Case Report

Percutaneous spinopelvic fixation technique using external fixation for focal kyphosis reduction in U-type sacral fractures: a case report

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Background: Sacral fractures, particularly U-type fractures characterized by a transverse fracture line, result in significant instability and deformity, including focal kyphosis. These fractures challenge biomechanical integrity and neural structures, often leading to long-term disability if not corrected. Surgical approaches vary, but percutaneous spinopelvic fixation offers benefits like reduced soft tissue trauma and expedited recovery. This case report highlights managing a displaced U-type sacral fracture with focal kyphosis using a percutaneous spinopelvic reduction technique followed by fixation, demonstrating its efficacy and potential benefits.

Case Description: A 30-year-old female with a complex medical history, including opioid use disorder managed with buprenorphine, housing instability, and hypothyroidism, presented with subacute back pain and impaired ambulation following a mechanical fall. The patient experienced persistent back pain, numbness, ambulatory difficulties, and intermittent urinary incontinence. An evaluation revealed pain-limited 4/5 motor strength bilaterally in lower extremity muscles, intact sensation, and preserved perianal sensation with normal rectal tone. Imaging confirmed a displaced U-type sacral fracture with 37.1 degrees of focal kyphosis and no ongoing nerve root compression. Given the focal kyphosis and associated complications, a multidisciplinary team with orthopaedic trauma and spine expertise recommended percutaneous reduction spinopelvic fixation to achieve reduction and stabilization. The patient's significant risk factors, including active drug use and housing instability, raised concerns with a traditional open approach. A percutaneous approach using an external fixator aided reduction, followed by transiliac trans-sacral screw placement and S1-pelvis fixation, was chosen. This technique achieved the desired reduction in sacral kyphosis, improving spinopelvic alignment and reducing postoperative soft tissue complications. Postoperative imaging showed appropriately placed hardware and a 20-degree reduction in sacral kyphosis.

Conclusions: This case highlights the successful management of a displaced U-type sacral fracture with focal kyphosis using a percutaneous spinopelvic external fixator-based reduction technique. A minimally invasive approach can achieve significant reduction in deformity while minimizing soft tissue complications, making it viable for patients with complex medical histories. The clinical impact includes improved postoperative recovery and reduced risk of long-term disability. This case underscores the importance of individualized surgical planning and the potential benefits of percutaneous techniques in managing complex sacral fractures.

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Introduction

Sacral fractures represent a spectrum of injuries, encompassing insufficiency fractures seen in osteoporotic individuals to high-energy fractures resulting from trauma. Within this spectrum, U-type sacral fractures emerge as a distinct subset, characterized by a transverse fracture line traversing the sacrum above the inferior aspect of the sacroiliac (SI) joints, in which the spine has dissociated from the remainder of the pelvic ring (1,2). These fractures frequently lead to significant instability and deformity, including focal kyphosis, posing challenges to both biomechanical integrity and neural structures (1). Roy-Camille *et al.* further divided these injuries based on the characteristics of the deformity in the sagittal. Type 1 fractures are angulated but not translated; in type 2 fractures, the upper sacrum translates posteriorly; type 3 injuries show anterior translational displacement of the cephalad fragment (3). Strange-Vognsen and Lebech later added a type 4 injury which consists of an injury where the upper sacrum is comminuted as a result of axial impaction (4). Outcome studies have additionally demonstrated significant long-term disability following unstable and displaced fractures (5,6). In particular, injuries with sacral kyphosis, especially in the context of U-type fractures, present multifaceted challenges concerning pain management, neurological compromise, and functional impairment (7).

While conservative management may suffice for stable fractures, surgical intervention becomes imperative in cases of instability with neurologic compromise or significant deformity, where the potential for progression and long-term sequelae necessitates correction and stabilization (7). This focal kyphosis is essentially an acute change in pelvic incidence resulting in increased shear forces across the lumbosacral junction (8). Furthermore, patients may compensate via hyperlordosis through the lumbar spine to maintain an upright posture, which requires higher energy expenditure and greater stress through the lumbar segments (8). These increased stress forces across the spine and compensatory mechanism may have important implications for lumbar degeneration and the development of sagittal based deformity as patients' ability to compensate diminishes with age (9).

Surgical approaches for sacral fractures vary from open to percutaneous techniques, each with different indications that offer distinct advantages (10,11). The percutaneous spinopelvic fixation technique, when an acceptable reduction is feasible, presents benefits such as reduced soft tissue trauma, diminished blood loss, and expedited recovery (10). However, the decision-making process for the operative approach requires consideration of several key factors.

Firstly, the need for neurologic decompression determines whether an open approach is warranted. Secondly, achieving reduction involves a spectrum of techniques, ranging from minimally invasive maneuvers to more invasive methods such as open reduction and internal

Highlight box

Key findings

- U-type sacral fracture with focal kyphosis was successfully reduced using percutaneous spinopelvic fixation.
- This approach facilitated significant reduction of sacral kyphosis while minimizing soft tissue trauma and blood loss with traditional open approaches.

What is known and what is new?

- Displaced U-type sacral fractures with significant kyphosis are a distinct subset of sacral fractures that pose significant challenges due to instability, deformity, and potential neurological compromise. Traditional management often involves open surgical techniques to achieve stabilization.
- A novel percutaneous spinopelvic reduction technique to manage a displaced U-type sacral fracture, demonstrating significant kyphosis reduction comparable to open techniques while minimizing soft tissue damage.

