

96. Multicenter Treatment Patterns and Surgical Outcomes in Marfan Syndrome Associated Scoliosis

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Hypothesis

Surgery for Marfan Syndrome (MFS) achieves radiographic correction but carries substantial complication risk, with differential outcomes between growth-friendly (GF) and posterior spinal fusion (PSF) subgroups.

Design

Retrospective, multicenter cohort.

Introduction

Scoliosis in MFS presents earlier and progresses more rapidly than in AIS. However, surgical outcomes and quality of life (HRQoL) remain incompletely defined. This study evaluates treatment patterns and longitudinal outcomes in a large multicenter MFS cohort.

Methods

159 patients with MFS were identified, of whom 121 underwent surgery and were included. Treatment included GF surgery (N=97, 80%) and PSF (N=24, 20%). Radiographic parameters, major complications (MCDS $\geq$ III), and HRQoL (EOSQ-24) were assessed at pre- and post-index, 2 years, and 5 years after surgery. Surgery type and complication and revision rates were compared temporally in 5-year cohorts using chi-square and Fisher's exact tests. Temporal trends in complications were assessed using logistic regression, stratified by GF and PSF subgroups.

Results

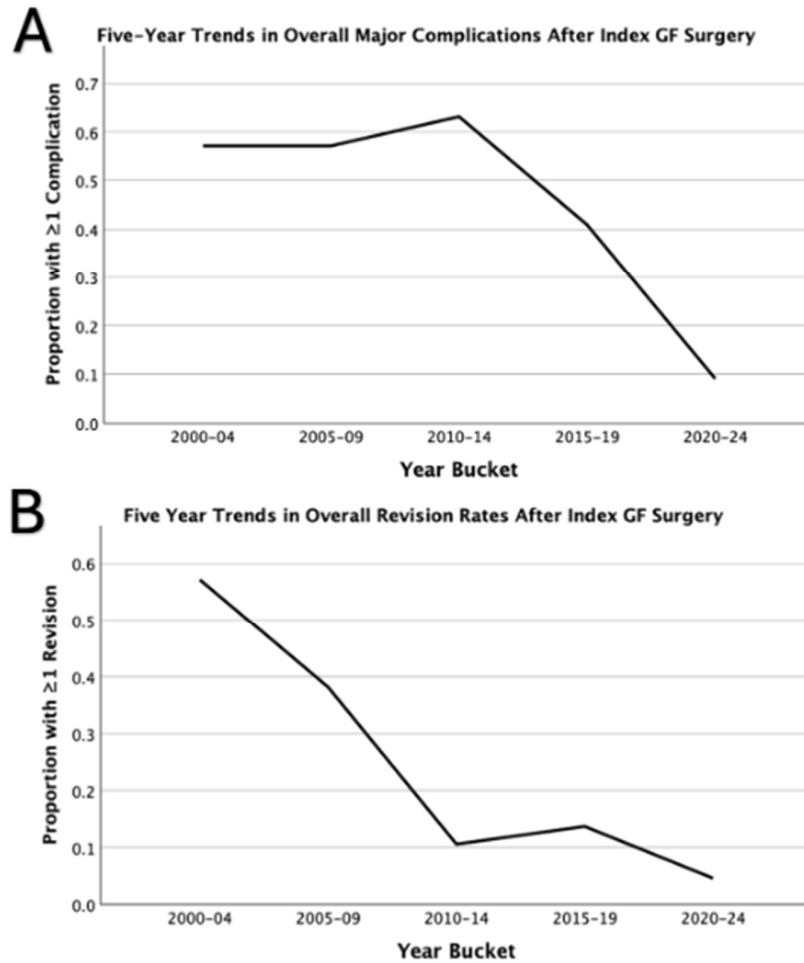
Compared to GF patients, PSF patients were older at index (12.7 ± 3.8 vs 5.7 ± 2.7 years, $p < 0.001$) and had smaller residual coronal deformity at all timepoints, while GF demonstrated greater spine growth (38 vs 18 mm). The proportion of PSF increased from 0% in 2000-09 to 21% in 2010-14, and 30% in 2015-24 ($p = 0.030$). Major complications occurred in 34%, highest in VEPTR/TGR (51%) versus PSF (12.5%) ($p = 0.008$). Complication and revision rates declined across 5-year index surgery cohorts, driven by improvements in the GF subgroup ($p < 0.001$). Among GF patients, later surgery year was associated with reduced complications (OR 0.92, $p = 0.008$), while no association was observed for PSF patients. Total EOSQ-24 scores did not differ between PSF and GF patients at pre-index (68.7 vs 72.4, $p = 0.58$), post-index (67.5 vs 67.0, $p = 0.93$), or latest follow-up (68.1 vs 71.0, $p = 0.69$).

