

Percutaneous Instrumentation of Pathologic Vertebral Fractures

Michelle J Clarke, MD,¹ Reza Yassari, MD,² Daniel M Sciubba, MD,³ Peter Rose, MD⁴ and Mark B Dekutoski MD⁴

1. Assistant Professor of Neurosurgery, Department of Neurologic Surgery, Mayo Clinic; 2. Assistant Professor, Department of Neurosurgery, Albert Einstein College of Medicine; 3. Assistant Professor of Neurosurgery, Oncology and Orthopaedic Surgery, Department of Neurosurgery, Johns Hopkins University School of Medicine; 4. Assistant Professor of Orthopaedics, Department of Orthopaedics and Department of Pediatric and Adolescent Medicine, Mayo Clinic

Abstract

Vertebral metastatic disease leading to pathologic compression fractures is becoming increasingly common as patients with cancer are surviving for longer. Pathologic compression fractures severely limit quality of life; pain is nearly universal, and neurologic deficits are also common. Traditional treatment options have been limited to non-operative modalities, cement augmentation, or large circumferential decompressive procedures. Percutaneous spinal fixation provides another less invasive option, and can be used as a stand-alone procedure or in conjunction with open or minimally invasive decompression. This procedure may improve the quality of life of patients who would be deemed poor surgical candidates due to short life expectancy or medical comorbidities precluding major surgery.

Keywords

Pathologic fracture, percutaneous instrumentation, spinal metastasis, spinal fusion, minimally invasive surgery (MIS)

Disclosure: The authors have no conflicts of interest to declare.

Received: March 9, 2010 **Accepted:** December 8, 2010 **Citation:** *US Oncology & Hematology*, 2011;7(2):98–102 DOI: 10.17925/OHR.2011.07.2.98

Correspondence: Michelle J Clarke, MD, Department of Neurologic Surgery Go8S, Mayo Clinic, 200 First Street, Rochester, MN 55905. E: clarke.michelle@mayo.edu

As cancer survival steadily improves, the prevalence of metastatic spine disease will continue to increase. Cancer is the second leading cause of death in the US (behind heart disease) with an estimated 1.5 million new cases diagnosed annually.¹ Recent advances in cancer therapy resulting in prolonged life expectancy seem to have resulted in more patients surviving long enough to present with spinal metastases. Additionally, spinal metastases are often diagnosed at an early stage due to the widespread use of magnetic resonance imaging (MRI).² The most common site of bony metastatic disease is the spine.³ In autopsy studies, up to 70 % of terminal cancer patients have been found to have spinal metastases.⁴ Of patients diagnosed with cancer, 10 % will have symptomatic spinal lesions complicating their disease.⁵ In many cases, metastases result in pathologic fracture, which is a collapse of the vertebral body due to loss of structural integrity from tumor invasion. Pathologic fractures can cause pain, neurologic deficit, and spinal deformity.

