

## Outcomes and Complications of Extension of Previous Long Fusion to the Sacro-Pelvis: Is an Anterior Approach Necessary?

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### Key words

- Complications
- Deformity
- Iliac screws
- Pedicle subtraction osteotomy
- Revision
- Sacro-pelvic instrumentation
- Spine
- Surgery

### Abbreviations and Acronyms

**APSF:** Anterior-posterior spinal fusion

**BMI:** Body mass index

**CT:** Computed tomography

**PSF:** Posterior-only spinal fusion

**PSO:** Pedicle subtraction osteotomy

**SPO:** Smith-Peterson osteotomy

**SRS:** Scoliosis Research Society

**SVA:** Sagittal vertical axis



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### INTRODUCTION

With advances in spinal instrumentation, spine surgeons have been able to treat an increasing array of spinal disease. However, the durability of spinal fusion operations has been an area of concern, especially in those patients initially treated as adolescents or young adults. It is well recognized that a subset of patients treated for scoliosis present later in life with evidence of painful degeneration below long-segment fusions ending in the distal lumbar spine. Manifestations of this degeneration include steno-

■ **BACKGROUND:** Patients with previous multilevel spinal fusion may require extension of the fusion to the sacro-pelvis. Our objective was to evaluate the outcomes and complications of these patients, stratified based on whether the revision was performed using a posterior-only spinal fusion (PSF) or combined anterior-posterior spinal fusion (APSF).

■ **METHODS:** A retrospective, multicenter evaluation of adults (>18 years old) with a history of prior spinal fusion for scoliosis ( $\geq 4$  levels) terminating in the distal lumbar spine requiring extension of fusion to the sacro-pelvis (including iliac fixation in all cases), with minimum 2-year follow-up, was performed. Patients were stratified based on approach (APSF vs. PSF) and inclusion of pedicle subtraction osteotomy (PSO). The PSF group included patients treated with an anterior interbody fusion done through a posterior approach, whereas patients in the APSF group all had both anterior and posterior surgical approaches. Clinical outcomes were based on the Scoliosis Research Society (SRS-22) questionnaire.

■ **RESULTS:** Between 1995 and 2006, 45 patients (mean age = 49 years) met inclusion criteria, with a mean follow-up of 41.9 months (range 24 to 135 months). Demographic, preoperative, operative, and postoperative radiographic, SRS-22, and follow-up results were similar between APSF (n = 30) and PSF (n = 15) groups. The APSF group had more complications (13 of 30 vs. 3 of 15) and a greater number of pseudarthrosis (4 of 30 vs. 0 of 15) than the PSF group; however, these differences did not reach statistical significance. Patients treated with a PSO (n = 13) had greater sagittal vertical axis correction (7.7 cm vs. 2.2 cm;  $P = .04$ ) compared with patients not treated with a PSO (n = 32). There were no differences in complication rates or follow-up SRS-22 scores based on whether a PSO was performed ( $P > .05$ ).

■ **CONCLUSIONS:** Among adults with previously treated scoliosis requiring extension to the sacro-pelvis, PSF produced radiographic and clinical outcomes equivalent to APSF, whereas complication rates may be lower. PSO resulted in greater sagittal plane correction, without an increase in overall complication rates.

tations of this degeneration include stenosis, listhesis, and loss of lumbar lordosis with resultant negative effects on global sagittal alignment (5, 6, 12, 14). Revision surgery after long fusions is therefore not infrequent (15).

Although there are multiple studies addressing pelvic fixation and its benefits, such as decreased rates of pseudarthrosis (10, 11, 13, 17), few studies have specifically

evaluated the extension of previous long fusions to the sacrum and pelvis (7, 9, 12). Patients requiring extension to the sacro-pelvis often need challenging revision surgeries. Previous investigators have recommended combined anterior and posterior instrumented fusions coupled with osteotomies to address degenerative deformity and loss of lordosis (12). However, these procedures have been associated with high

complication rates, including pseudarthrosis rates that approach 40% (9).

This study seeks to add to the understanding of best practice approaches to patients requiring extension of long-segment lumbar fusion to the pelvis by evaluating the efficacy and morbidity of different surgical approaches. In addition, comparisons of clinical, operative, and radiographic outcomes were performed between patients treated with and without pedicle subtraction osteotomy (PSO).

