

105. Biological Age Predicts Short-Term Outcomes After Adult Spinal Deformity Surgery

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Hypothesis

Biological age (BA), an objective biomarker-based measure, predicts short-term outcomes after adult spinal deformity (ASD) surgery.

Design

Retrospective cohort study using the American College of Surgeons NSQIP database (2016–2020).

Introduction

ASD surgery carries substantial perioperative risk, yet CA incompletely captures physiologic vulnerability. Frailty and comorbidity drive outcomes, but existing tools require additional data entry or are inconsistently coded. BA, derived from preoperative biomarkers, offers a scalable, complementary indicator of surgical risk.

Methods

Adults undergoing ASD surgery were identified using CPT/ICD codes for spinal fusion and deformity correction. BA was calculated using the Levine outcome-trained framework, derived in the National Health and Nutrition Examination Survey, based on nine biomarkers (albumin, alkaline phosphatase, total bilirubin, AST, BUN, creatinine, WBC, hematocrit, and platelets). Logistic regressions evaluated associations between BA (per 1 SD increase) and 30-day outcomes: mortality, overall morbidity, any complication, serious complication, readmission, reoperation, and non-routine discharge. Adjusted models included CA, demographics, and comorbidities.

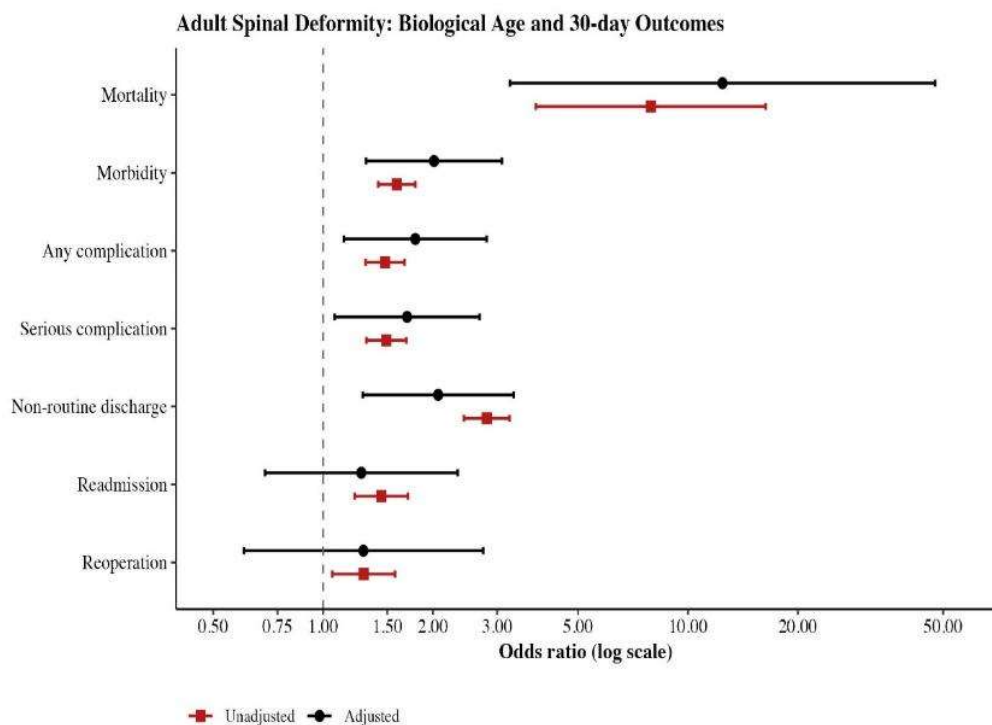
Results

Among 2,306 ASD patients (median CA = 62 [49–71]; median BA = 63 [49–73]), mortality was 1.0% and morbidity 20.6%. BA was independently associated with all short-term outcomes (all $P < .001$). Each SD increase in BA increased odds of mortality (OR = 7.91 [95% CI 3.83–16.34]), morbidity (OR = 1.59 [1.42–1.79]), any complication (OR = 1.48 [1.31–1.67]), serious complication (OR = 1.49 [1.32–1.69]), non-routine discharge (OR = 2.81 [2.43–3.24]), reoperation (OR = 1.29 [1.06–1.58]), and readmission (OR = 1.44 [1.22–1.71]). After adjustment, BA remained a significant predictor of mortality (aOR = 12.43 [3.25–47.50]), morbidity (aOR = 2.01 [1.31–3.09]), any complication (aOR = 1.79 [1.14–2.81]), serious complication (aOR = 1.70 [1.08–2.68]), and non-routine discharge (aOR = 2.07 [1.28–3.33]). The effect of CA was attenuated in all models except non-routine discharge.

Conclusion

In ASD surgery, BA derived from routine labs strongly predicts short-term mortality, morbidity, and discharge outcomes. By quantifying physiologic reserve, BA enhances risk prediction in complex spine surgery.

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



Unadjusted and adjusted odds ratios of biological age when predicting 30-day postoperative outcomes

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

106. Surgical Correction of ASD Is Associated with Slower Epigenetic Age Acceleration

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Hypothesis

ASD surgical correction will slow the rate of age acceleration

Design

Prospective longitudinal cohort study

Introduction

Adult spinal deformity (ASD) disproportionately affects older adults and is associated with substantial morbidity. Beyond structural pathology, ASD may function as a chronic physiologic stressor that accelerates biological aging. Epigenetic age (EA), derived from DNA methylation patterns, reflects biological aging and may better capture biological resilience and recovery than chronological age (CA). Whether ASD is associated with accelerated biological aging, and whether this process is modifiable following surgical correction, remains unclear.

Methods

Patients undergoing ASD surgery were prospectively enrolled. Peripheral blood mononuclear cells were collected preoperatively, at 1 and 2 year follow-up. DNA methylation profiling was performed, and EA was estimated using the Horvath DNAmAge algorithm. Age acceleration was defined as EA minus CA. EA in ASD patients was compared with healthy controls. Longitudinal changes following surgery were assessed using paired testing, with directional trends evaluated using binomial tests.

Results

A total of 114 patients undergoing ASD surgery were compared with 54 healthy controls. Preoperatively, ASD patients demonstrated a greater epigenetic age acceleration (EA–CA), with a mean difference of +9.19 years (95% CI, 7.40–10.98; $p < 0.001$), indicating that ASD patients were epigenetically older than their chronological age relative to controls. A higher proportion of ASD patients exhibited EA exceeding CA compared with healthy controls (88.9% vs 29.6%; $p < 0.001$). Among patients with 2-year follow-up ($n = 19$), epigenetic aging rates slowed postoperatively: 79% ($n = 15$) demonstrated a reduction in EA–CA, with a mean decrease of 2.8 years ($p = 0.002$), suggesting partial reversal of preoperative biological aging following surgical correction.

Conclusion

Patients with ASD exhibit greater epigenetic age acceleration compared with healthy individuals, supporting ASD as a contributor to accelerated biological aging. Surgical correction is associated with postoperative deceleration of biological aging, suggesting that ASD-related biological vulnerability may be partially reversible. These findings position ASD as a potentially modifiable driver of biological aging and support DNA methylation–based metrics as dynamic biomarkers of physiologic reserve and recovery following deformity surgery.