What is the implication, and what should change now?

- The successful outcome of this case suggests that percutaneous spinopelvic reduction and fixation can be a viable alternative to open surgery for managing U-type sacral fractures. This approach may reduce perioperative morbidity and expedite recovery. Surgeons should consider this technique in suitable cases and be aware of the associated technical challenges and learning curve.

fixation. Additionally, deciding which approach to apply also necessitates consideration of whether instrumentation needs to be placed across the lumbosacral junction, which may depend on factors such as degree of displacement, presence of additional spine fractures, bone quality, the available bony corridors to transiliac trans-sacral fixation, and degree of stability (2). Balancing the degree of exposure needed for reduction, the amount of fixation required for a stable construct to allow for healing, and protection of the tenuous soft tissue envelope requires careful consideration.

Therefore, the management of U-type sacral fractures entails a comprehensive understanding of both fracture characteristics and patient-specific factors to optimize outcomes and mitigate complications. In this report, we present a case of a displaced U-type sacral fracture and focal kyphosis reduced with a percutaneous external fixator for provisional reduction followed by definitive fixation with a transiliac trans-sacral screw and lumbopelvic percutaneous fixation, highlighting the surgical intricacies and potential benefits of this approach. We present this case in accordance with the CARE reporting checklist (available at https://jss.amegroups.com/article/view/10.21037/jss-24-86/rc).

Case presentation

A 30-year-old female, with a complex medical history including opioid use disorder managed with buprenorphine, housing instability, and hypothyroidism, presented with subacute back pain and impaired ambulation following a mechanical fall at a train station. The patient reported persistent back pain, numbness, ambulatory difficulties, and intermittent urinary incontinence.

Evaluation of lower extremity strength revealed 4/5 motor strength bilaterally in the quadriceps (L3), tibialis anterior (L4), extensor hallucis longus (L5), and gastrocnemius (S1). Assessment of the iliopsoas muscle was hindered by significant pain. Sensation remained intact bilaterally to light touch from L2 to S1 dermatomes, accompanied by a negative Babinski sign and absence of clonus. Rectal examination demonstrated preserved perianal sensation, normal resting and voluntary rectal tone.

Pelvic radiographs were performed and were indeterminate. Therefore, a computed tomography (CT) scan of the abdomen and pelvis was obtained. This scan unveiled an acute, transverse fracture spanning from the bilateral sacral ala with significant displacement (*Figure 1A*). Review of the CT confirmed transverse sacral fracture line extending along the S2 body, consistent with displaced U-type sacral fracture consistent with a Roy-Camille type 1 pattern. There was dorsal translation of the distal fragment as well as shortening of the sacrum with 37.1 degrees of focal kyphosis at the level of the transverse fracture line (*Figure 1B*). Magnetic resonance imaging (MRI) demonstrated the U-type sacral fracture extending at least to the left S1 neural foramen with associated presacral and prevertebral edema extending to and surrounding the S1 and S2 nerve root (*Figure 1C*). The sacral canal did not show any ongoing nerve root compression.

Given focal kyphosis and associated complications, sacral reduction and spinopelvic fixation were recommended to achieve reduction and stabilization and to allow for immediate weight-bearing given concerns with the patient adhering to weight-bearing restrictions. Based on the imaging, it was determined that a percutaneous approach may allow for an adequate reduction and fixation of the sacral fracture while preserving the soft tissue envelope. The patient's significant risk factors, namely active drug use and housing instability raised concerns associated with a traditional open approach. Here we describe such a technique comprised of percutaneous external fixator aided reduction followed by a transiliac trans-sacral screw to maintain reduction and then placement of S1-pelvis posterior spinal fixation. This strategy was able to achieve improvement in sacral kyphosis in effort to restore spinopelvic alignment while reducing the risk of post-operative soft tissue complications and avoiding spanning the lumbosacral facets. If the S1 pedicle screw purchase was poor, consideration would be given to extending instrumentation cranially to L5.

Surgical technique

The patient was transferred to the flat Jackson table with a transverse chest bolster. The distal traverse bolster was shifted more distally to the thigh and additional cushions were placed under the thighs, legs, and feet to keep the hips and lower extremities in an extending position. This positioning allowed the patient's lumbosacral region sag through the table, and in doing so, exert a lordotic moment across the sacrum to aid in reduction of the focal sacral kyphosis.

Utilizing fluoroscopy guidance, the optimal skin entry point for S1 pedicle cannulation was determined. Bilateral 2 cm incisions were made in the skin in line with trajectory of the S1 pedicle, then dissection proceeded through the fascia until reaching the level of the sacral ala in line

