Long-segment Spinal Fixation Using Pelvic Screws

Luis M. Tumialán, M.D.
Department of Neurosurgery,
Emory University School of Medicine,
Atlanta, Georgia

Praveen V. Mummaneni, M.D.
Department of Neurosurgery,
UCSF Spine Center,
University of California, San Francisco,
San Francisco, California

Reprint requests:
Praveen V. Mummaneni, M.D.,
Department of Neurosurgery,
UCSF Spine Center,
505 Parnassus Avenue,
M-779, Box 0112,
University of California, San Francisco,
San Francisco, CA 94143.
Email: vmum@aol.com

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OBJECTIVE: Long spinal constructs that extend to the sacrum place added stress on sacral screws. To prevent premature loosening of sacral fixation in these cases, the addition of pelvic screw (iliac screw) fixation has gained in popularity. Pelvic screw fixation has also been used in cases where sacral screw fixation is not possible (e.g., in sacral tumors). Pelvic screw fixation is more straightforward than prior pelvic rod fixation techniques (e.g., the Galveston technique). We describe our technique for pelvic screw fixation and review our experience with this technique.

METHODS: Twenty consecutive patients who underwent spinal-pelvic fixation were followed over a 3-year period (2004–2007). The patient population consisted of 11 men and 9 women with an average age of 58.8 years. Indications for spinal-pelvic fixation in this series included kyphoscoliosis, lumbosacral pseudoarthrosis, sacral fractures, lumbosacral spondylolisthesis, sacral tumors, and lumbar osteomyelitic fractures. Radiographic outcomes were assessed using flexion-extension x-rays and computed tomographic scans. Clinical outcomes were assessed using Odom's criteria and modified Prolo scale.

RESULTS: One patient was lost to radiographic follow-up. One patient died after surgery. The mean follow-up for the remaining patients was 13 months (range, 1–21 mo). Odom's outcomes were rated as good to excellent in 11 (58%), fair in 7 (37%), and poor in 1 (5%) (one patient died). Preoperative and postoperative modified Prolo scores were 10.4 and 12.9, respectively (mean improvement, 2.5). Radiographic fusion across the lumbosacral junction was obtained in 16 (89%) of the 18 patients with follow-up. One patient required revision of a pelvic screw. There was one infection requiring explantation of hardware.

CONCLUSION: Pelvic screw fixation is a safe and effective technique that provides added structural support to S1 screws in long-segment spinal fusions. Furthermore, pelvic screw fixation provides a distal point of fixation in cases where sacral screw fixation is not possible. The use of polyaxial screws and connectors makes this technique easier than Galveston rod fixation of the pelvis.

KEY WORDS: Iliac screw, Lumbosacral pseudoarthrosis, Pelvic fixation, Sacral pedicle screw

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Spine surgeons can achieve rigid immobilization and fusion of the lumbosacral spine with lumbosacral pedicle screw fixation. It is important to note, however, that the sacral pedicles typically have a large diameter and are filled with cancellous bone, and this anatomic feature may limit the ability of the surgeon to achieve solid screw purchase at S1. To offset this anatomic limitation, many spine surgeons have attempted to place S1 screws that traverse the posterior and anterior cortices of the sacrum (bicortical purchase). Others have aimed these S1 screws at the promontory of the sacrum to capture the anterior and superior cortices of the sacrum as well as the posterior cortex to achieve "tricortical" screw purchase (19).

ABBREVIATION: ALIF, anterior lumbar interbody fusion

In cases where S1 screw fixation is potentially inadequate or impossible, the addition of pelvic fixation should be considered. The primary indications for pelvic fixation include lumbosacral spondylolisthesis (Grade II or higher) as well as long-segment fusions (L2 or above to sacrum) for spinal deformity, osteomyelitic fractures, or traumatic fractures. In addition, revision of symptomatic lumbosacral pseudoarthrosis (with loosened S1 screws) is another indication for extension of fixation to the pelvis (*Table 1*). In these cases, the purpose of pelvic screw fixation is to provide added caudal structural support that unloads the biomechanically weak S1 screws until lumbosacral fusion has taken place. Ultimately, these pelvic screws

TABLE 1. Indications for extension of lumbosacral fusions to the ilium

Grade II or higher L5–S1 spondylolisthesis
Long-segment fusions to the sacrum (L2 or above to S1)
Spinal deformity (scoliosis or kyphosis)
Lumbar fractures
Trauma
Osteomyelitis
Neoplasm
Lesions that destroy the sacrum
Neoplasm
Osteomyelitis
Fractures
Treatment of L5–S1 pseudoarthrosis

may loosen over time because a fusion is not performed across the sacroiliac joint. However, their added structural support in the short term helps prevent issues such as S1 screw loosening or catastrophic failures such as sacral fractures from heavily overloaded S1 screws (5–8, 12, 14, 17).