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

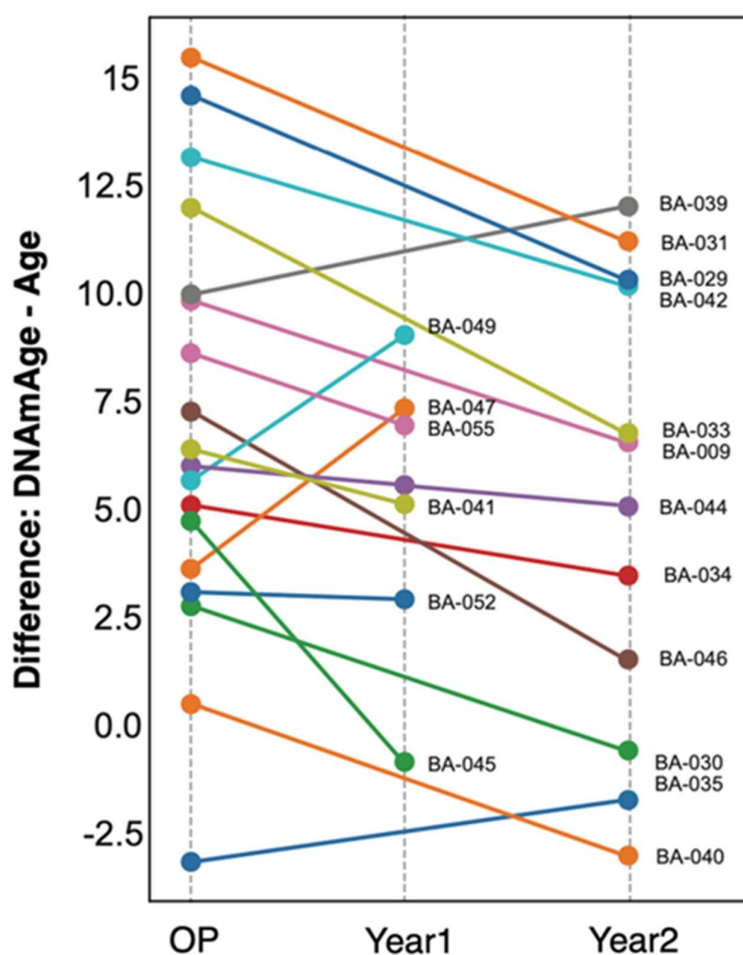


Figure 1. Longitudinal changes in epigenetic age acceleration following ASD surgery.

Individual patient trajectories of epigenetic age acceleration (epigenetic age – chronological age) are shown preoperatively (OP), at 1 year, and at 2 years postoperatively. Each line represents a single patient. Most patients demonstrate a reduction in age acceleration over time, indicating postoperative deceleration of biological aging.

107. Insulin-like Growth Factor Outperforms Sarcopenia as a Predictor of Postoperative Recovery

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Hypothesis

Insulin-like growth factor-1 (IGF-1) will outperform MRI-based measures of sarcopenia in predicting postoperative recovery following adult spinal deformity surgery

Design

Single-surgeon retrospective cohort study.

Introduction

Recent research has focused on imaging metrics to estimate postoperative risk in ASD patients. Given that postoperative recovery is mediated by changes in the IGF-1/GH hormonal axis, serum biomarkers related to this axis may be more accurate predictors of postoperative recovery reserve.

Methods

Adults undergoing spinal fusion >4 levels for adult spinal deformity were included. Outcomes included discharge destination, length of stay (LOS), distance walked with physical therapy (PT) on postoperative day (POD) 2–3, in-hospital complications, and return to OR within 2 years. Multivariate logistic and linear regression models adjusted for confounders, including MRI-based measures of sarcopenia (paralumbar cross-sectional area [pCSA] and Goutallier classification).

Results

32 patients (19 male; mean age 68 years) met inclusion criteria. Mean IGF-1 z-score was 0.66 (Fig 1A). Mean follow-up 321 days (IQR 267-4580). IGF-1 z-score was linearly associated with non-home discharge (OR of 1.5, 95% CI 1.0-2.3, $p = 0.031$, Fig 1B) for each 0.1 unit increase). An IGF-1 z-score <0 was associated with LOS increase of 9 days (CI 4.4-13.9, $p = <0.001$). An IGF-1 z-score < 0 was also associated with a reduction of 75 feet walked on POD2–3 (CI 22.2-127, $p = 0.010$, Fig 1D). Finally, z-score < 0.5 corresponded to a higher likelihood of medical complication (OR 26.3, CI 1.4-506, $p = 0.030$, Fig 1E). IGF-1 was not associated with reoperation. Measures of sarcopenia were not independently associated with any outcome, and for each model, the addition of pCSA and Goutallier grade did not improve model fit.

Conclusion

IGF-1 outperforms imaging-based metrics of sarcopenia in prediction of early recovery after ASD surgery. Rather than use opportunistic, indirect measures of physiologic reserve, future comprehensive risk prediction models should consider inputs directly related to the hormonal changes that mediate the physiologic response to sterile trauma.

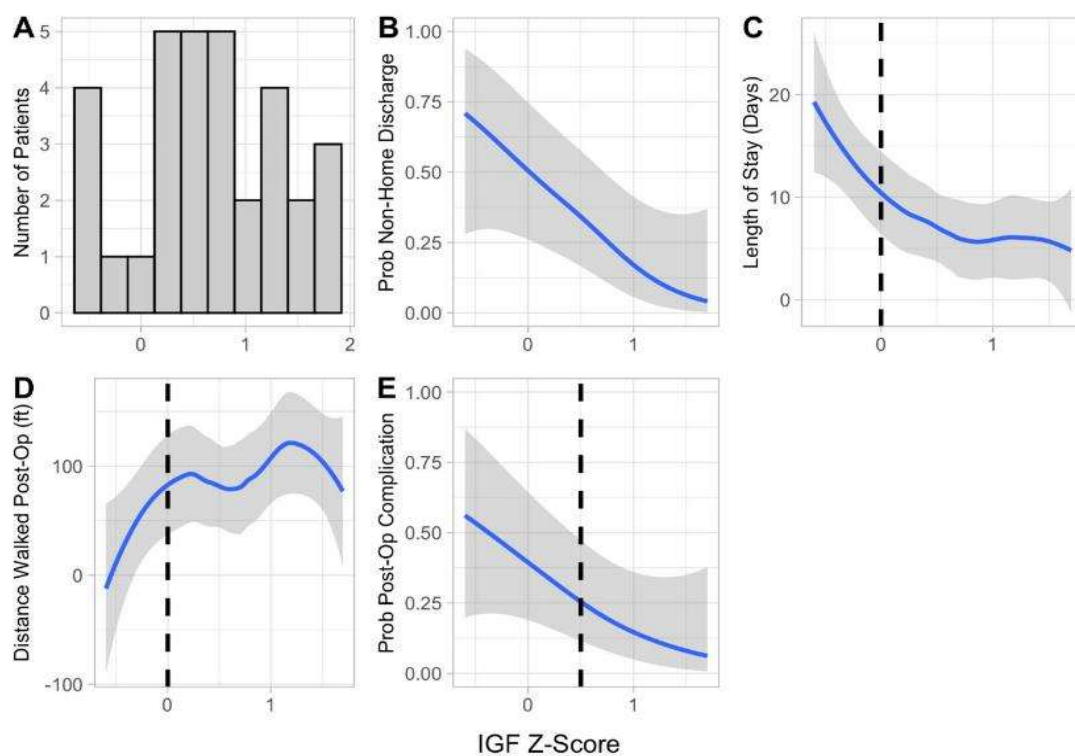


Figure 1: IGF-1 z-score distribution (A) and associations with discharge (B), LOS (C), distance walked (D), and medical complications (E). Dashed line corresponds to thresholds; shaded areas represent 95% CIs.

108. Osteosarcopenia of the Spine Drives Mechanical Complications After Thoracolumbar Adult Spine Deformity Operations

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Hypothesis

We hypothesized that osteoporosis and sarcopenia measures are interrelated and that high-fidelity markers of bone and muscle health predict mechanical complications after adult spinal deformity (ASD) surgery.

Design

Retrospective cohort study of consecutive patients undergoing primary thoracic-to-pelvis ASD correction at a single institution (2018–2023).

