Percutaneous lumbopelvic fixation for pathologic sacral fractures and spinopelvic dissociation: patient series

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BACKGROUND Because patients with advanced cancer live longer, the number of patients with the sequelae of metastatic spine disease has increased. Pathologic instability of the mobile spine has been classified, and minimally invasive surgery has been well described. However, pathologic sacral instability is uncommon and often underdiagnosed. Although most sacral fractures are stable, patients with unstable U- or H-type fractures have spinopelvic dissociation and can experience progressive pain, sacral kyphosis, and neurological injury. Open lumbopelvic fusion carries a high perioperative risk for this patient population, which has often been previously radiated and is medically frail. The authors investigated the utility and safety of percutaneous lumbopelvic fixation, as previously described for traumatic spinopelvic dissociation, in the oncological setting. The authors retrospectively reviewed five consecutive patients with unstable pathologic sacral fractures who had undergone percutaneous lumbopelvic fixation after conservative management failed.

OBSERVATIONS Patients experienced significant improvement between pre- and postoperative visual analog scale scores (9.2 and 1.6, respectively) and Eastern Cooperative Oncology Group grades (median 3 and 1, respectively). All patients were independently ambulatory at the final follow-up. Sagittal alignment remained stable in four patients and worsened in one. There were no major medical or surgical complications.

LESSONS Percutaneous lumbopelvic fixation shows promising results for palliation, durability, and safety for pathologic sacropelvic instability.

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As modern multidisciplinary management has lengthened the life expectancy of patients with metastatic cancer, the number of patients living with the sequelae of metastatic disease has increased. The 5-year survival rate for patients with cancer increased from 49% in 1980% to 69% in 2008, and the advent of molecular therapy and immunotherapy has driven the figure even higher. Bone is the third most common site of metastasis after the lungs and the liver, and the most common site of bone metastasis is the spine. Symptomatic spinal metastases occur in 10% of all patients with cancer and 50% of these metastases require some form of treatment. Although treatment consists primarily of systemic therapy, radiotherapy, and other nonsurgical modalities, 5%–10% of spinal metastases require surgical management. As survival times increase, it is important for the durability of surgical intervention to increase in parallel.

Sacral metastases account for 7%–10% of spinal metastases. Metastatic sacral disease can occur via hematogenous seeding, intradural drop metastases, or regional invasion of pelvic neoplasms, such as rectal cancer. The morbidity of metastatic sacral disease is high and includes motor deficit, bowel and bladder dysfunction, cauda equina syndrome, intractable neuropathic pain, fracture, mechanical instability, and decreased ambulatory capacity. Additionally, patients with reduced ambulation may become bedbound, which can increase the risk of deep vein thrombosis and other complications in an already high-risk population.

Although much of the symptom burden is directly attributable to progressive tumor growth and infiltration of bony and neurological structures, there may also be functional pain from pathologic fracture. The majority of sacral fractures among patients with metastatic...
tumors are of a stable pattern, such as vertical sacral ala insufficiency fractures, and do not require surgical stabilization. However, a subset of patients develops unstable pathologic sacral fractures, such as the U- or H-type patterns that define spinopelvic dissociation in the trauma population. Unlike stable-pattern sacral fractures, which often improve with time, unstable fractures are more likely to cause recalcitrant functional pain and disability; left untreated, the fracture deformity can increase, resulting in progressive sacral collapse or kyphosis of the S1 vertebral body. The sequelae can be significant and include compromise of the sacral canal with impingement of the cauda equina, and poor sagittal alignment with the loss of standing and walking tolerance.

Historically, because this presentation is uncommon, it has been relatively unfamiliar to surgeons and oncologists.1 Sacral metastases are often diagnosed late in their course, after they have extended beyond the bony anatomy and into the canal and neuroforamina.8 Because of the complex osseous and neurological anatomy of the sacrum, difficulty in imaging the area, and nonspecific early symptomatology, patients often have a prolonged symptom duration prior to surgical evaluation.5,6 Surgical management has been associated with a high risk of adverse events, leading surgeons to avoid operating on this population.4 The benefit of surgery in these patients is not well defined,9 particularly when patients present with advanced cancer, when they are compromised by chemotherapy, or when the surgical field has been heavily pretreated with radiation. For these reasons, the management of pathologic sacral fractures at our institution has historically focused on medical or interventional pain management, such as neural blockade.