Other indications for pelvic fixation include destructive lesions of the sacrum (neoplastic or infectious processes or fractures) that preclude instrumentation of the sacrum altogether because of involvement of the sacral pedicles. In these cases, we take care to perform either L5–S1 anterior lumbar interbody fusion (ALIF) (if possible), or we place bone graft laterally from the L5 transverse process to the sacral ala and onto the medial ilium to attempt to achieve a bone fusion.

Traditionally, pelvic fixation was often achieved by bending the lumbosacral rod and inserting it into the pelvis (Galveston technique) (1, 2, 7, 10). In our experience, this technique requires several multiplanar rod bends and is technically difficult and time consuming. Furthermore, rods may fracture at the site of these bends because of biomechanical stress (3, 7, 10). More recently, spine surgeons have used iliac bolts (fixed-angle iliac screws) or polyaxial pelvic screws (also known as polyaxial iliac screws) to achieve pelvic fixation. In this article, we report our results using iliac bolts and polyaxial pelvic screws and highlight our preferred pelvic screw fixation technique.

PATIENTS AND METHODS

Twenty consecutive patients who underwent spinopelvic fixation by the senior author (PVM) were followed over a 3-year period (2004–2007). The patient population consisted of 11 men and 9 women with an average age of 58.8 years (*Table* 2). Indications for sacropelvic fixation included thoracolumbar kyphosis and scoliosis (nine patients), symptomatic pseudoarthrosis of previous lumbosacral fusion for spondylolisthesis (five patients), sacral tumor (one patient), and osteomyelitic lumbar fractures (five patients). Radiographic outcomes were assessed using flexion-extension x-rays and computed tomographic scans in questionable cases. Clinical outcomes were assessed using Odom's criteria and a modified Prolo Scale (*Table* 2) (26).

TABLE 2. Modified Prolo scale[a]

Score	Description
Pain	
P1	Unbearable pain
P2	Severe pain
P3	Moderate pain
P4	Mild pain
P5	No pain
Functional status	
F1	Total incapacity
F2	Can do activities at home
F3	Activities outside home with limitation
F4	Limitation with strenuous act
F5	Able to do everything
Economic status	
E1	Unable to do tasks around home
E2	Able to do tasks around home but unable to work
E3	Able to work at sedentary capacity
E4	Able to work at moderate capacity
E5	Able to work at heavy capacity or previous job
Medication	
M1	10 or more hydrocodone tablets or equivalent
M2	6–9 hydrocodone tablets or equivalent
M3	3–5 hydrocodone tablets or equivalent
M4	Regular NSAIDs or occasional hydrocodone
M5	None or occasional hydrocodone
Total	

[a] Adapted from, Salehi SA, Tawk R, Ganju A, Lamarca F, Liu JC, Ondra SL: Transforaminal lumbar interbody fusion technique and results in 24 patients. **Neurosurgery** 54:368–374, 2004 (26). NSAIDs, nonsteroidal anti-inflammatory drugs.

Operative Technique

(see video at web site)

The patient is positioned prone on either blanket rolls or bolsters that support the chest and anterior pelvis. Care is taken to position the lumbar spine in a lordotic position (to avoid postoperative flat back). A midline incision is made above the level to be fused and extended downward to the bottom of S2. Subperiosteal dissection of the lumbar paraspinous muscles is performed with Bovie (Bovie Medical Corp., St. Petersburg, FL) and periosteal elevators. We prefer to place the cephalad hardware and perform any necessary decompression of the neural elements before exposing the midsacrum and posterior superior iliac spine to limit blood loss from muscle exposure. Subsequently, subperiosteal dissection is extended over the midsacrum and laterally to expose the medial overhang of the ilium. We take care to skirt the

Bovie catheter around the dorsal sacral foramina to avoid bleeding, and we do not insert the Bovie catheter into the sacroiliac joint.

We expose the posterosuperior iliac spine, including the distal overhang of this structure over the sacrum. This exposes the entry point for the pelvic screw, which is 1 cm rostral to the palpated inferior overhang of the posterosuperior iliac spine and 1 cm below the superficial ridge of the posterosuperior iliac spine. It is important to place the screw head deep to the superficial ridge of the posterosuperior iliac spine because this structure is the most prominent bony structure that individuals feel when they sit against a hard-backed chair (*Fig. 1*).

After exposure, the pelvic screw entry point is decorticated with a small drill. The pelvic gearshift is then placed into the entry point and aimed toward the thick bone that is just superior to the greater sciatic notch (which provides very solid purchase) and potentially onward toward the anteroinferior iliac spine (taking care not to violate the top of the acetabulum). The gearshift is gradually advanced 60 mm or more to reach the target bone above the greater sciatic notch. Care must be taken not to enter the greater sciatic notch itself to avoid injuring the neurovascular structures that traverse it (i.e., the superior gluteal vessels and sciatic nerve). In the experience of the senior author (PVM), anteroposterior fluoroscopy provides adequate guidance to direct the pelvic gearshift to the bone just superior to the greater sciatic notch. The angle of the gearshift from the entry point is typically 30 to 45 degrees inferiorly in the coronal plane and 30 to 45 degrees anteriorly in the axial plane.

