Management of spinal cord injury–related scoliosis using pedicle screw–only constructs

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OBJECT Almost all pediatric patients who incur a spinal cord injury (SCI) will develop scoliosis, and younger patients are at highest risk for curve progression requiring surgical intervention. Although the use of pedicle screws is increasing in popularity, their impact on SCI-related scoliosis has not been described. The authors retrospectively reviewed the radiographic outcomes of pedicle screw–only constructs in all patients who had undergone SCI-related scoliosis correction at a single institution.

METHODS. Medical records and radiographs from Shriners' Hospital for Children–Philadelphia for the period between November 2004 and February 2011 were retrospectively reviewed.

RESULTS. Thirty-seven patients, whose mean age at the index surgery was 14.91 ± 3.29 years, were identified. The cohort had a mean follow-up of 33.2 ± 22.8 months. The mean preoperative coronal Cobb angle was $65.5^\circ \pm 25.7^\circ$, which corrected to $20.3^\circ \pm 14.4^\circ$, translating into a 69% correction ($p < 0.05$). The preoperative coronal balance was 24.4 ± 22.6 mm, with a postoperative measurement of 21.6 ± 20.7 mm ($p = 1.00$). Preoperative pelvic obliquity was $12.7^\circ \pm 8.7^\circ$, which corrected to $4.1^\circ \pm 3.8^\circ$, translating into a 68% correction ($p < 0.05$). Preoperative shoulder balance, as measured by the clavicle angle, was $8.2^\circ \pm 8.4^\circ$, which corrected to $2.7^\circ \pm 3.1^\circ$ (67% correction, $p < 0.05$).

Preoperatively, thoracic kyphosis measured $44.2^\circ \pm 23.7^\circ$ and was $33.8^\circ \pm 11.5^\circ$ postoperatively. Thoracolumbar kyphosis was $18.7^\circ \pm 12.1^\circ$ preoperatively, reduced to $8.1^\circ \pm 7.7^\circ$ postoperatively, and measured $26.8^\circ \pm 20.2^\circ$ at the last follow-up ($p < 0.05$). Preoperatively, lumbar lordosis was $35.3^\circ \pm 22.0^\circ$, which remained stable at $35.6^\circ \pm 15.0^\circ$ postoperatively.

CONCLUSIONS. Pedicle screw constructs appear to provide better correction of coronal parameters than historically reported and provide significant improvement of sagittal kyphosis as well. Although pedicle screws appear to provide good radiographic results, correlation with clinical outcomes is necessary to determine the true impact of pedicle screw constructs on SCI-related scoliosis correction.

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KEY WORDS paralytic; pedicle; pediatric; screw; scoliosis; deformity

APPROXIMATELY 1.99 per 100,000 people are traumatized by spinal cord injury (SCI) each year in the United States, and the etiologies for such injuries range from motor vehicle accidents (MVAs), which are most common, to diving accidents, sports-related injuries, gunshot injuries, falls, transverse myelitis, and tumors.^{9,27,28} However, only 4%–14% of SCIs occur in children younger than 15 years of age.^{10,14} Nonetheless, pediatric spine trauma carries an immense clinical impact. More than one-

third of the children with injury to the cervical spine have signs of SCI, and mortality rates as high as 18% have been associated with cervical spine injuries, albeit with a high concordance of closed-head injury.^{7,14,25}

Most children with spinal cord trauma suffer from incomplete neurological injuries, and many will recover significantly over time. Birney and Hanley reported that 44% of pediatric patients with cervical spine trauma had associated SCI, but that only 24% had complete neurological im-

ABBREVIATIONS CSVL = central sacral vertical line; EKG = electrocardiography; MVA = motor vehicle accident; SCI = spinal cord injury.