Introduction

In ASD surgery, sarcopenia and osteoporosis contribute to surgical frailty and are considered risk factors for complications. However, it remains unclear which measures of muscle quality and bone density best predict poor postoperative outcomes.

Methods

We retrospectively reviewed patients undergoing ASD surgery between 2018 and 2023. Bone density was assessed using femoral neck DXA T-scores, L1 Hounsfield units (HU), and vertebral bone quality (VBQ) scores. Biomechanical CT (BCT) was used to measure volumetric bone mineral density (vBMD) and bone strength (BS) at L1. Sarcopenia was assessed using Goutallier grading and cross-sectional area (CSA) of the psoas, multifidus, and erector spinae (ES). Multivariate logistic regression analyzed predictors of reoperation for mechanical complications.

Results

125 patients were included in the study with mean follow-up of 30 months, of which 107 had BCT analysis. 37(30%) patients had reoperations for mechanical failure. On multivariate regression, the vBMD ($p<0.05$), but not BS, was an independent osteoporosis factor related to re-operation. Regarding sarcopenia, only psoas CSA ($p<0.05$), but not multifidus or ES CSA or Goutallier grade, was an independent risk factor for re-operation. Outside of these bone and muscle quality measures, only the presence of a pure sagittal deformity was an independent predictor ($p<0.05$). There was a significant relationship between ES CSA and vBMD ($r=0.19$, $p<0.05$) and between psoas CSA and BS ($r=0.21$, $p<0.05$), suggesting that there is a deep inter-relationship between bone and muscle quality in this population that may drive results, with overlapping phenotypes of disease states.

Conclusion

Biomechanical CT analysis with vBMD measurements, not HU or DXA, was independently predictive of mechanical complications in our ASD cohort. Psoas CSA was independently predictive. We found relationships between bone density, strength and muscle volume. These findings suggest that both osteoporosis and sarcopenia need to be evaluated pre-operatively separately and together.

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

109. Preoperative Musculoskeletal Burden Predicts 1-Year Junctional Complications After Adult Spinal Deformity Surgery

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Hypothesis

Higher preoperative musculoskeletal(MSK) burden is associated with greater distal compensation and independently predicts junctional complications at 1 year following adult spinal deformity(ASD) surgery.

Design

Retrospective analysis of prospectively collected data.

Introduction

Junctional complications remain a major source of morbidity after ASD surgery and may be influenced by patient-level MSK health and compensatory reserve. We applied a novel multidomain MSK Burden Index to quantify cumulative MSK burden(mobility, muscle mass, strength, bone quality, joint health) and predict junctional outcomes.

Methods

Primary ASD patients with full-standing radiographs and 1-year outcomes undergoing long-segment fusion with pelvic fixation and UIV $\geq$ T12 were included. Validated cutoffs were used:Timed Up & Go 3m(TUG) 0(<10s), 1(10–20s), 2($\geq$ 21s); Grip 0/1 weak(<27kg men,<16kg women); Thigh sarcopenia 0/1 if both AP thigh(<12.47cm men,<10.68cm women) and LAT quadriceps thickness(<3.23cm men,<2.20cm women); Osteoporosis 0/1(T-score $\leq$ -2.5); osteoarthritis(OA) burden 0(none), 1(knee only), 2(hip only), 3(both)(KL $\geq$ 3). MSK burden was quantified using:MSK Index=3 $\times$ Grip weakness+1 $\times$ OA burden+5 $\times$ TUG+4 $\times$ Thigh sarcopenia+1 $\times$ Osteoporosis(range 0–21), stratified low(0–5), intermediate(6–10), high($\geq$ 11) MSK burden.

Results

214 ASD patients were included: low(51.4), intermediate(35.0), high(13.6%). Increasing MSK burden was associated with older age(60.7 vs 67.2 vs 71.0 years) and higher Edmonton frailty(2.0 vs 3.5 vs 5.0). UT UIV(T1–T6) was more common in low burden(67.3 vs 41.3 vs 41.4%)(all $p<0.05$). Baseline TK(35.1 vs 34.2 vs 41.2°) was similar($p>0.05$) but higher burden had greater SVA(33.7 vs 64.2 vs 74.5mm), CL(8.5 vs 9.7 vs 20.1°), KFA(1.7 vs 5.5 vs 6.2°)($p<0.05$). At 1 year, higher burden had greater SVA(12.1 vs 22.2 vs 36.5mm), TK(45.3 vs 49.4 vs 52.5°), KFA(0.1 vs 4.4 vs 6.2°)($p<0.05$). Junctional complications increased with burden: PJK(40.2 vs 45.3 vs 64.3%), PJKn(11.8 vs 21.3 vs 37.9%), PJF(7.5 vs 13.3 vs 21.4%)($p<0.05$). Adjusted models confirmed increasing MSK burden category predicted PJK(OR 1.65;AUC 0.66), PJKn(OR 2.25;AUC 0.78), PJF(OR 2.66;AUC 0.78)($p<0.05$).

Conclusion

Increasing preoperative MSK burden identifies patients with lower extremity compensation and higher risk of 1-year junctional complications, validating its potential role in ASD preoperative risk stratification and surgical counseling.

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

MSK Burden Categories and 1Y PJK/PJF Outcomes

Low MSK Burden



— BASELINE MSK DOMAINS —
Age: 66 | Grip (0) | OA (2) | TUG (0)
Sarco (0) | Osteo (0)
MSK Index = 2

— RADIOGRAPHIC (BL → 1Y | Δ) —
TK: 26.5° → 46.4° (+19.9)
PI-LL: 27.9° → -9.5° (-37.4)
C2-T3: -6.7° → -6.3° (+0.4)
SVA: 67.2° → -23.4° (-90.6)
KFA: 12.0° → 4.4° (-7.6)
PJK: No | PJKn: No | PJF: No

Medium MSK Burden



— BASELINE MSK DOMAINS —
Age: 69 | Grip (0) | OA (2) | TUG (1)
Sarco (0) | Osteo (0)
MSK Index = 7

— RADIOGRAPHIC (BL → 1Y | Δ) —
TK: 37.9° → 50.0° (+12.1)
PI-LL: 3.6° → -12.0° (-15.6)
C2-T3: 0.8° → 9.1° (+8.3)
SVA: 26.8° → -11.8° (-38.6)
KFA: 9.7° → 8.1° (-1.6)
PJK: No | PJKn: No | PJF: No

High MSK Burden



— BASELINE MSK DOMAINS —
Age: 66 | Grip (1) | OA (3) | TUG (1)
Sarco (0) | Osteo (1)
MSK Index = 12

— RADIOGRAPHIC (BL → 1Y | Δ) —
TK: 24.1° → 62.6° (+38.5)
PI-LL: 10.9° → -7.3° (-18.2)
C2-T3: 26.4° → 49.2° (+22.8)
SVA: 57.0° → 36.1° (-20.9)
KFA: 3.1° → 5.9° (+2.8)
PJK: Yes | PJKn: Yes | PJF: Yes

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

110. Adult Spinal Deformity Surgery in Patients With Lower Extremity Weakness: Do Preoperative Neurologic Deficits Influence Outcomes?

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Hypothesis

Preoperative lower extremity motor deficits confer worse outcomes in adult spinal deformity (ASD) surgery compared to no preoperative deficits.

Design

Retrospective analysis of prospective multicenter study

Introduction

We evaluated the impact of preoperative lower extremity motor deficits on: 1) perioperative morbidity, 2) complications, and 3) patient-reported outcome measures (PROMs).

