

Focused Review

Vertebroplasty of the First Sacral Vertebra

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The treatment of sacral insufficiency fractures remains an area of active investigation and development, which has typically concentrated on the lateral elements of the sacrum and the sacral ala. Although these fractures frequently involve the first sacral (S1) vertebral body, this structure has eluded a successful technique to accurately access its central portion for percutaneous cannula placement and cement delivery.

In this article, we describe a percutaneous cannula placement technique developed in cadaver models, utilizing fluoroscopic imaging to enter the S1 vertebral body using a transpedicular approach. The pedicle provides an anatomically safe entry point, but limits the cannula trajectory to the lateral aspect of the S1 vertebral body, which makes delivery of poly(methyl methacrylate) (PMMA) cement to the central body of S1 difficult and unreliable by cannula placement alone. To access the central body of S1 we describe the application of the AVAflex curved nitinol needle, which can be readily directed though the cannula, previously placed through the S1 pedicle, into the central body of S1. The PMMA cement is delivered through the AVAflex needle under fluoroscopic monitoring and results in controlled deposition and good distribution within the central body of S1. The technique employs an extreme caudad angulation of the fluoroscope image intensifier that provides excellent visualization of the sacral spinal canal similar to that obtained with an axial view under CT scan. This view allows for improving transpedicular cannula placement at S1, and real-time fluoroscopic monitoring of the cement deposition to quickly detect and avert possible extravasation toward the central spinal canal. This technique can be used with CT guidance for cannula placement combined with fluoroscopy for cement deposition or done entirely under fluoroscopy alone. Sacroplasty of the lateral sacral element and sacral ala may also be performed at the same time as the S1 vertebroplasty. It appears that with this curved nitinol needle technique, sacral insufficiency fractures that involve the S1 vertebral body may now be safely and accurately addressed.

Conclusion: The treatment of sacral insufficiency fractures by sacroplasty remains an evolving field. The technique using the curved AVAflex nitinol needle is another way to address the S1 component.

Key Words: Vertebroplasty, sacroplasty, kyphoplasty, vertebral augmentation, sacral insufficiency fractures, osteoporosis.

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The treatment of sacral insufficiency fractures continues to evolve with improved techniques and devices for cannula placement and controlled poly(methyl methacrylate (PMMA) cement deposition. The use of various imaging modalities allows for several treatment options depending on available imaging equipment, such as CT scans, combined CT fluoroscopy or fluoroscopy alone (1,2). Techniques for fluoroscopically guided percutaneous sacral fracture treatment remains an attractive alternative for the

ease of use and ready availability of fluoroscopy units in many hospitals, outpatient surgery centers, and physicians offices. In a previous study, we defined the fluoroscopic landmarks for cannula placement into the ala and lateral sacral compartments that can assist the operator in successful cannula placement (3). These fluoroscopic landmarks are useful for defining the boundaries of cement deposition patterns to insure that the material remains within the confines of the intramedullary space, and avoid cement extravasation

outside the sacral cortical surfaces. A significant concern in performing sacroplasty is possible fracture involvement of the sacral foramen and the risk of cement extravasation into one or more sacral foramen with inherent potential for nerve damage. Typically, the sacral foramen are well visualized in an AP view where they align with the L5 and S1 pedicles extending in a line following the caudad direction. The AP view is carefully monitored during cement delivery, so as to avoid cement extravasation into a sacral foramen and risk injury to sacral nerve elements.

Unfortunately, sacroplasty using this approach with fluoroscopic landmarks is limited to treatment of the vertically aligned lateral components of the sacral insufficiency fracture. Many patients with sacral insufficiency fractures often present with a more complex fracture that includes a horizontal contribution through the body of the first sacral segment, S1.