A common problem encountered during advancement of the pelvic gearshift is violation of the superficial cortex of the ileum before reaching the target bone above the greater sciatic notch. This typically occurs because the pelvic gearshift is directed too superficially in the axial plane. Another potential pitfall is entry of part of the probe into the sacroiliac joint, with subsequent violation of the anterior cortical wall of the pelvis. Early on, in our experience, we dissected the gluteal musculature off the dorsal surface of the ilium lateral to the posterosuperior iliac spine to palpate the "downslope" of the ilium to guide our axial angle. However, as our experience increased, we ceased this added exposure. Fluoroscopy can be of assistance in lining up the pelvic screw. Specifically, pelvic inlet views and obturator views may help to guide the pelvic screw down the intended trajectory (15).

After the pilot hole in the ilium has been created with a gearshift, we then probe the pilot hole with a ball-tipped feeler probe to ensure that we have no cortical violations in the screw path. We then tap the hole with an undersized tap (typically 6 mm wide) and then place the pelvic screw (typically 7 mm wide and ≥65 mm long). We take care to avoid violating the sacroiliac joint with this and subsequent steps.

Subsequently, the pelvic screw is threaded into the pilot hole until the head of the screw is recessed into the posterosuperior iliac spine. This step in screw placement is important because recession of the screw head into the bone prevents the patient from feeling a prominent screw head when sitting against a hard-backed chair. It is important to note that some prominence of the pelvic screw heads may be unavoidable in thin patients who have limited muscular covering of the lumbosacropelvic area. However, burying the screw heads below the superficial portion of the posterosuperior iliac spine helps to prevent superficial skin breakdown and pressure sores in these patients (*Table 3*).

The final step is to connect the pelvic screw to the lumbosacral rod. It is important to create the pelvic screw connection to the lumbosacral rod inferior to S1 to avoid interference of rod linkage with the S1 screw (if present). In the past, we have used iliac bolts (fixed-angle iliac screws) (Liberty; Medtronic Sofamor Danek, Memphis, TN) to fixate the pelvis, and we connected them with closed connectors to the lumbosacral rod (*Fig. 2*). However, we now prefer to use polyaxial pelvic screws, which can easily link to the rod either directly or via an open top connector or closed connector (Expedium; Depuy Spine, Raynham, MA) (*Figs. 3* and *4*).

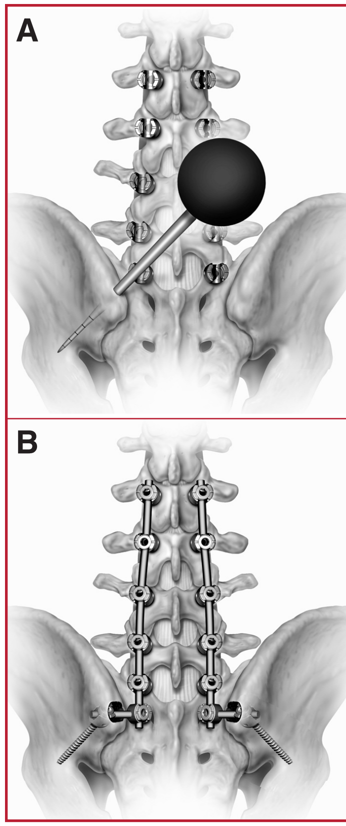

FIGURE 1. A, *illustration of a pelvic gearshift probe inserted at the entry point for pelvic screw fixation (1 cm rostral to the inferior end of the posterosuperior iliac spine and 1 cm deep to the superficial ridge of the posterosuperior iliac spine). The gearshift is aimed toward the thick cortical bone overlying the greater sciatic notch. The gearshift is angled 30 to 45 degrees anteriorly in the axial plane to avoid breaching the superficial cortex of the ilium.* **B**, *illustration of completed spinopelvic fixation construct. Note that the polyaxial pelvic screw heads are buried into the posterosuperior iliac spine deep to its superficial ridge to prevent hardware prominence. Furthermore, the end of the screw is placed into the thick cortical bone superior to the greater sciatic notch. Also note that the polyaxial screws are connected to the lumbosacral rod using open-top offset connectors (Expedium; Depuy Spine, Raynham, MA).*

TABLE 3. Steps in pelvic screw fixation technique
Expose the posterior superior iliac spine
Locate the entry point of the pelvic screw (iliac screw)
1 cm deep to the superficial edge of the posterosuperior iliac spine
1 cm proximal to the palpated inferior end of the posterosuperior iliac spine
Decorticate the entry point with a drill or awl
Use a gearshift probe to create the pilot hole for the screw
Aim for the thick bone just above the greater sciatic notch
Typically 30–45 degrees down angle in the axial plane and 30–45 degrees inferior in the coronal plane
Typical depth is 60–80 mm
May use anteroposterior, pelvic inlet, and obturator fluoroscopic views to guide trajectory
May expose superficial surface of ilium to guide screw trajectory in the axial plane
Tap pilot hole (undersize tap)
Probe for cortical wall violation
Place pelvic screw
Recess head into posterosuperior iliac spine
Connect to lumbosacral rod inferior to S1 level
May use connector