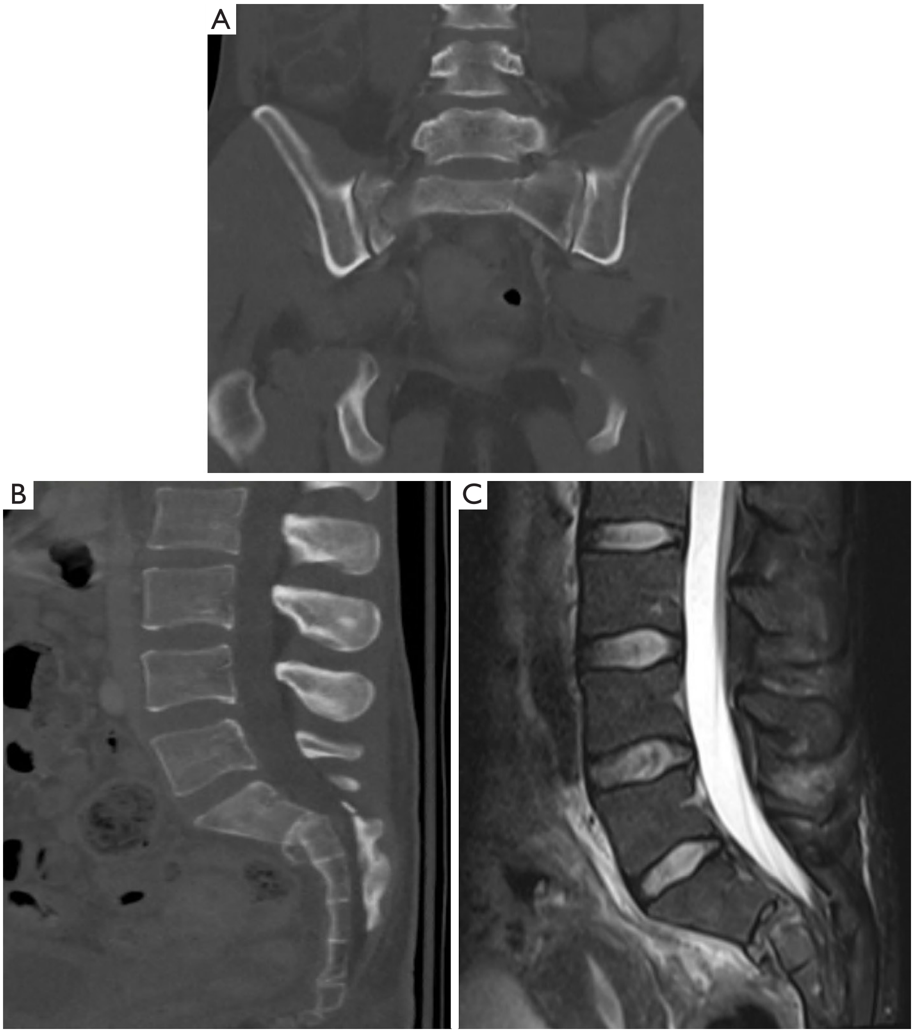

Figure 1 Preoperative imaging of a U-type sacral fracture demonstrating focal kyphosis and fracture lines. (A) CT image showing vertical and transverse fracture lines. (B) Sagittal CT image illustrating focal kyphosis along the transverse fracture line. (C) Sagittal MRI image re-demonstrating the transverse fracture line and patent sacral canal. CT, computed tomography; MRI, magnetic resonance imaging.

with the equator of the pedicle. A Jamshidi needle was positioned on the lateral border of the pedicle, advanced to the medial border, and guided by lateral imaging to ensure accurate placement within the sacral body, targeting the sacral promontory. Subsequent advancement of a guidewire, followed by tapping of the track, facilitated the introduction of a 5 mm Schanz pin bilaterally into the S1 pedicles aimed at the sacral promontory was advanced slightly bicortically to maximize purchase as confirmed on the pelvic inlet view. This process was repeated on the contralateral S1 pedicle (*Figure 2A,2B*).

Pelvic Schanz pin placement through a stab incision over the posterior superior iliac spine. The Schanz pins were advanced into the ilium under fluoroscopic guidance using the "Obturator inlet-iliac oblique" fluoroscopic technique (12) along the sciatic buttress, commonly used for pelvic fixation (*Figure 2C-2E*).

At this stage, Schanz pins were present in the sacropelvic region: two in the S1 pedicles and two in the pelvis along the sciatic buttress (*Figure 3*). Next, to reduce the sacral fracture and improve the focal kyphosis, an external extension/lordotic force was applied using the Schanz pins placed in S1 and the pelvis (*Figure 4A-4D*). Confirmation of improvement of the focal kyphosis as well as improvement in the length of the sacrum was demonstrated through fluoroscopy, with a focused effort on correcting focal