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pairment.⁶ The significantly improved clinical outcomes among children with SCI may partially be attributable to an overrepresentation of SCI without radiological abnormality (SCIWORA) in younger patients. The prognosis for SCIWORA is more favorable, and many patients will have significant functional recovery over time.¹⁷

Nonetheless, pediatric patients who suffer from SCI not only have to cope with associated medical problems, such as wound care, ulcer prevention, muscle atrophy, recurrent urinary tract infections, functional adaptation, contractures, spasticity, and nutritional demands, but also have to monitor for progressive spinal deformity. Almost all pediatric patients who incur an SCI will develop scoliosis,^{5,8,21} and younger patients, especially those who have an injury prior to the adolescent growth spurt, are at highest risk for curve progression requiring surgical intervention.^{16,21}

Prior series have described surgical outcomes of SCI-related scoliosis using earlier instrumentation designs, such as unit rods, wiring, hooks, and Luque rods, but the literature regarding surgical outcomes with more recent pedicle screw constructs is sparse and interspersed among series mostly describing neuromuscular scoliosis with various other etiologies.^{3,4,16,19,29,32,34–39} Although pedicle screw constructs have been associated with greater coronal and axial correction in adolescent idiopathic scoliosis, their impact on SCI-related scoliosis has not yet been described.^{1,33} We investigated outcomes using pedicle screw-only constructs in treating SCI-related scoliosis.

Methods

Local institutional review board approval was obtained, and medical records and radiographs were retrospectively reviewed from a single institution, Shriner's Hospital for Children–Philadelphia, for the period from November 2004 to February 2011. All consecutive pediatric patients (age < 18 years) with SCI and paralytic scoliosis were identified. Only those who had undergone deformity correction surgery using pedicle screw constructs (> 80% screws) at our institution were included.

Clinical and radiographic measurements were recorded. Collected data included patient age, sex, weight, neurological level of injury, functional parameters, etiology of injury, curve pattern, and radiographic parameters. Thoracic kyphosis was measured from T-2 to T-12 unless the kyphosis extended beyond T-12 with the loss of lumbar lordosis; the kyphosis was then measured from the appropriate lumbar level to obtain maximal values of kyphosis. Thoracolumbar kyphosis was measured from T-10 to L-2, and lumbar lordosis was obtained from L-1 to S-1. Sagittal balance was measured as the distance (in mm) between a vertical line dissecting the posterior edge of the sacrum and a plumb line from the centroid of C-7. Coronal balance was inferred from the distance (in mm) between the central sacral vertical line (CSVL) and a line from the centroid of C-7. Pelvic obliquity was calculated by measuring the angle subtended between the line tangential to both iliac crests and the horizontal. Shoulder balance was inferred by measuring the clavicle angle as described by Kuklo et al.¹⁵ Standing radiographs were obtained if the patient was ambulatory; otherwise, we obtained sitting radiographs.

Statistical analysis using SPSS 12.0.2 software was performed with Student t-tests, chi-square tests, and Fisher exact tests, as appropriate. All results were reported as the means $\pm$ standard deviation. A p value of 0.05 was considered statistically significant.

Results

Demographics

We identified 37 patients who had been treated for paralytic scoliosis using pedicle screw instrumentation at our institution. All patients had progressive coronal curvature or kyphosis beyond 50°. Twenty-four patients were male and 13 were female. The mean age at the time of injury was 6.53 ± 4.95 years (range birth to 17 years), and the mean age at surgery was 14.91 ± 3.29 years. The mean interval between injury and surgical management for deformity was 8.38 ± 4.76 years. The majority of patients (59%) had thoracic level injuries, 38% had cervical, and 3% had conus level injuries. Eighty-one percent had complete neurological injuries, and the most commonly encountered mechanism of injury was MVA (51%; Table 1). The mean number of levels fused was 16, with the majority of patients having fixation extending to the pelvis (89%). The cohort had a mean follow-up of 33.2 ± 22.8 months (range 0.7–81.7 months, median 33.0 months).

Coronal Plane

The majority of patients (70%) had a typical long, sweeping C-shaped curve, while the remaining patients had double curves. The mean preoperative maximal coronal Cobb angle was $65.5^\circ \pm 25.7^\circ$, which corrected to $20.3^\circ \pm 14.4^\circ$, translating into a 69% correction ($p < 0.05$; Fig. 1 and Table 2). At the last follow-up, the mean Cobb angle was maintained at $19.1^\circ \pm 15.3^\circ$ ($p = 1.00$). The preoperative coronal balance (CSVL to C-7 translation) was 24.4 ± 22.6 mm, with a postoperative measurement of 21.6 ± 20.7 mm ($p = 1.00$) and a last follow-up measurement of 18.7 ± 12.6 mm ($p = 1.00$). No significant change in coronal balance was observed at any time interval.