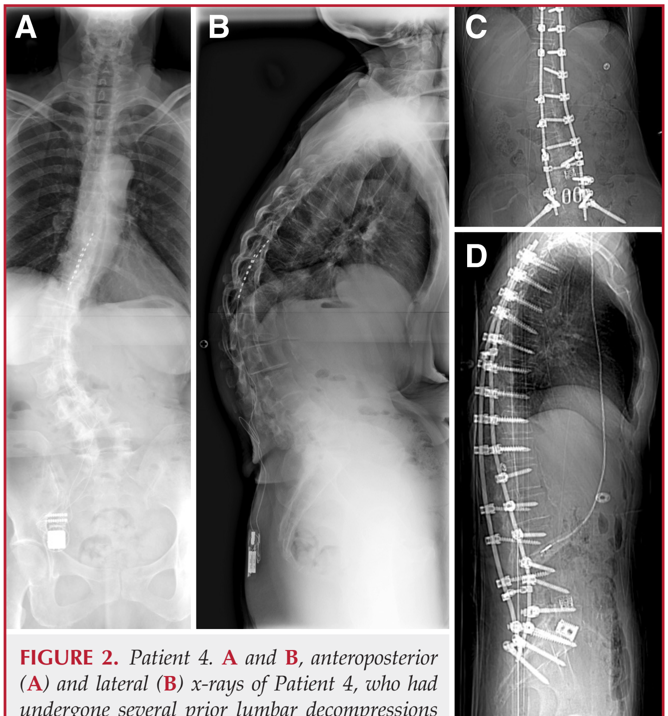

FIGURE 2. *Patient 4.* **A** *and* **B**, *anteroposterior (***A***) and lateral (***B***) x-rays of Patient 4, who had undergone several prior lumbar decompressions and insertion of a dorsal column stimulator for persistent back and leg pain. Her scoliosis progressed after the lumbar decompressions, and the stimulator did not help her back pain.* **C** *and* **D**, *anteroposterior (***C***) and lateral (***D***) x-rays obtained after removal of dorsal column stimulator, further lumbar decompression, and then spinopelvic fixation using iliac bolts (fixed-angle iliac screws)(Liberty; Medtronic Sofamor Danek, Memphis, TN) linked to the lumbosacral rod (Legacy; Medtronic Sofamor Danek) with a fixed offset connector. Note also the anterior lumbar interbody fusion (ALIF) at L4–S1.*

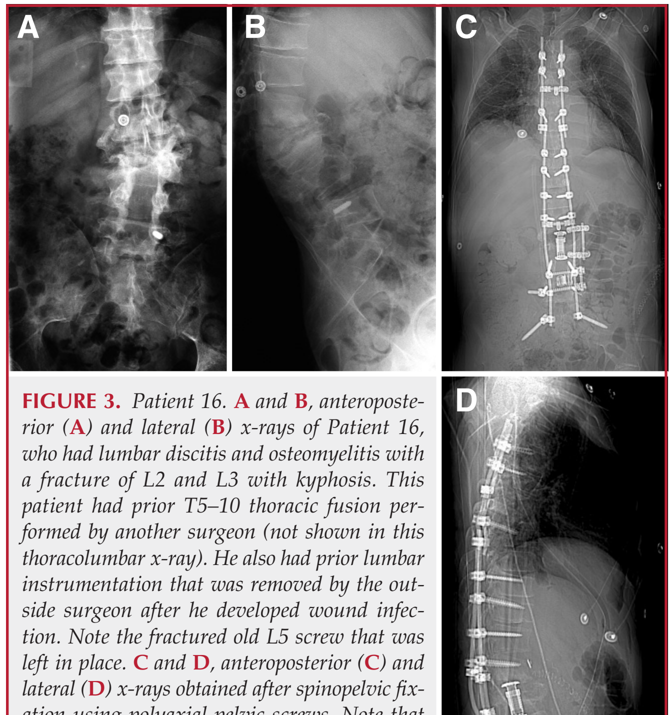

FIGURE 3. *Patient 16.* **A** *and* **B**, *anteroposterior (***A***) and lateral (***B***) x-rays of Patient 16, who had lumbar discitis and osteomyelitis with a fracture of L2 and L3 with kyphosis. This patient had prior T5–10 thoracic fusion performed by another surgeon (not shown in this thoracolumbar x-ray). He also had prior lumbar instrumentation that was removed by the outside surgeon after he developed wound infection. Note the fractured old L5 screw that was left in place.* **C** *and* **D**, *anteroposterior (***C***) and lateral (***D***) x-rays obtained after spinopelvic fixation using polyaxial pelvic screws. Note that one polyaxial pelvic screw is linked directly to the lumbosacral rod without a connector and the other is linked with the use of an offset connector (Expedium; Depuy Spine, Raynham, MA). Domino connectors linked the new T11-to-iliac construct with the T5–10 construct from the patient's prior surgery. The patient also underwent corpectomies of L2 and L3 and ALIF with cage and anterior screw-rod construct at L4–L5.*