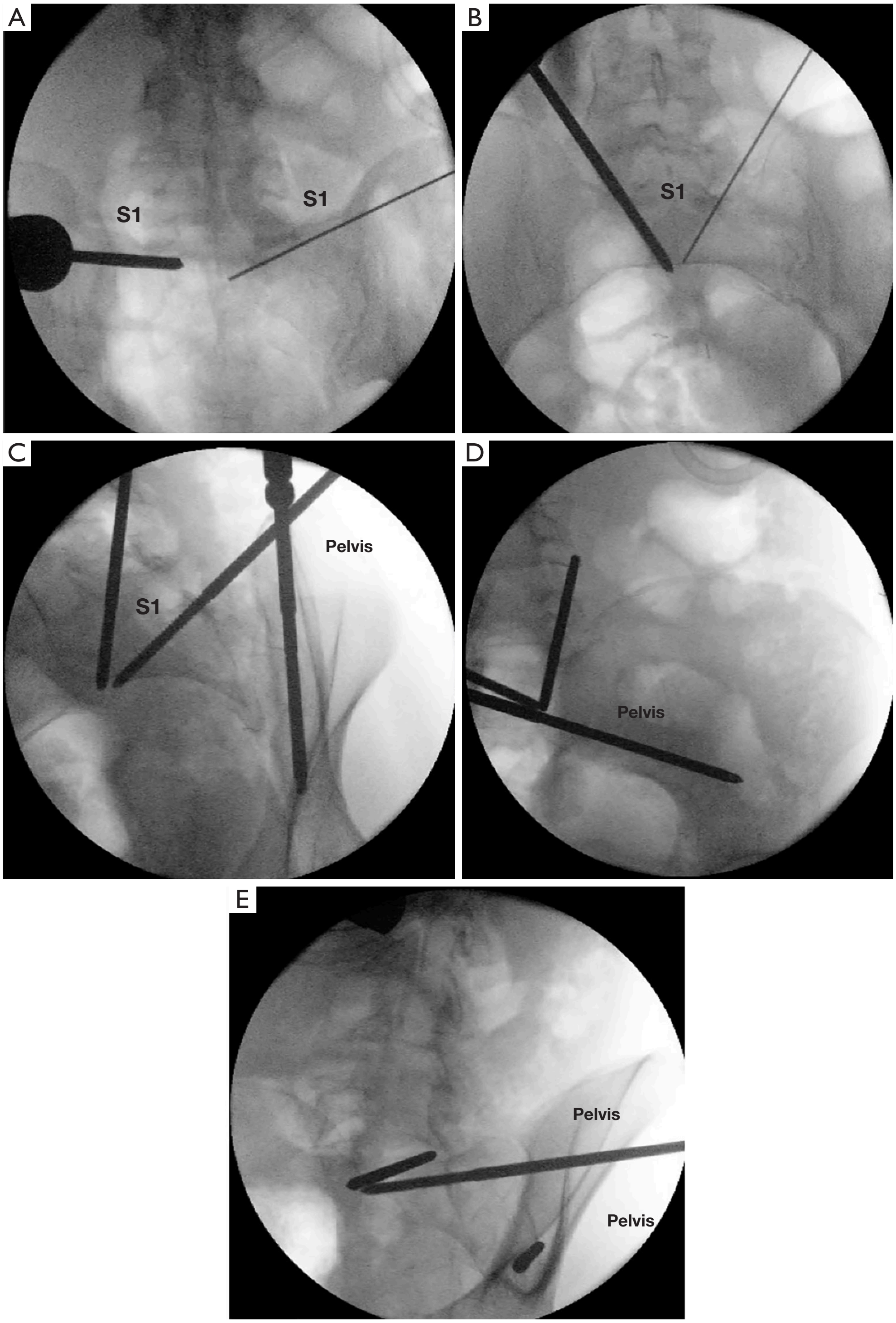

Figure 2 Intraoperative fluoroscopy images showing Schanz pin placement in the sacropelvic region. (A) Placement of Schanz pin into the S1 body, pelvic outlet view. (B) Pelvic inlet view of the Schanz pin in the S1 body. (C) Obturator inlet view during Schanz pin placement along the sciatic buttress. (D) Iliac oblique view showing Schanz pin placement in the pelvis. (E) "Tear drop" view confirming correct placement of the Schanz pin in the pelvis.

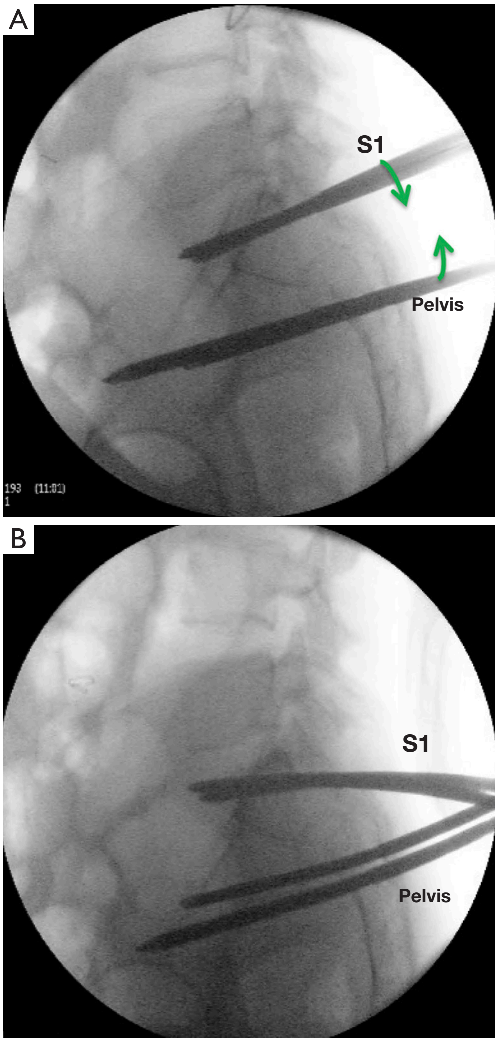

Figure 3 Intraoperative fluoroscopy lateral images showing the S1 and pelvic Schanz pins prior to lordotic reduction force application (A) and after reduction (B). Green arrows denote the direction of external force applied to the pins resulting on the crossing of the pins and improved alignment of the focal sacral kyphosis.

kyphosis (*Figure 3B*). Although residual posterior translation of the lower sacral segment was noted, it was deemed minimal and did not compromise the neural structures within the canal. The reduction was secured using an external-fixator bar with appropriate clamps (*Figure 4D,4E*) and maintenance of reduction was confirmed.