Methods

A retrospective cohort study (2009-18) was performed of patients undergoing ASD surgery. Primary exposure was preoperative lower extremity motor deficits (lower extremity motor score <50). Primary outcomes were: 1) perioperative morbidity: estimated blood loss, operative times, and length of stay, 2) complications/reoperation, and 3) 2-year PROMs: Oswestry Disability Index (ODI) scores, Short-Form 36 physical function (SF36-PF), and Scoliosis Research Society-22r (SRS-22r) satisfaction. Univariate/multivariable regression was performed, controlling for age, sex, body mass index (BMI), and total instrumented levels.

Results

Of 1,290 patients undergoing ASD surgery with baseline neurologic motor exams, mean age was 61.7±13.5 years, 70.3% were female. 323 patients (25.0%) had preoperative lower extremity motor deficits. Perioperative Outcomes: Preoperative lower extremity motor deficits were independently associated with longer operative times (β :17.3, 95%CI:0.4-34.1, $p=0.044$). Complications: Preoperative motor deficits were independently associated with new postoperative motor deficits (OR:1.9, 95%CI:1.1-3.1, $p=0.018$) and major complications (OR:1.6, 95%CI:1.2-2.3, $p=0.006$). PROMs: Preoperative motor deficits were significantly associated with higher/worse 2-year ODI (β :4.5, 95%CI:1.5-7.4, $p=0.003$) and lower/worse SF36-PF (β :-2.0, 95%CI:-3.7- -0.4, $p=0.018$). 52.4% of patients with motor deficits achieved full lower extremity recovery (score 50/50) by 6-weeks postoperatively, but motor recovery was not associated with 2-year PROMs (all $p>0.05$).

Conclusion

Preoperative lower extremity motor deficits before ASD surgery were independently associated with longer operative times, new motor deficits, major complications, and worse long-term disability. These data support potentially intervening before a neurologic deficit ensues, in addition to counseling these patients of the more challenging postoperative course.

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

111. Impact of Enhanced Recovery After Surgery (ERAS) Protocol on Postoperative Pain and Clinical Recovery in Adult Spinal Deformity Surgery

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Hypothesis

This study aimed to evaluate the effects of an Enhanced Recovery After Surgery (ERAS) protocol on perioperative outcomes and postoperative analgesic efficacy in patients undergoing Adult Spinal Deformity (ASD) correction.

Design

Prospective cohort study conducted between March 2021 and December 2024.

Introduction

While ERAS protocols have demonstrated benefits in accelerating recovery and ensuring patient safety for ASD correction, their impact on postoperative analgesic efficacy and clinical outcomes remains underexplored.

Methods

Seventy-seven ASD patients who underwent posterior-only correction surgery at a single institution were included. Patients receiving the ERAS protocol were prospectively enrolled in the ERAS group (n=40), while those without ERAS were retrospectively identified from institutional databases as controls (non-ERAS group, n=37). Primary outcomes included surgical time, estimated blood loss (EBL), postoperative nausea and vomiting (PONV) incidence, total morphine sulfate equivalent (MSE) consumption, and visual analog scale (VAS) pain scores. Secondary outcomes encompassed perioperative recovery milestones: time to ambulation, oral intake initiation, Foley catheter removal, drainage tube removal, and length of stay (LOS).

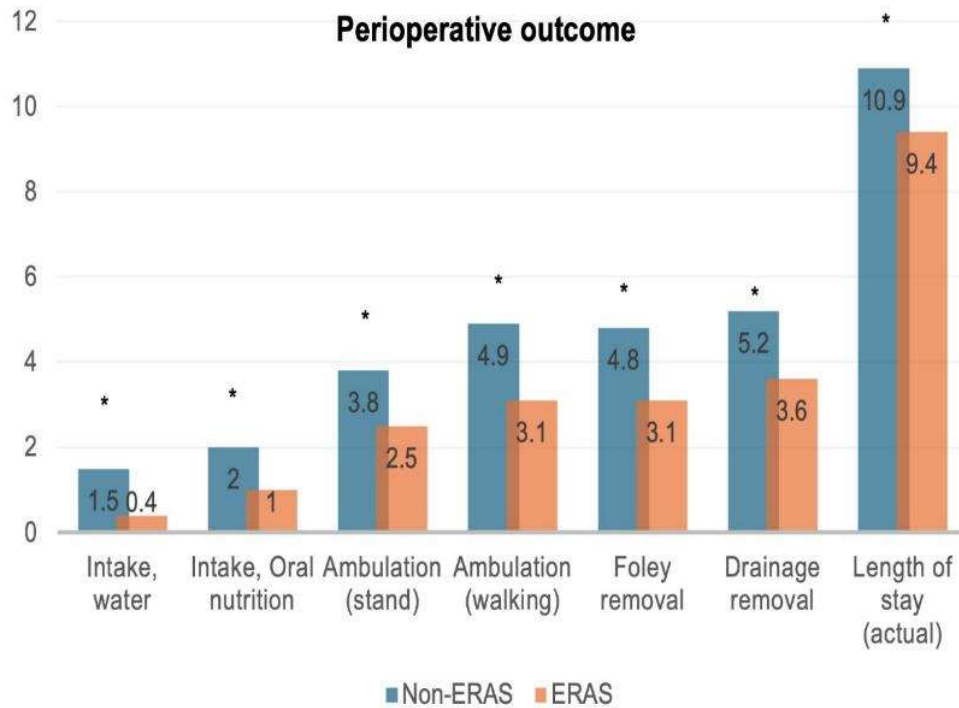
Results

The ERAS group demonstrated significantly shorter operative times (359 ± 80 vs. 433 ± 143 minutes, $p=0.008$) and reduced MSE consumption (18.8 ± 20.4 vs. 77.7 ± 51.0 mg, $p<0.001$) compared to controls. Fewer ERAS patients required patient-controlled analgesia (45% vs. 70.3%). The protocol group achieved an average of 1 day earlier functional recovery, with reduced time to ambulation, oral intake initiation, and catheter removal. Mean VAS scores were consistently lower in the ERAS group at postoperative day 1 (1.9 ± 1.1 vs. 4 ± 1.2 , $p<0.001$), day 2 (2.0 ± 1.1 vs. 3.4 ± 0.8 , $p<0.001$), and day 3 (2.1 ± 1.2 vs. 3.2 ± 0.8 , $p<0.001$). Hospital stays were also significantly shorter in the ERAS group (9.4 vs. 10.9 days, $p=0.005$).

Conclusion

Implementation of an ERAS protocol for ASD correction surgery significantly improves perioperative recovery trajectories, enhances postoperative pain control, and optimizes overall recovery quality. These findings support the standardized adoption of ERAS principles in adult spinal deformity surgery.

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



Recovery timelines between groups following ERAS and non-ERAS protocols. * statistically significant

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

112. Implications of Non-Tobacco Nicotine Use on Adult Spinal Deformity Surgery

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Hypothesis

To evaluate whether non-tobacco nicotine dependence (NTND) is associated with increased risk of pseudarthrosis and postoperative complications following adult spinal deformity (ASD) surgery.

Design

Retrospective cohort study.

Introduction

As non-tobacco nicotine use (vaping, pouches) has increased in popularity, its impact on ASD surgery remains unclear. This study aims to investigate the association between non-tobacco nicotine dependence (NTND) on pseudarthrosis and medical complications after ASD surgery.

Methods

The TriNetX U.S. Collaborative Network was queried for adults (≥ 18 years) undergoing ASD surgery between 2016 and 2026. Patients with documented NTND were propensity score-matched 1:1 to controls with no tobacco or nicotine use. Postoperative outcomes were assessed at 90 days, 1 year, and 2 years, including pseudarthrosis, hardware failure, proximal junctional kyphosis (PJK), thromboembolic events, and medical complications.