RESULTS

Of the 20 patients reported here, one was lost to radiographic follow-up (although he did have early clinical follow-up), and one died postoperatively. The patient who died presented with lumbar osteomyelitis and was immunocompromised; he died as a result of sepsis. The mean follow-up of the remaining patients was 13 months (range, 1–21 mo). Odom's outcomes were rated as good to excellent in 11 (58%), fair in 7 (37%), and poor in 1 (5%). Preoperative and postoperative modified Prolo scores were 10.4 and 12.9, respectively (mean improvement, 2.5). We will further discuss outcomes in the diagnosis-specific groupings that follow (*Table 4*). The complications in this series included two pseudoarthroses and one deep wound infection. In addition, one patient reported prominence of the iliac hardware but refused hardware revision/removal.

Radiographic fusion across the lumbosacral junction was obtained in 16 (89%) of the 18 patients available for radiographic follow-up. There was some mild loosening of the pelvic screws in many of the patients who had a radiographic fusion across the lumbosacral junction. This is expected because pelvic fixation was used in these cases as a temporary structural adjunct until lumbosacral fusion could develop, and we did not fuse the sacroiliac joints (14).

Of the two patients who had a pseudoarthrosis of L5–S1, one patient had a deep wound infection (Patient 10). This patient initially presented to us with a pseudoarthrosis after a prior attempt by another surgeon to fuse his lumbosacral segment for Grade III spondylolisthesis, and we performed L4–S1 pelvis fixation with L5–S1 transforaminal interbody fixation. He developed a persistent deep wound infection that required explantation of his hardware, followed by a prolonged course of intravenous antibiotics.

The second patient (Patient 7) who had a pseudoarthrosis at L5–S1 (in spite of pelvic fixation) presented to us with a neuromuscular spinal deformity (postpolio scoliosis). He did not have interbody fixation at L5–S1 and ultimately had a pseudoarthrosis across that segment posteriorly. In spite of this, he had a significant improvement in his Prolo score and an excellent Odom's outcome.

Group I: Kyphoscoliosis

Nine patients (Patients 1–9) underwent long-segment instrumentation for scoliosis or neuromuscular spinal deformity (*Table 4*). Two of the patients had previous fusions with Harrington rods (which we removed). Instrumentation in all of these patients was extended into the pelvis.

Six of these patients had interbody cage fixation at the lower lumbar segments to augment the posterior construct. Five of

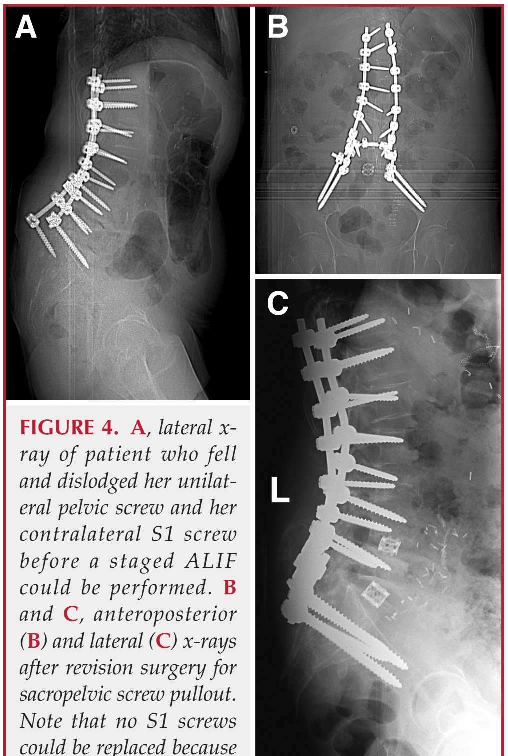

FIGURE 4. **A**, *lateral x-ray of patient who fell and dislodged her unilateral pelvic screw and her contralateral S1 screw before a staged ALIF could be performed.* **B** *and* **C**, *anteroposterior (***B***) and lateral (***C***) x-rays after revision surgery for sacropelvic screw pullout. Note that no S1 screws could be replaced because of poor purchase. Bilateral, dual iliac screws were placed for added fixation at the inferior end of the construct and connected to the lumbosacral rod with offset connectors (Expedium; Depuy Spine, Raynham, MA). This patient reported hardware prominence from the iliac fixation.*

these patients had a two-level ALIF at L4–L5, L5–S1 (*Fig. 2*). Three patients did not have interbody fixation across L5–S1 (Patients 1, 5, and 7). One patient had an L4–S1 transforaminal interbody fixation (Patient 9). Radiographic fusion across the L5–S1 segment (either posteriorly or anteriorly) was achieved in eight of these nine patients. Only Patient 7 had a pseudoarthrosis across L5–S1 (he had no interbody cage support at L5–S1). In spite of this pseudoarthrosis, this patient (who had postpolio deformity) has an excellent clinical outcome and is leading a very active lifestyle. He refuses hardware revision.