## MATERIALS AND METHODS

This study was conducted through the International Spine Study Group, a multi-center group consisting of 11 sites at which complex adult spinal deformity surgery is commonly performed. Five sites from the International Spine Study Group participated in the present study by contributing consecutive cases of long-segment posterior thoracolumbar fusions ( $\geq 4$  levels) for spinal deformity treatment that did not include sacral or pelvic fixation at the time of the primary procedure but were later revised to include pelvic fixation. Institutional review board approval was obtained at each study site before initiation of the present study.

The present study was a retrospective cohort analysis. Inclusion criteria were: age  $>18$  years; history of multilevel ( $\geq 4$  levels) spinal arthrodesis for deformity with distal extension to L3, L4, or L5; subsequent extension of this prior fusion to the sacro-pelvis (including iliac screws) between the years 1995 and 2006; and minimum 2-year clinical and radiographic follow-up. Patients were excluded if spinal fusion had been performed for neuromuscular deformity, tumor, or infection. Cases were identified based on surgeon case logs, and preoperative and postoperative clinical records and radiographs were reviewed for data extraction.

Patients were divided into combined anterior-posterior spinal fusion (APSF) and posterior-only spinal fusion (PSF) groups. The PSF group included patients treated with an anterior interbody fusion done through a posterior approach, whereas patients in the APSF group all had both anterior and posterior surgical approaches. Patients treated with a PSO were also identified, and a subgroup analysis was per-

formed. Comparisons were made with those patients not receiving a PSO but with a preoperative sagittal vertical axis (SVA)  $>5$  cm. Posterior lumbosacral instrumentation included standard pedicle screw fixation as well as hook-screw constructs. Iliac fixation was used in all cases. Revision graft material varied, but generally consisted of local autograft, morselized allograft, and in some cases iliac crest. Interbody support materials also varied, and included femoral ring allograft, carbon fiber cages, and Harms cages.

Data collected included intraoperative parameters, preoperative and postoperative radiographic data (including SVA, coronal alignment, Cobb angle, lumbar lordosis, and thoracic kyphosis), health-related quality of life information (Scoliosis Research Society [SRS-22]), and perioperative and postoperative complications. Information on gender, age, and body mass index (BMI) was also recorded from the time of revision surgery. Follow-up radiographic and SRS-22 data were gathered at last follow-up at a minimum of 2 years after revision.

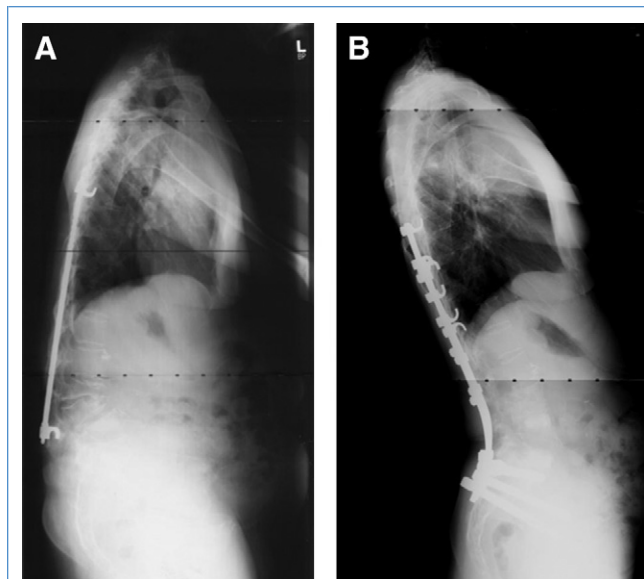
Pseudarthrosis was determined based on a combination of plain radiographic imaging and computed tomography (CT) imaging. Over the minimum 2-year follow-up period, any evidence of screw halos, instrumentation failure, or ab-

normal motion on dynamic plain radiographs was further investigated with CT imaging. Based on CT imaging, lack of evidence of bony bridging across the vertebral level was classified as pseudarthrosis.

Descriptive statistics were performed to determine means, medians, and standard deviations. Comparisons between independent groups were performed using Wilcoxon rank-sum tests. Comparisons of categorical variables between the groups were performed with Fisher exact tests. Analyses were performed using SPSS statistical software (SPSS Inc., Chicago, Illinois, USA). Significance was set at  $P < .05$ .