Conclusion

Surgical management of MFS-associated scoliosis achieves effective deformity correction, with PSF providing more durable alignment and GF surgery preserving spinal growth with higher complication rates, though these have improved over time. Surgical strategy shifted toward increased use of PSF over the study period. Despite differing surgical risk profiles, HRQoL outcomes were comparable between GF and PSF patients. Further study to clarify appropriate indications is warranted.

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

Figure: Trends in major complications (A) and revisions (B) after index GF surgery



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97. A Two-Year International Retrospective Cohort Study Comparing the Efficacy and Complication Rates of the OWSER and MCGR Systems in the Treatment of Spinal Muscular Atrophy

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Hypothesis

We hypothesize that the OWSER and MCGR systems yield comparable radiographic outcomes and complication rates in SMA patients

Design

Retrospective international cohort study

Introduction

Scoliosis is a common and progressive complication in children with spinal muscular atrophy (SMA) and can significantly impair sitting balance, mobility, and respiratory function. Growth-sparing techniques, including magnetically controlled growing rods (MCGRs), have been introduced to mitigate these risks, yet remain associated with substantial complication and revision rates. The One-Way Self-Expanding Rod (OWSER) system is a novel fusionless technique designed to allow passive spinal growth while minimizing the need for repeated surgical interventions. The objective of this retrospective international cohort study was to compare the two-year complication rates and clinical efficacy of the OWSER system and MCGRs in the surgical management of scoliosis in patients with spinal muscular atrophy.

Methods

SMA patients who underwent primary surgical treatment with either the OWSER system or MCGRs between 2016 and 2024 and had a minimum follow-up of two years were included. The primary outcome was the overall two-year complication rate. Secondary outcomes included revision surgery and radiographic correction.

Results

Sixty-five patients (38 female) were included. Baseline characteristics, Cobb angle and T1S1 height were similar in both groups. Figure 1 shows the demographic and radiological data of both groups. In the OWSER group, three complications occurred; 1. revision due to insufficient rod lengthening, 2. prominent cross-link causing delayed scar forming, 3. medical treatment of neurogenic bladder. In the MCGR group, two complications occurred; 1. screw pull-out requiring revision, 2. rod breakage resulting in rod revision.

Conclusion

This study represents the first large international comparison of MCGRs and the OWSER system in patients with spinal muscular atrophy. Comparable radiographic and complication-related outcomes were observed between the two treatment modalities. However, patients operated on with the MCGR required an average of 13 lengthening procedures in two years time. To provide more clinically relevant evidence, a large international retrospective cohort study is currently conducted.

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	OWSER	MCGR
Number (f)	34 (19)	30 (19)
Age at initial surgery, years, mean (SD)	8.6 (2.3)	7.8 (1.4)
Weight, kg, mean (SD)	19.8 (7)	17.2 (1.6)
Preoperative Cobb angle, degrees, mean (SD)	73 (13)	71 (12)
Postoperative Cobb angle, degrees, mean (SD)	38 (12)	41 (7)
Two-year postoperative Cobb angle, degrees, mean (SD)	37 (12)	40 (10)
Preoperative T1S1 height, mm, mean (SD)	264 (33)	280 (33)
Postoperative T1S1 height, mm, mean (SD)	307 (39)	303 (31)
Two-year postoperative T1S1 height, mm, mean (SD)	318 (43)	320 (33)
Average number of lengthening procedures at two-year follow-up	0	13
<i>Abbreviations: F = female, kg = kilograms, SD = standard Deviation, mm = millimeters</i>		

Figure 1, demographic and radiological data

98. Scoliosis in Pediatric Severe Osteogenesis Imperfecta: A Multicenter Study of Progression and Surgical Outcomes

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Hypothesis

Patients with severe osteogenesis imperfecta (OI)-associated scoliosis are at higher risk for progression of deformity and surgical complications compared to idiopathic scoliosis.

