SURGICAL TECHNIQUES

SACRAL ALAR ILIAC FIXATION FOR
SPINE DEFORMITY

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Published outcomes of this procedure can be found at: *Spine (Phila Pa 1976)*. 2010;35(20):1887-92.

Introduction

As the anatomy of the lumbosacral junction presents a unique challenge for the spine surgeon with regard to achieving a solid fusion, we describe the sacral alar iliac (SAI) technique, which can be used for the placement of pelvic anchors during posterior spinal arthrodesis. Since Hibbs, in 1911, reported on what we believe were the first 3 patients with Pott disease who were treated with spinal arthrodesis¹, there have been major advances in techniques to achieve lumbosacral fusion. In the 1960s, Harrington introduced specialized spinal instrumentation consisting of transverse process or laminar hooks attached to rods with the ability to create compression and distraction forces². This technique resulted in pseudarthrosis rates across the lumbosacral junction as high as 40%³⁻⁵. To address the high rates of pseudarthrosis, Allen and Ferguson, in the 1980s, popularized the Galveston technique, which involved insertion of anchors into the posterior superior iliac spine^{6,7}. Although this technique sometimes resulted in implant prominence, it achieved fusion rates from 88% to 94% across the lumbosacral junction^{8,9}.

First proposed in 2007, the SAI technique introduced the concept of using the S2 ala with a starting point between the S1 and the S2 dorsal foramina for pelvic fixation¹⁰, as opposed to using the posterior superior iliac spine starting point, which is traditionally used for pelvic fixation. The advantages of this approach are that (1) the pelvic anchors are in line with the rest of the spinal instrumentation and do not require connectors; (2) it leads to reduced dissection of the soft-tissue envelope and obviates the need to dissect the paraspinal muscles overlying the iliac crest and the posterior superior iliac spine; (3) the anchors are placed, on average, 15 mm deeper than iliac screws¹¹; (4) screws extend beyond the lumbosacral pivot point and are placed in a robust channel connecting the second sacral segment to the anterior inferior iliac spine, against which powerful compression and distraction maneuvers can be performed; and (5) the more laterally directed screw trajectories may potentially lead to reduced back-out^{12,13}.

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Indications & Contraindications

Indications

- In children with neuromuscular conditions, the SAI technique is frequently used for the correction of pelvic obliquity (Figs. 1-A and 1-B)¹⁴. Patients with a neuromuscular condition who have poor trunk control, a curve apex caudad to L3, or pelvic obliquity should receive consideration for arthrodesis to the pelvis.
- The SAI technique is useful for many patients with a connective tissue disorder or other syndromes who require arthrodesis to the pelvis.
- The SAI technique is also used in some patients with early-onset scoliosis who are treated with growing-rod constructs anchored to the pelvis¹⁵.
- In adults, the SAI technique is indicated in a variety of conditions, including arthrodesis for degenerative spinal conditions, deformity correction, sacral abnormality, and long fusions across the lumbar spine involving ≥ 5 levels^{12,16,17}.
- Spinal deformity surgery involving 3-column osteotomies in the lumbar spine may be an indication for spinopelvic fixation using the SAI technique (Figs. 2-A and 2-B)¹⁸⁻²².
- The SAI technique may also be indicated for the surgical treatment of some patients with high-grade (a grade of ≥ 3) spondylolisthesis with rigid lumbosacral kyphosis (Figs. 3-A and 3-B)²³.
- Patients with pelvic insufficiency fractures²⁴, sacral fractures with spinopelvic disassociation²⁵, or lumbosacral pelvic instability in the setting of pseudarthrosis²⁶ may also benefit from the SAI technique.

Contraindications

- The SAI technique is contraindicated in patients with sacral agenesis, sacral tumors, or dysmorphic pelvic anatomy with segmental loss of the S2 pedicle bone. These patients may benefit from pelvic fixation using other methods such as iliac bolts.

Fig. 1-A

Fig. 1-B

Fig. 2-A

Fig. 2-B

Fig. 3-A

Fig. 3-B

Figs. 1-A and 1-B Preoperative (**Fig. 1-A**) and postoperative (**Fig. 1-B**) radiographs of a 12-year-old boy with spinal muscular atrophy who was treated with instrumented posterior spinal arthrodesis with spinopelvic fixation using SAI screws.

