

# The Role of Computed Tomography for Postoperative Evaluation of Percutaneous Sacroiliac Screw Fixation and Description of a “Safe Zone”

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## Abstract

We sought to determine whether computed tomography (CT) is an accurate tool for evaluation of reduction, prediction of neurologic deficit, and evaluation of need for revision surgery in unstable pelvic ring injuries treated with percutaneous sacroiliac (SI) screw fixation and whether any neural foramen penetration violation is safe. Using medical records and radiographic data, we retrospectively evaluated 46 patients with 51 fractures or widenings of the SI joint that were surgically treated with percutaneous SI screw fixation, either alone or associated with anterior fixation. Using the Young and Burgess classification, there were 3 vertical shear injuries, 13 lateral compression injuries, 17 anterior-posterior injuries, 7 sacral fractures, and 6 combination or unclassifiable pelvic injuries. Satisfactory reduction was obtained in all cases.

All patients had postoperative CT scans, and 23 of 51 screws had some foramen penetration with an average of 3.3 mm (range, 1.4-7.0 mm). After percutaneous screw fixation, 10 of 46 patients had postoperative

neurologic deficit, 4 of which were unchanged from preoperative evaluation. Of the 6 patients with new or worsened neurologic deficit, CT showed neural foramen penetration of 2.1 and 7.0 mm in 2 patients. Both patients underwent screw revision, resulting in improved neurologic deficit. The remaining 4 patients did not have foramen penetration; their neurologic function improved, with full return at 6 weeks without screw removal. Neural foramen penetration documented with CT did not correlate with neurologic deficit unless the penetration was greater than 2.7 mm. Postoperative CT showing neural foramen penetration was the cause of revision surgery in 2 of 10 patients with postoperative neurologic deficit after percutaneous SI screw fixation.

Based on these findings, we recommend postoperative CT only in those cases where there is new neurologic deficit and screw removal if foramen penetration is greater than 2.1 mm. We also describe a new “safe zone” for screw insertion encompassing the superior 2 mm of the sacral foramen with adequate pelvic reduction.

Pelvic injuries account for 3% of all skeletal fractures.<sup>1</sup> Injury to the sacroiliac (SI) joint is frequently associated with unstable pelvic ring fractures, which are potentially life-threatening injuries. Surgical fixation of these injuries is preferred to nonoperative treatment given the potential for improved reduction and early mobilization and weight-bearing, thereby decreasing perioperative morbidity and improving functional outcome.<sup>2</sup>

The classic method of surgical fixation of the SI joint consisted of open reduction and internal fixation. This method carried a substantial risk for large dissection, iatrogenic nerve injury, and increased blood loss to the already traumatized

patient.<sup>3</sup> Percutaneous fixation allows for a shorter operating time, decreased soft-tissue stripping, and decreased blood loss compared with a traditional open procedure.<sup>4</sup> However, posterior pelvic anatomy is complex and variable, and reports have found screw misplacements as high as 24%<sup>5</sup> and neurologic complication rates up to 18%.<sup>6-9</sup>

Various imaging modalities, including fluoroscopy,<sup>5</sup> computed tomography (CT),<sup>6-7</sup> fluoroscopic CT, and computer-assisted techniques<sup>5,9</sup> have been used to achieve proper screw placement. Conventional fluoroscopy is the standard for intraoperative screw placement. However, acceptable reduction of the SI joint and proper implantation of the screws without

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perforation of the neural foramina is challenging, especially when coupled with difficulties of fluoroscopic imaging and variations in pelvic anatomy.

Sacral dysplasia has been reported to occur in up to 20% to 40% of the population and has significant implications in patients indicated for iliosacral screw placement.<sup>10</sup> Incorrect placement of iliosacral screws may result in iatrogenic neurovascular complications.<sup>11-13</sup> Malpositioned screws using fluoroscopic guidance have been reported in 2% to 15% of patients with an incidence of neurologic compromise between 0.5% and 7.7%. As little as 4° of misdirection can result in damage to neurovascular structures.<sup>14</sup>

At our institution, we routinely obtained postoperative CT to evaluate the placement of SI screws. The objective of this retrospective study is to evaluate the rate of revision surgery of percutaneous SI screw fixation, to determine whether CT is an accurate tool for evaluation of the reduction and the need for revision surgery, and to decide if any violation of the neural foramina is safe.