Design

Retrospective multicenter review

Introduction

Treatment of scoliosis in pediatric patients with OI is challenging, particularly in severe forms such as Sillence type III. In this largest-to-date series, we explored the progression of spinal deformity and surgical outcomes.

Methods

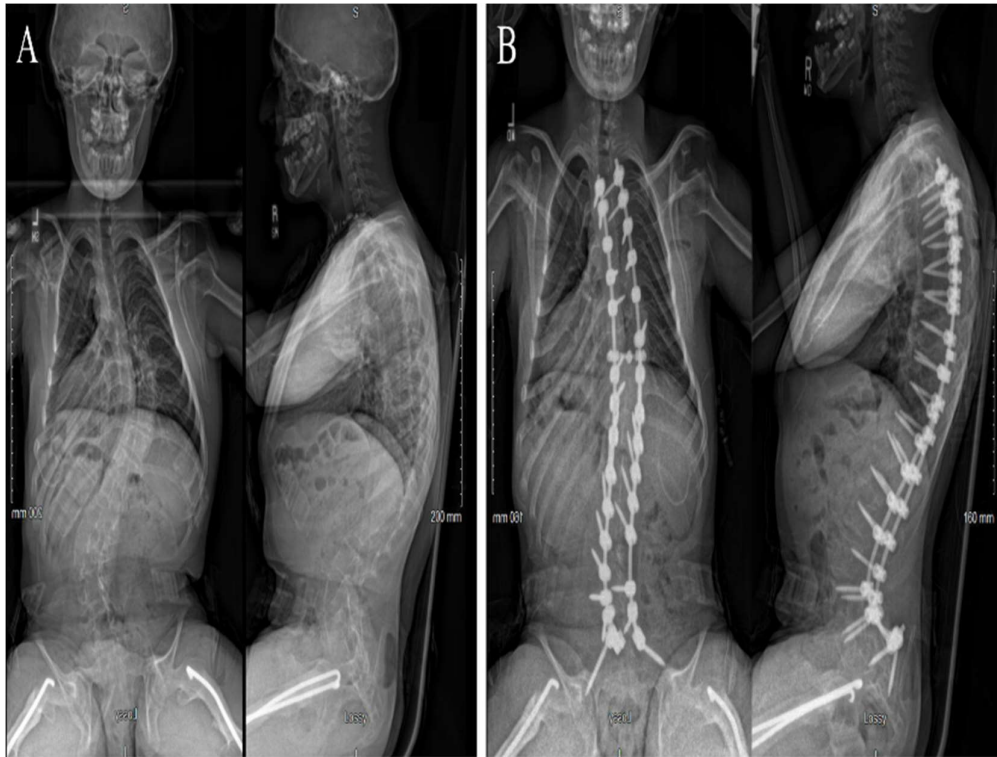
Multicenter data search identified pediatric patients with type III OI and scoliosis that had >2 years follow up. Clinical details and radiographic measurements were collected and analyzed.

Results

77 patients from 21 hospitals were included. Mean follow-up was 9.5 ± 3.1 years. Major curves progressed a mean 6.4° per year. At skeletal maturity (defined as 14 for females, 16 for males) 88.9% of the patients had a curve $>50^\circ$. Larger major Cobb angle at the time of diagnosis correlated with curvatures $>50^\circ$ at skeletal maturity ($p=0.01$). 44 patients (57%) had spinal fusion. Mean preoperative major Cobb angle was $82.6 \pm 18.8^\circ$ which decreased postoperative to $45.0 \pm 22.7^\circ$ with a reduction of $47.9 \pm 21.1\%$. 17 patients had preoperative halo gravity traction (HGT) for average 4.3 weeks. Patients with curves $\geq 80^\circ$ and HGT had significantly better postop major Cobb angle reduction ($p<0.05$); 11.7% had a traction pin complication. Fusion did not change thoracic kyphosis or sagittal vertical axis but significantly decreased lumbar lordosis from $62.3 \pm 26.6^\circ$ to $55.2 \pm 16.7^\circ$ ($p<0.05$). Intraoperative and total complication rate was 7.1% and 28.6%, respectively. The most common complications were: neuromonitoring events, wound dehiscence and HGT pin issues. All patients recovered neurologically. Patients with Lenke 5 or 6 curves and fused to pelvis had higher postop major curve improvement ($p=0.02$) but 1/3 lost their ambulatory status postop.