Six of the nine patients in Group I had good or excellent outcomes according to Odom's criteria. Two patients had a fair outcome, and one patient had a poor outcome (*Table 4*). The mean improvement in modified Prolo scores within this group was 1.9 (from 11.9 preoperatively to 13.8 postoperatively).

The one patient in this group who had a poor outcome complained of back pain and hardware prominence (Patient 3). This patient initially presented with severe lumbar kyphosis, back pain, and inability to ambulate distances; her preoperative Prolo score was only 8. She initially underwent a first-stage lumbosacropelvic fixation. This patient was very thin and was fixated with only a unilateral pelvic screw because of potential hardware prominence. Before a second-stage ALIF could be performed, she fell while ambulating and partially pulled out her sacral and pelvic screws (*Fig. 4A*). She was taken back to the operating room and underwent L4–S1 ALIF and posterior revision of the pelvic fixation using dual, parallel pelvic screws (a total of four pelvic screws were placed). The S1 screws could not be salvaged because of poor bone purchase and were removed (*Fig. 4, B* and *C*). At the latest radiographic follow-up with computed tomographic scanning, this patient did achieve fusion across her L5–S1 ALIF cages. However, she continues to complain of back pain and also reports hardware prominence from the four pelvic screws. Because she did fuse across L5–S1, she is a candidate for removal of the prominent pelvic screws. However, she is refusing revision of the hardware.

Group II: Pseudoarthrosis after Fixation for L5–S1 Spondylolisthesis

Five patients (Patients 10–14) underwent revision of a previous L5–S1 fusion for Grade II or III spondylolisthesis (*Table 4*). None of these patients had their initial surgery for spondylolisthesis performed by the senior author (PVM). For all of these patients, their lumbosacral pedicle screw instrumentation was replaced and extended into the pelvis with iliac screws to augment the lumbosacral unit. Four of these five patients achieved a radiographic fusion across L5–S1. The sole pseudoarthrosis patient in this group had a postoperative deep wound infection which, despite multiple incisions and drainages, required complete posterior hardware explantation with a resultant pseudoarthrosis. Three of the five patients in this group had either good or excellent outcomes by Odom's outcome criteria. Two of the patients had fair outcomes. The mean improvement in modified Prolo scores in this group was 2.8 (8.8 preoperatively and 11.6 postoperatively).

Group III: Sacral Reconstruction for Tumor

One patient (Patient 15) presented with a giant cell tumor of the sacrum that had advanced into the S1 body and the pedicles. The patient was offered complete sacrectomy but refused because of the probable ensuing bladder incontinence and sexual dysfunction associated with amputation of the thecal sac at L5–S1. The patient underwent subtotal sacrectomy with lumbopelvic stabilization. He had an excellent outcome with a radiographic fusion posterolaterally (from L5 to the remaining sacral ala and pelvis).

Group IV: Osteomyelitis

Five patients (Patients 16–20) presented with osteolytic destruction of the lumbosacral vertebral bodies (*Table 4*, *Fig. 3*). Each patient had stabilization of the lumbosacropelvic unit with corpectomy of the infected segment(s) and placement of bone graft into the corpectomy defect. Three also had cage placement in the corpectomy defect. All patients in this group were given a prolonged course of intravenous antibiotics. There was one perioperative death in this group, an immunocompromised man who died as a result of sepsis after debridement of osteomyelitis and posterior stabilization (Patient 18). One patient in this group was lost to radiographic follow-up; he had only immediate postoperative clinical follow-up (Patient 20). In the remaining three patients, radiographic evi-

TABLE 4. Patient demographics and outcomes[a]