We hypothesize that modern minimally invasive surgical techniques may overcome the barriers to surgical stabilization of unstable pathologic sacral fractures. Minimally invasive surgical (MIS) techniques and navigation have significantly improved safety and efficacy of spinal surgery, expanding its role in the spine tumor population.9 However, there is a paucity of data on the surgical management of metastatic sacral disease, because these patients are often excluded from studies on metastatic disease of the mobile spine. Moreover, there are no data on the outcomes of sacral disease treated with modern spine techniques, including navigated minimally invasive surgery. The purpose of this study is to describe the use of navigated percutaneous lumbopelvic fixation for mechanically unstable metastatic sacral and sacroiliac disease in a series of five patients and to report the outcomes.

Study Description

We retrospectively reviewed consecutive cases of patients with pathologic sacral and sacroiliac fractures who had undergone percutaneous lumbopevic fixation performed by a single surgeon at a quaternary care cancer center between April 2020 and January 2022. The indication for surgery was an unstable pathologic spinopelvic dissociation that resulted in severe mechanical pain and functional limitations and that had not responded to conservative treatments. We recorded demographic, oncological treatment, and surgical details. Pre- and postoperative visual analog scale (VAS) pain scores, Eastern Cooperative Oncology Group (ECOG) functional status grades, and ambulatory status were recorded. Other patient-reported outcomes and objective variables, such as the 10-foot timed up and go (TUG) test, were reported when available. Pre- and postoperative pelvic incidence (PI) was measured on a lateral radiograph. This investigation was performed with approval from the institutional review board.

Surgical Technique

Five patients (mean age, 63 years) underwent surgery during the study period. All patients had metastatic disease to bone, and the primary tumor histology varied (Table 1). All patients had previously received radiotherapy, with a mean bioequivalent dose of 51.5 Gy. Each patient underwent percutaneous instrumentation from L4 to the pelvis. Reduction was attempted via positioning and joystick manipulation of the percutaneous instrumentation. In one patient, a distractor was used percutaneously. Fenestrated lumbar pedicle screws were used for cement augmentation in some cases. The construct was supplemented by a transiliac-transsacral screw in one patient and by bilateral cement-augmented iliosacral screws in another. Four constructs were bilateral, and one was unilateral. Stereotactic navigation was used in four cases, and fluoroscopy alone in one. One patient underwent simultaneous laminectomy for cauda equina syndrome, whereas the remainder underwent stabilization without decompression. The median blood loss was 200 mL, and the median time in the operating room (OR) was 289 minutes.

Illustrative Cases

Case 1

A 45-year-old female with cervical adenocarcinoma and sacral metastasis who had been treated with stereotactic body radiotherapy consisting of 40 Gy in five fractions 1 month earlier presented with an unstable pathologic fracture through S1. She had radicular pain in the right L5–S1 distributions that was 5/10 at rest and 8/10 with weight bearing. Epidural steroid injection did not provide durable relief, and implantation or intrathecal pain pump was considered. Imaging revealed pathologic fracture of S1 with sacral body collapse and lumbopevic dissociation, resulting in compression of the S1 nerve root in the neuroforamen, and of the L5 nerve root.