## Materials and Methods

After institutional review board approval, we retrospectively reviewed and evaluated medical records and radiographs of all patients who sustained unstable pelvic ring fractures between July 1, 2005, and June 30, 2010. We identified all patients who were treated with closed reductions and percutaneous iliosacral screw fixation, according to the method described by Routt in 1995.<sup>4</sup> We excluded all pelvic fractures in patients who underwent open reduction for the posterior injury or did not have percutaneous SI screws placed, those with spinal injury, and those without follow-up. Of the 46 patients who met the inclusion criteria were 26 men and 20 women with a mean age of 42 years (range, 16 to 73 years). Motor vehicle accidents accounted for 13 cases; 19 were crush injuries and 14 were falls from height. Seventeen patients (37%) met the radiographic criteria for sacral dysmorphism. Forty-two of the 46 patients were polytrauma patients with associated musculoskeletal injuries and/or abdominal, chest, or head injuries.

Six patients presented with some neurologic deficit at the time of injury; all fractures were closed. The initial imaging study included plain anteroposterior (AP), inlet, and outlet radiographs of the pelvis and a pelvic CT scan. Using the classification of Young and Burgess,<sup>15</sup> there were 3 vertical shear injuries, 13 lateral compression-type injuries, 17 anterior-posterior-type injuries, 7 sacral fractures, and 6 combination- or unclassifiable-type pelvic injuries. Of the sacral fractures, there were 3 Denis zone 1, 3 Denis zone 2, and 1 Denis zone 3.

The pelvic CT scan included the entire pelvis from the ilium to the ischial tuberosities. Each scan consisted of either a 5.0-mm or a 2.5-mm sequential axial image. A picture archiving and communication system (PACS) workstation using Centricity version 2.1 (GE Medical Systems, Waukesha, Wisconsin) was used to analyze each scan with a bone algorithm. On PACS, each initial displacement was characterized by the amount of SI joint widening at the level of the S1 and was measured using digital calipers.

## Surgery

Mean time to surgery was 4 days (range, 2 to 15 days) after the injury. A total of 51 SI screws were implanted in 46 patients. We achieved closed reduction of the posterior pelvic ring by various techniques, including compression with percutaneous partially threaded screw fixation. In the cases in which the posterior ring lesion was associated with a pure pubic symphysis disruption, the anterior pelvis was initially reduced and stabilized with small-fragment plate fixation (Synthes, Inc, Paoli, Pennsylvania). The posterior complex was stabilized with 1 screw in 41 patients, 2 cases required a transiliac screw, and 2 screws (S1 and S2) were placed in each of the remaining 3 cases. Definitive stabilization of the posterior pelvis was achieved with percutaneous, partially threaded 7.3- or 7.5-mm-diameter cannulated screws (Synthes, Inc, and Zimmer Inc, Warsaw, Indiana, respectively) in 42 fractures and 6.5-mm screws (Synthes, Inc) in 4 fractures. In 11 cases where the fracture was through the sacrum, fully threaded cannulated screws were used to avoid compression. Screw insertion was performed under fluoroscopic guidance with inlet, outlet, and lateral sacral views. One of 2 fellowship-trained trauma surgeons performed the surgeries. Rehabilitation plans were customized to each patient based on concomitant injuries.

## Postoperative Assessment

AP, lateral sacral, and inlet and outlet postoperative radiographs were taken in all cases within 24 hours after surgery. Pelvic CT was also obtained within 24 hours of surgery to review reduction and screw placement.

Using the measurement tool on the PACS system, we measured the penetration of the screw into the foramen. Screws were graded as intraosseous (completely contained within the sacral bone), skived (less than 2 mm of partial penetration into the S1 foramen), or extruded (the screw not contained by the bone). Screw penetration of the S1 was evaluated on the radiographic images as well as the axial images of the CT scans.

After surgery, the senior orthopedic resident and attending surgeon performed and documented detailed neurologic evaluations. They reviewed the medical record for neurologic deficit following surgical fixation.