## RESULTS

Of the 55 consecutive patients identified, 45 (82%) had more than 2-year radiographic follow-up and were included in this study. Thirty-six (80%) of the 45 patients had more than 2-year SRS-22 scores. The mean length of follow-up was 42 months (range 24 to 135 months). Thirty-nine (87%) of the patients were women. The mean patient age was 49.5 years (SD 11.7 years, range 21 to 73 years). The mean BMI was 26.5 (SD 6.1, range 17.4 to 44.3). Thirty patients received APSF, and 15 patients received PSF only. Of the patients in the APSF group, 19



**Figure 1.** (A) Lateral full-length radiograph of an adult patient with prior long-segment thoracolumbar fusion for scoliosis presenting with painful degeneration at the caudal aspect of the fusion. (B) Lateral full-length radiograph of the same patient after revision that included extension of the fusion to the sacro-pelvis using a posterior-only approach.

**Table 1.** Preoperative Radiographic Measurements for the Posterior-Only and Combined Anterior/Posterior Groups

	Thoracic Cobb Angle	Thoracolumbar Cobb Angle	Sagittal Balance (Sagittal Vertical Axis)	Coronal Balance	Thoracic Kyphosis	Lumbar Lordosis
Posterior-only spinal fusion (n = 15)	34.7 (20.9)	30.4 (18.8)	6.3 (7.8)	2.89 (5.1)	29.3 (24.8)	-33.9 (16.3)
Combined anterior/posterior spinal fusion (n = 30)	34.1 (13.9)	40.0 (15.6)	7.1 (5.7)	2.56 (3.3)	35.7 (21.9)	-26.6 (25.4)
P values	0.9	0.08	0.7	0.6	0.4	0.3

Data presented as mean (standard deviation).

underwent both anterior and posterior procedures in a single stage and 11 underwent anterior and posterior procedures in separate stages during the same hospitalization. In addition to placement of anterior interbody support at L5-S1, anterior grafts were placed at L4-5 in 16 patients and at L3-4 in two patients. Ten of 15 PSF patients (67%) received posterior interbody fusion. The numbers of posterior spinal fusion levels were similar for APSF and PSF (13.3 vs. 12.6, respectively;  $P = .8$ ). Five (33%) patients in the PSF group and eight (27%) patients in the APSF group were treated with a PSO ( $P = .7$ ). **Figure 1** demonstrates an example of a patient requiring sacro-pelvic extension of a prior long-segment thoracolumbar fusion for scoliosis.

There were no statistically significant differences between the APSF and PSF groups in terms of preoperative thoracic and thoracolumbar Cobb angles, coronal alignment, SVA, lumbar lordosis, and thoracic kyphosis (**Table 1**). Patients in the two groups also did not differ statistically in terms of age (52.4 vs. 48.0;  $P = .25$ ) or BMI (24.4 vs. 27.6;  $P = .12$ ). Patients treated with a PSO had similar preoperative radiographic measurements as those not treated with a PSO (**Table 2**). The most common level at which PSO was performed was L3 (46%), followed by L4 (38%) and by L2 (16%). Although there was a trend toward higher preoperative

SVA in those treated with a PSO (9.7 cm) vs. those not treated with a PSO (5.6 cm), this was not statistically significant ( $P = .052$ ).

Patients in the APSF and PSF groups had similar radiographic parameters at last follow-up, including coronal alignment (PSF 0.2 cm vs. APSF -0.6 cm;  $P = .36$ ), and SVA (PSF 4.7 cm vs. APSF 2.1 cm;  $P = .21$ ; **Table 3**). SRS-22 total scores at last follow-up were similar between the APSF and PSF groups (3.64 vs. 3.67;  $P = .9$ ).

Patients treated with a PSO had greater correction in lumbar lordosis (22.5° vs. 11.1°;  $P = .041$ ) and greater correction of SVA (7.7 cm vs. 2.2 cm;  $P = .048$ ), compared with patients not treated with a PSO (**Table 4**). SVA at last follow-up was similar between patients treated with or without a PSO (1.7 cm vs. 3.4 cm, respectively;  $P = .30$ ). In addition, SRS-22 scores at last follow-up did not differ significantly based on whether a PSO was performed (3.69 vs. 3.64;  $P = .87$ ).