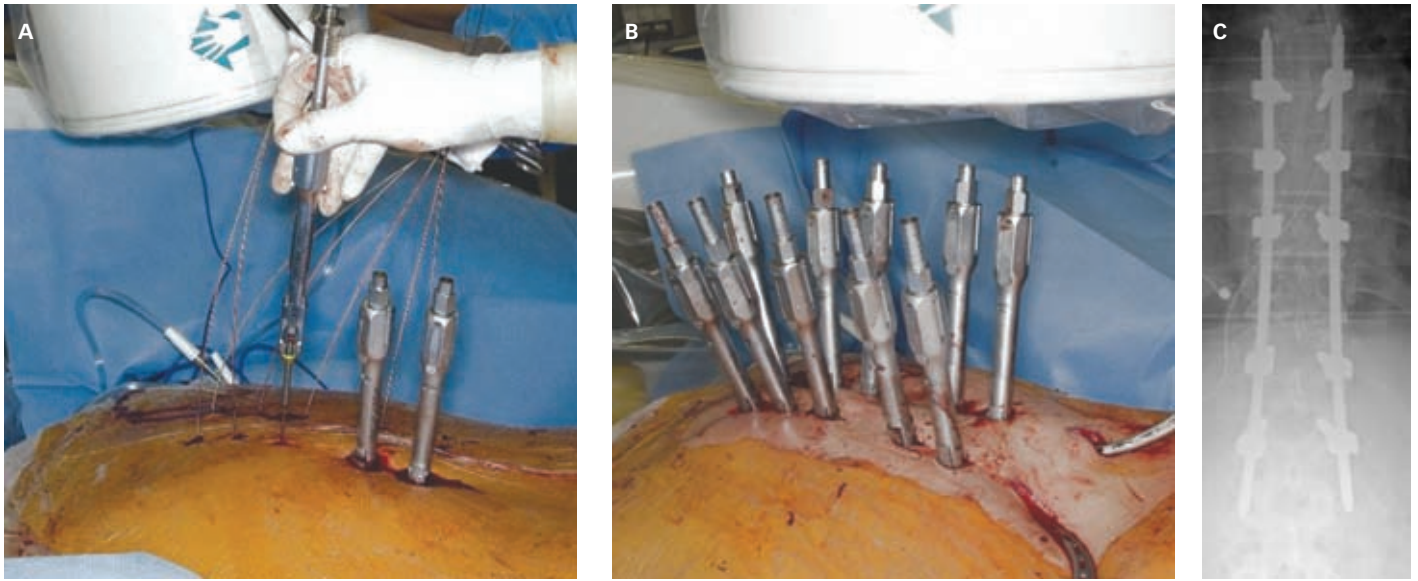
For symptomatic patients with metastatic spine disease, the most common presenting complaint is pain, occurring in 83–95 %.^{6,7} Three distinct pain subtypes are seen: local, radicular, and mechanical. Local pain is constant, does not worsen with movement, and is not improved with recumbency. This type of pain is usually attributed to periosteal stretching due to an expanding tumor mass and is often relieved with radiation.² Radicular pain occurs in a dermatomal distribution and is usually caused by direct compression of a nerve root by the tumor mass or bone fragments in the case of pathologic fracture.² Mechanical pain is caused by mechanical instability of the spinal column and worsens with movement, often rendering patients immobile, and is a significant

cause of morbidity. Imaging studies usually reveal a pathologic fracture with associated vertebral body collapse and spinal deformity. Mechanical pain is effectively relieved with spinal stabilization.²

Additionally, spinal metastasis can cause spinal cord compression leading to motor, sensory, and autonomic dysfunction.⁸ The vertebral column is the most common location of spinal metastasis, accounting for 85 % of cases.⁹ In most cases, the tumor initially involves the posterior half of the vertebral body, and later invades the anterior half of the body and the posterior elements.¹⁰ Of those patients with spinal column metastases, 10–20 % will develop spinal cord compression.¹¹ The majority of metastatic spine lesions become symptomatic due to painful pathologic compression fractures, which often retropulse bone and tumor into the spinal canal and cause symptomatic neural compression. Posterior extension of the tumor may cause compression without an associated fracture as well.

Treatment Evolution

Metastatic spine disease has traditionally been treated with a combination of radiation, chemotherapy, and open surgery. Historically, metastatic epidural spinal cord compression (MESCC) was treated with a posterior decompressive laminectomy. However, with the advent of radiotherapy, studies demonstrated no advantage of laminectomy and radiotherapy over radiotherapy alone,^{12–18} and surgical treatment was largely abandoned. However, posterior decompression through laminectomy does not address compression caused by the vast majority of tumors that occur in the vertebral body anterior to the spinal cord.^{19,20} Additionally, decompression alone may destabilize

Figure 1: Percutaneous Thoracic Stabilization

A: Under fluoroscopic guidance, a pedicle screw is inserted over a previously placed Kirschner wire through a stab incision. B: All 10 pedicle screws have been placed, as shown by the aligning screw extenders. A rod is being passed through the screw heads on the patient's right side using a separate stab incision. The left rod is in place. C: Post-operative anterior-posterior view of the fixation construct.