Results

A total of 2,271 patients were included in each matched cohort. At 90 days postoperatively, no significant differences were observed between NTND and control cohorts in hardware failure, thromboembolic events, infectious, neurologic, pulmonary, or other medical complications (all $p > 0.05$). At 1 year, there were no significant differences in rates of pseudarthrosis, hardware failure, pulmonary embolism, or PJK. At 2 years, pseudarthrosis (9.2% vs. 10.2%, $p = 0.249$) and PJK (2.9% vs. 2.9%, $p = 1.00$) remained similar between groups; however, NTND was associated with a significantly higher rate of hardware failure compared with controls (10.5% vs. 8.4%, $p = 0.017$).

Conclusion

Non-tobacco nicotine use was associated with significantly increased risk of hardware failure at two years after major adult deformity surgery. PJK, venous thromboembolic events, neurological or medical complications at any time point up to two years postoperatively. Surgeons should counsel patients of risks with NTND preoperatively.

113. Utility of Chemical Anticoagulation After Adult Spinal Deformity Surgery: A Retrospective Cohort Study

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Hypothesis

Chemical anticoagulation after adult spinal deformity surgery decreases rates of postoperative venous thromboembolic events

Design

Retrospective cohort study

Introduction

Venous thromboembolism (VTE), including deep vein thrombosis (DVT) and pulmonary embolism (PE), is a clinically significant complication following adult spinal deformity (ASD) surgery. Many risks and benefits exist and remain controversial regarding chemical prophylaxis after such surgeries. Guidance regarding optimal postoperative chemical VTE prophylaxis protocols following surgery remains unclear.

Methods

The TriNetX federated research network was queried to identify adults (≥ 18 years) undergoing ≥ 7 level posterior ASD surgery between 2015 and 2025. Patients with prior PE and DVT within 1 year on or before surgery, were excluded. Cohorts were defined by receipt of postoperative chemical anticoagulation therapy within 3 days of surgery versus no anticoagulation. Propensity score matching (1:1) based on demographics, BMI, and major comorbidities was performed, and outcomes were compared in the matched cohorts.

Results

The initial cohorts included 2,294 anticoagulated and 4,694 untreated patients. After propensity matching, 2,270 patients (48.4%/51.6% M/F; mean age 66.6 ± 13.9 years) were retained in the anticoagulated cohort and 2,270 patients (47.3%/52.7% M/F; mean age 67.4 ± 14.1 years) were retained in the untreated cohort. Thirty-day VTE occurred in 63/2,270 (2.8%) untreated patients compared with 42/2,270 (1.9%) anticoagulated patients (risk ratio 1.500, 95% CI 1.020–2.207; $p=0.038$). Thirty-day postoperative bleeding occurred in 37/2,270 (1.6%) untreated patients and 33/2,270 (1.5%) anticoagulated patients (risk ratio 1.121, 95% CI 0.704–1.786; $p=0.630$).

Conclusion

Over the past decade, there were two times as many patients that were not anticoagulated after spinal deformity surgery than received chemical anticoagulation. In this large multicenter cohort, postoperative chemical anticoagulation after adult spinal deformity surgery was associated with a significantly lower 30-day incidence of venous thromboembolism without an increase in postoperative bleeding. These findings suggest a potential protective association of early chemical prophylaxis following ASD surgery, though prospective studies are needed to define optimal patient selection and prophylaxis protocols.

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

114. Diagnostic and Predictive Value of Upright–Supine Imaging for Treatment Selection in Degenerative Lumbar Spondylolisthesis - A Two-Year PROM Based Comparison with Flexion Extension Radiographs

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Hypothesis

We hypothesized that segmental instability assessed by upright-supine imaging (USI) in patients with degenerative lumbar spondylolisthesis (DLS) would demonstrate stronger associations with postoperative outcomes than flexion-extension radiographs (FER), with greater instability predicting inferior outcomes after decompression-only surgery but superior outcomes after fusion.

Design

Retrospective cohort study.

Introduction

The optimal surgical management of DLS remains controversial. FER are commonly used to assess segmental instability but may underestimate clinically relevant instability due to reliance on active patient motion. USI, comparing upright radiographs with supine MRI, may offer a more sensitive alternative by assessing slip dynamics under physiological loading.

Methods

In 254 patients treated with decompression-only or fusion surgery, slip dynamics were quantified on FER and USI as between-position difference in relative translation (ΔRT ; Fig. 1). Multivariable regression and interaction analyses assessed associations with two-year ODI and LBP improvement. ROC analyses identified thresholds for clinically meaningful improvement.

Results

USI identified significantly more unstable segments than FER in both cohorts ($p < 0.001$). ΔRT_{USI} was independently associated with improvement in ODI and LBP ($p < 0.001$), whereas ΔRT_{FER} showed no association ($p = 0.434$; $p = 0.358$). USI-derived instability demonstrated inverse effects by surgical strategy: greater ΔRT_{USI} predicted less improvement after decompression-only but greater improvement after fusion ($p < 0.001$). ROC analyses identified thresholds of 7.9% for decompression-only and 5.7% (ODI)/5.3% (LBP) for fusion.

Conclusion

USI detects clinically meaningful occult instability missed by FER and demonstrates significant associations with postoperative outcomes. The impact of instability differs by surgical strategy, highlighting the value of integrating USI-derived slip dynamics into preoperative assessment for individualized surgical decision-making.

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

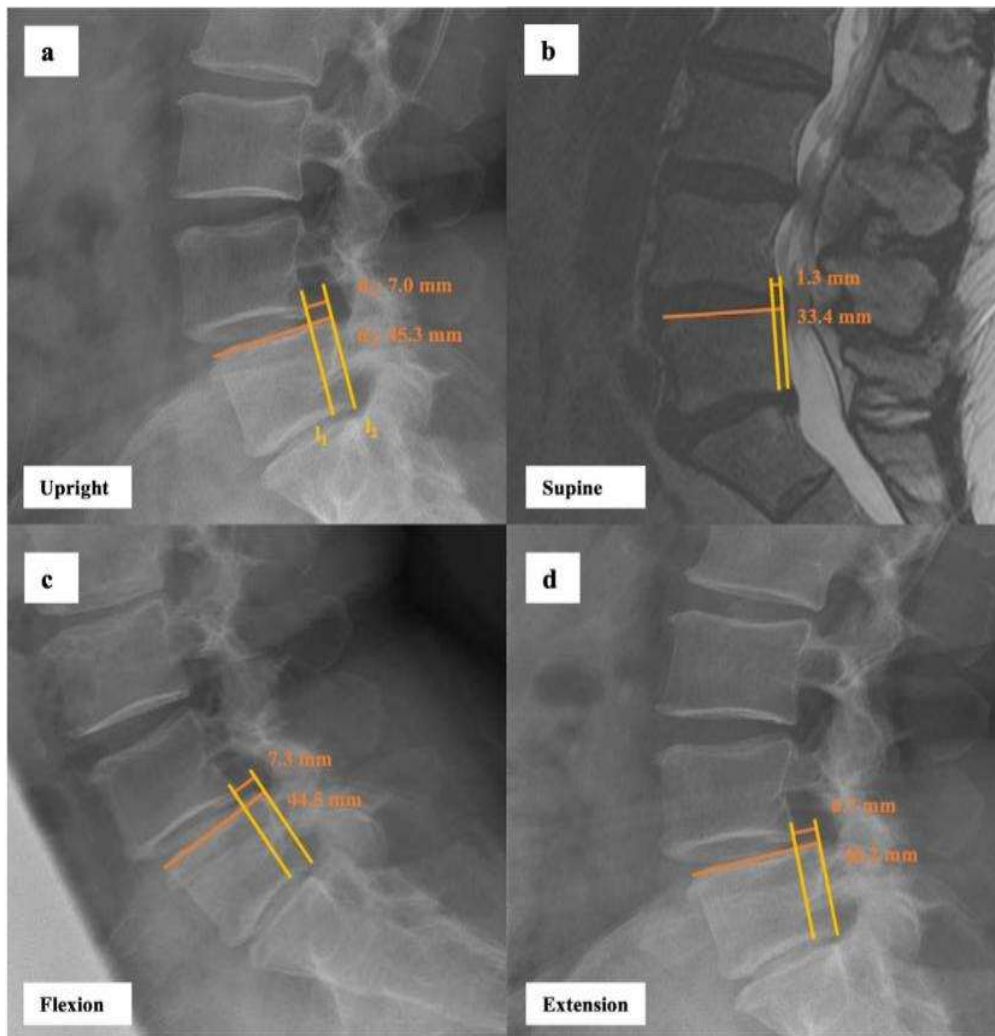


Figure 1. Sagittal slip dynamics in a 60-year-old patient with L4–5 degenerative spondylolisthesis across upright (A), supine (B), flexion (C), and extension (D) positions. Relative translation varied by only 1.9% between flexion-extension but increased to 11.6% between upright-supine imaging.