Conclusion

Almost 90% of pediatric patients with severe OI and scoliosis had curvatures $>50^\circ$ by skeletal maturity. Spinal fusion had a 29% complication rate and average curve correction was 48%. HGT in curvatures $\geq 80^\circ$ resulted in better coronal improvement, but risked traction pin complications. Fusing to pelvis in lumbar major curves led to better correction but risked ambulation. Scoliosis treatment in these patients requires careful individual consideration and counseling.



17-year-old male preop (A) and 1 year postop (B)

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‡SRS Funded Research Grant

99. Intraoperative Neuromonitoring In Neuromuscular Scoliosis: Feasibility, Obstacles, Outcomes, and Resolution

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Hypothesis

Patients with CP undergoing PSF with the use of IONM have better outcomes than those without

Design

Retrospective review of multicenter registry

Introduction

Intraoperative neuromonitoring (IONM) is commonly used in spine surgery to protect the spinal cord. Use of IONM in patients with cerebral palsy (CP) undergoing posterior spinal fusion (PSF) is not universal. We sought to evaluate whether the use of IONM provides any added value.

Methods

Our review included CP patients with a GMFCS (Gross Motor Function Classification System) level 4 or 5 who underwent PSF. Baseline demographics, deformity measures, and the use of IONM were gathered. Operative outcomes and perioperative complications were evaluated including neurologic deficits. Student's t-test, chi-square tests, and multivariate logistic regression were performed.

Results

409 patients (23% GMFCS 4 and 77% GMFCS 5) with minimum 2y follow-up were identified. 59% had full (F) baseline IONM, 33% had partial (P) IONM (i.e. SSEPs only), and 8% had no (N) IONM attempted. 13 patients were not able to be monitored and were excluded. The groups were similar with respect to baseline clinical and radiographic characteristics. EBVL, LOS and average transfusion volume were higher in group N ($p < 0.001$), while operative time was lower ($p = 0.022$). There were IONM alerts in 13% of patients (groups F and P combined), and patients with larger curves were more likely to have alerts (96° vs. 80° , $p < 0.001$). There were 2 neurological deficits and 7 postoperative bladder dysfunctions in group F, 7 postoperative bladder dysfunctions in group P, and 2 in group N. There were no reported neurologic deficits in group N; however, group N did have significantly more medical complications ($p < 0.001$) and were more likely to have multiple complications ($p < 0.001$). Patients with severe-profound cognitive deficits were more likely to have partial IONM available ($p = 0.004$), and there were no significant differences in outcomes between groups F and P.

Conclusion

Our study found a 13% rate of IONM alerts and 0.5% new neurological deficit in CP patients undergoing PSF. No neurologic deficits were found in patients who were not monitored; however, this complication may be challenging to determine. Patients with partial monitoring available had similar outcomes to those with full IONM. It is likely that IONM alerts led to interventions that potentially avoided permanent neurological deficit.

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	Pre - Major Cobb Angle (p=0.444)	FE - Major Cobb Angle (p=0.359)	2y - Major Cobb Angle (p=0.437)	Pre - Pelvic Obliquity (p=0.54)	FE - Pelvic Obliquity (p=0.213)	2yr - Pelvic Obliquity (p=0.027)
None	85°	30°	33°	29°	6°	5°
Partial	81°	27°	29°	27°	7°	9°
Full	84°	29°	30°	28°	8°	10°
Total	83°	28°	30°	28°	8°	9°

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100. Perioperative Complication Severity is Associated with GMFCS Sub-Classification in Cerebral Palsy

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Hypothesis

GMFCS V patients will experience higher CDS complication severity than GMFCS IV patients after posterior spinal fusion. Within GMFCS IV and within GMFCS V, increasing GMFCS sub-classification will be positively associated with increasing CDS grade.

Design

Retrospective Cohort

Introduction

The Gross Motor Function Classification System (GMFCS) is used to classify functional mobility in patients with cerebral palsy. Although GMFCS IV and V are considered severe, both represent a heterogeneous group of patients with varying degrees of central neurological impairment. Prior work has demonstrated that presence of G-tube, seizure history, non-verbal status, and tracheostomy predict overall rate of complications after scoliosis surgery in this population. However, the correlation of central neurological impairment with complication severity has not been established.

