Stress fracture of the lumbar pedicle bilaterally: surgical repair using a percutaneous minimally invasive technique

Case report

JEREMIAH N. JOHNSON, M.D., AND MICHAEL Y. WANG, M.D.

Department of Neurological Surgery, University of Miami Miller School of Medicine, Miami, Florida

Bilateral pedicle fractures in the spine are uncommon in the absence of bony abnormality, previous surgery, or trauma. The authors report a case of spontaneous bilateral lumbar pedicle fracture in a 50-year-old sedentary woman, which caused intractable pain and did not respond to months of conservative management. The fractures were surgically treated using a percutaneous, minimally invasive technique with screws placed directly through the fractures into the vertebral body. The pedicles were strategically tapped to achieve the lag effect and reapproximate the posterior fragment with the anterior elements. The patient tolerated the procedure well and experienced early improvement of her symptoms, and follow-up imaging showed evidence of fracture healing. Transpedicular fixation and the use of the lag effect could be a useful strategy in the treatment of future cases involving poorly healing pedicle fractures causing persistent symptoms. (DOI: 10.3171/2009.7.SPINE08373)

KEY WORDS • pedicle • stress fracture • back pain • neural arch • minimally invasive approach • spondylolysis

Low-back pain in the adult population is a common occurrence in the outpatient setting. The majority of cases have a muscular or ligamentous etiology and resolve with conservative therapy. In a small percentage of cases, however, back pain is due to osseous fractures, and this pathology can be located at any site along the neural arch. Fractures involving the lumbar pedicles are uncommon given their typically high tensile strength. Published cases of pedicle fractures have primarily been unilateral and associated with contralateral spondylolysis with a concurrent laminar fracture, or following surgical fusion. Reports in the literature of bilateral lumbar pedicle stress fractures without previous bony abnormality, trauma, or surgery are limited. Here we report a case of bilateral lumbar pedicle stress fractures in a middle-aged woman without significant trauma but with moderate osteopenia who was effectively treated using a percutaneous surgical technique.

History and Examination. This 50-year-old woman with a history of lupus, rheumatoid arthritis, insulin-independent diabetes, and moderate obesity (body mass index 33) presented with a 1-year history of moderate to severe low-back pain and mild leg pain primarily in the hamstrings bilaterally. The pain was mechanical in nature; exacerbated by exercise, flexion, or extension while sitting; improved with lying down; and was limiting her activities. The patient had been treated with epidural steroid injections, hip joint injections bilaterally, and physical therapy with incomplete symptom relief. She had a history of low-dose steroids for the treatment of lupus and rheumatoid arthritis and had undergone bone mineral density testing that showed moderate osteopenia. Her physical examination was remarkable only for focal tenderness to palpation over the lumbar region and pain with flexion and extension movements. There was mild hip-flexor weakness associated with back pain but no other neurological deficits.

Plain radiographs were suggestive of pedicle fractures, and CT scanning (Fig. 1) and MR imaging showed fractures through the base of the L-4 pedicle bilaterally. There were no other pathological findings in the lumbar spine. A bone scan with SPECT demonstrated reactive changes within the posterior elements of L-4 (Fig. 2). Conservative management of the pedicle fractures was attempted using external bracing for 3 months with only transient benefit, and there was no radiographic evidence of fracture healing on follow-up studies.
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Operation. Nonoperative management having failed, the patient consented to undergo bilateral percutaneous L-4 pedicle screw placement under fluoroscopic guidance with electrophysiological monitoring. With the patient in a state of general anesthesia, the L-4 pedicles were localized using anteroposterior and lateral fluoroscopy, and Jamshidi needles were placed into the pedicles through 1-cm-long paramedian incisions. The K-wires were passed through the Jamshidi needles, allowing for the use of cannulated awls and taps in the trajectory typical of transepidermal screws.

The insulated taps were electrophysiologically stimulated at 15 mA on the right and 20 mA on the left, confirming that there were no nerve roots directly in the screw trajectory. Cannulated pedicle screws (DePuy Spine, Inc.) were placed through the pedicles with attention paid to lagging the screw heads against the posterior elements to apply a compression force across the fracture lines bilaterally. To properly compress the fractured surfaces together, standard pedicle screws were used with over-tapping of the dorsal elements. Compression was achieved by placing the K-wires into the pedicles in standard percutaneous fashion. The tract was then tapped completely using 5.0-mm-diameter, cannulated cancellous bone taps. Larger diameter (7.0-mm) taps were used to enlarge the tract through the posterior elements and the dorsal portion of the pedicle. Percutaneous screws (6.0 mm) were successfully placed, primarily engaging the deeper portion of the pedicle and vertebral body. As the saddle of the screw contacted the dorsal surface of the facet joint–transverse process complex, further screw tightening compressed the fractured ends together under fluoroscopic guidance. Final anteroposterior and lateral radiographs demonstrated proper hardware placement.