Figs. 2-A and 2-B A 71-year-old woman with marked sagittal imbalance that had been treated with extended pedicle subtraction osteotomy at L3. Lateral radiographs made before (**Fig. 2-A**) and after (**Fig. 2-B**) instrumented posterior spinal arthrodesis from T11 to the sacrum.

Figs. 3-A and 3-B A 74-year-old woman with high-grade spondylolisthesis at L5-S1. Lateral radiographs made before (**Fig. 3-A**) and after (**Fig. 3-B**) treatment with instrumented posterior spinal arthrodesis from L2 to the sacrum.

Step 1: Patient Positioning

Position the patient prone on a radiolucent table.

- The patient should be placed in a prone position on a radiolucent table.
- Intraoperative fluoroscopy or surgical navigation can be used.

Step 2: Surgical Approach

In approaching the starting point, perform limited dissection of the soft tissue between the S1 and S2 dorsal foramina, while taking care to minimize unnecessary dissection and blood loss.

- The incision and approach used are similar to those used to fuse and instrument to the sacrum. However, the exposure may need to be extended caudally by approximately 2.5 cm to allow for probing of the S1 and S2 dorsal foramina.
- Perform limited dissection of the soft tissue between the S1 and S2 dorsal foramina and gently palpate the S1 and S2 foramina with a blunt surgical instrument (e.g., a Woodson elevator).
- Identify the starting point, one-third of the way caudal to the dorsal S1 foramen (in line between the S1 and S2 foramina), approximately 25 mm lateral to the midline (Fig. 4).
- The SAI technique also lends itself to minimally invasive surgery approaches (in this case, a midline incision over the sacrum).

Fig. 4

Fig. 4 The SAI screw starting point is one-third of the way caudal to the dorsal S1 foramen, approximately 25 mm lateral to the midline. The crossing red lines indicate the ideal screw starting point.

Step 3: Channel Creation

As the ideal screw pathway is one-third in the sacral ala and two-thirds in the ilium, start at the junction between the 1st and 2nd sacral segments, cross the sacroiliac joint, travel caudally toward the sciatic notch, cross between the inner and outer table of the ilium, and end close to the anterior inferior iliac spine cranial to the acetabular roof (Figs. 5-A and 5-B).

- Use an awl to start the channel between the 1st and 2nd sacral segments until it encounters the increased resistance of the sacroiliac joint.
- Using your other hand, localize the greater trochanter to provide a landmark to estimate the correct trajectory, ensuring that both femora are neutrally positioned on the table.
- Bring the fluoroscopy machine into the field and make a posteroanterior radiograph.
- Make any needed adjustments so that the awl passes just cranial to the sciatic notch.
- Use the consistency of cancellous bone as a guide to intraosseous placement. If this is not felt, obtain an obturator oblique inlet radiograph by aiming the beam approximately 30° caudally and 30° laterally, allowing direct visualization of the screw trajectory from the S2 pedicle starting point to the anterior inferior iliac spine. Visualization of the teardrop in this manner avoids breach of the lateral or medial iliac cortices. Superior and inferior aiming in the sagittal plane is performed by directing the beam toward the greater trochanter. Alternatively, surgical navigation may be used.
- If resistance is encountered when the awl or drill is advanced, it frequently means that the device is abutting the lateral wall of the ilium; in that case, choose a new starting point or redirect the awl. Further, when the awl or drill crosses the sacroiliac joint, there can be a tendency for it to deflect anteriorly, risking malposition. If that occurs, take a curved probe and angle it to redirect the awl or drill, which may solve this problem.
- After a satisfactory screw pathway is created, use a dilator or tap to expand the channel.
- Use a long depth-gauge to measure the channel length, abutting the far cortex. We generally do not aim to engage the far pelvic cortex.
- Alternatively, the screw pathway can be created using a power drill; a 2.5-mm or 3.2-mm-long drill bit is typically used, according to the same principles outlined above.
- Instead of fluoroscopy, the aforementioned steps can also be performed under navigation guidance, which can help to facilitate accurate advancement of the surgical awl or the power drill for channel creation.