Traditionally, these S1 contributions were not specifically addressed and only the lateral sacral elements were treated by the instillation of PMMA cement. Despite several studies that suggest the pain relief with sacroplasty is typically good, many anecdotal discussions with physicians who routinely treat sacral insufficiency fractures often observe that the pain relief obtained with treatment of the sacral fractures is not as far reaching or complete as can be achieved with treatment of the thoracic or lumbar vertebral segments (4-6). Although, not specifically studied, it stands to reason that the sacral S1 body contribution that is not addressed may be a source of persistent pain despite good stabilization of the lateral sacral elements. Some practitioners perform sacroplasty using CT scan for guiding cannula placement; however, fluoroscopy is still required for cement delivery to monitor the path of cement in real time imaging. Some practitioners use CT-guided imaging to place a cannula into the body of S1 by traversing the pedicle of S1; or, alternatively, the cannula may be placed via a trans-sacroiliac joint approach. The CT scan does offer the advantage for axial imaging of the sacrum to visualize the central spinal canal and thereby help avoid placing the cannula within the spinal canal. However, even with CT scan imaging, the available trajectories for the cannula for a transpedicular approach are vastly limited due to the presence of the iliac crest and the posterior iliac spine that eclipses the pedicle from a dorsal percutaneous trajectory. The result is a more steeply angled cannula that tends to localize to the lateral aspects of the S1 body. This limits the successful spread

of PMMA cement to the lateral compartment of the S1 body. Even with the use of 2 cannulas, cement still may not reach the medial/central real estate of the S1 body.

Due to these anatomic difficulties, the S1 vertebral fracture has remained a challenge for physicians treating patients with sacral insufficiency fractures involving the S1 vertebral segment. The main factor impeding placement of cement is the steep angle of access to the S1 pedicle from the posterior approach that limits the trajectory of the cannula to the lateral aspect of the vertebral body. To compound the problem, the central spinal canal containing the spinal nerve root is not easily imaged with standard AP and lateral fluoroscopic viewing. A CT scan can be more useful for identifying the central spinal canal in the sacral region for cannula placement, but is ineffective in improving the cannula trajectory for the transpedicular approach. The trans-sacroiliac approach involves placing the cannula under CT guidance from a near horizontal trajectory through the iliac bone and traversing the sacroiliac joint to enter the body of S1. However, there is no literature that supports one technique as superior to another or which has fewer side effects, such as injury to the sacroiliac joint resulting in possible increased postoperative pain. In addition, not all interventional pain physicians have ready access to a CT scanner or specific training in CT-guided procedures, which limits its usefulness to the general interventional pain physician or spine surgeon. Also, the CT scan is too slow to provide real-time monitoring of cement delivery to avoid extravasation into the spinal canal, sacral foramen, or some other undesirable areas. Therefore, fluoroscopic imaging is still a necessary component of the procedure for cement delivery, even if the cannulas are placed under CT guidance.

Among patients undergoing surgical fusion with pedicle screw fixation, the S1 pedicles can be visualized by direct open inspection by the surgeon. However, the trajectory remains similarly limited by the iliac crest tending to localize the pedicle screw into the lateral compartment of the S1 vertebral body. Moreover, the central spinal canal generally is not readily or directly visible either, resulting in risk of misplaced pedicle screws traversing the spinal canal or actually contacting or injuring delicate spinal nerves. Due to this potential complication, many spine surgeons utilize fluoroscopic imaging while placing these pedicle screws into the body of S1, or other vertebral bodies as needed. During pedicle screw placement at S1, surgeons frequently

utilize an extreme caudad angulation of the C-arm with the image intensifier rotated from a direct AP view to a far caudad orientation. This angulation offers a trans-sacral axial view of the central spinal canal at S1 and a partial axial view of the body of S1, as well as an axial view of the ala and ventral border of the entire sacrum. With this view, the pedicle screws can be advanced into the lateral body of S1 using fluoroscopic monitoring to remain lateral to the spinal canal but still within the vertebral body, and not breach the ventral boundary of the S1 vertebral body.

