Complications in ambulatory pediatric patients with nonidiopathic spinal deformity undergoing fusion to the pelvis using the sacral-alar-iliac technique within 2 years of surgery

Richard Menger, MD, MPA, Paul J. Park, MD, Elise C. Bixby, MD, Gerard Marciano, MD, Meghan Cerpa, MPH, David Roye, MD, Benjamin D. Roye, MD, MPH, Michael Vitale, MD, MPH, and Lawrence Lenke, MD

Department of Orthopedics, Columbia University Medical Center/NewYork-Presbyterian, The Och Spine Hospital, New York, New York

OBJECTIVE Significant investigation in the adult population has generated a body of research regarding proximal junctional kyphosis (PJK) and proximal junctional failure (PJF) following long fusions to the sacrum and pelvis. However, much less is known regarding early complications, including PJK and PJF, in the ambulatory pediatric patient. As such, the objective of this study was to address the minimal literature on early complications after ambulatory pediatric patients underwent fusion to the sacrum with instrumentation to the pelvis in the era of sacral-alar-iliac (S2AI) instrumentation.

METHODS The authors performed a retrospective review of pediatric patients with nonidiopathic spinal deformity < 18 years of age with ambulatory capacity who underwent fusion to the pelvis at a multisurgeon pediatric academic spine practice from 2016 to 2018. All surgeries were posterior-only approaches with S2AI screws as the primary technique for sacropelvic fixation. Descriptive, outcome, and radiographic data were obtained. The definition of PJF included symptomatic PJK presenting as fracture, screw pullout, or disruption of the posterior osseoligamentous complex.

RESULTS Twenty-five patients were included in this study. Nine patients (36.0%) had 15 complications for an overall complication rate of 60.0%. Unplanned return to the operating room occurred 8 times in 6 patients (24.0%). Four patients (16.0%) had wound issues (3 with deep wound infection and 1 with wound breakdown) requiring reoperation. Three patients (12.0%) had PJF, all requiring reoperation. A 16-year-old female patient with syndromic scoliosis underwent extension of fusion due to posterior tension band failure at 6 months. A 17-year-old male patient with neuromuscular scoliosis underwent extension of fusion due to proximal screw pullout at 5 months. A 10-year-old female patient with congenital scoliosis underwent extension for PJF at 5 months following posterior tension band failure. One patient had pseudarthrosis requiring reoperation 20 months postoperatively.

CONCLUSIONS Fixation to the pelvis enables significant deformity correction, but with rather high rates of complications and unexpected returns to the operating room. Considerations of sagittal plane dynamics for PJK and PJF should be strongly analyzed when performing fixation to the pelvis in ambulatory pediatric patients.

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KEYWORDS outcomes; pediatric spinal deformity; pelvic fixation; unplanned return to the operating room; spine
ening, and shifted sitting posture. Specific early complications of sacropelvic fixation include curve progression, sitting imbalance, or both. Expected increases in operative time, blood loss, and hospital stay are also described; however, they are not consistently found across studies.

As such, the objective of this study was to address the minimal literature on early complications following fusion to the sacrum with instrumentation to the pelvis in the era of sacral-alar-iliac (S2AI) instrumentation in ambulatory pediatric patients.

**Methods**

Approval for this study was obtained from our institution. Retrospective cohort data of ambulatory pediatric patients who underwent fusion to the sacrum with instrumentation to the pelvis from 2016 to 2018 were retrieved from the Children’s Hospital of New York operative database. Inclusion criteria were pediatric patients with any ambulatory capacity undergoing fusion to the pelvis for spinal deformity. Demographic information was extracted, including age, sex, race, operative etiology, presence of previous spine surgery, and diagnosis. The appropriate risk severity score was applied. Operative information consisted of the upper instrumented vertebra (UIV), type of pelvic fixation, use of osteotomy, blood loss, use of the pelvic kickstand technique, use of preoperative halo fixation, and surgical approach. Operative complications were queried from the clinical record, including hardware prominence, durotomy, pain, weakness, deep wound infection (DWI) below the fascia, seroma, and PJK or PJF. PJK was defined as a sagittal proximal junctional angle from the caudal endplate of the UIV to the cephalad endplate of UIV+2 ≥ 10° and/or a change ≥ 10° compared with the preoperative condition.