## Results

The mean follow-up time was 12 months (range, 8 months to 2 years). Two patients expired secondary to associated injuries. There were no early deaths related to the pelvic surgery. Stable fixation, including bone or ligamentous healing, as well as full weight-bearing status, was noted in every case. No case exhibited loss of reduction or implant failure or infection.

According to Matta's criteria of anatomic reduction within 1 cm, all patients were found to have satisfactory reductions.<sup>7</sup> Six of 46 patients had documented preoperative neurologic deficits. After percutaneous screw fixation, 10 of 46 patients had postoperative neurologic deficit, 2 of which were unchanged from preoperative evaluation. Of the 8 patients with new/ altered postoperative neurologic deficit, CT showed neural foramen penetration greater than 2.1 mm in only 2 patients.

**Table. Radiologic Results of Screw Penetration on Computed Tomography**

Pelvis Type	No. of Patients	No. of SI Screws	No. of SI Screws With Foramen Penetration	No. of SI Screws With No Penetration	SI Screw Penetration, mm		No. of Patients With New Neurologic Deficit
					Average	Range	
Dysmorphic	17	21	11	10	3.3	1.6-5.7	1
Nondysmorphic	29	30	12	18	2.7	1.4-7	1
<b>Total</b>	<b>46</b>	<b>51</b>	<b>23</b>	<b>28</b>	—	—	<b>2</b>

Abbreviation: SI, sacroiliac.

Both patients underwent screw revision, resulting in improved neurologic deficit. The remaining 4 patients did not have foramen penetration and improved their neurologic function over the course of 2 weeks with return to presurgical status by 6 weeks without necessitating screw removal.

Twenty-three of the 51 screws (45%) had some violation of the S1 foramen on the CT. There were 17 patients with dysmorphic sacrum in which 21 SI screws were placed. Eleven of 21 (52%) screws showed some penetration of the S1 foramen on CT. There were 29 patients with normal sacral morphology in which 30 SI screws were placed. Twelve of 30 (40%) screws penetrated the S1 foramen. All violations were in the superior one-third position of the foramen. Two of 46 (4%; 1 with dysmorphism, 1 without) had a new neurologic deficit associated with the surgery (Table). CT showed sacral foramen penetration, and both screws were revised with a better neurologic examination.

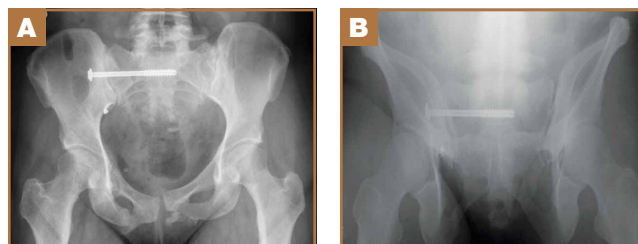
High-resolution CTs were obtained in 32 patients, while 14 patients underwent the standard 5.0-mm-cut CTs. Of the 32 patients in which a 2.5-mm high-resolution CT was obtained, 20 (62.5%) had evidence of screw penetration (Figures 1, 2). All violations of the S1 neural foramen were in the superior portion of the foramen.

When compared with patients who had a 5.0-mm CT, the patients who underwent a high-resolution CT were more likely to show neural foramen penetration ( $P = .3$ ). The average screw penetration into the S1 neural foramen measured 3.3 mm (range, 1.6-5.7 mm) in dysmorphic sacrum and 2.7 mm (range, 1.4-7 mm) in normal sacrum. However, in our study, any foramen penetration of less than 2.1 mm on CT did not result in neurologic deficit.

## Discussion

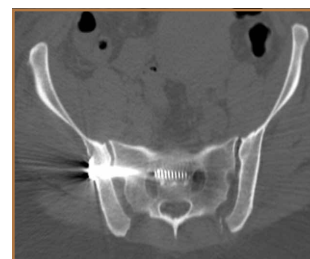
Pelvic fractures are fairly common and represent approximately 5% of all trauma admissions and 3% of all skeletal fractures nationwide.<sup>1</sup> The current treatment for SI disruption is either nonoperative or operative. Surgical fixation is technically demanding and surgeons often need a long learning curve to acquire the demanding technique because of the limitations of radiographic visualization of the relevant landmarks.<sup>16</sup>