### TABLE 1. Individual case details

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Primary Cancer</th>
<th>Radiation BED (Gy)</th>
<th>VAS Score Preoperative</th>
<th>Postoperative</th>
<th>ECOG Grade Preoperative</th>
<th>Postoperative</th>
<th>Ambulation Status Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>Cervical adenocarcinoma</td>
<td>72</td>
<td>10</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>Walker</td>
<td>Unassisted</td>
</tr>
<tr>
<td>59</td>
<td>Multiple myeloma</td>
<td>39</td>
<td>10</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>Bed</td>
<td>Unassisted</td>
</tr>
<tr>
<td>64</td>
<td>Rectal carcinoma</td>
<td>59.47</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>Bed</td>
<td>Walker</td>
</tr>
<tr>
<td>83</td>
<td>Thyroid cancer</td>
<td>59.5</td>
<td>7</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>Walker</td>
<td>Cane</td>
</tr>
<tr>
<td>63</td>
<td>Prostate cancer</td>
<td>28</td>
<td>9</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>Bed</td>
<td>Unassisted</td>
</tr>
</tbody>
</table>

BED = bioequivalent dose.
between the L5 transverse process and sacral ala. The unstable fracture pattern contributed to dynamic radiculopathy with axial load (Fig. 1). Given the risk of wound complications posed by open surgery soon after high-dose radiotherapy, percutaneous fixation and indirect decompression were pursued.

Cement-augmented, fenestrated L4 and L5 pedicle screws were placed bilaterally, as were S2 alar-iliac screws, in a percutaneous navigated fashion. The rod was introduced submuscularly, and iliac set screws were tightened. A distractor was placed percutaneously between the L5 and pelvis screws to distract and reduce the sacral fracture. The lumbar set screws were then tightened.

The patient's pain decreased rapidly following surgery. On postoperative day 3, she had no radicular pain and 3/10 pain at the surgical site. Her TUG time was 28 seconds with a walker. At 6 weeks postoperatively, she reported no back or radicular pain, and she was ambulating without an assistive device. Her 10-foot TUG time was 11 seconds. The patient remained independently ambulatory until she died 1 year postoperatively from progression of disease.

Case 2
A 59-year-old female with multiple myeloma presented with pathologic H-type sacral ala fracture and lower back pain radiating down the left leg, rated 4/10 at rest and 10/10 with weight bearing. She had received conventional radiotherapy consisting of 30 Gy in 10 fractions 5 months earlier. Medical management and sacroplasty at an outside hospital did not provide relief. She was unable to walk any significant distance because of pain and was largely bedbound. The patient underwent navigated triangular osteosynthesis with bilateral percutaneous L4 to pelvis fixation and transiliac-transsacral screw placement (Fig. 2). At 2 months postoperatively, she rated her pain as 1/10 and was able to ambulate comfortably with a walker. At the final follow-up 1 year after surgery, she was able to ambulate without an assistive device. The patient died 16 months after surgery because of oncological disease.

Outcomes
Mean preoperative and postoperative VAS scores were 9.2 and 1.6, respectively. Preoperatively, three patients were bedbound and two ambulated limited distances with a walker. Postoperatively, all patients remained independently ambulatory until the final follow-up, with three patients using no assistive device, one requiring a cane, and one requiring a walker (Table 1). Postoperative TUG times were recorded for two patients; their times were 11 and 17 seconds, compared with a complete inability to stand up from the chair preoperatively.

Four patients had relatively stable postoperative pelvic incidence (median increase in kyphosis, 6°), but kyphosis increased by 24° in the remaining patient despite intact hardware. This latter patient, who had presented with an acutely kyphotic fracture and cauda equina syndrome (Fig. 3), had ongoing difficulty with an upright stance but did not wish to undergo revision surgery.

There were no major medical or surgical complications (including wound infection and neurological deterioration) within 30 days of surgery. There were no cases of hardware malposition. One patient who had presented with dense cauda equina syndrome had persistent bladder dysfunction at 1 year postoperatively. Two patients died during follow-up (at 12 and 16 months postoperatively) because of progression of their underlying malignancies. There was one case of rod fracture and one case of rod disengagement from the iliac screw, both asymptomatic. In the latter case, the patient underwent rod reduction and set-screw revision in conjunction with surgery for an unrelated femoral neck fracture.

Patient Informed Consent
The necessary patient informed consent was obtained in this study.