In light of the above considerations, a fully fluoroscopically guided technique for addressing sacral insufficiency fractures involving the body of S1 would be a great value to the interventional pain practitioner, interventional radiologist, or spine surgeon. In this article, a technically attractive approach using fluoroscopic guidance will be described for cannula placement and cement deposition that utilizes the extreme caudad angulation of the C-arm and a curved AVAflex nitinol needle to successfully access the central body of S1.

METHODS

To define and test the feasibility of accessing the S1 body, a cadaveric specimen with an intact lumbar spine and sacrum was prepared and a standard C-arm unit was utilized for imaging. An AP view of the L5/S1 segment with the spinous process of L5 centralized was first obtained. Then the C-arm was rotated cephalad until the superior endplate of S1 was squared off. To access the right S1 pedicle, the C-arm was then rotated right anterior oblique (RAO) until the medial margin of the right posterior iliac crest came within one to 2 mm of the lateral border of the S1 pedicle. (In some instances, the S1 pedicle is not well developed, but the superior articular process of S1 at the L5/S1 facet may also be helpful as a fluoroscopic anatomic landmark.) With this oblique view, an 11-gauge vertebroplasty cannula is aligned with the fluoroscopic beam and inserted through the skin until bony contact is made with the outline of the pedicle making sure there is space between the medial border of the pedicle and the medial margin of the 11-gauge cannula (Fig 1). An entrance into the S1 pedicle that is too medial runs a risk of directing the cannula into the central spinal canal, while an entrance that is too lateral runs the risk of missing the S1 vertebral body altogether and may stray outside the sacrum and into the soft tissues of the pelvis or its many vascular struc-

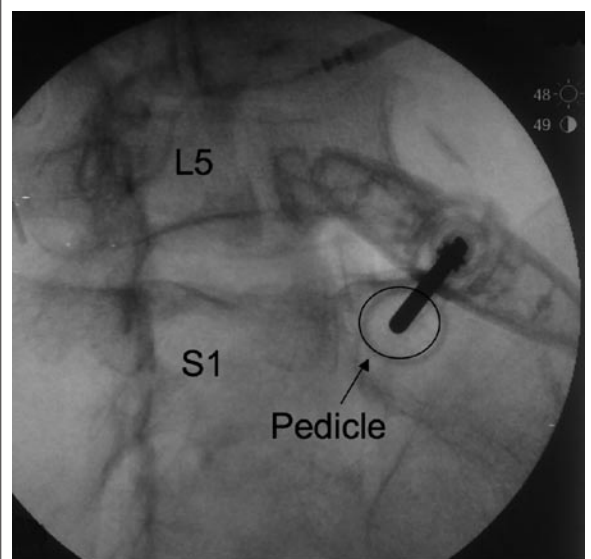


Fig 1. Cannula placement from RAO view through pedicle of S1.

tures and organs. After engaging the pedicle with the cannula tip, the C-arm is rotated to obtain a complete lateral view of the sacrum, and the cannula trajectory angle is adjusted to be relatively parallel with the superior endplate of S1 (Fig 2).

Once the S1 pedicle is engaged and the trajectory confirmed in the lateral view, the C-arm is then rotated back to the AP where the spinous process of L5 is directly in the mid position. The image intensifier is then rotated to the coveted extreme caudad view, which allows visualization of the sacral spinal canal. The cannula trajectory is very easily visualized and can be adjusted to stay lateral to the spinal canal, and is advanced until the tip is 2–3 mm more ventral than the ventral floor of the spinal canal. In this view, the entire breadth of the S1 body is visible ventral to the spinal canal (Fig 3).