Preoperative and postoperative motor strength examination findings were obtained during retrospective chart review.

Radiographic measurements were obtained, including pelvic parameters (pelvic incidence, sacral slope, sagittal vertical axis, and coronal vertical axis), and the main structural coronal curve was measured.

**Results**

Twenty-five patients were included in this study. Nine patients (36.0%) had 15 complications for an overall complication rate of 60%. Diagnoses were syndromic scoliosis in 36.0% (9/25), congenital scoliosis in 28% (7/25), neuromuscular scoliosis in 28% (7/25), oncological in 4% (1/25), and spondylolisthesis in 4% (1/25). Congenital and neuromuscular conditions each contributed 28.0% of the group (7/25). Nearly half of the cohort had previous spinal surgery (12/25, 48.0%), and preoperative halo fixation was used in 32.0% (8/25). Female patients accounted for 52% of the cohort. Surgery was performed by two attending surgeons simultaneously in 20.0% (5/25) of the cases. The mean blood loss was 784 mL, and the median number of levels of fusion was 13.8.

Specific outcomes are shown in Table 1. Five patients (20.0%) had wound complications, 3 with DWI, 1 with seroma, and 1 with wound breakdown. Four patients required formal return to the operating room due to wound-related issues. Three patients (12.0%) had PJF, all requiring reoperation. A 16-year-old female patient with syndromic scoliosis underwent extension of fusion due to posterior tension band failure at 6 months. A 17-year-old male patient with neuromuscular scoliosis underwent extension of fusion due to proximal screw pullout at 5 months. A 10-year-old female patient with congenital scoliosis underwent extension of fusion for PJF at 5 months following posterior tension band failure (Fig. 1). One patient had pseudarthrosis that presented 20 months after the index procedure for congenital scoliosis. Gait patterns were shifted by a later leg lengthening procedure, resulting in rod fracture at the pseudarthrosis site (Figs. 2–4). Radiographic measurements are shown in Table 2. Following the unplanned returns to the operating room, there were no further spine-related issues, and the patients resumed their postoperative course of recovery.

**Discussion**

Our study illustrates one institution’s experience with
extension of fusion to the sacrum and instrumentation to the pelvis in an ambulatory pediatric cohort. Instrumentation to the pelvis in the ambulatory pediatric cohort allows for powerful deformity correction, with 36.0% (9/25) of the patients having a complication within a mean follow-up of 24.3 months. The most common complication was PJF (3/25, 12.0%), all of which occurred within 6 months of the index procedure. The incidence of DWI was also 12.0% (3/25).

**PJK in Patients With AIS**

PJK is better studied in the adolescent idiopathic scoliosis (AIS) population than in patients with nonidiopathic spinal deformity. The prevalence of PJK after posterior instrumented fusion in patients with AIS has been reported to range from 26% to 46%.6,7 Several preoperative factors have been shown to be associated with an increased risk of PJK. Lee et al. found that 1-level junctional kyphosis ≥ 5° above the planned UIV had high sensitivity and specificity for PJK development.7 Additionally, it has been shown that increased preoperative thoracic kyphosis (T5–12) has been linked with a likelihood of PJK, from 10% in thoracic kyphosis < 10°, up to 44% in patients with thoracic kyphosis > 40°.8,9 With regard to curve classification, those with Lenke type 3 and 6 curves were found to be at a higher risk of developing PJK.10

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**FIG. 1.** Images obtained in a 10-year-old female patient with PJF within 6 months after index procedure (left) and postoperative correction (right).