Subsequent attention was directed towards provisional pelvic fixation by placing a transiliac trans-sacral screw in the upper sacral segment as there was an available corridor on preoperative CT. When this corridor is not available in S1, there is usually one in S2 that could be used. Placing this screw provided provisional fixation of the sacral fracture and would allow exchanging the S1 and pelvic Schanz pins for traditional percutaneous pedicle and pelvic screw fixation. Localization of the start site, facilitated by the guidewire on inlet and outlet views, enabled precise insertion of a 4.5 mm drill over the wire, advanced across the SI joint up to the foramen. Comprehensive radiographic confirmation of the safe position of the drill bit relative to the iliac cortical density and S1 foramen was meticulously performed, ensuring precise placement. Following the insertion of a 6.5 by 155 mm screw over the guidewire and intraosseous confirmation on radiographic imaging, sacral reduction was maintained with the assistance of the Schanz pins connected to the external fixator bar (*Figure 5A*).

Sequential removal of Schanz pins in the S1 and pelvis preceded the placement of S1 pedicle screws and iliac bolts, which was confirmed under fluoroscopy to ensure optimal positioning within the bilateral ilium. All tulips were confirmed to be below the fascia. Subsequent connection of the S1 pedicle screw to the ilium with an appropriately sized rod, secured with locking caps, further reinforced sacral reduction and stabilization (*Figure 5B,5C*).

Final imaging confirmed the precise placement of all hardware and optimal reduction of the sacrum (*Figure 5D,5E*). A layered closure was performed with attention given to the fascial layer. All reduction maneuvers and fixation were performed via small percutaneous incisions which allowed for preservation of the soft tissue envelope of the posterior pelvic and sacrum (*Figure 6*). The patient was carefully transitioned back to the stretcher, extubated, and transferred to the post-operative care unit in stable condition, with an uneventful intraoperative course and unchanged sponge and needle count.

Post-operative

Following surgery, the patient was transitioned to the medical floor in a stable condition. Improvement was noted in the bilateral lower extremity motor function, with 5/5 strength bilaterally throughout all muscle groups. Consequently, weight-bearing was permitted as tolerated on her bilateral lower extremities.

Diligent medication management ensured adequate control of postoperative pain, optimizing the patient's comfort and facilitating participation in rehabilitation activities. Prior to discharge, pelvis anteroposterior (AP), inlet, and outlet X-ray (XR) were obtained which showed