A subanalysis of the 13 patients treated with PSO was performed to determine whether there were differences in radiographic follow-up parameters between those that underwent APSF vs. PSF procedures. There were no significant differences found in terms of SVA correction (8.1 cm vs. 7.1 cm;  $P = .8$ ) or change in lumbar lordosis (21.9° vs. 23.6°;  $P = .77$ ). Of the 32 patients

not treated with a PSO, 11 were treated with multiple Smith-Petersen osteotomies (SPO) at levels throughout the lumbar spine. At last follow-up, these patients did not demonstrate a statistically significant increase in lumbar lordosis (14.7° vs. 9.1°;  $P = .49$ ) or change in SVA (2.6 cm vs. 2.0 cm;  $P = .76$ ) when compared with those patients not treated with any osteotomy.

Seventeen complications were reported in 16 patients, including four pseudarthroses (**Table 5**). Other complications included four neurological injuries (three nerve root injuries and one cauda equina injury). There were four postoperative infections (all posterior wounds), one dural tear, and one deep venous thrombosis. Three of the 15 PSF patients (20%) had at least one complication, and 13 of 30 (43%) APSF patients had at least one complication. Although there were more total complications in the APSF group, there was no statistically significant difference in complication rates ( $P = .189$ ). All cases of pseudarthrosis were reported in the APSF group (13%;  $P = .54$ ). SRS-22 scores at last follow-up were similar between those with complications and those without (3.31 vs. 3.81, respectively;  $P = .08$ ). Those with a complication and those without did not have significantly different numbers of spinal levels operated (14

**Table 2.** Preoperative Radiographic Measurements Stratified Based on Whether a Pedicle Subtraction Osteotomy Was Included in the Surgical Procedure

	Thoracic Cobb Angle	Thoracolumbar Cobb Angle	Sagittal Balance (Sagittal Vertical Axis)	Coronal Balance	Thoracic Kyphosis	Lumbar Lordosis
PSO (n = 13)	32.4 (15.5)	30.8 (18.2)	9.7 (6.9)	3.17 (3.0)	28.5 (28.4)	-25.4 (15.3)
No PSO (n = 32)	35.1 (16.9)	38.6 (16.8)	5.6 (6.0)	2.45 (3.9)	20.6 (20.6)	-30.5 (25.3)
P values	0.63	0.21	0.052	0.43	0.73	0.51

Data presented as mean (standard deviation).  
PSO, pedicle subtraction osteotomy.

**Table 3.** Postoperative Radiographic Measurements for the Posterior-Only and Combined Anterior/Posterior Groups

	SVA Correction* (cm)	SVA at Last Follow-up (cm)	Change* in Lumbar Lordosis (°)	SRS-22 at Last Follow-up
APSF (n = 30)	4.7 (5.7)	2.3 (3.8)	15.2 (21.2)	3.64 (0.75)
PSF (n = 15)	2.1 (6.7)	4.2 (3.9)	12.8 (18.3)	3.67 (0.64)
P values	0.21	0.13	0.70	0.9

Data presented as mean (standard deviation).  
SVA, sagittal vertical axis; SRS, Scoliosis Research Society; APSF, anterior-posterior spinal fusion; PSF, posterior-only spinal fusion.  
\*Sagittal vertical axis correction and change in lumbar lordosis are the differences between the preoperative and last follow-up values.

vs. 12.5,  $P = .08$ ) or significantly different changes in SVA (1.2 cm vs. 4.6 cm,  $P = .08$ ).

## DISCUSSION

Revision spinal surgery after a previous long fusion to the distal lumbar spine often requires extension of the fusion to the sacro-pelvis. Three previous studies have reported on this specific patient population (7, 9, 12). Kostuik et al. reported on the results of previously surgically treated idiopathic scoliosis patients (12). Treatment methods included varying instrumentation and techniques. In the latter half of the time period, the investigators reported lower pseudarthrosis rates and improved outcomes with APSF procedures by combining the advantages of anterior interbody support with posterior lumbo-sacral instrumentation. The investigators, however, reported a 17% vascular injury rate and multiple ureteral injuries associated with the anterior approach.

Islam et al. later reported the results of 41 previously fused adolescent idiopathic scoliosis patients treated with extension of a previous fusion to the sacro-pelvis (9). The majority of the pa-

tients were treated with APSF approaches. Varying techniques for sacro-pelvic fusion were used, with seven receiving iliac fixation. The use of osteotomies was not reported or discussed. Thirty of 41 patients (73%) had a minimum of one complication, including a 37% pseudarthrosis rate (15 of 41 patients). Patients with iliac fixation demonstrated a lower rate of pseudarthrosis (53% vs. 21%).