The majority of patients (89%) had instrumentation extending to the pelvis, and the entire cohort had a preoperative pelvic obliquity of $12.7^\circ \pm 8.7^\circ$. Postoperatively, the pelvic obliquity measured $4.1^\circ \pm 3.8^\circ$, translating into a 68% correction ($p < 0.05$). Pelvic obliquity at the last follow-up was $5.0^\circ \pm 7.1^\circ$. Although not the exact same cohort, 89% of patients also had instrumentation extending to the low cervical (C-7) or upper thoracic spine (T1–4), with most terminating at T-1 or T-2. Preoperative shoulder balance, as measured by the clavicle angle, was $8.2^\circ \pm 8.4^\circ$, which corrected to $2.7^\circ \pm 3.1^\circ$ (67% correction, $p < 0.05$). At the last follow-up, this measure remained stable at $2.4^\circ \pm 2.1^\circ$ ($p = 1.00$).

Sagittal Plane

Preoperatively, thoracic kyphosis measured $44.2^\circ \pm 23.7^\circ$; postoperatively, $33.8^\circ \pm 11.5^\circ$ ($p = 0.14$); and at the last follow-up, $36.0^\circ \pm 15.4^\circ$ (Fig. 2 and Table 2). Thoracolumbar kyphosis was $18.7^\circ \pm 12.1^\circ$ preoperatively, reduced to $8.1^\circ \pm 7.7^\circ$ postoperatively, and measured $26.8^\circ \pm 20.2^\circ$ at the last follow-up ($p < 0.05$). Preoperatively, lumbar lor-

TABLE 1. Demographic summary for 37 pediatric patients with SCI-related scoliosis treated with pedicle screw-only constructs

Factor	No.
% Male:% female	65:35
Mean age at injury in yrs	6.53
Mechanism of injury (%)	
MVA (any vehicle)	19 (51)
Iatrogenic	6 (16)
Other	12 (32)
Level of injury (%)	
Cervical	14 (38)
Thoracic	22 (59)
Lumbar	1 (3)
Type of injury (%)	
Incomplete	6 (16)
Complete	30 (81)
Unknown	1 (3)
Age at surgery in yrs	
Mean	14.91
Range	10–20.7
Time btwn index surgery & last FU in mos	
Mean	33.2
Median	33.0
Range	0.7–81.7

FU = follow-up.

dosis was $35.3^\circ \pm 22.0^\circ$, which remained stable at $35.6^\circ \pm 15.0^\circ$ postoperatively and $38.8^\circ \pm 17.1^\circ$ at the last follow-up ($p = 1.00$). Sagittal balance was 44.6 ± 44.0 mm preoperatively, 35.4 ± 26.9 mm postoperatively, and 47.3 ± 26.4 mm at the last follow-up ($p > 0.05$).

Eight patients had kyphosis that exceeded the magnitude of their coronal curvature, ranging from 52° to 101° of kyphosis. The mean kyphosis for this subgroup was $72.5^\circ \pm 16.9^\circ$ along with a mean coronal Cobb angle of $38.5^\circ \pm 25.1^\circ$. Both corrected significantly to $40.5^\circ \pm 14.8^\circ$ ($p < 0.05$) and $15.2^\circ \pm 18.8^\circ$ ($p < 0.05$), respectively. The remaining radiographic parameters were not significantly different, but a trend toward significance was observed between preoperative and postoperative sagittal balance with a change from 70.6 ± 64.8 mm to 30.3 ± 28.9 mm ($p = 0.08$; Table 2).

Intraoperative, Perioperative, and Postoperative Parameters and Complications

Average weight at the time of surgery was 49.1 ± 15.2 kg (Table 3). Eighty-nine percent (33 patients) underwent a fusion to the pelvis, and 9% (3) of these patients had two-stage surgeries. A combination of allograft and autograft was used in 33 patients (89.2%), autograft alone was used in 2 (5.4%), allograft and bone morphogenetic protein were used in 1 patient (2.7%), and no bone graft was used in 1 patient (2.7%). Surgical time averaged 507 ± 161 minutes (range 294–1183 minutes) with an average estimated blood loss of 2720 ± 1808 ml (range 550–10,000 ml). The average amount of cell saver blood transfused was $593 \pm$

FIG. 1. Left: Preoperative anteroposterior radiograph showing an 87° C-shaped curve with significant pelvic obliquity. **Right:** Postoperative radiograph displaying scoliosis correction using a pedicle screw construct.