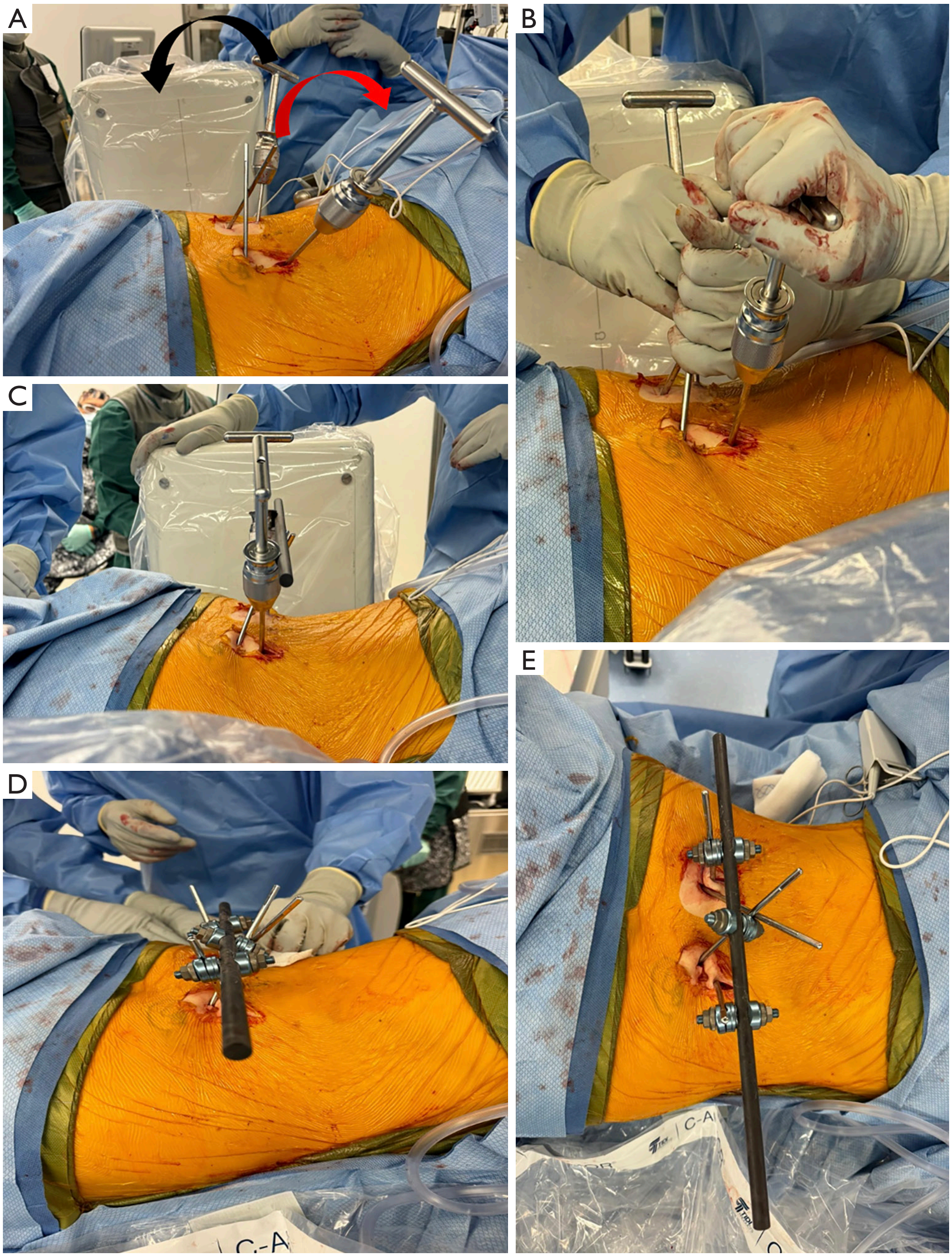

Figure 4 Intraoperative photographs showing the S1 (with T-handle chucks attached) and pelvic Schanz pins prior to lordotic reduction force application. (A) The black arrow represents the direction of the applied extension force aimed at reducing the sacral fracture, while the red arrow indicates the direction of the lordotic force applied to correct focal kyphosis. (B) Reduction maneuver in progress, and (C-E) the completed reduction held in place with external fixator bars and clamps.

appropriately placed hardware (*Figure 7A-7D*). A CT scan was also obtained for finer detail of hardware placement as well as sacral alignment, which demonstrated appropriately placed hardware. Compared to preop CT scan, an approximate 20-degree reduction of the sacral focal kyphosis was observed (preop 37.1 to postop 17.7; *Figure 8A-8D*).

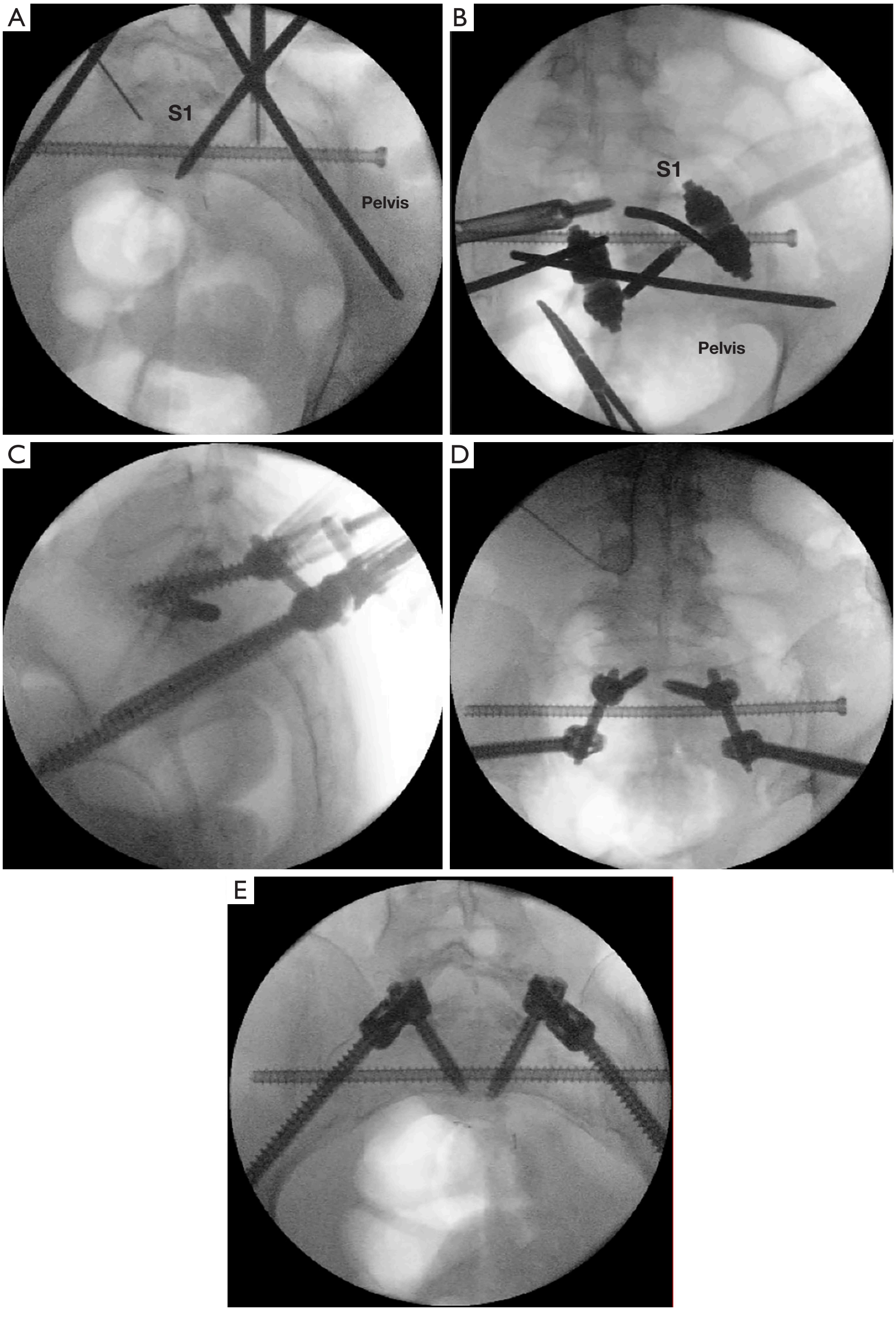

Figure 5 Intraoperative fluoroscopy images showing sequential placement final hardware after S1 transiliac transsacral screw placement. (A) Inlet view showing the exchange of the S1 Schantz pin with percutaneous guidewire into the S1 pedicle on one side, with sacral reduction maintained using transiliac transsacral screw and contralateral Schantz pins connected to the external fixator bar. (B) Outlet view demonstrating subsequent placement of the S1 pedicle screw over the guidewire. (C) Lateral view demonstrating the placement of S1 to ilium construct. Pelvic outlet view (D) and pelvic inlet (E) confirming safe hardware placement within the sacrum.