Patient no.	Age (yr)/sex	Diagnosis	Modified Prolo score: Follow-up (mo)	Modified Prolo score: Preoperative	Modified Prolo score: Postoperative	Complications	Odom's	Levels fixated	Radiographic fusion (lumbosacral junction)
1	59/M	Thoracolumbar kyphoscoliosis, hemivertebrae, achondroplastic dwarf	21	16	18	None	Excellent	T8–S1–pelvis	Yes
2	63/M	Thoracolumbar scoliosis	12	14	16	None	Excellent	T12–S1–pelvis, ALIF L4–S1	Yes
3	63/F	Thoracolumbar kyphoscoliosis	12	8	7	S1 and iliac screw pull-out requiring revision	Poor	T11–S1–pelvis, ALIF L4–L5, L5–S1	Yes
4	72/F	Thoracolumbar kyphoscoliosis	14	11	13	None	Good	T3–pelvis, ALIF L4–L5, L5–S1	Yes
5	68/F	Thoracolumbar kyphoscoliosis, Parkinson's disease, pseudoarthrosis at L4 after T3–L4 fixation	16	9	9	None	Fair	T3–S1–pelvis (revision from previous T3–L4 fusion)	Yes
6	54/F	Thoracolumbar scoliosis	11	12	15	None	Good	T8–S1–pelvis, ALIF L4–L5, L5-S1	Yes
7	61/M	Neuromuscular spinal deformity (postpoliomyelitis)	8	14	20	None	Excellent	T11–S1–pelvis	No
8	67/F	Scoliosis	14	12	14	None	Good	T10–S1–pelvis, ALIF L4–L5, L5–S	Yes
9	65/F	Scoliosis, had initial T11–L5 fusion with L4–L5 TLIF and subsequent degeneration of L5–S1	12	11	12	None	Fair	T11–S1–pelvis with L4–L5 and L5–S1 TLIFs	Yes
10	37/M	L5–S1 spondylolisthesis, pseudoarthrosis	18	7	7	Infection, explantation, pseudoarthrosis	Fair	L3–S1–pelvis, L5–S1 TLIF	No
11	74/M	L5–S1 spondylolisthesis, pseudoarthrosis, S1 fracture	15	8	9	None	Fair	L3–S1–pelvis	Yes
12	63/F	L5–S1 spondylolisthesis, pseudoarthrosis	17	12	15	None	Good	L4–S1–pelvis	Yes
13	70/F	L5–S1 spondylolisthesis, pseudoarthrosis	20	8	13	None	Good	L4–S1–pelvis	Yes
14	70/F	L5–S1 spondylolisthesis, pseudoarthrosis	19	9	14	None	Good	L3–S1–pelvis	Yes
15	32/M	Sacral giant cell tumor	12	18	17	None	Excellent	L4–L5–pelvis	Yes
16	52/M	Osteomyelitis L2–L3, prior T5–T10 fusion for scoliosis	12	8	11	None	Fair	T5–L5–pelvis, L2–L3 corpectomies, cage, L4–L5 ALIF	Yes
17	34/M	Osteomyelitic fracture L5/S1, Down syndrome	19	11	20	None	Excellent	L2–L4–pelvis, L5 corpectomy	Yes
18	59/M	L5 osteomyelitic fracture	1	4	N/A	Death	Poor	L3–S1–pelvis	N/A
19	54/M	L4–L5 osteomyelitic fractures	3	5	8	None	Fair	L2–S1–pelvis, L4–L5 TLIF	Yes
20	55/M	L5–S1 discitis, L3 and L4 osteomyelitic fractures	1	5	8	None	Fair	L3 and L4 corpectomies, L5–S1 ALIF, T11–S1–pelvis	N/A

[a] ALIF, anterior lumbar interbody fusion; TLIF, transforaminal interbody fixation; N/A, not applicable.

dence of fusion in the lumbosacral spine was documented. Among the surviving patients, there were three patients with fair outcomes and one patient with an excellent outcome. Modified Prolo scores increased from a mean of 7.3 to 11.8, an improvement of 4.5.

DISCUSSION

Historically, fusions of the lumbosacral spine in long-segment scoliosis and high-grade spondylolisthesis have been difficult to attain (24). The widened cancellous pedicles of the sacrum in conjunction with the elevated biomechanical forces unique to the lumbosacral junction have led to high pseudoarthrosis rates in both of these clinical scenarios (6, 14, 29). Allen and Ferguson (2) first addressed these challenges by introducing sacropelvic fixation for the management of scoliosis in 1984. These authors modified the Luque system of segmental instrumentation, which had pseudoarthrosis rates as high as 41%, by inserting angled rods into the ilium and passing them into hard cortical bone above the greater sciatic notch to achieve a rigid fixation of the lumbosacropelvic spine (1, 2, 24). What became known as the Galveston technique increased biomechanical strength by extending instrumentation into the pelvis. Conceptually, this technique became an ideal adjunct for long-segment fusions in scoliosis and pelvic obliquity, but the inherent limitations, primarily related to the complex three-dimensional contouring for insertion into the ilium (occasionally accompanied by rod fracture), prompted the development of other techniques for lumbosacropelvic fixation (3–5, 8, 12, 16, 20, 22, 28).

The introduction of fully threaded fixed-angle iliac bolts and polyaxial pelvic screws that can be connected to longitudinal rod constructs with offset connectors has made extension of fixation to the pelvis easier. Pelvic screws have the additional advantage of modularity and allow the capacity to place up to two screws on each side (8, 17). Furthermore, the very nature of a threaded screw design as opposed to the smooth Galveston rod, makes these screws less prone to pull out (18). The ability to bury the screw heads deep to the superficial surface of the posterosuperior iliac spine helps to prevent prominence of the hardware, which may be bothersome to thin patients. The feasibility of instrumentation of the ilium has allowed for its increased use beyond scoliosis to the treatment of lumbosacral pseudoarthrosis, high-grade spondylolisthesis, osteomyelitic fractures, lumbosacral trauma, and reconstruction of the lumbosacral unit after removal of destructive neoplasms (6, 9, 10, 13, 17, 24, 29).