504 ml (range 0–2000 ml). Postoperatively, patients spent an average of 3.7 days (range 1–25 days) in the pediatric intensive care unit, and the average total hospital stay was 19 days (range 7–102 days).

Overall, 54% (20) of patients experienced a perioperative complication (41 complications total; Table 4). The intraoperative complication rate was 11% (4 complications in 4 patients), which included a dural tear in 2 patients (5%), an optic nerve injury (3%), and an instance of electrocardiography (EKG) changes that caused early cessation of the surgical procedure. No new spinal neurological changes occurred. There were no deaths at the final follow-up.

Twelve medical complications occurred in 10 patients (27%). Six patients (16%) had minor medical complications that included nonoperative decubitus ulcers (3 patients), EKG changes (1 patient), prolonged mechanical ventilation (1 patient), and significant edema (1 patient). Six patients (16%) had major medical complications, including new pressure ulcers necessitating debridement (4 patients), sepsis (1 patient), and acute respiratory distress syndrome (1 patient).

Nineteen surgical complications occurred in 14 patients (38%). The minor surgical complication rate was 16% (6 patients) with 3 patients having superficial wound complications (2 of them requiring debridement). In addition 3 patients had instrumentation failure not requiring revision surgery at the last follow-up. The major surgical complication rate was 22% (13 complications in 8 patients) with deep wound infections being the most common (4 patients [11%]). Four patients (11%) had a pseudarthrosis. Two patients (5%) had proximal junctional kyphosis, and both eventually underwent extension of the posterior spinal fusion. Three patients (8%) had instrumentation failure requiring revision surgery at the last follow-up.

The number of levels fused, estimated blood loss, duration of surgery, and preoperative Cobb angle were not sig-

TABLE 2. Radiographic outcomes in 37 patients with SCI-related scoliosis treated with pedicle screw-only constructs

Factor	Preop				Immediate Postop				Final FU		p Value *			
	Mean	Median	Range		Mean	Median	Range		Mean	Median	Range	Comparison Btwn Preop & Immediate Postop	Comparison Btwn Preop & Final FU	Comparison Btwn Postop & Final FU
Coronal Cobb angle (°)	65.5	65.0	5.0–118		20.3	19.2	0–56.0		19.1	14.6	0–63.2	<0.05	<0.05	1.00
Thoracic kyphosis (°)	44.2	42.6	4.9–101		33.8	34.3	13–63.4		36.0	33.5	16.2–71.4	0.14	0.73	1.00
Thoracolumbar kyphosis (°)	18.7	16.5	3.0–40.3		8.1	4.7	0–22.5		26.8	22.6	0.8–71.4	<0.05	0.70	<0.05
Lumbar lordosis (°)	35.3	32.5	3.0–93.5		35.6	32.2	12–84.5		38.8	36.4	10.1–85.6	1.00	0.64	1.00
Coronal balance (mm)	24.4	14.0	0–88.0		21.6	18.0	0–100.0		18.7	15.0	0–43.0	1.00	1.00	1.00
Sagittal balance (mm)	44.6	33.5	0–196.0		35.4	30.0	0–113.0		47.3	45.5	0–94.0	1.00	1.00	0.39
Pelvic obliquity (°)	12.7	12.5	1–34.4		4.1	3.7	0–15.0		5.0	3.3	0–30.9	<0.05	<0.05	1.00
Shoulder balance (°)	8.2	5.1	0–36.3		2.7	2.0	0–10.5		2.4	2.5	0–6.5	<0.05	<0.05	1.00

* Boldface type indicates statistical significance.

FIG. 2. Left: Preoperative lateral radiograph showing an overall kyphotic spine with the loss of lumbar lordosis. Right: Postoperative lateral radiograph showing reduction of the kyphosis using pedicle screws.

nificantly associated with the presence of any infection or specifically with a deep infection. However, the presence of a deep infection showed a significantly higher risk of pseudarthrosis than the absence of a deep infection (50% vs 3%, respectively, $p = 0.03$).

The number of levels fused, estimated blood loss, and duration of surgery were not significantly associated with the occurrence of any complication or specifically with a major surgical complication. There was a trend for an increased overall complication rate in patients with a preoperative Cobb angle $\geq 55^\circ$, as compared with that in patients having an angle $< 55^\circ$ (59% vs 27%, $p = 0.14$). No other trends were seen when assessing other preoperative Cobb angle cutoffs and the presence of any complication or a major surgical complication.