the spine, and does nothing to address the mechanical pain of a pathologic fracture. More recently, through advances in spinal instrumentation and operative technique, circumferential decompression and stabilization has become possible. In a multicenter, randomized trial, Patchell et al. established the superiority of direct circumferential decompressive surgery plus radiotherapy over radiotherapy alone in the treatment of MESCC.²¹

Unlike surgery for primary tumors, surgery for metastatic spine disease is palliative, not curative. In cases of spinal cord compression, the goal of surgery is to preserve function and maintain the patient's quality of life. For instance, Patchell demonstrated that treatment with surgery and radiotherapy allowed most patients to retain the ability to walk for the rest of their life, whereas those treated only with radiation spent a substantial portion of their time paraplegic.²¹ Surgically treated patients were also likely to survive for longer, although this benefit is probably linked to retention of ambulation and avoidance of the complications of immobility. Quality of life is also affected by pain.²² In patients without MESCC, mechanical pain due to pathologic fractures may lead to immobility. Mechanical pain is best treated through spinal column stabilization. Non-operatively, bracing offers some improvement, although it is uncomfortable, is difficult in obese patients, and does not offer rigid spine fixation. The alternative to this has been open spinal fusion, traditionally two levels above and two levels below the lesion.⁸ Thus, until recently, treatment for metastatic spine disease was limited to external bracing for stabilization or large open surgeries for stabilization and decompression.

Even with evidence of benefit, surgical indications for metastatic spine disease remain controversial. The Patchell study was limited to patients with an expected survival greater than three months who were medically fit to tolerate extensive open surgery.²¹ While three-month expected survival is somewhat arbitrary, it underscores the importance of

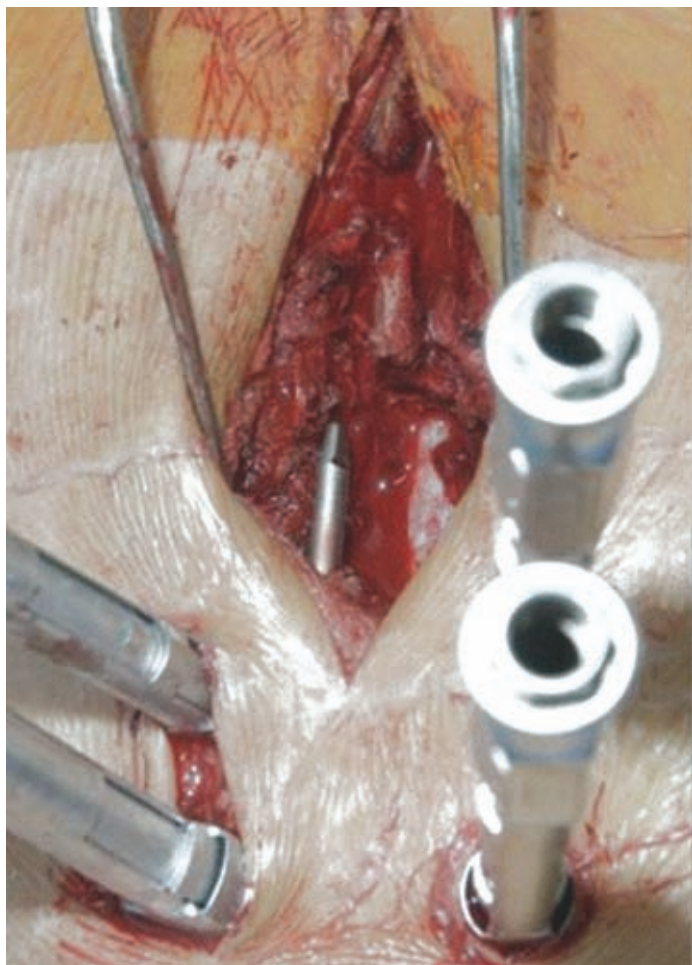
factoring recovery time into surgical decision-making. By definition, debulking a metastatic tumor is a palliative procedure. Thus, the patient needs to survive long enough to see a quality of life enhancement after the initial recovery period. Additionally, long anesthetic times and robust blood loss make these extensive surgeries difficult to tolerate medically. More recently, minimally invasive surgery (MIS) options have given the surgeon tools to decompress and stabilize the spinal column with shorter recovery times, less blood loss, and, often, shorter procedure times.