Discussion
Observations
We report on the minimally invasive management of unstable pathologic sacral fractures, whose treatment has historically posed...
a high risk of complications. We selected for surgery those patients who had signs and symptoms of mechanical instability that were recalcitrant to nonoperative modalities. The literature on sacral metastases has noted other indications for surgery, including tumor progression, neurological deficit, pain refractory to radiation therapy, spinal instability, need for tissue diagnosis, and prolonging survival in certain histologies such as renal cell cancer.1-6,10,11 Traditionally, studies have focused on open surgery; in one such study, 40% of patients had complications, and the rate was even higher (62%) among those who had had prior radiotherapy.1

Given the complication profile and limited life expectancy in this patient population, our approach is to limit surgical indications to mechanical instability and acute neurological compression that is amenable to surgical decompression. We approach tumor control in the metastatic setting primarily with nonoperative modalities (e.g., radiotherapy), as surgical tumor control requires morbidity skeletal and neurological sacrifice.

Modern radiotherapy techniques have demonstrated high rates of tumor control in the sacrum.12 However, dose limitations related to tumor volume, prior pelvic radiotherapy, and proximity to the sacral plexus and rectum may compromise the durability of control.13 The potential for intervention techniques, such as cryotherapy, and for surgery to establish durable tumor control is limited by tumor size and proximity to critical structures, such as the neurological elements and rectum.13

A limitation of tumor control is an inherent problem in treating patients with spinal metastases and highlights the difficulty of effectively treating all symptoms in this patient population. Our cohort had several comorbidities, including general frailty, neurological compression, and skeletal instability, that contributed to pain and functional deficits. Although spinal instrumentation is effective for treating mechanical symptoms, patients can remain symptomatic and functionally deficient from nerve compression or systemic disease burden. They can also experience progressive sacral tumor infiltration not amenable to surgical decompression.

As most sacral fractures are of the stable pattern, the recognition of unstable fractures is sometimes delayed. The severity of functional pain and the presence of a new neurological deficit should raise suspicion of instability. It is critical to review sagittal imaging to identify sacral kyphosis. Furthermore, coronal computed tomography (CT) or magnetic resonance imaging (MRI), reformed in the plane of the sacrum, is needed to accurately identify the transverse fracture limb that often defines an unstable sacral fracture.

These fracture patterns are inherently rotationally unstable and are therefore less suitable for percutaneous iliosacral fixation with a cannulated screw. In the trauma population, the failure rate of iliosacral screws in the setting of unstable sacral fractures is as high as 26%,14 and the rate could be higher in the absence of available sacral bony purchase, such as in patients with lytic sacral disease. Prior studies have shown lumbopelvic fixation and triangular osteosynthesis to be the most mechanically stable constructs.5-15

In contrast to fractures in the trauma population, pathologic sacral fractures rarely heal; therefore, the instrumentation must be sufficiently robust to withstand ongoing fracture instability for the patient’s lifetime. We aim to maximize implant durability while minimizing surgical invasiveness and operative time for this frail population. We instrument up to L4 routinely, although further experience may prove that L5 is sufficient in certain cases,13 particularly those using cement-augmented screws. Though one patient underwent unilateral instrumentation because of the uniquely unilateral distribution of his disease, most patients have bilateral sacral involvement. We supplemented with transiliac-transsacral or cement-augmented iliosacral screws when there was sufficient bone stock available for screw purchase in the sacral body to help resist the flexion moment of the proximal fragment.

Lessons
Ours is the first study to report on the management of unstable pathologic sacral fractures with MIS lumbopelvic fixation. It is important to note that our selection criteria and indications were intended to mitigate the complication risk that has been reported in the literature. All the patients in our series had been heavily pretreated, had had prior radiotherapy at the surgical site, had advanced systemic disease, and were at high risk for wound breakdown and infection. Although our series is small, we had no cases of wound breakdown, all our patients had improvement in their pain control and ECOG scores, and all were independently ambulatory at the final follow-up.