Fig. 5-A

Fig. 5-B

Figs. 5-A and 5-B The SAI screws are an average of 15 mm deeper to the posterior superior iliac spine than iliac screws and are directed approximately 40° caudally. They traverse through the sacral ala and the ilium toward the anterior inferior iliac spine. The yellow and red lines indicate the ideal screw trajectory in the axial (**Fig. 5-A**) and sagittal (**Fig. 5-B**) planes.

Step 4: Screw Placement

In most children and adults, use screws with an outer diameter ≥ 9 mm, which are recommended to prevent screw breakage.

- Insert the guidewire into the dilated channel and advance it toward the anterior inferior iliac spine (Figs. 5-A and 5-B). The usual screw pathway is approximately 25 mm lateral to the midline and directed approximately 40° caudally (Figs. 6-A, 6-B, and 6-C, Video 1).
- Advance a cannulated screw over the guidewire. The longest possible screws, generally ≥ 90 mm, can be safely placed in most children and adults. Because the lateral bending strength of the screw is proportional to the radius to the 4th power, the widest possible screws, generally those with an outer diameter of ≥ 9 mm, are recommended.
- Bury the SAI screws into the S2 bone to the level of the housing on the polyaxial head of the screw. Also, advance it until its head (“tulip”) is at the same depth as the S1 screw. Of note, in most cases in which SAI screws are used, S1 screws are placed bilaterally prior to SAI screw placement, using the standard technique for S1 screw placement. This ensures an anchor in line with the S1 pedicle screw and the remaining proximal screws.

Fig. 6-A

Fig. 6-B

Fig. 6-C

Figs. 6-A, 6-B, and 6-C Intraoperative fluoroscopic images of SAI screw insertion. **Fig. 6-A** A starting awl is advanced toward the anterior inferior iliac spine, marked by the Kocher clamp. **Fig. 6-B** A guidewire is inserted in the dilated channel. **Fig. 6-C** An SAI screw is advanced over the guidewire. **Video 1** The video illustrates the steps of SAI screw insertion.

Step 5: Rod Placement

Ensure that the SAI screws are in line with the remainder of the spinal anchors to allow for ease of rod insertion.

- With the SAI screws aligned with the spinal anchors, thread an appropriately contoured rod through the screw heads and lock using a torque wrench.
- At least 2 cm of the rod should project distal to the screw if distraction maneuvers are required for the deformity correction. Otherwise, 1 cm of distal projection should be adequate.

Step 6: Wound Closure

Perform carefully layered wound closure per routine at the end of the case, with special attention to meticulous hemostasis.

- The wound can be closed in a layered fashion in a standard manner.
- Topical vancomycin powder may be used for infection prophylaxis according to the surgeon's preference.

Results

In a review of the cases of 32 pediatric patients treated with SAI fixation, Sponseller et al.²⁷ reported a mean pelvic obliquity correction of 70% and a mean major coronal Cobb angle correction of 67%. The authors reported no deep infections, implant prominence, or migration using the SAI technique. They did not look at screw fractures; however, we have found anecdotally that fractures tend to occur in screws with an outer diameter of ≤ 8 mm (Fig. 7).

In our review of the cases of 51 adults treated with SAI fixation with a radiographic and clinical follow-up at a minimum of 5 years, we reported a screw breakage rate of 6%²⁸. There was no evidence of degeneration of the sacroiliac joint or the fusion in any patient, and none of the patients was found to have pseudarthrosis at the L5-S1 level. In this series, the posterior arthrodesis was augmented with L5-S1 anterior lumbar interbody arthrodesis performed several weeks after the posterior arthrodesis.

Fig. 7

Fig. 7 Anteroposterior pelvic radiograph of an 18-year-old man with cerebral palsy who had postoperative fracture of an 8-mm-diameter SAI screw. The man remained asymptomatic.