In patients with short life expectancies or multiple medical comorbidities precluding treatment, palliative treatment options are available. In patients with pain, bed rest, orthotics, non-steroidal anti-inflammatory drugs (NSAIDs), and narcotic medications can be used; however, body habitus may preclude effective stabilization with bracing. Radiotherapy can be effective in treating local tumor pain, but does not stabilize the spine. More recently, vertebroplasty has been used to augment radiotherapy, providing immediate pain relief and stabilization. Vertebroplasty is a minimally invasive procedure in which polymethyl-methacrylate cement is percutaneously injected into the vertebral body, effectively strengthening the vertebral body. By stiffening the bone, pain relief may result from stabilization of microfractures,²³ although a thermal and antitumoral effect has been proposed.²⁴ This procedure is useful in patients with severe, localized, mechanical back pain related to a pathologic fracture without evidence of epidural tumor, but is not useful if the collapsed vertebra is less than one-third of the original height. Although not an absolute contraindication, posterior wall destruction increases possibility of contrast extravasation into the spinal canal, which could cause neurologic deficits.^{25,26}

Percutaneous Spinal Fixation

Advances in surgical techniques have resulted in spine surgery becoming less invasive for the patient. Recently, a push towards using

Figure 2: Intra-operative Picture of a Combined Percutaneous Fixation—Open Decompression Case



Four extenders are visible, indicating that pedicle screws have been placed. Through the open incision, the decompressed spinal cord is visible. Additionally, the tip of a rod is visible as it is passed from the inferior to superior (not visible) pedicle screws.

minimally invasive techniques for the treatment of metastatic lesions has occurred. Percutaneous spinal fixation allows surgeons to stabilize the spinal column while avoiding a large traditional midline spinal fusion procedure. Initially attempted in patients suffering from traumatic thoracolumbar compression fractures,^{27,28} percutaneous spinal pedicle screws immobilize the spine and promote healing by acting as an internal fixator, restoring the posterior tension band. In one study, 40 patients with single-level burst or flexion–distraction injuries were stabilized with percutaneous fixation. In this series, the average operative time was 75 minutes, with trivial blood loss, no infections, and good to excellent outcomes in 87.5 % of patients.²⁹ Although it is impossible to directly compare these results, Verlaan et al. provide an excellent overview of open procedures in their systematic review of thoracolumbar fracture treatment. In this study, depending on approach, median blood loss ranged from 828 to 1,453 ml and operative time ranged from 2.5 to six hours.³⁰ One downside to this approach is the lack of true fusion; however, the minimally invasive approach appears to decrease the approach-related morbidity of a large open surgery.