**FIG. 2.** A and B: Anteroposterior preoperative radiograph (A) obtained in a 12-year-old female patient and postoperative radiograph after index surgery (B). C: Radiograph with pseudarthrosis and a rod fracture after a leg lengthening procedure obtained 20 months after the initial spinal instrumentation and fusion. D: Postoperative radiograph following the revision procedure for the patient’s pseudarthrosis.
Intuitively, patients undergoing posterior fusion were more likely to develop PJK relative to those undergoing anterior spinal fusion. As posterior fusion constructs gained popularity, another study looked at the use of all-pedicle screw constructs versus hybrid constructs (proximal hooks with distal pedicle screws) and all-hook constructs. All-pedicle screw constructs were found to have a relatively higher incidence of PJK compared with hybrid constructs; however, the number of fixation points at the upper construct did not seem to be significant. Wang et al. also found that pedicle screws at the UIV were associated with a higher incidence of PJK. Reduction of kyphosis during correction was found to predispose patients to developing PJK as well.

Several studies have found that those with an increased number of levels fused had a higher risk of PJK (> 8 segments). Wang et al. found that fusions below the L2 level were associated with increased PJK. This may be due to decreased motion segments, leading to increased stress at the proximal extent of the construct by altering sagittal alignment. This becomes an important consideration when instrumentation is extended to the pelvis, as with our cohort. In a recent study in adult patients, it was shown that those requiring revision surgery for PJK had a significantly higher postoperative lumbar lordosis with an associated change in sagittal balance. Again, those patients who undergo fusion that extends to their pelvis will have a fixed lumbar lordosis and will not be able to compensate further.

**PJK in Pediatric Patients With Nonidiopathic Spinal Deformity**

While PJK in AIS patients has been well studied, the rates of PJK in the pediatric patient with nonidiopathic spinal deformity (neuromuscular, congenital) are not as clear. One study looked at 113 pediatric patients undergoing posterior spinal fusion for congenital scoliosis over an average of 2 years; it was found that the overall incidence of PJK was 18.6%. The authors similarly found that patients with longer fusion levels and greater preoperative thoracic kyphosis were at significant risk for developing PJK. A study by Syed and Hammerberg found an incidence of PJK of 24% over 2 years in patients with neuro-
muscular scoliosis. These were generally long constructs, averaging 15.68 levels in patients with PJK and 16.59 levels in those who did not develop PJK. Other studies in younger patients with nonidiopathic scoliosis who underwent growing rod construct surgery had an incidence of PJK ranging from 26% to 56%. In our study, the PJF rate was 12% (3/25), with all cases due to failure of the posterior ligamentous tension band.

**PJK in Adult Patients**

The type of failure responsible for PJK can vary. Maruo et al. found that fracture at the UIV was the most common mechanism (51%), followed by disc degeneration (22%), failure of implant fixation (14%), fracture above the UIV (8%), and subluxation (5%). In contrast, Yagi et al. found that 81% of PJK cases were the result of disc and ligamentous failure, though this might be a reflection of their younger patient population. Indeed, in our series, all 3 cases were due to ligamentous posterior band failure. In addition to age, mode of failure may be influenced by the UIV, with soft-tissue failure being more common (65%) with the UIV above T7 and fracture being more common (62%) at T7 and below.

The etiology of PJK is multifactorial, with various studies supporting a number of patient-specific, construct-specific, and deformity- or correction-specific factors, of which the relative importance has not been fully delineated. In terms of patient-specific factors, 3 different studies reported that patients who develop PJK are older than those who do not, by about 3.5 years. A meta-analysis by Zou et al. similarly found that patients with PJK were significantly older and that age > 55 years was a risk factor for PJK.

Both under- and overcorrection of sagittal alignment have been proposed as potential risk factors leading to the development of PJK. Undercorrection can result in persistent or worsening positive global sagittal alignment that may induce a positive sagittal vertical axis, which may in turn lead to an increase in the mechanical stress at the proximal junction of instrumentation, resulting in PJK. Overcorrection may not be biomechanically sustainable by the instrumentation or anatomically sustainable, resulting in PJK as the spine shifts back into its preoperative sagittal alignment.