This study was retrospective, and we do not routinely collect disease-specific outcomes, such as those assessed by the Spine Oncology Study Group Outcomes Questionnaire (SOSGOQ), in this population. Only one paper has reported SOSGOQ outcomes after surgery, and the authors found improvement in scores between pre- and postoperative assessments but not to a statistically significant degree.16 There is a real need for studies with disease-specific outcomes on sacral metastatic disease to further define the role of surgery in this complex patient population.

It is worth noting that the treatment of this condition mirrors the management of traumatic lumbopelvic dissociation, which until recently had received little attention in the literature. Early articles on the subject from Harborview Medical Center in Seattle reported high rates of infection (16%) and return to the OR (42%);17,18 Systematic reviews have corroborated these findings.13 Although the rates of these complications in the setting of previously radiated pathologic sacral fractures is unknown, they are likely to be significantly higher. Studies on percutaneous reduction and screw fixation in traumatic lumbopelvic dissociation have demonstrated good radiographic results and lower rates of complications.19 Jazini et al.20 reported on percutaneous lumbopelvic fixation for traumatic injuries and found lower rates of infection (8%) and return to the OR (12%) than those documented in prior historical open cohorts. Our study results suggest that these MIS techniques can similarly improve the

FIG. 3. Sagittal CT (A) and axial T2-weighted MRI (B) demonstrating severe sacral canal stenosis due to kyphotic angulation of a pathologic H-type sacral fracture.
complication profile in our frail patient population, thus expanding the treatment options for patients for whom stabilization had previously been considered prohibitively risky.

Sacral kyphosis may negatively affect quality of life in the short and medium term. Gottfried et al.19 assessed pre- and postoperative PI in a series of patients who had undergone en bloc sacrectomy and found that PI increased by an average of 13.6% if there was complete sacroiliac disarticulation. In a study of postoperative PI after the treatment of traumatic spino-pelvic dissociation, Hart et al.20 reported that the final PI averaged 82° and was correlated with lumbar lordosis. One of their patients with sacral kyphosis and a PI of 115° had fatigue when standing. None of their other patients had difficulty with an upright posture. This is consistent with our findings. The patient presenting with a significant kyphotic fracture deformity had a preoperative PI of 88° and immediate postoperative PI of 86°, although she experienced progressive sacral kyphosis and a PI of 112° by her latest follow-up, presumably due to deformation of the hardware. She had difficulty maintaining an upright posture. It is possible that she would have benefited from additional reduction maneuvers at the time of stabilization surgery. Closed reduction with Scharn pins coupled with an external fixator18 and with bifemoral traction were reported and should be considered for patients presenting with significant pathologic fracture deformity. The other patients in our series had a stable PI between their intermediate postoperative and final assessments and did not have postural complaints.

This study is the first, to our knowledge, to report on the use of MIS lumbopelvic fixation in unstable pathologic sacral fractures due to metastatic disease. It can serve as a starting point for further research to optimize the management of this difficult clinical condition. This study represents a single surgeon experience using clearly defined indications for operative intervention, which limits variability. However, it also introduces potential limitations, notably selection bias and a risk of decreased generalizability. A further limitation is the small sample, which is a product of a rare disease presentation and evolving intervention. Nonetheless, several themes unify the patients in our series, including that they were at high risk for complications from open surgery because of preoperative radiotherapy and that they had intractable pain from mechanical instability despite attempts at conservative management, making them excellent candidates for percutaneous fixation.

In conclusion, percutaneous lumbopelvic fixation is a viable treatment option for unstable pathologic sacral fractures due to metastatic disease. Quality of life studies are needed to quantify the effects of intervention and improve the management of patients with sacral metastases. MIS spinal instrumentation will play an increasingly important role in the treatment of cancer patients, and there are significant opportunities to advance the care of this challenging patient population.

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References


Disclosures
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Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Vaynrub. Administrative/technical/material support: Vaynrub. Study supervision: Vaynrub.

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