Technique

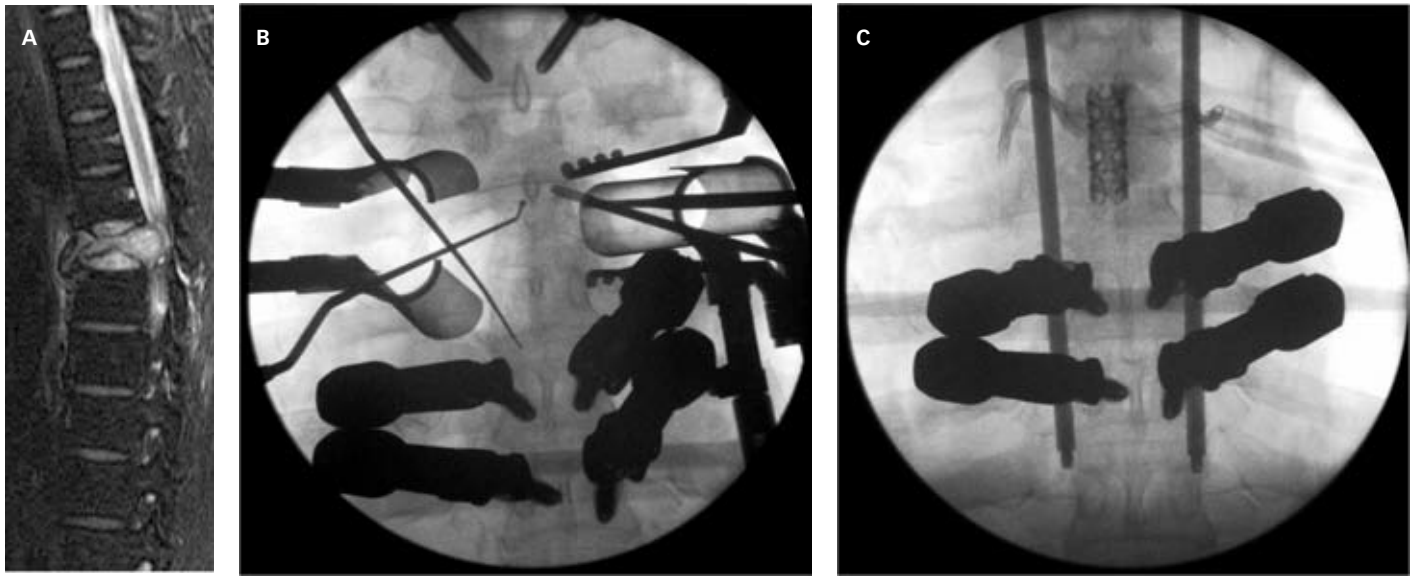
The following section describes the technical steps for a percutaneous spinal fixation. The patient is placed under general anesthesia and positioned prone on a radiolucent operative table. Fluoroscopic imaging is used to localize the level of interest. The pedicles are cannulated using a cannulated bone needle (e.g. Jamshidi needle) in the anterior-posterior fluoroscopic view. Following such cannulation, Kirshner wires are inserted down the center of the bone biopsy needles. Such wires are then used in a modified Seldinger technique over which all other instruments are safely passed into the pedicle and vertebral body. Pedicle screws are then advanced over the Kirshner wires, again under fluoroscopic guidance, via small stab incisions. The screws themselves are placed on removable ‘screw extensions’ that protrude from the stab incisions and give the surgeon the ability to manipulate the screw heads outside the body and compress or distract the construct as needed (see *Figure 1*). Once the pedicle screws and screw extensions are placed, rods are passed through small stab incisions into the screw heads via channels in the extensions. Similar to threading a needle, the rod slides perpendicularly through the channels in the extensions, at which point the rod can be pushed towards the spine and seated in the screw head. In short segment fixations, some instrumentation systems allow a pendulum-like attachment to connect to the towers and drive the rod through in an arc. In longer segment constructs, the rod may need to be guided through the towers by hand, with verification that it has been correctly seated at each level. If the rod is properly seated in the screw head, confirmation of engagement is further supported by an inability to spin the screw extensions. This technique can be used to verify optimal rod placement. Once appropriately positioned, the construct can be tightened to provide rigid internal fixation.

Percutaneous pedicle fixation is reliable and may have advantages over traditional open procedures. Depending on the imaging and navigation system used, surgeons have found a lumbar cortical breakthrough rate of 5.3 % radiographically, which is comparable to open surgery.^{31,32} However, the incidence of clinically significant breaches that lead to patient discomfort or dysfunction is likely to be substantially lower than the incidence of radiographic breach. Additionally, the surgery may be more medically tolerable for patients. This procedure allows surgeons to avoid the large traditional midline incision and associated paraspinous muscle dissection. Blood loss and tissue trauma are also lessened considerably,^{31,33} which may lead to fewer wound complications post-operatively, especially in patients with poor tissue quality due to advanced systemic cancer spread.