The C-arm is then rotated back to the cephalad AP view where the superior end plate of S1 is squared off again to confirm that the trajectory of the cannula is moving medially and not straight down through the pedicle. The cannula tip should eclipse the medial border of the S1 pedicle in an AP view at this point. If the cannula tip is too vertically oriented, the C-arm may be returned to the extreme caudad view, and the cannula may be pulled back slightly, then the diamond tip trocar may be replaced with a beveled trocar to



Fig 2. *S1 pedicle cannula placement parallel to superior endplate of S1 vertebral body.*

redirect the cannula more medially as required to correct the trajectory. Again, care must be taken not to breach the medial wall of the pedicle and trespass into the lateral spinal canal. If there is any question of cannula tip location, the trocar may be removed and the cannula aspirated. If cerebrospinal fluid is obtained, the cannula tip is incorrectly lying within the spinal canal. Any complaints of leg or radicular pain should alert the operator of an undesirable cannula placement that has encountered a nerve. If the cannula is situated within the S1 pedicle, there should be no elicitation of radicular pain. The final cannula tip position should be just ventral to the floor of the spinal canal with a lateral to medial trajectory as viewed in the extreme caudad view and in the AP view.

With the cannula successfully placed using these landmarks, a second cannula may be inserted in an identical fashion through the contralateral S1 pedicle. In the final placement, the cannula tips should both be ventral to the ventral floor of the spinal canal in the extreme caudad view. The cannula tips should not be too ventral at this point or it will impede the insertion of the curved nitinol needle that follows next. The natural curve of the AVAflex needle does require sufficient path length to allow the curve to develop and direct the needle tip in the desired direction. If the cannula tip is advanced too ventrally, this will com-

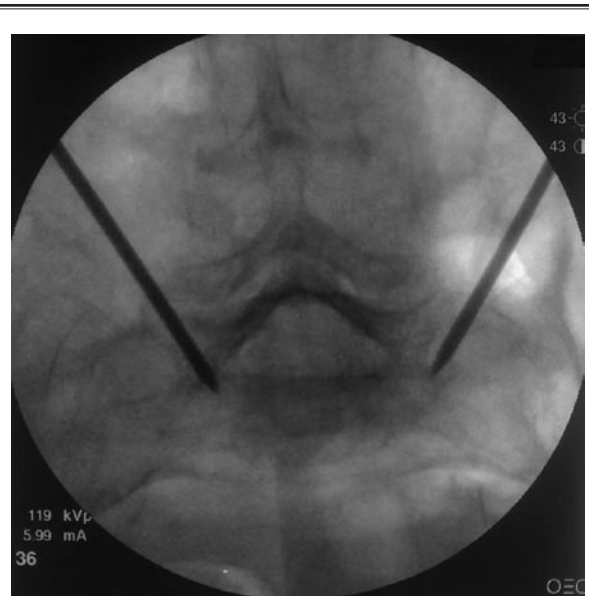


Fig 3. *Extreme caudad view of cannula trajectories lateral to the central sacral spinal canal. The cannulas should be advanced until the tips are just ventral to the floor of the spinal canal.*

promise the path length for the AVAflex needle and limit the degree of medial trajectory. With sufficient trajectory path, the AVAflex needle may even be positioned past the mid point to the contralateral side of the S1 vertebral body, thereby allowing for a unilateral approach.

After satisfactory placement of the cannula an AVAflex curved nitinol is inserted with the direction of curvature oriented medially, which is easily identified by the arrow on the handle of the needle. The C-arm is then repositioned in the extreme caudad angulation and the AVAflex needle is advanced until it is seen to exit the tip of the cannula. The curved AVAflex needle is then advanced in this view with the curve oriented medially and directed into the central body of S1. Care must be taken not to advance the AVAflex needle too vigorously and risk puncture of the ventral wall of the S1 body. A fracture involving the S1 vertebral body may offer minimal resistance to the curved nitinol cannula and result in a breach outside the confines of the S1 vertebral body. The AVAflex needle should be advanced ventrally and as far medially as possible. If the cannula has crossed the mid portion of the S1 vertebra as viewed on the extreme caudad view and AP view it may be possible to place the PMMA cement using a