Postoperative Course. The patient awoke at her neurological baseline. She ambulated the day of the procedure and was subsequently discharged.

At the 6-week postoperative follow-up visit, she had good pain relief and had returned to her routine daily activities. Radiographs showed good hardware placement and alignment (Fig. 3). Four months after surgery a CT showed evidence of bony fusion at the fracture sites (Fig. 4), and she reported resolution of her low-back pain.

She returned for another follow-up at 16 months posttreatment and described near-complete resolution of her preoperative symptoms. Her only symptom was occasional, mild right hamstring and low-back aching on prolonged standing as well as right thigh pain with mild right quadriceps muscle weakness while walking long distances. The patient stated that overall she is very happy with her outcome and had early, effective pain relief allowing for a timely return to normal activities. The 16-month follow-up CT studies showed fusion across the fracture lines bilaterally (Fig. 5).

Discussion

In a normal lumbar spine, the vertebrae articulate through the intervertebral disc and superior and inferior articulating facets: the load supported by the spine is distributed among these 3 structures. Up to 30% of the anteroposterior force on the spine is transmitted through the facets, and the pedicles share much of this load. Mechanical testing of the neural arch has revealed that the pedicle is the second most likely site for fracture, after the pars interarticularis. The pedicle has a shorter lever arm and greater intrinsic strength than the pars interarticularis, making it less likely to fracture under great force.

A stress fracture of the lumbar pedicle is rare but can occur, especially in conditions in which the load on the neural arch is abnormally distributed. One setting in which the pedicle can experience increased stress is after surgery involving the posterior elements. Unilateral fractures have been reported after laminectomy and spinal fusion, especially at junctional levels, but can also occur within the fusion mass. There have been 4 cases of postsurgical bilateral pedicle fractures reported in the literature, and all followed multilevel posterolateral fusion. It is theorized that pedicles associated with...
Posterolateral fusion masses experience abnormal repetitive shear forces due to continued motion through intervertebral discs, and the pars interarticularis, which normally shares these forces, is fixed in the fusion mass.\textsuperscript{27}

Fractures of the pedicle can also be due to nonsurgically acquired disturbances of the neural arch. Unilateral spondylolysis can alter the biomechanics of the neural arch resulting in contralateral reactive sclerosis and hypertrophy of the pedicle.\textsuperscript{31,37,39} Progression to "pediculolysis"\textsuperscript{31} fracture of the hypertrophied pedicle can occur.\textsuperscript{2,3,13,31,37,38} This type of reactive fracture is more common than an isolated stress fracture of the pedicle.

Bilateral pedicle stress fractures without acquired or iatrogenic structural abnormalities of the neural arch are uncommon. To date, there have been 5 cases of spontaneous bilateral pedicle stress fractures reported in the literature.\textsuperscript{1,16,27,30,35} The first case was described by Abel\textsuperscript{1} in 1985 when CT scans were increasingly being used to investigate back pain. Of the 5 reported cases, 3 involved teenage girls (2 were athletes) and 2 involved adult females. One of the athletes underwent surgery\textsuperscript{37} and the other 3 females were treated conservatively. The treatment of 1 patient was not detailed.\textsuperscript{1}

Pedicle screw fixation has proven to be safe and is now routinely used to treat a number of spinal pathologies.\textsuperscript{19} Nonsurgical management has failed in only 1 other case of bilateral pedicle stress fracture, besides the case described here.\textsuperscript{27} In that case, a young athlete underwent anterior interbody fusion, segmental pedicle screw fixation, and posterolateral fusion and was able to return to competition the following season. Parvataneni et al.\textsuperscript{27} explained that surgery with interbody fusion was performed to immobilize the adjacent vertebral bodies as well as the posterior elements in an attempt to prevent refracture by shear forces during exercise. Our sedentary patient underwent minimally invasive percutaneous pedicle screw fixation directly through the fractured pedicles bilaterally. Her lifestyle did not include any unusually strenuous activities, and it was believed that surgical fusion was not necessary. It was also believed that a minimally invasive percutaneous approach would reduce surgical morbidity and speed recovery to baseline functional status.\textsuperscript{28} In addition, the direct fracture repair allowed for preservation of the neighboring motion segments.