A direct comparison between open and minimally invasive fixation in metastatic spine disease has not been attempted. Even in the thoracolumbar trauma literature, no well-controlled prospective studies exist. However, evidence suggests that clinical outcomes are equivalent, if not superior, in the MIS stabilization group compared with standard open procedures. Additionally, in the traumatic fracture population, MIS procedures appear to result in reduced post-operative recovery time, pain, and time to return to work.²⁸

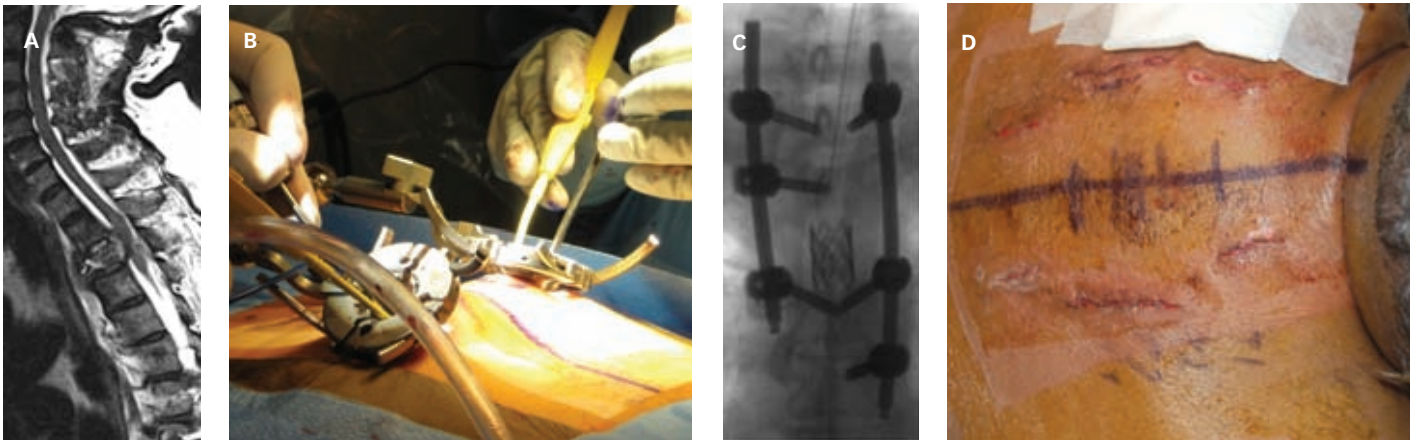
There is very little information in the literature on the use of percutaneous spinal fixation in metastatic spine disease. However, we have used this approach as a stand-alone procedure or to augment a decompressive

Figure 3: Combined Percutaneous Fixation and Minimally Invasive Decompression



A: Magnetic resonance image (MRI) demonstrating pathologic fracture with retropulsion into the canal causing spinal cord compression. B: Intra-operative fluoroscopy showing placement of pedicle screws and attached extenders. Two minimally invasive retractors have been placed in the field to provide exposure for the corpectomy. Probes have been placed through the retractor onto the spine to demonstrate the extent of exposure possible through this retractor system. C: Following corpectomy and cage placement, bilateral rods have been threaded through the screw heads with the removable towers in place.

Figure 4: Case Example



A: Pre-operative sagittal magnetic resonance image (MRI) demonstrating pathologic fracture and tumor/bone retropulsed into the spinal canal causing metastatic epidural spinal cord compression (MESCC). B: Surgeons performing a corpectomy via bilateral minimally invasive ports. Twin retractor systems are seen in this image. C: Intra-operative anterior-posterior fluoroscopy showing final instrumentation placement. D: Post-operative image showing incisions.

procedure in 12 patients. Overall, an average of 4.7 levels were instrumented with a mean operative time of 2.5 hours and mean blood loss of 150 ml. No fractures progressed in the instrumented areas. Six patients died of disease at a mean of nine months, and at 16-month follow-up four were alive with disease, one had no evidence of disease, and one was diagnosed with a benign condition.³⁴ We are continuing to analyze the data from our small series, but initial results indicate that the procedure is very well tolerated.