Figure 6 Intraoperative photograph showing the small size of the percutaneous incisions used for reduction and placement of hardware, illustrating the preservation of the posterior sacral soft tissue envelope.

Ethical consideration

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committees and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

Discussion

Managing U-type sacral fractures remains a formidable

Figure 7 Postoperative outlet (A), AP (B), inlet (C), and lateral (D) radiographs demonstrated appropriately placed hardware and improved sacral alignment. AP, anteroposterior.

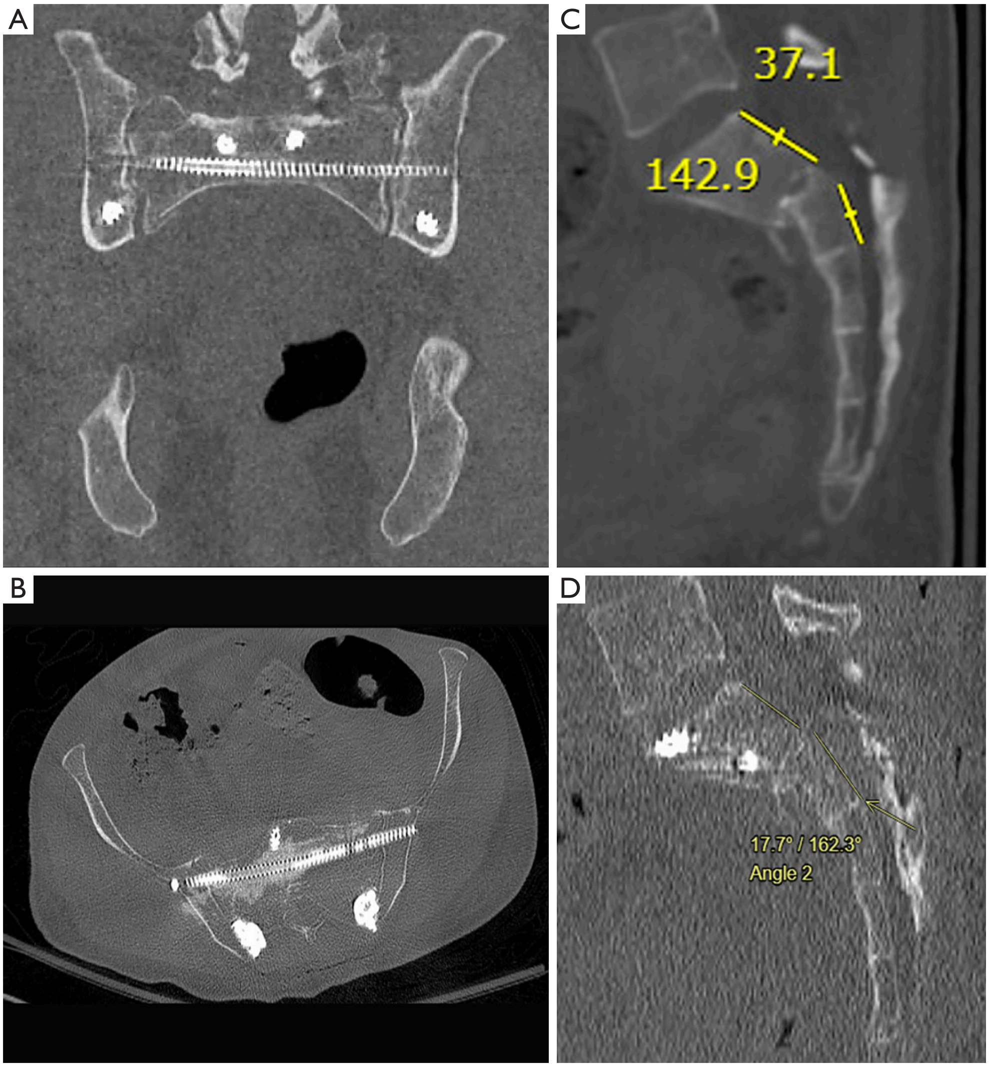

Figure 8 Postoperative CT images demonstrating hardware placement and sacral alignment improvement. (A) Coronal CT image showing pelvic bolt tulips situated under the fascia. (B) Axial CT image of correctly positioned hardware. (C) Preoperative sagittal CT showing sacral kyphosis with a measured angle of 37.1 degrees, indicating the extent of the deformity; the lines represent the posterior S1 and S2 bodies. (D) Postoperative sagittal CT illustrating approximately 20 degrees of improved sacral alignment, with a corrected angle of 17.7 degrees, reflecting kyphosis correction; the lines represent the posterior S1 and S2 bodies showing the change postoperatively, and the arrow designates the postoperative measurement demonstrating reduced focal kyphosis between S1 and S2. The numbers 162.3 and 142.9 are the values obtained by subtracting the degree of kyphosis from 180, indicating the sacral inclination angle pre- and postoperatively. CT, computed tomography.

challenge due to the complexity of associated deformities and potential neurological compromise. Our case underscores several crucial aspects in the management of such fractures, offering valuable insights and lessons learned for future clinical practice.

