Low back pain is a difficult diagnostic and therapeutic challenge. Further, evaluation and treatment of persistent low back pain following posterior spinal fusion can also be problematic as continued disabling pain following a solid posterior spinal fusion has been reported.1,2

This article presents a case of symptomatic degenerative disk disease following posterior spinal fusion caused by pedicle screw violation of the superior vertebral endplate, proven by provocative diskography prior to and after the index procedure.

**CASE REPORT**

A 35 year-old man presented with a surgical history significant for a L4-5 laminectomy and discectomy for a para-central disk herniation with persistent right L5 radiculopathy. Following this, he was enrolled in an aggressive physical therapy program; however, pain persisted, predominately in the lumbar spine. Subsequent evaluation included plain radiographs, magnetic resonance imaging (MRI), and provocative diskography that was considered concordant at L4-5 and L5-S1. L3-4 was considered nonconcordant with 1/5 pain. Subsequently, he underwent a L4-S1 posterior spinal fusion with pedicle screw instrumentation one year later. Pain persisted and increased over the following year despite physical therapy, pain management and psychiatry consultation, multiple narcotic pain medications, epidural steroid injections, and a transcutaneous electrical nerve stimulator unit.

One year later, the patient presented with persistent debilitating lumbar pain. He reported increased pain particularly with forward flexion. He described his symptoms as 90% back pain and 10% leg pain, with his right leg pain greater than the left. He was taking numerous narcotic pain medications at that time. On examination, he had a well-healed posterior midline incision with mild paraspinal palpation tenderness. Decreased spinal rhythm was noted, however, and Waddell signs were negative. He demonstrated 5/5 strength, symmetric deep tendon reflexes, and intact sensation in the lower extremities bilaterally. He had normal, palpable pulses distally in the lower extremities.

Standing anteroposterior and lateral lumbar radiographs demonstrated a possible pseudarthrosis with obvious superior vertebral endplate violation by the right L4 pedicle screw (Figure 1). Computed tomography (CT)-myelogram with 3-dimensional reconstruction confirmed these findings (Figure 2). Because of the endplate violation, provocative diskography was obtained to assess the nature of his back pain and the L3-4 disk. Diskography was consistent with 5/5 concordant pain at L3/L4, with 1/5 and 2/5 pain at L2/L3 and L4/L5, respectively (Figure 3).

Subsequently, the patient underwent a revision anterior-posterior spinal fusion from L3-S1 with VG-2 allograft bone spacers anteriorly (VertiGraft 2 VG-2; DePuy Acromed,

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Raynham, Mass). After removal of the right L4 pedicle screw, the screw tract was probed and found to violate the superior vertebral endplate and penetrate the superior disk. A tectonic pseudarthrosis was present without incorporation of the previously placed allograft bone. Postoperative radiographs confirmed good sagittal alignment and screw placement (Figure 4). The patient’s postoperative course was otherwise uncomplicated, and he was discharged on postoperative day four. At latest follow-up, he continues to do well.

**DISCUSSION**

Adjacent segment disk degeneration following posterior spinal fusion is well-recognized.\(^3\)\(^6\)\(^7\) Meter et al\(^7\) reported a simple radiographic technique to evaluate intraoperative pedicle screw position in relation to the superior vertebral endplate. Various etiologies have been proposed for this condition. We report the first confirmed case of superior endplate violation as an accelerated adjacent disk degeneration causation and persistent lumbar pain following posterior spinal fusion.

**Adjacent Segment Degeneration**

Accelerated adjacent segment degeneration is relatively common and concerns adverse effects following spinal fusion. It is believed that this accelerated degeneration is due in large part to increased mechanical stress on the adjacent motion segments. Cadaveric studies have shown an increased stress on the “juxta-free” segment to spinal fusions, including a 21% increase in the average compressive load and a 92% increase in the average bending moment.\(^8\)\(^9\) These studies also found that posterior fusion produced greater stress on adjacent motion segments than anterior fusion. Chow et al\(^10\) noted increased compensatory mobility in flexion and markedly increased intradiskal pressures following simulated anterior interbody fusion on six cadaveric spines. The degree of compensatory motion and intradiskal pressure increased with a two-level fusion compared to a one-level fusion. Frymoyer et al\(^11\) noted that nonfusion patients possessed a greater overall lumbar range of motion, whereas fusion patients reflected a significant compensatory motion at levels above the fusion, thus implying increased motion and stress at each motion segment.