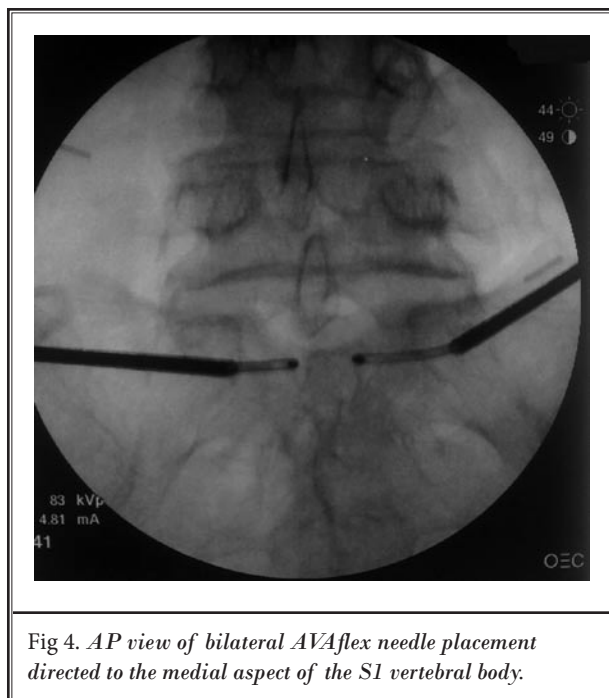


Fig 4. AP view of bilateral AVAflex needle placement directed to the medial aspect of the S1 vertebral body.

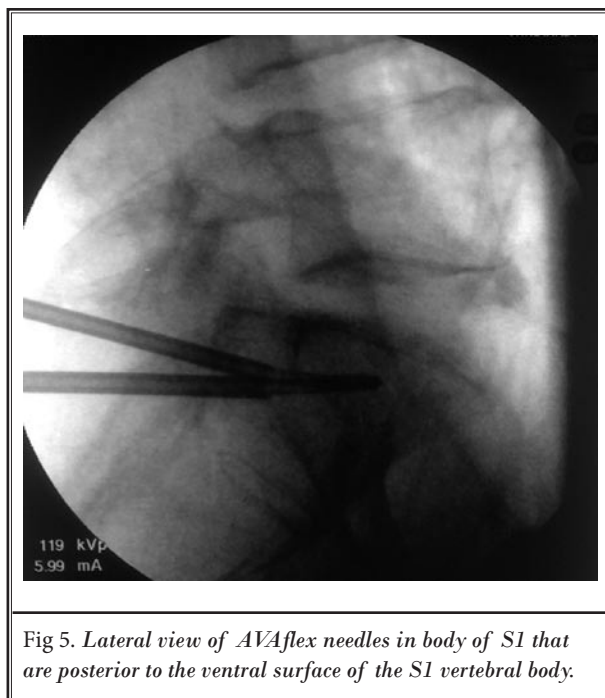


Fig 5. Lateral view of AVAflex needles in body of S1 that are posterior to the ventral surface of the S1 vertebral body.

single pedicle approach. If the curved nitinol needle cannot cross the midline, a second AVAflex needle may be inserted from the opposite cannula, and directed ventrally and medially, as is technically achievable within the confines of the anatomy encountered (Fig 4). The AVAflex needle should remain within the confines of the S1 vertebral body and not breach the ventral surface as viewed on a lateral image (Fig 5).

If during cement delivery there is insufficient cross to the contralateral portion of the S1 vertebra, the same AVAflex needle can be withdrawn and inserted into the opposite cannula, where injection can resume to fill the contralateral vertebral body as needed. However, the same care must be taken to position the AVAflex needle properly before cement delivery.