Pitfalls & Challenges

- Minimize unnecessary dissection and preserve the soft-tissue envelope to reduce the risk of intraoperative bleeding and postoperative infection. We recommend just enough dissection over the S2 sacral segment to visualize the starting point and the intersection of the sacral ala with the ilium. Decortication at the intersection of the sacral ala and the ilium is suggested to facilitate arthrodesis. However, dissection over the iliac crest or the posterior superior iliac spine is unnecessary.
- A common source of profuse bleeding is violation of the soft tissue overlying the S1 and S2 dorsal foramina. We recommend gently palpating the foramina during identification of the starting point.
- During screw placement, the most common cortical breach is laterally along the outer table of the ilium. This can be prevented by lateralizing the starting point and obtaining a more vertical trajectory (pointing more caudally), abutting the bone proximal to the sciatic notch. This can help to avoid the isthmus of the iliac wing, where lateral breach is likely. This is of special importance in patients with neuromuscular scoliosis who may frequently have transverse plane asymmetry of the pelvis²⁹.
- In patients with coronal plane deformity, after corrective maneuvers have been performed, a residual convex curve may remain adjacent to the SAI anchors. It is crucial to recognize and correct this. We recommend the use of a T-square instrument as proposed by Andras et al.³⁰. Failure to correct this residual curve may result in persistence of coronal imbalance³¹.

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References

1. Hibbs RA. An operation for progressive spinal deformities: a preliminary report of three cases from the service of the orthopaedic hospital. *New York Med J.* 1911;93(21):1013-6.
2. Harrington PR. Treatment of scoliosis. Correction and internal fixation by spine instrumentation. *J Bone Joint Surg Am.* 1962 Jun;44:591-610.
3. Balderston RA, Winter RB, Moe JH, Bradford DS, Lonstein JE. Fusion to the sacrum for nonparalytic scoliosis in the adult. *Spine (Phila Pa 1976).* 1986 Oct;11(8):824-9.
4. Devlin VJ, Asher MA. Biomechanics and surgical principles of long fusions to the sacrum. *Spine: State Art Rev.* 1996;10(3):515-44.
5. Kostuik JP. Treatment of scoliosis in the adult thoracolumbar spine with special reference to fusion to the sacrum. *Orthop Clin North Am.* 1988 Apr;19(2):371-81.
6. Allen BL Jr, Ferguson RL. A pictorial guide to the Galveston LRI pelvic fixation technique. *Contemp Orthop.* 1983;7(3):51-61.
7. Allen BL Jr, Ferguson RL. The Galveston experience with L-rod instrumentation for adolescent idiopathic scoliosis. *Clin Orthop Relat Res.* 1988 Apr;229:59-69.
8. Gau YL, Lonstein JE, Winter RB, Koop S, Denis F. Luque-Galveston procedure for correction and stabilization of neuromuscular scoliosis and pelvic obliquity: a review of 68 patients. *J Spinal Disord.* 1991 Dec;4(4):399-410.
9. Saer EH 3rd, Winter RB, Lonstein JE. Long scoliosis fusion to the sacrum in adults with nonparalytic scoliosis. An improved method. *Spine (Phila Pa 1976).* 1990 Jul;15(7):650-3.
10. Sponseller PD. The S2 portal to the ilium. *Roundtables in Spine Surgery.* 2007;2(2):83-7.
11. Chang TL, Sponseller PD, Kebaish KM, Fishman EK. Low profile pelvic fixation: anatomic parameters for sacral alar-iliac fixation versus traditional iliac fixation. *Spine (Phila Pa 1976).* 2009 Mar 1;34(5):436-40.
12. Kebaish KM. Sacropelvic fixation: techniques and complications. *Spine (Phila Pa 1976).* 2010 Dec 1;35(25):2245-51.
13. O'Brien JR, Yu WD, Bhatnagar R, Sponseller P, Kebaish KM. An anatomic study of the S2 iliac technique for lumbopelvic screw placement. *Spine (Phila Pa 1976).* 2009 May 20;34(12):E439-42.
14. Joshi R, Kebaish K, Sponseller PD. Sacral-alar-iliac fixation in pediatric deformity: two to five-year follow-up. Read at the 47th Annual Meeting of the Scoliosis Research Society; 2012 Sep 5-8; Chicago, IL. Paper no. 64.
15. Sponseller PD, Yang JS, Thompson GH, McCarthy RE, Emans JB, Skaggs DL, Asher MA, Yazici M, Poe-Kochert C, Kostial P, Akbarnia BA. Pelvic fixation of growing rods: comparison of constructs. *Spine (Phila Pa 1976).* 2009 Jul 15;34(16):1706-10.
16. Mattei TA, Fasset DR. Low-profile pelvic fixation with sacral alar-iliac screws. *Acta Neurochir (Wien).* 2013 Feb;155(2):293-7. Epub 2012 Nov 23.
17. Tumialán LM, Mummaneni PV. Long-segment spinal fixation using pelvic screws. *Neurosurgery.* 2008 Sep;63(3)(Suppl):183-90.
18. Bridwell KH, Lewis SJ, Lenke LG, Baldus C, Blanke K. Pedicle subtraction osteotomy for the treatment of fixed sagittal imbalance. *J Bone Joint Surg Am.* 2003 Mar;85(3):454-63.