115. More is better! Multicenter Analysis of Failure Rates and Risk Factors Between Bilateral Single and Multiple Pelvic Fixation in Adult Spinal Deformity Surgery

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Hypothesis

Multiple pelvic fixation (MPF) in adult spinal deformity (ASD) surgery significantly reduces mechanical failure requiring reoperation compared with single pelvic fixation (SPF).

Design

Retrospective analysis of a multicenter prospective ASD database.

Introduction

Despite biomechanical rationale supporting MPF, clinical evidence remains limited. We compared MPF versus SPF outcomes in 196 ASD patients across three centers to evaluate lumbosacral junction stability.

Methods

196 ASD patients from three centers with ≥ 2 -year follow-up underwent fusion to the sacrum meeting SRS-Schwab radiographic criteria. All patients underwent L5–S1 interbody arthrodesis, multilevel fusion (≥ 5 levels), three-column osteotomy, or multiple two-column osteotomies. MPF (≥ 3 pelvic fixation points with ≥ 1 bilateral dual construct) was compared with SPF (bilateral two-screw fixation). Failure was defined as distal implant or construct failure requiring reoperation, excluding proximal failure or adding-on. Propensity scores were adjusted for demographic, operative, and radiographic variables due to preferential fixation use in greater deformity. Propensity-adjusted logistic regression was used to assess failure risk, with sensitivity analyses for low event rates.

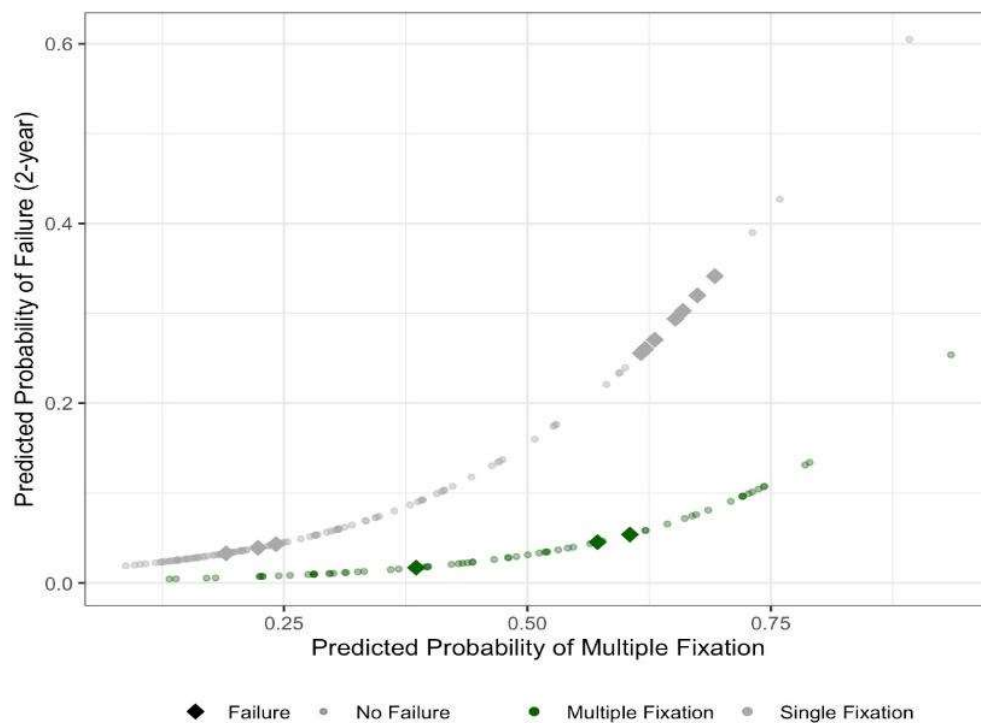
Results

Of the 196 patients, 50.0% were female, with a mean age/BMI of 69.9 years/28.7 kg/m². Mean preoperative PT/pelvic incidence was 25.1°/54.8°. Mean fusion length was 8.8 levels, with an average of 2.72 pelvic screws (mean diameter 8.71 mm, mean length 82.04 mm; 49.5% S2AI, 44.9% iliac, 5.6% both). Seventy-two patients (36.7%) received MPF, with 3 failures (4.2%), and 124 (63.3%) received SPF, with 11 failures (8.9%). Compared with SPF, MPF was associated with an 82.4% reduction in failure risk at 2 years (adjusted OR 0.18; 95% CI 0.03–0.67; $p=0.019$), adjusting for propensity score incorporating age, BMI, and deformity severity. A 0.10 increase in the latent propensity score was associated with a 72% increased failure risk (adjusted OR 1.72; 95% CI 1.29–2.36; $p<0.001$).

Conclusion

In ASD patients, MPF significantly reduces mechanical failure at 2 years compared with SPF, even after adjustment for baseline severity of deformity. These findings support the use of MPF constructs to improve mechanical and clinical durability in patients undergoing corrective surgery.

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



Pelvic Fixation and Failure Risk

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

116. Comparison of Perioperative Outcomes and Frailty in Minimally Invasive and Open Surgery for Adult Spinal Deformity: A Multi-Center Analysis

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Hypothesis

Minimally invasive surgery (MIS) for adult spinal deformity (ASD) may have better perioperative outcomes compared to open surgery in a modern cohort, especially in patients with frailty.

Design

Retrospective analysis of a multicenter prospective database

Introduction

As technology and clinical pathways for MIS have evolved, it is unclear if this has translated into better perioperative outcomes.

Methods

ASD patients who underwent surgery between 2022-2025 (n=1068) were classified as MIS (n=156) or open (n=912). Baseline alignment and demographic characteristics, including Edmonton frailty index, were compared. Perioperative outcomes of interest were length of hospital (LOS) and ICU stay, discharge disposition, operative time, blood loss, and transfusion. Outcomes of interest in the 90d postoperative period were complication (any), reoperation, or readmission. 2:1 propensity score matching (open to MIS) was based on baseline alignment abnormalities (PI-LL, PT, GCM, lumbar Cobb, GCM). A doubly robust estimate for LOS was created based on social (opioid MME, work and living status) and surgical factors (number levels fused, osteotomies, and PI-LL and SVA correction).