Methods

We retrospectively identified 96 GMFCS V and 25 GMFCS IV patients with cerebral palsy who underwent posterior spinal fusion over a 10 year period. Patients were subclassified based on the number of baseline central neurological impairments (gastrostomy tube, tracheostomy, seizure history, non-verbal status) from x.0 (none) to x.4 (four). Complications within 90 days were graded using the Clavien-Dindo-Sink (CDS) classification system. Associations were assessed using Spearman correlation, Kruskal–Wallis testing with Bonferroni correction, and appropriate parametric or categorical tests.

Results

GMFCS subclass correlated with complication severity ($p = 0.491$, $p < 0.001$) after scoliosis surgery. Complication grade differed across GMFCS classes ($p < 0.001$), with higher severity in GMFCS V compared with IV ($p < 0.001$). Subclassification remained associated with complication grade within GMFCS IV and V patients ($p = 0.467$, $p < 0.001$, Figure 1). GMFCS V patients had larger preoperative Cobb angles than GMFCS IV patients (85° vs 70° , $p = 0.010$), with no differences in blood loss, operative time, or BMI.

Conclusion

Greater accumulation of central neurological impairments in patients with cerebral palsy, resulting in higher GMFCS subclass, was associated with greater postoperative complication severity following posterior spinal fusion. GMFCS sub-classification may aid not only in the overall complication rate prediction, but also is associated with complication severity.

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

101. Longer Operative Times are Associated with Increased Morbidity in Pediatric Neuromuscular Scoliosis Surgery

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Hypothesis

We hypothesized that longer operative time is associated with increased morbidity in pediatric neuromuscular scoliosis surgery.

Design

Multicenter retrospective cohort study.

Introduction

Longer operative time has been associated with increased risk of morbidity in various surgical specialties.

Methods

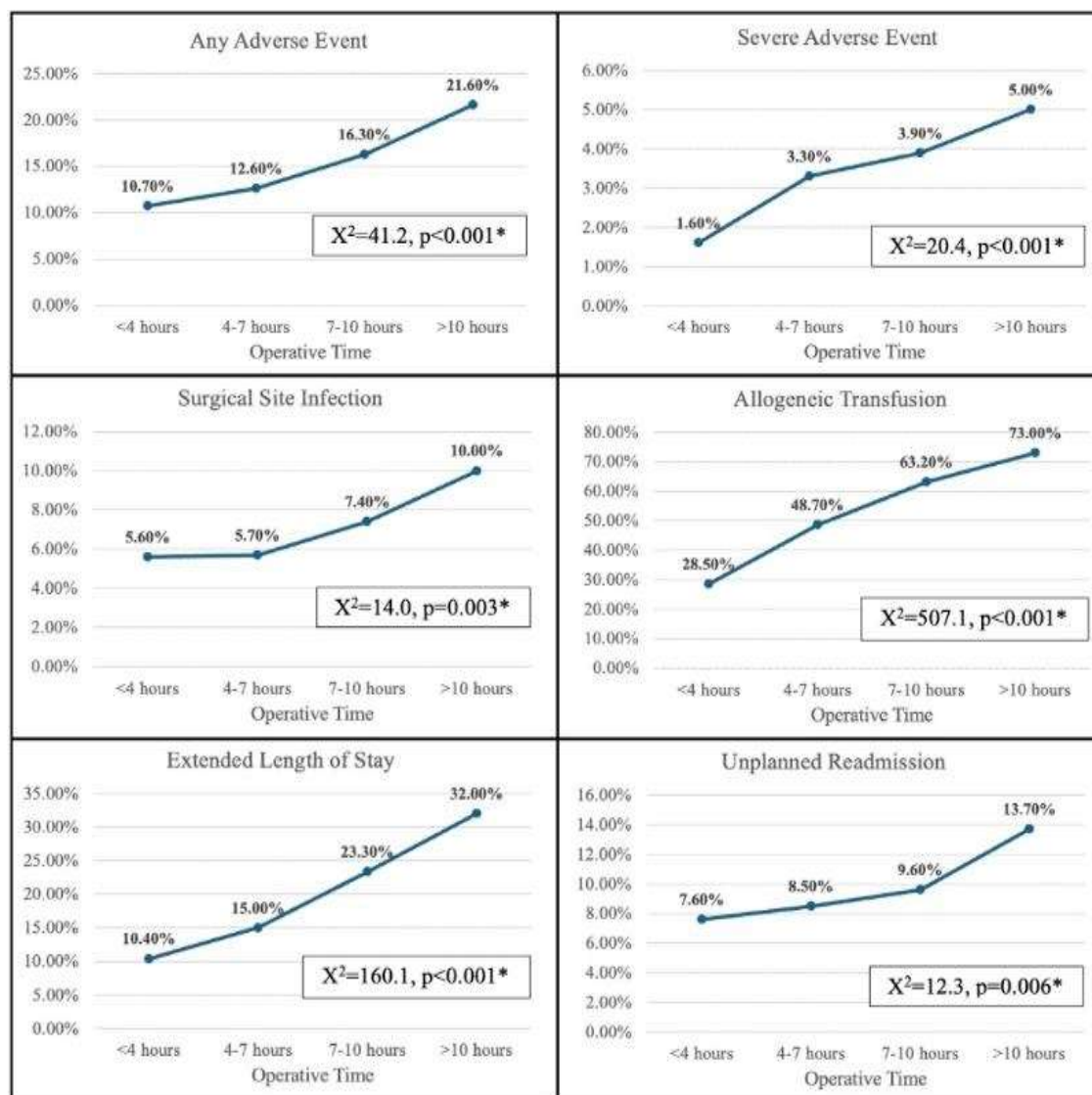
Patients were included in this study if they received a posterior spinal fusion for neuromuscular scoliosis. Operative time was stratified into <4 hours, 4-7 hours, 7-10 hours, and >10 hours and rates of any adverse event, severe adverse event, perioperative allogeneic transfusion, surgical site infection, extended length of stay (>10 days), and unplanned readmission for each category were determined and compared. Multivariable logistic regression analysis was performed to determine the relationship between operative time and the outcomes of interest.