The prevention and treatment of adjacent segment degeneration remains controversial. In a retrospective study of 94 patients with an average follow-up of 33 years, Lehmann et al\(^6\) determined that accelerated degeneration at the segments superior to a solid lumbar fusion occurs radiographically; however, they questioned the clinical significance of this finding as only 5% of these patients required revision. However, he reported segmental instability above the fusion mass in 45% of patients. Similarly, Herkowitz et al\(^3\) argued against fusing an adjacent disk when performing an L5-S1 fusion for spondylolisthesis, despite MRI degeneration appearance, due to questionable clinical relevance, worse outcomes with two-level fusions, and a general lack of scientific evidence. However, Albert believed that the additional fusion level was warranted in some instances to prevent retrolisthesis, and he suggested that provocative diskography could identify patients appropriate for the additional level of fusion.\(^8\) Lee\(^8\) presented 18 patients with adjacent segment degeneration following posterior spinal fusion. Five of these patients had degenerative disk disease, with 11 patients reporting symptoms within 5 years of posterior spinal fusion.

Wiltse\(^8\) reported on several patients with severe pain despite an “unquestionably” solid fusion whereas Weatherley et al\(^1\) presented five cases of persistent diskogenic pain with solid posterior fusions. These patients were treated with anterior interbody fusion of the symptomatic level with satisfactory results. Although such pain is often dismissed as being psychogenic in origin, Weatherly used computerized tomography to confirm solid fusion and lateral diskography to identify the symptomatic level.

**Provocative Diskography**

We used provocative diskography to assess the L3-4 disk because it was the adjacent level to an apparent pseudarthrosis. Lindblom\(^12\) is credited with performing the first diskogram in 1948, whereas Wise and Weiford\(^13\) reported the first series in the United States in 1951. Since that time, the role and use of diskography has been controversial and the study has met resistance in becoming an accepted diagnostic technique. In 1968, Holt\(^14\) demonstrated a high rate of false-positive results in 30 asymptomatic prisoners. This study has been widely cited en route to the conclusion that diskography is obsolete due to the reliability of high resolution computed tomography and MRI.
significant pain was used as a decisive cri-

Figure 4: Lateral radiograph demonstrates good hardware placement following revision anterior-posterior L3-S1 fusion with relief of symptoms.

However, more recent studies have shown that diskography is a reliable and useful diagnostic tool due to improve tech-

niques with radiographic needle localization combined with greater emphasis on the pain provocation aspect of the study in awake patients. Simmons and Segil15 reported a diagnostic accuracy of 82.2% in 393 patients, whereas Grubb et al16 reported 78% accuracy in localizing an organic source of pain in 108 patients with chronic low-back pain. This is compared to 37% accuracy for combined radiographs and myelograms. Likewise, Vanharanta et al17 found that only 20% of “normal” disks by CT and diskography produced some pain, whereas 77% of disks with exact pain reproduction demonstrated severe annular disruption. They concluded that as disk deterioration increased, provocative diskography was significantly more likely to be painful. More recently, Simmons et al18 found that provocative diskography correlated with MRI on 80% of diseased disk levels and that 76% of abnormal disks reproduced symptoms in a study of 167 consecutive patients with chronic low back pain who had failed conservative therapy. Walsh et al19 reproduced pain in 6 of 7 symptomatic patients by using provocative diskography. They also found that when significant pain was used as a decisive cri-

teria for a positive diskogram, zero false-positives and a specificity of 100% in 10 asymptomatic volunteers.

Superior Endplate Violation

Meter et al7 described a technique for evaluating pedicle screw position relative to the superior vertebral endplate, with the goal of avoiding violation. In their study, pedicle screws were inserted into 11 cadaveric lumbar spines with the intention of breaching or nearly breaching the super-

ior endplate in some instances. Two experienced spine surgeons independently evaluated pedicle screw position with standard anteroposterior, lateral, and 10° lateral oblique radiographs. The specimens were then dissected to determine the true, anatomic screw location.

Initial radiographic evaluation proved accurate 80.1% of the time. However, the oblique radiographs were incorrect 31% of the time, and when only the true lateral and anteroposterior radiographs were con-

sidered, the false-negative rate dropped from 7.1% to 3.7%, with the remaining false negatives being deemed anatomically insignificant. Furthermore, by establishing a “safe zone” of 3 mm between the screw tip and the apparent vertebral endplate (due to the concave nature of the superior vertebral endplate) on the true anteroposterior and lateral radiographs, the accuracy of their technique was perfect when confirmed anatomically (0/214, with a 95% confidence interval 0% to 1.4%). They concluded that combining the use of this technique with careful intraoperative visualization via true anteroposterior and lateral fluoroscopic radiographs could pre-

vent vertebral endplate violation by pedi-

cle screws.

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