**Instrumentation to the Pelvis**

It is hypothesized that fusion to the sacrum or pelvis distally excludes this region from any compensatory motion, necessitating that any compensation occurs at the proximal end of the construct. This added stress proximally could lead to kyphosis and potentially failure, that is, PJK. Indeed, a number of studies have identified fusion to the sacrum as a risk factor for PJK, including Yagi et al., who reported that lower instrumented vertebra at the sacrum had twice as high a rate of PJK as those with a mobile lumbosacral joint (30.5% vs 15.3%). Zou et al. similarly identified fusion to the pelvis as a risk factor for PJK. Furthermore, long fusions in adults that leave L5–S1 unfused are associated with high rates of adjacent-segment disease at this level; thus, many surgeons still advocate for fusion to the sacrum and often instrumentation to the pelvis for additional support.

Yilgor et al. illustrated the importance of pelvic harmony and normal sagittal alignment with the Global Alignment and Proportion score in adults. Distribution of lordosis, pelvic anteversion, and negative malalignment are validated within a pelvic incidence–based proportional parameter. The key emphasis within those with fusion to the pelvis would be the inability to compensate. Lordosis specifically is locked into place, as would be the

FIG. 4. Preoperative standing anteroposterior radiograph (A), supine preoperative radiograph (B), and 3D preoperative CT reconstruction (C) obtained in a 12-year-old female patient (same patient as in Figs. 2 and 3) with pseudarthrosis and a rod fracture after a leg lengthening procedure 20 months after the initial spinal instrumentation and fusion.
lordosis distribution index (L4–S1 lordosis divided by the L1–S1 lordosis multiplied by 100) and corresponding pelvic parameters. Depending on extension of the proximal construct, so too would thoracic kyphosis and even distal cervical lordosis.

Unplanned Return to the Operating Room

Unplanned return to the operating room in patients with AIS hovers around 3.5%. In neurosurgical data, long deformity fusions in adults were associated with a 5% return to the operating room within the first 30 days. Lee et al. found that 59 (2.1%) of 2758 patients who underwent spinal deformity surgery, with an average age of 16.07 years, had reoperation within 30 days. The main reasons included implant failure (20/59, 33.9%) and wound infection (12/59, 20.4%).

Jain et al. noted an 8.0% readmission and 3.8% reoperation rate for patients undergoing pediatric spinal fusions. The most common reoperation was irrigation and debridement; 2.6% of the patients in the series specifically required a reoperation for wound-related issues. Reoperation was 5.4 times more common in the congenital or kyphoscoliosis cohort, 10 times more common in the syndromic cohort, 4.4 times more common in the cerebral palsy cohort, and 4.2 times more common in the other neuromuscular group than in the AIS cohort. Indeed, in our series the mode of presentation was syndromic scoliosis followed by congenital or neuromuscular etiology.

Study Limitations

In our study, data are limited based on the number of patients available for retrospective review. The average follow-up was only 24.3 months due to the rarity of this patient population. Lower neuro motor strength examination and gait physical examination findings were compared among different attending surgeons, with only clinical notes providing information. The inherent biases among examinations between attending surgeons and retrospective reviews are present as typical. This study also does not include complete patient-reported outcomes. This proves to be challenging in a diverse patient population with a relatively rare disease. These data would add

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CVA = coronal vertical axis; LIV = lower instrumented vertebra; LL = lumbar lordosis; NA = not available; OR = operating room; PI = pelvic incidence; PT = pelvic tilt; SVA = sagittal vertical axis; TK = thoracic kyphosis; WD = wound dehiscence; 3CO = three-column osteotomy.

Mean values are given where appropriate.
depth to the current study, but our main goal is to help further understand how to optimize treatment for this patient population and potentially mitigate early complications in the future. Further study in this rare patient population is warranted.

Conclusions

Fixation to the pelvis enables significant deformity correction, but with rather high rates of complications and unexpected returns to the operating room. Considerations of sagittal plane dynamics for PJK and PJF should be strongly analyzed when performing fixation to the pelvis in ambulatory pediatric patients.

References


Disclosures

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Correspondence
Meghan Cerpa: Columbia University Medical Center, The Spine Hospital, New York, NY. mc4338@cumc.columbia.edu.