Decisions on which surgical intervention should be careful consideration of fracture characteristics, neurological status, and patient-specific factors. While conservative management may suffice for stable fractures, surgical intervention becomes imperative in cases of instability with neurologic compromise or significant deformity, as highlighted in our case (13). The decision to proceed with percutaneous spinopelvic fixation was guided by the patient's challenging social factors (active drug use and housing instability), severity of the fracture, focal kyphosis, and the need for stabilization to prevent further displacement and neuro-compression, while decreasing the risks of an open procedure.

Our decision to instrument S1 as opposed to L4 or L5 allowed us to spare the lumbosacral junction and preserve motion. This also allowed us to avoid a second surgery for removal of hardware after fracture healing to restore motion. It is important to mention that S1 pedicle screw placement is only an option when the fracture does not involve the S1 pedicles and where the vertical limbs of the U type injury extend lateral to the pedicles. In this scenario, the S1 pedicles allow for meaningful fixation with Schanz pins at the time of reduction and with the eventual S1 pedicle screws. In our case the fracture was not vertically unstable. However, when vertical stabilization of the pelvic fracture is required, it is important to ensure that the S1 pedicle screws and the pelvic fixation are not placed at the same level (10,11).

The literature supports the notion that surgical stabilization is often necessary for U-type sacral fractures with spine-pelvic instability (14-16). Bellabarba *et al.* evaluated surgical stabilization of high-grade sacral fracture dislocations with spine-pelvic instability and reported favorable outcomes in terms of neurological recovery and maintenance of reduction, albeit with notable complications. While a high rate of traumatic dural tear or avulsion and hardware failure was observed, the majority of patients experienced bowel and bladder recovery (17). This highlights the importance of surgical intervention in restoring neurological function and preventing further complications associated with unstable sacral fractures (18).

In contrast, the minimally invasive approach demonstrates promising results, with successful fracture healing and resolution of deficits in a majority of patients (19). Although hardware failure is more prominent, the absence of wound infections and the low rate of unplanned surgeries underscore the potential benefits of percutaneous techniques in reducing postoperative morbidity (19).

Bellabarba *et al.* open series involving 19 patients undergoing open lumbopelvic fixation and decompression showed an overall preoperative kyphosis of 43 degrees, which was reduced to 20 degrees postoperatively (17). In contrast, Nork *et al.* evaluated 13 patients undergoing percutaneous transiliac trans-sacral stabilization for U-type sacral fractures and demonstrated preoperative kyphosis of 29 degrees, with minimal reduction to 28 degrees postoperatively (19).

In our case report, we achieved a notable 20-degree reduction of sacral kyphosis using a percutaneous spinopelvic fixation technique. This reduction is comparable to the average reduction achieved in Bellabarba's open series and much greater than the *in situ* fixation done in Nork's series (17,19). This may be attributed to our use of both patient positioning to provide a gravitational assist in reduction in conjunction with the direct lordotic reduction force applied through the S1 and pelvic Schanz pins (*Figure 5A-5D*). The Nork series relied only on external patient positioning for the reduction and no additional percutaneous methods of reduction were employed (19). Further, the use external fixator and transiliac trans-sacral screw described in our case report likely aided our ability to maintain the reduction while to placing our final fixation. Our case underscores the potential benefits and capability of percutaneous techniques in achieving significant reduction of sacral kyphosis while minimizing soft tissue trauma and blood loss. However, it is essential to recognize the inherent challenges associated with percutaneous techniques, including the learning curve and potential limitations in achieving anatomical reduction (20).

There are several avenues of research that could offer valuable insights when managing U-type sacral fractures. Firstly, studying normative sacral kyphosis/alignment in the general population could provide a baseline for understanding deviations seen in sacral fractures and guide goals for surgical correction (21). This would involve large-scale studies utilizing advanced imaging techniques to quantify sacral alignment parameters across diverse demographic groups. However, these displaced sacral-U-type fractures and their variants are relatively infrequent and the follow-up is notoriously poor amongst this trauma population. Additionally, investigating the long-term impact of residual sacral kyphosis in terms of pain, function, and the need for later surgery could inform clinical decision-making and patient counseling. Furthermore, comparative studies that quantitatively compare sacral kyphosis reduction using open versus percutaneous techniques would contribute to optimizing surgical approaches (22). Bellabarba *et al.* have highlighted the importance of surgical stabilization for sacral fractures with spine-pelvic instability, but further research is needed to assess the efficacy and outcomes of different surgical methods in achieving reduction and maintaining stability over time (17). Finally, this case study was performed on a Roy-Camille type 1 fracture that involved kyphosis with no translation. The next step to assess the efficacy of this technique would be to apply it in the management of sacral fractures with associated translation. These efforts would advance our understanding and management of U-type sacral fractures, potentially improving patient outcomes and quality of life with a more minimally invasive yet effective approach.

Conclusions

U-type sacral fractures pose complex challenges, often requiring surgical intervention to prevent long-term complications. Our case illustrates the effectiveness of percutaneous spinopelvic fixation in reducing sacral kyphosis with minimal tissue damage. Surgical decisions should carefully consider fracture characteristics, neurologic status, and individual patient factors. Further research comparing surgical techniques and assessing long-term outcomes is necessary to refine treatment strategies.

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Footnote

Reporting Checklist: The authors have completed the CARE reporting checklist. Available at https://jss.amegroups.com/article/view/10.21037/jss-24-86/rc

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committees and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

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