Discussion

In SCI, the development of scoliosis is thought to be primarily related to paraspinal neuromuscular imbalance, but several other factors have been associated with scoliotic curves, such as wheelchair dependence, paraplegia, complete neurological injuries, hip flexion contractures, and age.^{3,4,16} However, many of these associations are most likely consequences of a similar pathophysiological process rather than causative, with the exception of age at SCI onset.

The onset of SCI prior to skeletal maturity is the most common and reproducible factor associated with the development of SCI-related scoliosis. Lancourt et al. noted that patients with the largest curves in their cohort had a mean age of 5.2 years at injury as opposed to 15.6 years in those without scoliosis and 13.2 years in a subgroup with smaller curves.¹⁶ Furthermore, Betz et al. noted that 100% of skeletally immature patients in their series developed

TABLE 3. Intraoperative and perioperative parameters in 37 patients treated with pedicle screw-only constructs

Parameter	Mean $\pm$ SD	Range
Weight at surgery in kg	49.1 $\pm$ 15.2	24.4–87.0
No. of levels fused	16 $\pm$ 2.9	7–18
Surgical time in minutes	507 $\pm$ 161	294–1183
Estimated blood loss in ml	2720 $\pm$ 1808	550–10,000
Amount of cell saver transfused in ml	593 $\pm$ 504	0–2000

scoliosis.⁵ Similarly, Lancourt et al. reported scoliosis development in all patients younger than 10 years of age and with an SCI.¹⁶ While 100% of skeletally immature patients who have an SCI will develop scoliosis, other series have identified scoliosis in 78%–98% of all pediatric spinal cord-injured age groups.^{3–5,8,16,21} Mayfield et al. further reported that 96% of all their pediatric patients with SCI also had progressive curves.¹⁹

A significant proportion of patients who develop SCI-related scoliosis will require surgical correction of the curvature. Although precise criteria for surgical intervention vary by surgeon preference, several authors have reported 45%–77% of patients requiring surgery.^{8,19,21} Although surgery is required in most patients, bracing has also been shown to help reduce the number of patients requiring fusions and to postpone the timing of surgical intervention.²¹ In a series of 123 patients with a mean follow-up of 7.7 years, 45% of the patients who presented with small curves and were braced did not require surgery, whereas 77% of those without bracing required surgical intervention.⁴ Other alternatives to definitive instrumentation include fusionless wedge osteotomies with a temporary rod, but outcomes have not been directly compared with those for standard instrumented fusions.^{12,20}

Fusion outcomes in the literature are sparse and limited to older instrumentation types (wiring, Luque rods) and mixed neuromuscular pathological entities. Spinal cord injury-related scoliosis tends to appear in a small fraction of these series, with most patients having other types of neuromuscular scoliosis such as myelomeningoceles.^{32,34,35} Although similar, these pathological entities may have subtle differences. Although the more rostral extent of neurological impairment in patients with myelomeningocele has been strongly correlated with the risk of scoliosis development, that association has not been consistently reproduced among patients with SCI.^{2,4,16,18,24,26,30,31} Furthermore, patients with myelomeningocele represent a congenital developmental process as opposed to SCI, which is a post-developmental injury. Modi et al. compared pedicle screw constructs in neuromuscular scoliosis cases and noted a 58% correction from 82° to 34°.²³ Their series comprised 37 patients, only 1 of whom had posttraumatic etiology. The authors concluded that pedicle screw utilization was “safe,” although 27% had breaches and more than 90% of the breaches occurred within a defined overall safe zone.

Similarly, prior series of 10–18 patients assessing only paralytic scoliosis using older instrumentation techniques have reported coronal curve corrections ranging from 44% to 55%.^{16,36} We noted a mean correction of 69% in the