Letournel<sup>17</sup> developed the technique for iliosacral screw fixation for the treatment of posterior pelvic ring injuries, where 1 or 2 large screws (6.5-7.3 mm in diameter) are inserted



**Figure 1.** (A) Inlet and (B) outlet radiographs of an S1 screw with SI penetration without neurologic deficit.

under fluoroscopic guidance through the ilium, across the SI articulation, and into the superior sacral vertebral bodies using percutaneous techniques. Currently, the standard procedure to accomplish the percutaneous placement of iliosacral screws derives mainly from the technique described by Matta with the C-arm fluoroscopy visualizing the pelvis in 3 views: strict AP, inlet, and outlet views.<sup>7</sup>



**Figure 2.** Computed tomography scan showing superior S1 foramen penetration without neurologic deficit.

Rouff and colleagues<sup>4</sup> recommend a strict lateral view of the sacrum, particularly when crossing the narrow zone of the sacral alar. They reported high union rates and accurate placement of the screws.<sup>4</sup> There are limitations to the use of biplanar fluoroscopy because the intraoperative images are not orthogonal, with the average arc (67°) between the ideal inlet and outlet. However, because of the variability in sacral anatomy, CT guidance was recommended by others.<sup>2,6,8,18</sup> Operating in a CT suite had other complications. Misinterpretation of CT led to “in-out-in” screws, which resulted in neurapraxia.

In our study, we used the technique described by Matta and colleagues for placement of the screws and performed a postoperative CT to evaluate screw placement and to assess pelvic reduction.<sup>7</sup> We had a high penetration rate using CT, which increased with better resolution, even though none of the radiographs showed any obvious evidence of misplacement

of the screws. Ebraheim and colleagues<sup>6</sup> described the relationship of the S1 nerve root in its neural foramen and found it to be approximately 8.7 mm inferior and 7.8 mm medial to the starting point for a pedicle screw. Given these numbers, it is possible that a large amount of skiving can be tolerated contingent on an adequate reduction of the SI joint.

Because of our high rates of skiving and low rates of neurologic deficit, a new “safe zone” for screw insertion can be expanded to include skiving of the S1 neural foramen up to 3 mm without fear of nerve root injury. However, drilling and screw insertion at higher speeds can also cause neurologic injury secondary to thermal injury or soft tissue being caught up in a rotating drill/screw.

Evaluation of placement of percutaneous SI screw placement in our study resulted in neural foramen penetration in 43% of SI screws, which is higher than other studies.<sup>14,19,20</sup> Our study showed that screw penetration up to 2 mm does not correlate with neurologic deficit. Iatrogenic neurologic deficit secondary to perforation of the foramina occurred in only 1 patient. Penetration of the foramina in all cases was in the superior portion of the foramen. We propose that there is a safe zone within the S1 neural foramen, and small amounts of penetration in the superior one-third of the foramen on axial CT images do not correlate with neurologic deficit. This potential safe zone is predicated on adequate reduction of the SI joint.

Neural foramen penetration shown on postoperative CT does not necessarily correlate with neurologic deficit. A postoperative CT is not indicated unless there are findings of a postoperative nerve injury. Our ideal screw placement skives the superior S1 foramen allowing for a larger screw diameter in a safe zone.

CT-guided placement has been proposed; however, concerns about radiation exposure, cost, and feasibility with similar outcomes compared with fluoroscopic-guided screw placement has resulted in its falling out of favor.

Iatrogenic nerve injuries are reported to occur in 0% to 6% of all percutaneous SI screw placement.<sup>14,21</sup> Risk factors for iatrogenic nerve injury while using fluoroscopic guidance include sacral morphologic abnormalities, presence of intestinal gas, or contrast.<sup>22</sup> Although these may be minimized with proper use of fluoroscopy, obtaining anatomic reduction as well as a thorough understanding of the pelvic morphology, the surgeon must be prepared to obtain further studies, such as a CT scan, if there is postoperative neurologic deficit.

Based on our findings, we do not routinely obtain a postoperative CT for SI screw placement, unless there is concern for malreduction or there is neurologic deficit. We also believe that up to 2 mm of foramen penetration is safe and does not result in neurologic deficit.

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