Results

There were 8,753 patients. The rates of any adverse event, severe adverse event, perioperative allogeneic transfusion, surgical site infection, extended length of stay, and unplanned readmission were 13.1%, 3.1%, 47.6%, 6.1%, 16.0%, and 8.6%, respectively. The rates significantly increased with increasing operative time, with surgeries greater than 7 hours having rates higher than the rates of the entire cohort. For any adverse event, the rates for surgeries <4 hours and >10 hours were 10.7% and 21.6%, respectively. For allogeneic transfusion, the rates for surgeries <4 hours and >10 hours were 28.5% and 73.0%, respectively. For extended length of stay, the rates for surgeries <4 hours and >10 hours were 10.4% and 32.0%, respectively. In the multivariable logistic regression analysis, compared to surgeries <4 hours, surgeries that were 7-10 hours had higher odds of any adverse event (OR 1.42, $p=0.001$), severe adverse event (OR 2.02, $p=0.002$), allogeneic transfusion (OR 3.41, $p<0.001$), and extended length of stay (OR 2.75, $p<0.001$). Surgeries >10 hours had higher odds of any adverse event (OR 2.14, $p<0.001$), severe adverse event (OR 2.81, $p=0.004$), surgical site infection (OR 1.71, $p=0.029$), allogeneic transfusion (OR 5.77, $p<0.001$), extended length of stay (OR 4.56, $p<0.001$), and unplanned readmission (OR 1.75, $p=0.009$).

Conclusion

Longer operative times were independently associated with higher odds of perioperative morbidity in pediatric neuromuscular scoliosis surgery.



Rates of events stratified by operative time.

102. Sacro-Alar Angle as a Morphologic Predictor of S2AI Screw Infeasibility in Pediatric Neuromuscular Scoliosis with Pelvic Asymmetry

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Hypothesis

A larger sacro-alar angle (SAA) on the supporting hemipelvis is associated with reduced feasibility of S2-alar-iliac (S2AI) screw placement in pediatric neuromuscular scoliosis.