The "lag effect" is the concept of pulling 2 fractured bony elements together, with a screw anchored in the proximal bone and the screw head pulling the distal fragment toward the proximal fragment as the screw head tightens. This strategy was used in our case to bring the pedicle fracture lines closer together and promote healing. To achieve the lag effect, we placed standard threaded pedicle screws and strategically used larger-diameter taps in the posterior portion of the pedicle and lamina as well as smaller taps in the proximal portion of the pedicle and body. This tapping strategy allowed the screw threads to preferentially engage the body and proximal pedicle while more loosely engaging the posterior fragment and allowing the saddle of the screw to compress the posterior elements against the proximal elements. However, it can be argued that the ideal piece of hardware for achieving the lag effect is the lag screw. The use of lag screws is unusual in thoracolumbar spine surgery but is common in screw fixation of odontoid fractures and in orthopedic surgery.

![Figure 3](image-url) Postoperative radiographs, anteroposterior (a) and lateral (b) views, showing paired pedicle screws at L-4.

![Figure 4](image-url) Axial CT scan (a) obtained at 4 months postoperatively, showing transpedicular screws bilaterally at L-4 and healing pedicle fractures. Sagittal reconstructed CT scan showing a pedicle screw through the left (b) and right (c) L-4 pedicles along with healing fractures.
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fracture repair procedures. The lag screw is designed with a threaded distal portion, a smooth proximal portion, and a wide head to simultaneously reapproximate the proximal and distal fragments during the final phase of screw tightening and to achieve fixation. Although traditionally fully threaded screws with modification of the tap strategy were utilized in this procedure, lag screw fixation may be the ideal instrumentation strategy for future cases of bilateral pedicle fracture.

A potential flaw in the use of transpedicular screws to promote pedicle fracture healing is the interruption of blood supply to the fracture line. Theoretically, the advantage gained by immobilization and approximation of the fractured pedicle by a screw might be offset by interruption of the trabecular blood supply to the fracture site by a foreign body. However, no cases of avascular necrosis or delayed fracture of the pedicle have been found in multiple large reviews of pedicle screw placement complications. After searching the literature, we did not find any reports of complications attributable to pedicle vascular compromise in the setting of pedicle fracture or with the use of pedicle screws. Pedicle screw placement in the setting of pedicle fracture is uncommon; therefore, it is difficult to completely assess its impact on healing. Our patient had good healing of both fracture lines on delayed imaging after pedicle screw fixation (Fig. 5).

Evoked electromyography is an adjunctive procedure often used during pedicle screw placement in the thoracolumbar spine to detect pedicle wall breakthroughs, allow redirection or abandonment of screw placement, and prevent postoperative radiculopathy. This form of electrophysiological monitoring detects pedicle wall breakthroughs by passing an electrical current through the screw tract and recording the voltage needed to stimulate the adjacent nerve root. Stimulation voltage thresholds are highest in an intact pedicle (> 15 mA), lower in a wall breakthrough without nerve root contact (7–15 mA), and lowest in a pedicle wall breakthrough with direct nerve root contact (< 7 mA). In our patient with preexisting pedicle wall fractures, stimulation of the nerve roots at voltages somewhat lower than the thresholds for intact pedicles was anticipated; however, extremely low stimulation voltages were not expected as there would be several millimeters of bone separating the probe from the nerve root with good screw trajectory. During the procedure, the nerve roots were stimulated at 15 mA on the right and 20 mA on the left, suggesting that there was no wall breach resulting in direct nerve root contact; therefore, an acceptable intrapedicular screw trajectory was confirmed.

In summary, we describe a rare case of bilateral L-4 pedicle fractures that failed conservative management and were successfully treated using minimally invasive, percutaneous pedicle screw fixation. The patient reported an early return to normal activities. At the 16-month follow-up she described near-complete pain relief, and imaging showed fracture healing. This percutaneous, transpedicular fracture fixation technique is a viable treatment option in patients with bilateral pedicle fractures and potentially unilateral fractures showing nonunion after nonsurgical management.

Disclosure

Dr. Wang is a consultant for DePuy Spine, Inc., and Aesculap Implant Systems Spine Division.

References


Address correspondence to: Jeremiah N. Johnson, M.D., Department of Neurological Surgery, University of Miami Miller School of Medicine, Lois Pope Life Center, 1095 NW 14th Terrace, Miami, Florida 33136. email: JJohnson22@med.miami.edu.