Results

Before matching, the MIS cohort was older ($67.6 \text{ yrs} \pm 9.7$ vs 61.8 ± 15.0 ; $p < 0.001$), had more baseline neurological deficits (49% vs 36.6%; $p = 0.04$), and higher frailty (3.84 ± 2.2 vs 3.38 ± 2.4 ; $p = 0.02$); the open cohort had more complex baseline deformity (higher SVA & GCM; $p < 0.01$). After 2:1 matching on baseline radiographic alignment with 68 MIS patients vs 136 open patients, the MIS group was still older ($67.7 \text{ yrs} \pm 9.1$ vs 58.6 ± 17.5 ; $p < 0.001$) and more frail (3.66 ± 2.2 vs 3.0 ± 2.2 ; $p = 0.05$). After prognostic outcome regression, a doubly robust estimate yielded LOS of $4.8 \text{ days} \pm 2.3$ in the MIS group and $7.5 \text{ days} \pm 3.7$ in the open group (ATE = -2.7 days; $p < 0.001$). MIS had similar operative time, but less EBL, fewer transfusions, and fewer ICU admissions ($p = 0.01$ to < 0.001). 90-day readmission ($p = 0.001$) and minor complication rates were lower ($p = 0.002$). A similar number of patients went to inpatient rehab or nursing facility after surgery (26.4% MIS vs 35.5% open, $p = 0.45$).

Conclusion

In select patients, MIS may have advantages in perioperative outcomes, including 2.7-day shorter LOS. This may have implications for surgeons who are considering MIS or open surgery for increasingly frail ASD patients in the population.

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

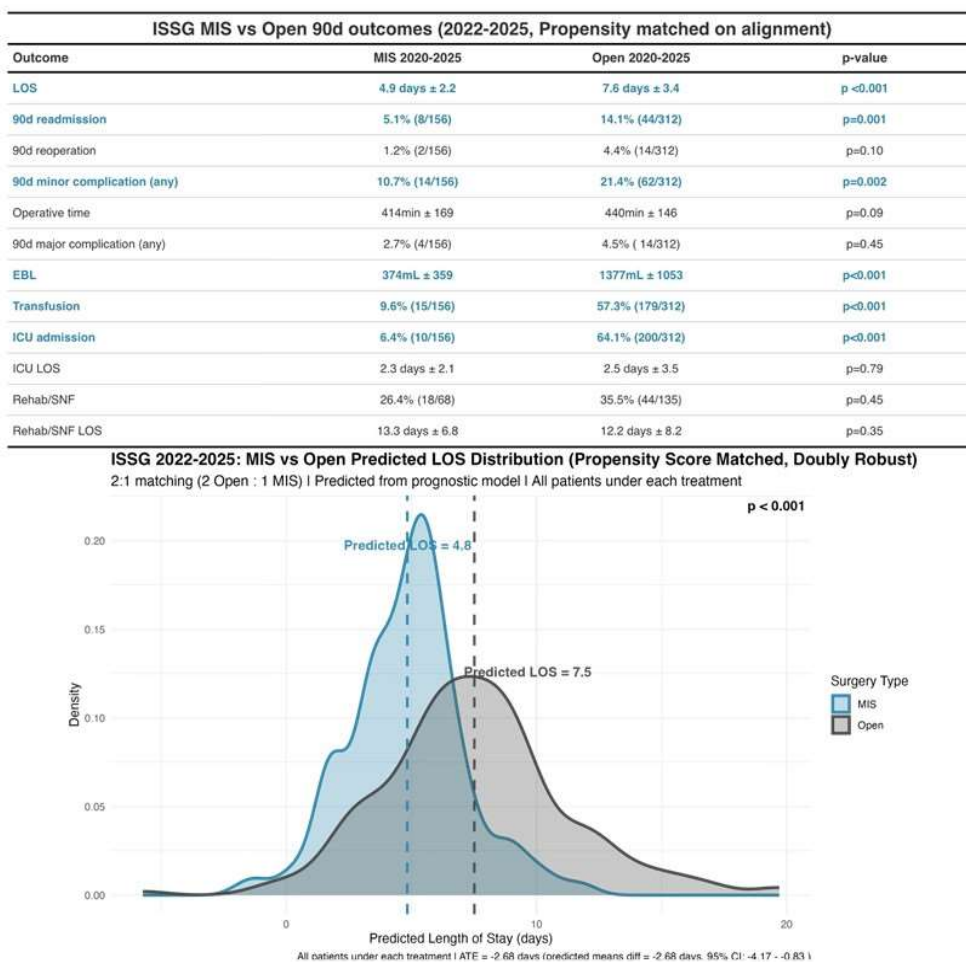


Figure 1. MIS for ASD has better perioperative outcomes in a matched patient sample.

117. Early Postoperative Neurologic Course is the Primary Determinant of Long-Term Lower Extremity Motor Recovery After ASD Surgery

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Hypothesis

Baseline(BL) pt vulnerability & early postoperative neurologic status are associated w/ maintenance/improvement in lower extremity motor scores(LEMS) at 2yrs postop

Design

Prospective, multicenter

Introduction

How baseline characteristics and early postop neurologic events influence long-term LEMS remains unclear

Methods

351 ASD pts undergoing open & MIS surgery w/ ≥ 2 yr fu were dichotomized as maintained/improved(G1) vs deteriorated(G2) at immediate postop(IPO) & 2yrs. Demographics, operative, XR, & neurologic data were compared. Multivariate logistic regression w/ backward elimination retained a priori confounders was built to discern significant factors

Results

At BL, 72% of pts had normal LEMS. At IPO, 10.5%(n=37) experienced LEMS decline (mean -3.6 points), w/ the largest deficits at the R L2(-0.51 , $p=0.005$) and L L5(-0.46 , $p=0.0076$) nerve roots. Despite similar BL LEMS, G2 pts were older, had higher BMI, greater sagittal malalignment, & underwent larger deformity corrections($p<0.05$). Operatively, G2 pts had higher ASA scores, more decompressions & PSOs, but fewer PCOs($p<0.05$); no differences were observed between open & MIS approaches. Neurologically, G2 pts experienced more IONM changes resulting in new motor deficits(40.5% vs 2.2%, $p<0.01$), frequently w/in 24hrs & often impairing ambulation (13.5% vs 0%, $p<0.01$). Multivariable regression adjusting for age, frailty, comorbidity burden, BL LEMS, SVA, & $\Delta T4PA$ identified higher ASA score($OR=0.35$, $p=0.0407$), IONM changes($OR=0.02$, $p=0.0037$), acute neurologic deficit onset($OR=0.09$, $p=0.0228$), & motor deficit at discharge($OR=0.03$, $p<0.0001$) as independently associated w/ IPO LEMS decline($AUC=0.88$). By 2yrs, 76% (28/37) improved, w/ 89% recovering to normal LEMS. Conversely, 12 pts w/ preserved IPO LEMS developed delayed decline(mean -4.1) & were older, frailer, & more comorbid ($p<0.05$). Adjusted regression identified lower W6 LEMS($OR=1.32$, $p=0.0096$) & ambulation-limiting deficits at discharge($OR=0.04$, $p=0.0108$) as independently associated w/ failure to maintain/improve LEMS at 2yrs($AUC=0.87$).

Conclusion

Although frailty & comorbidity burden reflect underlying pt vulnerability, early postop neurologic deficit limiting ambulation emerged as the primary determinant of long-term LEMS recovery after ASD surgery. Pts who experienced motor deficits impacting ambulation were significantly less likely to maintain/improve LEMS at 2yrs F/U.