Design

Retrospective analysis of a prospectively maintained database

Introduction

Pelvic fixation using S2AI screws is widely used in neuromuscular scoliosis (NMS). In severe pelvic asymmetry, safe intraosseous trajectories may be compromised, and objective morphologic predictors of S2AI infeasibility remain poorly defined. This study evaluates the sacro-alar angle as a radiologic predictor of S2AI feasibility and explores whether plain radiographs can raise preoperative suspicion of corridor compromise

Methods

Preoperative pelvic CT scans of 53 non-ambulatory pediatric patients with NMS were retrospectively analyzed. Three-dimensional reconstructions were generated and bilateral virtual S2AI trajectories simulated. Feasibility was defined as a fully intraosseous trajectory ≥ 50 mm. Sacro-alar angles were measured bilaterally. The supporting hemipelvis was identified based on pelvic asymmetry. Paired analyses compared angles and feasibility between sides. Logistic regression assessed the association between SAA and feasibility on the support side, and discrimination was evaluated using ROC analysis.

Results

Mean SAA was significantly greater on the supporting hemipelvis compared with the non-support side ($74.7^\circ \pm 11.2$ vs. $60.9^\circ \pm 8.5$). S2AI screw infeasibility occurred more frequently on the support side ($p < 0.001$). Logistic regression demonstrated that increasing SAA on the support side was independently associated with lower screw viability (OR 0.80 per degree increase; $p = 0.001$). The model showed excellent discrimination (AUC 0.91), with sensitivity of 95.2% and specificity of 84.4% at a probability cut-off of 0.5. In contrast, no significant association was observed between sacro-alar angle and screw viability on the non-supporting hemipelvis.

Conclusion

Pelvic asymmetry in neuromuscular scoliosis produces rotational deformity of the sacroiliac complex that narrows the S2AI osseous corridor. The sacro-alar angle is a strong independent morphologic predictor of S2AI infeasibility, with a clinically useful threshold of approximately 70° . Plain radiographs may raise suspicion of corridor compromise, but definitive assessment requires 3D CT planning.

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

103. Long Term Follow-up of Non-ambulatory Children with Cerebral Palsy (CP) Treated for Spine and Hip Pathoanatomy

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Hypothesis

In non-ambulatory children with CP, hip deformities predominate requiring earlier treatment, with subsequent scoliosis development.

Design

10-yr prospective evaluation of health-related quality of life (HRQoL), caregiver burden, radiographic outcomes and risk factors for premature mortality in non-ambulatory CP patients after hip and spine surgery.

Introduction

Hip instability and neuromuscular scoliosis occur in non-ambulatory children with CP, often concomitantly when hip deformities induce pelvic obliquity that provoke thoracolumbar scoliosis. We evaluated the effect of hip and/or spine surgery on HRQoL, caregiver burden, radiographic outcomes, and factors affecting mortality ≥ 10 yrs post-op.

Methods

IRB-approved prospective study of GMFCS IV/V patients, aged 3-25 yrs, undergoing hip reconstruction and/or spinal fusion 2011-2019. Of 82 patients screened, 72 consented, and 69 participated. At 10-year f/u 44 patients were available (26 hip, 18 spine). Longitudinal changes in HRQoL (CPCHILD), care-giver burden (ACEND), and radiographic outcomes were analyzed before and 6 wks, 3, 6, 12, 24, 60 and 120 months after surgery using linear mixed-effects models. Risk factors for mortality were determined.

Results

Hip instability preceded spine deformity. Spine patients were 6.5 yrs older than hip patients (14y5m vs 9y10m; $p < 0.001$) and were more disabled (GMFCS IV: 8% vs 51%; $p = 0.004$). Of 43 hip surgery patients, 15 required spine surgery 72 ± 39 months later, whereas 3 spine surgery patients required hip reconstruction 45 ± 36 months later. In hip patients, CPOCHILD domains improved for positioning, transferring/mobility, comfort/emotions, and health 2-3 years after surgery, remaining stable at 10-yrs. ACEND scores declined over 10-yrs. In spine patients, CPOCHILD domains showed smaller (-0.2-+2.8) and less sustained improvements. ACEND scores were unchanged from baseline. Radiographic improvements in hip stability (Migration %) and scoliosis correction (Cobb) remained relatively stable. Twelve (17%) patients (5 hip, 7 spine) died from respiratory issues at a median 4 yrs after surgery. Having > 3 comorbidities predicted mortality (HR=3.10; 95% CI: 1.23-7.84; $p = 0.02$).