Long-segment Fusion for Scoliosis

Traditionally, long-segment fusions in patients with idiopathic scoliosis with extension to the sacrum have resulted in high rates of pseudoarthrosis (12, 14). Similar patterns have been identified in adult degenerative lumbar scoliosis (11, 25). Biomechanically, long-segment fusions to the sacrum place a supraphysiological strain on the S1 pedicle screws, and these screws loosen or fail with flexion maneuvers (18, 21, 24, 27). This may ultimately lead to loosening of the screws, with subsequent pseudoarthrosis. The addition of iliac screws significantly reduces the strain exerted on the S1 screw (18). In a retrospective review of scoliosis fusions, Islam et al. (12) reported a pseudoarthrosis rate of 53% in those patients in whom fusion was limited to sacral fixation compared with 21% when both sacral and iliac fixation points were used. In another analysis of long-segment fusions and high-grade spondylolisthesis, Kuklo et al. (17) reported an overall fusion rate of 95.1% with bilateral sacral screws augmented with bilateral iliac screws.

One of the nine patients in our series with long-segment fusions (T3, T7, T8, T10, T11, or T12 to S1) did not achieve a radiographic fusion. This patient (Patient 7) did not undergo anterior interbody fixation at L5–S1, and the lack of anterior column support likely contributed to the pseudoarthrosis.

Lumbosacral Pseudoarthrosis after Fixation of Spondylolisthesis

Fusion rates in high-grade spondylolisthesis patients at the L5–S1 level are lower than fusion rates for degenerative spondylosis in the lumbar spine (6, 29). The increased biomechanical forces, widened sacral pedicles, and limited capacity for interbody cage placement are believed to be among the contributing factors to the elevated rate of pseudoarthrosis in L5–S1 high-grade spondylolisthesis cases (23). In our series, all five patients with lumbosacral spondylolisthesis had previously undergone unsuccessful lumbosacral fusion attempts for either Grade II or III spondylolisthesis without iliac fixation. These patients' high-grade listhesis generated biomechanical forces that were inadequately stabilized by the solitary caudal fixation point in the sacral pedicles. Thus, a more rigid construct was needed to stabilize the lumbosacral unit using pelvic screws, and four of these five patients went on to have fusion across the listhesis after iliac screw fixation.

Several authors have previously shown the efficacy of augmenting a lumbosacral pedicle screw construct in high-grade listhesis cases with iliac fixation (6, 8, 17, 29). Bridwell (6) reported his experience in salvaging pseudoarthrosis cases with L5–S1 spondylolisthesis and concluded that augmentation with anterior interbody fusion and iliac fixation was a successful treatment strategy. In one of the largest series in the literature, Kuklo et al. (17) reported their experience in the management of lumbosacral fusions for both spondylolisthesis and deformity using iliac screws. Twelve patients in their series had pseudoarthrosis after prior surgery at L5–S1, and 10 of these patients achieved a solid fusion after augmentation with iliac screws.

Iliolumbar Instrumentation in Osteolytic Neoplasms and Osteomyelitis

Osteolytic destruction of the lumbar and sacral bony elements in patients with a neoplastic or infectious process presents a unique challenge for stabilization of the lumbosacral spine. When a neoplastic process has eroded the pedicle fixation points at S1, stabilization must be considered beyond the sacrum. In our series, one patient presented with a giant cell tumor of the sacrum. Extensive involvement of the sacral body and pedicles required a near-total sacrectomy. Thus, lumbopelvic fixation was the only viable means of stabilization. Gokaslan et al. (10) and others (9, 13) have reported their experience in achieving stabilization in similar scenarios, primarily using a modified Galveston L-rod technique.

In a similar manner, osteomyelitis (often accompanied by discitis) in the lumbosacral spine may also result in the destruction of the fixation points at L5 and/or S1 that are needed for stabilization. In addition, some severe osteomyelitic fractures can result in lumbar kyphosis requiring long-segment fixation, including distal augmentation to the ilium. We successfully treated patients with this pathological process using pelvic screw-augmented fixation of the lumbosacral spine accompanied by iliac crest bone grafting along with a course of prolonged intravenous antibiotics.

It is important to note that, in many instances, iliac screw fixation may loosen over time because fusions are not performed across the length of the sacroiliac joint. Often, the purpose of iliac screws is to stress-shield S1 pedicle screws until fusion has occurred across the lumbosacral junction. Only in cases where S1 screw fixation is not possible (because of tumor or infection) do we make an attempt to fuse from the lumbar spine onto the medial ilium (which requires a significant volume of bone graft).

Iliac fixation is associated with complications including infection and hardware pull-out. One problem that can be minimized by surgical technique, however, is prominence of the iliac screw heads in thin patients. We have been able to avoid this in most cases by burying the screw heads into the posterosuperior iliac spine.

CONCLUSION

Iliac screw placement is a safe and valuable adjunct for management of various complex spine disorders that strain the sacral screws. We have used spinopelvic instrumentation to successfully augment the strength of the caudal construct in long-segment cases. Furthermore, we have used spinopelvic instrumentation successfully in the reconstruction of the lumbosacral spine in cases with destructive lumbosacral neoplasms or osteomyelitis. Finally, we have confirmed that spinopelvic fixation is an excellent salvage procedure with which to treat pseudoarthrosis after failed pedicle screw fixation for high-grade lumbosacral spondylolisthesis. Polyaxial pelvic screws with offset connectors have made the technique for spinopelvic fixation much easier than the Galveston method.

Disclosure

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