During injection of PMMA cement through the AVAflex needle, multi-planar views should be obtained frequently to monitor the deposition of the cement material. The lateral view should demonstrate the cement collecting and distributing in the ventral portion of the S1 vertebral body and not stray into the dorsal compartment where the spinal canal is situated (Fig 6). Of note, the cannula and nitinol needle may obscure the inadvertent flow of cement posteriorly as viewed in the lateral projection if it follows a line directly shadowed by the cannula and curved needle. To better monitor this potential hazard, the

C-arm should be frequently positioned in the extreme caudad projection. Any cement moving in a dorsal direction may be readily detected to avoid extravasation into the spinal canal. The distal opening on the AVAflex needle where the cement exits is located on the outer surface of curvature. However, this does not guarantee that the cement will exit and collect in the ventral aspect of the S1 vertebral body and not dorsally toward the spinal canal. In the setting of a vertebral fracture, the cement will typically follow the path of least resistance, which may be towards the spinal canal; so diligent care must be taken during the actual cement delivery to minimize the risk of inadvertent cement deposition into undesirable areas.

In many cases the S1 vertebral fracture is accompanied by a unilateral or bilateral sacral ala insufficiency fracture. All components of the fracture may be successfully treated by combining the usual sacral ala cannula placement technique along with the S1 technique just described. In this case, however, it is best to perform the S1 vertebral augmentation first. If cement is deposited in the lateral sacral ala first, it will obscure the subsequent S1 cement delivery from the lateral fluoroscopic view and make detection of dorsal cement extravasation more difficult. An AP view is not very effective in detecting stray cement extravasation in a dorsal direction, so frequent lateral and extreme

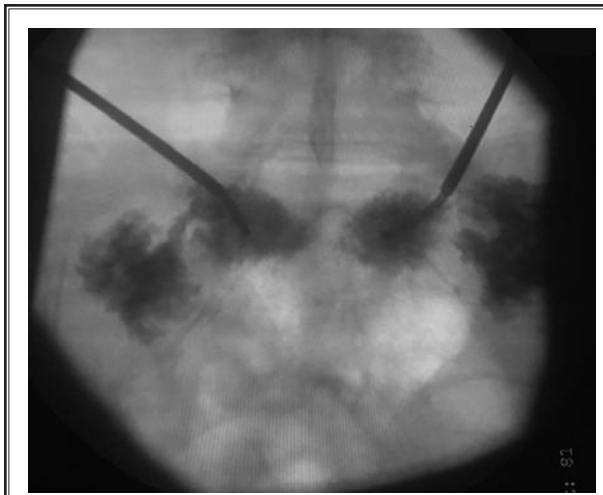


Fig. 6. AP view of cement deposition with AVAflex needles in place (bilateral sacral ala vertebroplasty cement deposition is also present in this image).

caudad fluoroscopic monitoring is advised. In contrast to S1 vertebroplasty, an AP view is typically monitored during injection of cement into the sacral ala to avoid cement extravasation into the sacral foramen; cement previously placed in the S1 vertebral body will not obstruct this view.

Discussion

Sacral insufficiency fractures are a common source of debilitating pain and present a complex problem for physicians to manage. Due to the difficult anatomy of the sacrum and accessing the S1 vertebral body, the solution to the successful treatment of these fractures has presented a formidable ongoing challenge. The lateral sacral elements have been successfully addressed with several excellent techniques for cannula placement and safe, controlled cement delivery using fluoroscopy with or without CT guidance, and using balloon augmentation or mechanical augmentation. In addition to the dorsal approach, some practitioners use a long axis cannula insertion technique that has been successful; however, the exact anatomy and cement deposition pattern has not been specifically confirmed by cadaver testing or post procedural CT scanning (7). Also, the extent of pain relief between the 2 approaches has not been addressed as to which is superior; nor has the stability of the fracture reduction been confirmed by biomechanical testing. So, additional research is certainly warranted to study the

preferred method of sacral fracture reduction and stabilization.

