSO (4.6 ± 1.3 days). The preoperative lumbar lordosis (LL) was 26.0° ± 11.6. Both ACR and PSO significantly increased the LL (24.7° ± 7.4° vs 23.3 ± 11.5° respectively), and there was no statistical difference in the LL increase between techniques (p = 0.65). The average follow-up for the cohort was 30.5 ± 8.7 months. 4% (1/26) of patients in the PSO group developed pseudoarthrosis compared to 0% (0/18) in the ACR group, these rates were not statistically different (P = 0.41)

Conclusion
ACR and PSO are viable options for size-able sagittal spine correction. ACR is less invasive and has a lower estimated blood loss. There was no difference in lordosis correction or pseudoarthrosis rates in this study.

Paper #27. 513 Three-Column Osteotomies for Adult Spinal Deformity: A Single Surgeon Experience over 17 Years

Winward Choy, MD; Jaemin A. Kim, Research Assistant; Terry Nguyen, Research Assistant; Tony Catalan, BS; Austin Lui, MS; Ping-Yeh Chiu, MD; David Mazur-Hart, MD; Vedat Deviren, MD; *Christopher P. Ames, MD*; Aaron J. Clark, MD

Hypothesis
Rates of complications following three column osteotomies have decreased in the modern era.

Design
retrospective cohort study

Introduction
Advances in surgical techniques have aimed to address have historically high rates of complications following three- column osteotomies (3CO). Here we report the largest single center series of 3CO over 17 years in literature to detail the evolution of 3CO and its complication profile.

Methods
Patients undergoing surgery with 3CO for the correction of thoracolumbar adult spinal deformity (ASD) performed by the senior author from 2006 to 2023 were included. Clinical, demographic and radiographic data were retrospectively collected and analyzed. Patients with minimum of 2 years of radiographic follow were included in the assessment of postoperative mechanical failures.

Results
512 patients undergoing 82 (16%) thoracic, 423 (82.6%) lumbar, and 7 (1.3%) sacral 3CO were included. There were 344 (67.1%) pedicle subtraction osteotomies and 148 (32.8%) vertebral column resections. Ligamentoplasty was performed in 40.2%, bone morphogenic protein was used in 35.7%, and multi-rod constructs were used in 70.1% of cases. Overall rate of perioperative complications was 31.3%. Rate of medical complications was 24.6%, most commonly cardiopulmonary (n= 57), infectious (n= 19) and gastrointestinal (n=13). Rate of surgical complications was 8.0% and postoperative neurological deficit was 4.2%. The 1-, 2-, and 5- year reoperation rates were 5.8%, 13.3% and 42%, respectively. The most common indications for reoperation was rod fracture (n = 56), pseudoarthrosis (n = 51), and proximal junctional failure (n = 44). Subgroup analysis by surgical year (2006-16 vs 2017-22) demonstrated significantly decreased rates of rod fracture (3.1 cs 40.2%, p < 0.001), pseudoarthrosis (4.6 vs 28.2%, p <0.001) and proximal junctional kyphosis (17.2 vs 29.3, p = 0.006) in the modern era.

Conclusion
3CO remains a powerful tool in ASD and advances in surgical technique and implementation of preventative measures have resulted in significant decreases in associated complications in the modern era.