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

Multivariable logistic regression analysis to discern significant factors associated with maintaining/improvement in LEMS by 1st postop		
	Adjusted OR [95% CI]	p-value
Age	0.96 (0.92 – 1.01)	0.0844
Frailty	0.92 (0.73 – 1.16)	0.4733
Number of Comorbidities	1.15 (0.84 – 1.57)	0.3929
Baseline LEMS	0.86 (0.68 – 1.10)	0.2368
BMI	0.92 (0.83 – 1.01)	0.0691
Baseline SVA	1.01 (1.00 – 1.02)	0.0947
Δ T4PA	1.05 (0.99 – 1.11)	0.1252
ASA Score	0.36 (0.13 – 0.96)	0.0407
IONM Deficit Onset		
Intraoperative	0.02 (0.00 – 0.29)	0.0037
Acute Postop	0.09 (0.01 – 0.71)	0.0228
Delayed Postop	2.43 (0.21 – 28.22)	0.4789
Motor Deficit prior to discharge	0.03 (0.01 – 0.18)	<0.0001
Model p-value <0.0001, AUC=0.88		
Multivariable logistic regression analysis to discern significant factors associated with maintaining/improvement in LEMS by 2yr postop		
	Adjusted OR [95% CI]	p-value
Age	0.95 (0.90 – 1.01)	0.0917
Frailty	0.82 (0.65 – 1.03)	0.0803
Number of Comorbidities	0.82 (0.62 – 1.09)	0.1657
Baseline LEMS	0.91 (0.72 – 1.14)	0.4160
LEMS at 1 st Postop Visit	1.33 (1.07 – 1.64)	0.0096
IONM alert resulting in a new postop deficit	0.31 (0.07 – 1.29)	0.1083
LE deficit involving impact on ambulation prior to discharge	0.04 (0.004 – 0.48)	0.0108
Model p-value <0.0001, AUC=0.87		

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

118. Neurologic Deficit Recovery After Revision Pedicle Subtraction Osteotomy for Fixed Sagittal Imbalance in Previously Fused Adults and its Impact on Patient-Reported Outcomes

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Hypothesis

Motor weakness persisting beyond the immediate postoperative period after revision PSO is associated with worse long-term patient-reported outcomes than early recovery.

Design

Retrospective cohort study of adults in a prospectively maintained database.

Introduction

Revision pedicle subtraction osteotomy (PSO) can restore sagittal alignment in rigid sagittal imbalance. Postoperative motor weakness occurs, but recovery kinetics and prognostic implications remain unclear.

Methods

Adults undergoing revision posterior fusion with a Schwab grade 3-4 lumbar PSO for fixed sagittal imbalance (2015-2022) were reviewed. Motor strength (0-5) across L2-S1 myotomes was recorded preoperatively and at POD5, 6 weeks, 3 months, and latest follow-up. Clinically meaningful weakness was defined as $\leq 3/5$ in any myotome. PROs (SRS-22r, VAS back/leg pain, ODI) were collected preoperatively and at follow-up. Latest follow-up PROs were compared by weakness status at POD5, 6 weeks, and 3 months.

Results

Forty-nine patients (mean age 63 years; mean follow-up 2.0 years (range 1.0-6.9)) were included. Clinically meaningful weakness was present in 4% preoperatively, 27% on POD5, 12% at 6 weeks, and 10% at 3 months. No patient had persistent $\leq 3/5$ weakness at latest follow-up. Weakness at 6 weeks was associated with worse SRS-22r Function (2.5 vs 3.3, $p=0.033$), Self-Image (2.8 vs 3.7, $p=0.012$), Mental Health (3.1 vs 4.0, $p=0.008$), and Satisfaction (2.9 vs 4.5, $p<0.001$) at latest follow-up. At 3 months, patients with weakness had lower Satisfaction (2.6 vs 4.5, $p=0.004$) and higher VAS leg pain (6.0 vs 3.9, $p=0.009$) at latest follow-up. Across the cohort, most PROs and sagittal alignment improved significantly by latest follow-up.

Conclusion

Clinically meaningful motor weakness after revision PSO is common early and typically resolves. However, weakness persisting to 6 weeks or 3 months is associated with worse long-term satisfaction and higher leg pain. These data link early neurologic recovery trajectories with long-term outcomes and support close neurologic surveillance, counseling, and targeted rehabilitation for patients with delayed strength recovery.

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

Section	Metric	Timepoint / Comparison	Value	p value
Demographics	Population		Adults undergoing revision posterior fusion with Schwab grade 3-4 lumbar PSO for fixed sagittal imbalance (2015-2022).	
	Clinically meaningful weakness definition		Motor strength $\leq 3/5$ in any L2-S1 myotome.	
	N		49	
	Mean age, years		63	
	Mean follow-up, years		2.0	
Weakness incidence	Clinically meaningful weakness ($\leq 3/5$), % of patients	Preoperative	4%	
	Clinically meaningful weakness ($\leq 3/5$), % of patients	Postoperative day 5	27%	
	Clinically meaningful weakness ($\leq 3/5$), % of patients	6 weeks	12%	
	Clinically meaningful weakness ($\leq 3/5$), % of patients	3 months	10%	
	Clinically meaningful weakness ($\leq 3/5$), % of patients	Latest follow-up	0% (no persistent $\leq 3/5$ weakness)	
Latest follow-up PROs by weakness status at 6 weeks	SRS-22r Function	Weak vs not weak	2.5 vs 3.3	0.033
	SRS-22r Self-Image	Weak vs not weak	2.8 vs 3.7	0.012
	SRS-22r Mental Health	Weak vs not weak	3.1 vs 4.0	0.008
	SRS-22r Satisfaction	Weak vs not weak	2.9 vs 4.5	<0.001
Latest follow-up PROs by weakness status at 3 months	SRS-22r Satisfaction	Weak vs not weak	2.6 vs 4.5	0.004
	VAS leg pain (0-10)	Weak vs not weak	6.0 vs 3.9	0.009

Notes: Values are means unless otherwise stated. PROs are reported at latest follow-up and stratified by presence of $\leq 3/5$ weakness at the indicated earlier timepoint.
 SRS-22r = Scoliosis Research Society-22r; VAS = Visual Analog Scale.

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

119. Understanding Bilateral MEP Changes during Cord Level Spinal Deformity Surgery: Etiology, Significance and Response

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Hypothesis

MEP alert patterns vary based on the preceding event

Design

Prospective multicenter international observational

Introduction

During spine surgery IONM can help reduce the risk of neurologic deterioration. This study aims to enhance our understanding of b/l MEP alerts that occur during cord-level spine deformity surgery.

Methods

20 international centers prospectively documented IONM (EMG, SSEP, MEP), demographics, radiographs and surgical events of patients (10-80 yrs) undergoing correction for a major Cobb > 80° or a cord-level osteotomy. Alerts were classified as MEP-only or MEP w/SSEP changes (MEP+SSEP). MEP alerts were defined as loss of ≥50% MEP amplitude from baseline. Surgical (exposure, implant placement, osteotomy, correction/rod placement, traction) and nonsurgical (systemic, anesthesia, technical) events preceding the alert were recorded. Relationships between b/l MEP alerts with mechanical events (osteotomies or implant placement) was assessed.

Results

Out of 349 cord-level surgeries, 25 pts experienced 34 b/l MEP alerts with 19 associated w/surgical events, 9 w/nonsurgical events, and 6 w/a combination. 85% of the b/l MEP alerts were MEP-only. 76% of the time a surgical event preceded a b/l MEP-only alert. Correction/rod insertion was the most common surgical event preceding the alert (16/22), followed by mechanical event (5/22) and other (3/22). 15% b/l MEP alerts were associated with SSEP changes. A surgical event preceded the MEP+SSEP alert 60% of the time. All MEP+SSEP alerts w/surgical preceding event occurred after a mechanical event. 80% b/l MEP alerts w/surgical preceding event had recovery at closure. Recovery rates varied based on the preceding event with 88% of alerts recovered after a mechanical event and 76% recovered after a nonmechanical event. Pts with a b/l MEP alert, 20% developed a neurological deficit immediately postop with 15% from the b/l MEP-only and 40% from the b/l MEP+SSEP. At discharge, 8% had a neurological deficit in MEP-only and 0 in MEP+SSEP group.

Conclusion

Bilateral MEP changes during cord-level deformity surgery are rare and usually linked to surgical events. Isolated MEP alerts are often related to correction or rod insertion, suggesting ischemia. MEP+SSEP changes after surgery are typically tied to mechanical events, with higher intraoperative recovery rates following corrective maneuvers

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