TABLE 4. Intraoperative and postoperative complications in 20 patients

Complication	No. of Complications	No. of Patients (%)
Overall no.	41	20 (54)
Intraop		
Total	4	4 (11)
Dural tear	2	2 (5)
Optic nerve injury	1	1 (3)
EKG changes	1	1 (3)
Medical		
Total	12	10 (27)
Minor		
Total	6	6 (16)
Nonoperative decubitus ulcers	3	3 (8)
Prolonged mechanical ventilation	1	1 (3)
EKG changes	1	1 (3)
Significant edema	1	1 (3)
Major		
Total	6	6 (16)
Ulcers needing debridement	4	4 (11)
Sepsis	1	1 (3)
ARDS	1	1 (3)
Surgical		
Total	19	14 (38)
Minor		
Total	6	6 (16)
Superficial wound infection (no I&D)	1	1 (3)
Superficial wound infection w/ I&D	2	2 (5)
Instrumentation failure not requiring revision surgery	3	3 (8)
Major		
Total	13	8 (22)
Deep wound infection	4	4 (11)
Pseudarthrosis	4	4 (11)
Junctional kyphosis	2	2 (5)
Instrumentation failure requiring revision surgery	3	3 (8)

ARDS = acute respiratory distress syndrome; I&D = incision and drainage.

entire cohort and improvement in all coronal radiographic parameters except for the coronal balance as measured from CSVL to C-7. Interestingly, coronal balance did not significantly improve in the cohort. When performing subgroup analysis, excluding the 8 patients who primarily had excessive kyphosis, we noted that the change in coronal balance was still not significantly improved ($p = 0.83$). Possibly, the degree of coronal imbalance preoperatively may have been mild because of the compensatory curvature; therefore, postoperative interval changes may have been marginalized. Although the parameters of coronal imbalance have not been correlated with functional outcomes in neuromuscular scoliosis, the mean coronal imbalance of 2.4 cm was smaller than the 4 cm associated

with functional outcomes in adult deformity and therefore may not have any significant clinical impact.¹¹

Tsirikos et al. reported pelvic obliquity improvement of 60%;³⁶ we noted 68% improvement of the pelvic obliquity in our study. The percent correction we observed in coronal parameters would suggest significant improvement with the use of pedicle screw constructs as compared with historical results, but statistical analysis is limited in comparisons between these cohorts.

In the sagittal plane, we only noted a significant change in the thoracolumbar kyphosis ($p < 0.05$). This alteration in the sagittal plane also significantly changed by the last follow-up, with a loss in the correction from 8.1° to 26.8°. This may reflect an initial overcorrection of the amount of kyphosis required by patients to function properly. Excessive reduction of the kyphosis may impair the functional ability of patients with SCI, as they rely on this forward position to feed or reach their mouths with limited upper extremity mobility and strength. Furthermore, in adolescent idiopathic scoliosis, pedicle screw constructs have been associated with decreased thoracic kyphosis postoperatively.¹³ However, a historical SCI patient comparison was not available, as most SCI-related series have not reported sagittal parameters. When we assessed the 8 patients who presented with kyphotic angulation greater than the coronal curvature, the postoperative change in overall kyphosis was statistically significant ($p < 0.05$).

Overall, pedicle screw constructs appear to provide better correction of coronal parameters and offer significant improvement in sagittal kyphosis as well. However, overcorrection, especially in the sagittal plane, may be counterproductive and may contribute to increased functional impairment. A limitation of the current study is the absence of a functional outcome analysis. Unfortunately, clinical parameters for most patients were not available for us to complete any analysis. Furthermore, there are currently no well-accepted functional outcome measures for this group of patients. However, we intend to investigate subjective feedback from the patients and caregivers who could help to elucidate the benefits and disadvantages of spinal deformity surgery in SCI. Although pedicle screws appear to provide good radiographic results, correlation with clinical outcomes is necessary to determine the true impact of pedicle screw constructs on SCI-related scoliosis correction. The impact on sitting balance and ulcer development is more important than simply improving the radiographic pelvic obliquity. Mercado et al. reviewed the literature and reported that spinal fusions appeared to positively influence quality of life measures in patients with cerebral palsy and muscular dystrophy but did not clearly benefit patients with scoliosis from myelomeningoceles.²² Currently, the literature is too sparse to draw any significant conclusions regarding SCI-related scoliosis. Ideally, additional prospective multicenter data are required to better determine the impact of pedicle screws on SCI-related scoliosis.

Conclusions

In SCI-related scoliosis, pedicle screw constructs appear to provide improved correction of the coronal plane and offer substantial improvement in the sagittal plane as

well. Significant correction can be achieved in coronal parameters, but caution should be exercised to avoid overcorrection of the sagittal plane. Further correlation of radiographic outcomes with clinical results is required to better determine the impact of pedicle screws on SCI-related scoliosis correction.

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