In terms of the S1 vertebral fracture, however, there remains a sizable challenge due to the difficulty of imaging the central spinal canal during cannula placement and cement delivery and accurately accessing the central portion of the S1 vertebral body from a dorsal approach. Only a CT scan could reliably place a cannula into the S1 vertebral body and allow for assessing the location of delivered cement. However, the CT scan does not allow for real-time monitoring of cement delivery that can result in cement deposition in the spinal canal or sacral nerve root during cement delivery. Fluoroscopic monitoring does provide the instantaneous assessment of cement localization during cement injection, thereby making the CT-only guided procedure relatively less attractive from a patient safety perspective. The patient would require a separate fluoroscope to monitor cement delivery after the cannulas were placed via CT guidance. The extreme caudad angulation view of the C-arm, however, does allow imaging of the axial central spinal canal at the S1 level similar to that of the CT scan axial view. Fluoroscopy, in contrast, does allow for real-time monitoring of cement delivery to accurately determine if cement extravasation toward the canal is occurring and allow for quick evasive action before clinically significant volumes are deposited.

Sacral-1 vertebral augmentation now appears to be amenable to successful cannula placement and safe cement delivery under fluoroscopy or CT scan, with the use of a curved nitinol-based needle. The curved needle solves the anatomic conundrum of a steep cannula trajectory via a dorsal transpedicular approach that makes the central portion of the S1 vertebral body relatively inaccessible to the straight cannula approach. Use of CT guidance could help fine tune the cannula trajectory, but the iliac crest often eclipses the S1 pedicle to such a degree that it severely limits how shallow an angle is geometrically possible. Thus, a straight-line solution to accessing the central portion of S1 does not exist without having to trespass the sacroiliac joint. The solution in this case comes in the form of a curved instrument for the final approach to reach the medial aspect of the S1 vertebral body.

As a repeat note of caution, even though the opening at the distal tip of the AVAflex needle is oriented outward from the radius of the curvature, the cement can and does move dorsally toward the spinal canal. Use of the extreme caudad, fluoroscopic view is

advised when injecting cement through the AVAflex needle via the S1 cannula to quickly assess if cement is veering toward the central spinal canal.

A notable limitation of this technique involves cases where the S2 or S3 vertebral body composes the central component of the sacral insufficiency fracture. Since the sacral levels below S1 do not have a pedicle, a similar transpedicular approach would not be feasible. In addition, the sacral foramen may be involved with fracture lines coursing through their elements that cannot be easily visualized under fluoroscopy. Fortunately, the S1 vertebral body sustains the majority of weight-bearing mechanical forces leaving the more caudad sacral levels likely to be only minor contributors to producing pain. In symptomatic cases, however, perhaps the long axis approach, combined with the curved nitinol needle, may be a potential technique for treating fractures involving S2 or S3.

Currently, there is no specific code for vertebroplasty or vertebral augmentation of the sacrum as described using the term sacroplasty. Efforts are underway to have CMS designate a sacroplasty code for billing purposes when performing this procedure, which would significantly improve reimbursement for what is currently an unlisted procedure. The appropriate codes should be stratified to include placement of cannulas and PMMA within all separate compartments

of the sacrum including the sacral ala, lateral sacral elements (unilateral or bilateral), the bodies of S1, S2 and S3 or S4 as indicated to treat all components of the sacrum that may be contributing to the pain from a sacral insufficiency fracture. The technology continues to advance for new applications of percutaneous, minimally invasive cannula placement for instilling PMMA or other materials that, unfortunately, move faster than the process for the designation of appropriate procedure codes. However, we should press on undaunted to pursue the development of new technologies or applications of existing technologies for the benefit of our patients, all the while actively lobbying for appropriate reimbursement for these novel treatments and medical services.

CONCLUSION

The treatment of sacral insufficiency fractures by sacroplasty remains an evolving field. The technique here described for addressing the S1 component using the curved AVAflex nitinol needle will certainly add to the tools available to treat these challenging fractures, and may improve overall pelvic stabilization resulting in more complete pain relief.

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