Recently, Crawford et al. evaluated extensions to the sacrum of prior long fusions for idiopathic scoliosis, with the purpose of comparing outcomes of patients whose extension was performed using iliac crest or bone morphogenetic protein (7). Although it was noted that the patients treated without bone morphogenetic protein were more likely to have undergone a thoracoabdominal approach, a comparison of APSF with PSF-only approaches was not specifically performed.

The previous studies demonstrate the challenging nature of revising long fusions to the sacro-pelvis. Although earlier studies have reported the results of predominantly APSF, posterior-only approaches are being increasingly used. Posterior approaches have been shown to

be effective in long fusions for adult scoliosis, although the question of whether posterior-only approaches for extension of fusion to the sacro-pelvis are effective has not been specifically addressed (8). The present study therefore sought to examine whether the type of surgical approach impacted outcome for extensions of previous fusions to the pelvis. Our results do not demonstrate any significant differences in radiographic or clinical outcomes between those treated with APSF vs. PSF. Postoperative SVA and SRS-22 scores were similar between the groups, suggesting that equivalent surgical results can be obtained with a PSF-only approach. Additionally, although not statistically significant, there were more complications and more pseudarthrosis in the APSF group compared with the PSF group. However, the lower pseudarthrosis rate with a posterior approach may be due to the low numbers in our study, particularly in the PSF group (n = 15).

This study also found that improvement in SVA was achieved only when a PSO was performed, regardless of whether a PSF or APSF approach was performed. The improvements in SVA and lumbar lordosis were consistent with previously reported average corrections (2-4, 16). Interestingly, patients in whom multiple SPOs were performed did not demonstrate significant improvement in SVA at follow-up. Previous reports have suggested that multiple SPOs can improve balance, even achieving similar results as a PSO (1, 4, 18). One possible explanation for this finding in our study is the relatively small number of patients treated with SPOs and that those patients with the worst SVA were treated with a PSO. These results do suggest that when correction of positive sagittal malalignment is a priority, a PSO should be considered.

It is important to recognize the potential limitations of this study. This is a retrospective analysis and may underreport some complications. Approach type was at the discretion of the surgeon and not randomized or controlled. The number of patients evaluated did not enable stratification of patients treated with a posterior-only approach based on whether interbody support was used. A prospective analysis is warranted to further assess the ideal method for achieving the best results in these challenging patients.

## CONCLUSIONS

Patients who undergo long-segment posterior spinal fusion that ends in the distal lumbar spine may require further surgery in their lifetime. In

**Table 4.** Postoperative Radiographic Measurements Stratified Based on Whether a Pedicle Subtraction Osteotomy Was Included in the Surgical Procedure\*

	SVA Correction* (cm)	Postoperative SVA (cm)	Change in Lumbar Lordosis* (°)	Postoperative SRS-22
PSO (n = 13)	7.7 (6.6)	1.7 (3.5)	22.5 (13.6)	3.68 (0.77)
No PSO (n = 32)	2.2 (5.3)	3.4 (3.9)	11.1 (21.5)	3.63 (0.71)
P values	0.048	0.30	0.041	0.87

Data presented as mean (standard deviation).  
SVA, sagittal vertical axis; SRS, Scoliosis Research Society; PSO, pedicle subtraction osteotomy.  
\*Sagittal vertical axis correction and change in lumbar lordosis are the differences between last follow-up and prerevision values.

**Table 5.** Distribution of Complications by Approach Group\*

Combined Anterior-Posterior Spinal Fusion	Posterior-Only Spinal Fusion
Pseudarthrosis × 4	Infection
Infection × 3	Cauda equina injury after fall
Dural tear	Worsening back pain
Nerve root injury × 3	
Painful instrumentation	
Deep venous thrombosis	
Worsening back pain	
*A total of 17 complications were reported, with 16 patients affected (15 patients had 1 complication and 1 patient had 2 complications).	

this study, patients who underwent either a PSF or an ASPF for extension to the sacro-pelvis achieved similar postoperative radiographic results and clinical outcome scores, at a minimum of 2-year follow-up. Patients in both groups achieved statistically significant improvement in SVA correction with the utilization of a PSO without an apparent increase in complications. The addition of an anterior approach for extension to the pelvis must be carefully weighed against its approach-related risks because the overall complication rate and pseudarthrosis rate may be greater with a combined anterior/posterior approach.

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