Conclusion

Hip and spine surgery improve HRQoL long term, especially for painful hips. Caregiver burden did not change as these children remain maximally dependent. Mortality was associated with > 3 comorbidities.

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

104. The Price of Alignment: Cost Drivers in Posterior Fusion for Neuromuscular Scoliosis

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Hypothesis

Increased length of hospital stay, patient complexity, and resource utilization are associated with increased perioperative costs in neuromuscular scoliosis (NMS).

Design

Single center retrospective review

Introduction

NMS imposes a substantial healthcare burden, with surgical costs exceeding those of idiopathic scoliosis. Despite the recognized economic impact of NMS surgery, the specific clinical and surgical factors driving costs remain poorly understood. The purpose of this study was to evaluate patients with NMS undergoing PSF and identify factors associated with increased perioperative surgical costs.

Methods

Patients aged 7-21 years with NMS who underwent PSF to the pelvis were reviewed at a single quaternary pediatric hospital. Clinical data were obtained from the electronic medical record and charge data was queried from the Pediatric Health Information System (PHIS) database. Hospital specific costs were calculated from charge data and inflation-adjusted hospital costs were analyzed using a generalized linear model with a gamma distribution and log link. Covariates were selected a priori based on deformity severity, instrumentation strategy, perioperative resource utilization, and patient comorbidities. Adjusted results are presented as percent change in cost.

Results

Ninety-five patients were included. Fusion length ranged from 12-16 levels, median length of stay was 7 days (range: 4-31), and median inflation adjusted PSF cost was \$112,689 (IQR \$90,763-\$146,897). In adjusted analyses, length of stay was a significant contributor to total inpatient cost of following fusion, with a 2.8% increase per additional day ($e^{\beta}=1.028$, $p<0.001$). Longer fusion constructs increased costs by 10.4% additional fusion level ($e^{\beta}=1.104$, $p=0.017$). Use of a temporary distraction rod was associated with a 32% increase in cost ($e^{\beta}=1.321$, $p=0.005$). Flexibility index was shown to decrease cost by 0.5% per degree ($e^{\beta}=0.995$, $p=0.047$). Preoperative curve magnitude, number of osteotomies, surgical time and patient comorbidities were not associated with total cost after adjustment.

Conclusion

Perioperative costs for pediatric NMS were primarily driven by length of hospital stay and fusion construct length rather than preoperative curve magnitude or patient comorbidities.

Figure 1A & 1B: Predicted Cost by Length of Fusion Construct and Inpatient Stay

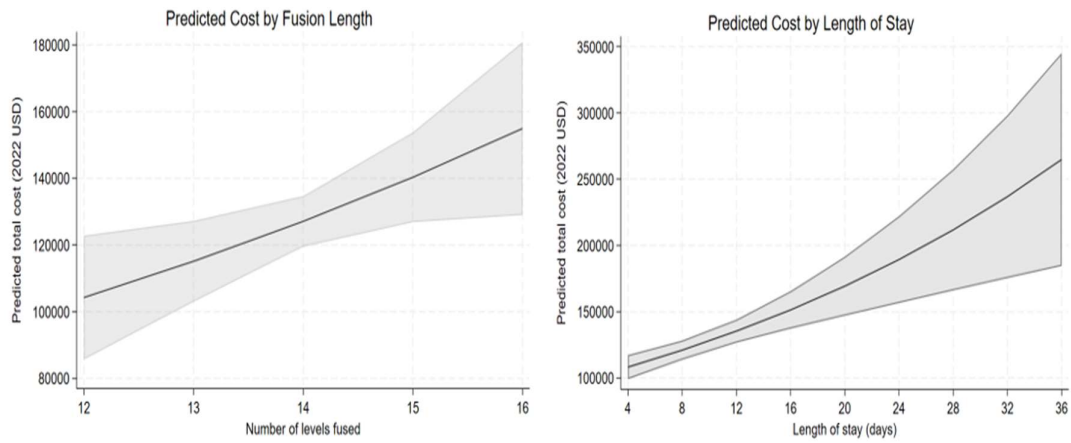


Figure 1A and 1B: Predicted Cost by Length of Fusion Construct and Inpatient Stay

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