19. Kim YJ, Bridwell KH, Lenke LG, Cheh G, Baldus C. Results of lumbar pedicle subtraction osteotomies for fixed sagittal imbalance: a minimum 5-year follow-up study. *Spine (Phila Pa 1976)*. 2007 Sep 15;32(20):2189-97.
20. Suk SI, Chung ER, Kim JH, Kim SS, Lee JS, Choi WK. Posterior vertebral column resection for severe rigid scoliosis. *Spine (Phila Pa 1976)*. 2005 Jul 15;30(14):1682-7.
21. Suk SI, Chung ER, Lee SM, Lee JH, Kim SS, Kim JH. Posterior vertebral column resection in fixed lumbosacral deformity. *Spine (Phila Pa 1976)*. 2005 Dec 1;30(23):E703-10.
22. Wang MY, Berven SH. Lumbar pedicle subtraction osteotomy. *Neurosurgery*. 2007 Feb;60(2)(Suppl 1):ONS140-6; discussion ONS146.
23. Bodin A, Roussouly P. Sacral and pelvic osteotomies for correction of spinal deformities. *Eur Spine J*. 2015 Jan;24(Suppl 1):S72-82. Epub 2014 Dec 11.
24. El Dafrawy MH, Kebaish KM. Percutaneous S2 alar iliac fixation for pelvic insufficiency fracture. *Orthopedics*. 2014 Nov;37(11):e1033-5.
25. Martin CT, Witham TF, Kebaish KM. Sacropelvic fixation: 2 case reports of a new percutaneous technique. *Spine (Phila Pa 1976)*. 2011 Apr 20;36(9):E618-21.
26. Mattei TA, Fassett DR. Combined S-1 and S-2 sacral alar-iliac screws as a salvage technique for pelvic fixation after pseudarthrosis and lumbosacropelvic instability: combined S-1 and S-2 sacral alar-iliac screws as a salvage technique for pelvic fixation after pseudarthrosis and lumbosacropelvic instability: technical note. *J Neurosurg Spine*. 2013 Sep;19(3):321-30. Epub 2013 Jun 28.
27. Sponseller PD, Zimmerman RM, Ko PS, Pull Ter Gunne AF, Mohamed AS, Chang TL, Kebaish KM. Low profile pelvic fixation with the sacral alar iliac technique in the pediatric population improves results at two-year minimum follow-up. *Spine (Phila Pa 1976)*. 2010 Sep 15;35(20):1887-92.
28. Strike S, Hassanzadeh H, Naef F, Sponseller PD, Kebaish K. Sacro-pelvic fixation using the S2 alar-iliac (SAI) screws in adult deformity surgery: a prospective study with minimum 5-year follow-up. Presented as a poster exhibit at the 48th Annual Meeting of the Scoliosis Research Society; 2013 Sep 18-21; Lyon, France. Poster no. 23.
29. Ko PS, Jameson PG 2nd, Chang TL, Sponseller PD. Transverse-plane pelvic asymmetry in patients with cerebral palsy and scoliosis. *J Pediatr Orthop*. 2011 Apr-May;31(3):277-83.
30. Andras L, Yamaguchi KT Jr, Skaggs DL, Tolo VT. Surgical technique for balancing posterior spinal fusions to the pelvis using the T square of Tolo. *J Pediatr Orthop*. 2012 Dec;32(8):e63-6.
31. Jain A, Ames CP, Lafage V, Neuman BJ, Sciubba DM, Hart RA, Scheer JK, Kelly MP, Bess S, Hostin R, Shaffrey CI, Gupta MC, Schwab FJ, Kebaish KM; International Spine Study Group. Postoperative coronal malalignment is associated with significantly poor patient reported outcomes in operatively treated adult spinal deformity. Read at the 22nd International Meeting on Advanced Spine Techniques; 2015 Jul 8-11; Kuala Lumpur, Malaysia. Paper no. 69.