Patient Selection

Percutaneous pedicle fixation as a stand-alone surgical procedure is best suited to patients complaining of mechanical pain without

associated neurologic dysfunction. Under-treatment of pain in cancer patients is a pervasive problem.³⁵ In the terminal phase of cancer care, the physician must assume an integrative palliative approach. Pain is one of the most predominant symptoms terminal cancer patients face, and likely one of the most feared symptoms.³⁶ Although a patient's disease may not respond to curative treatment, quality of life remains a paramount concern. As surgeons become more versed in percutaneous stabilization procedures, patients can make more informed decisions, balancing the risks and recovery time of surgery with a patient's anticipated life expectancy. While surgeons generally do not offer surgery to patients with a life expectancy of less than three to six months, MIS may push this limit. Additionally, MIS may

provide a more reasonable surgical alternative to patients with multiple medical comorbidities that would preclude a large, open procedure. However, it remains to be seen how aggressively pathologic fractures should be treated at the end of life, and what is the most appropriate use of resources.

Some authors have advocated prophylactic stabilization of metastatic spine disease to avoid pathologic fractures and the associated morbidities of pain and neurologic dysfunction.³⁷ However, identifying an appropriate candidate for such a procedure remains challenging, as it necessitates predicting the risk of pathologic fracture in a patient with an asymptomatic metastasis. Some studies, as predicted by biomechanical studies, correlate impending collapse with tumor size. Vertebral body involvement of 50–60 % in the thoracic spine and 35–40 % in the thoracolumbar/lumbar spine was predictive of collapse. Involvement of the dorsal elements and costovertebral joints lowered this threshold.³⁸ At this point, we do not advocate treating asymptomatic vertebral metastases. However, prophylactic spinal stabilization may become more widespread if risk factors for collapse are refined and the stabilization procedure itself is not onerous. Thus, percutaneous fixation may be an ideal tool should preventive palliation evolve.

Percutaneous Fixation as an Adjunct

Percutaneous fixation alone may be able to stabilize the spine and treat pain, but direct 360° decompression as advocated by Patchell in cases of MESCC may not always be possible. Thus, in cases of mechanical compression, further procedures are needed. In an effort to minimize surgery, percutaneous fixation may be used in addition to decompression, in either an open or a minimally invasive fashion, instead of a traditional open fusion procedure.

Circumferential decompression of the spinal cord, such as that espoused by Patchell in cases of MESCC, results in iatrogenic destabilization of the spine. In these cases, the tumor (and often bone fragments in cases of pathologic fracture) is retropulsed into the canal, causing anterior compression of the cord. To perform a 360° decompression, the posterior elements are removed so that the surgeon can reach under the spinal cord and resect the vertebral body and tumor. Further tumor and bone fragments can be pushed into the resection cavity to remove everything that had been compressing the anterior aspect of the spinal cord. The result is frank instability; the vertebral body that previously supported the patient's weight is gone, as are the posterior elements that provide lateral stability. The vertebral body is replaced by a strut—usually a titanium cage or cadaver bone strut. The lateralizing joints are replaced with pedicle screws extending superiorly and inferiorly at least two levels above and below. It is possible to perform an open decompression and percutaneous fixation, potentially limiting blood loss and procedural time (see *Figure 2*).

MIS can be further extended to combine a minimally invasive decompression with percutaneous fixation. In this case, retractor and lighting systems are used to provide exposure to the surgical site with minimal skin and muscle disruption. Technically, limiting exposure can be more challenging, thus the surgeon must be familiar with the MIS system and have an excellent understanding of the regional anatomy before proceeding (see *Figures 3 and 4*).

Conclusions

Percutaneous pedicle fixation provides a less invasive method of spinal stabilization than traditional open procedures. This technique may be applicable to patients suffering from metastatic spine disease either as a stand-alone procedure or an adjunct to decompression for MESCC. ■

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