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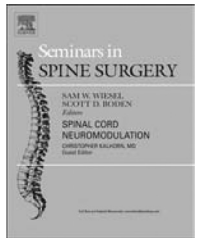

Post laminectomy instability

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ABSTRACT

Laminectomy is considered to be the gold standard of decompressive techniques. While the short-term benefits of laminectomy for lumbar spinal stenosis are widely accepted, concerns surrounding iatrogenic instability persist and the debate on the appropriate indications for concomitant fusion rages on. This review covers the various definitions, biomechanics, and incidence of post laminectomy instability and explores the patient, radiographic, and surgical risk factors that play a role in the development of this condition.

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1. Introduction

"We must, if possible, attempt to extract by an incision the compressing bone." This description of the first laminectomy by Paul of Aegina, a 7th century Greek physician, highlights one of the core tenets of spine surgery, decompression.[1] In 1829, A.G. Smith performed the first documented successful laminectomy on a patient who had fallen from a horse.[2] The majority of spine surgeries in the 19th century were decompressions in the setting of infection, trauma, or tumor; laminectomy for degenerative conditions did not occur until the turn of the 20th century.[2] In 1954, Verbiest detailed the constellation of symptoms associated with lumbar spinal stenosis (LSS) and the positive results he achieved following laminectomy in seven patients suffering from this condition.[3] Laminectomy quickly became the gold standard for surgical treatment of lumbar spinal stenosis.

While short-term results appeared favorable, the long-term efficacy of laminectomy remained controversial.[4–8] Iatrogenic instability induced by removal of the posterior stabilizing elements has been cited as a potential cause for deterioration of positive outcomes over time.[9] However, in their 1975 paper on the treatment of spinal stenosis, renowned surgeons Wiltse, Kirkaldy–Willis, and McIvor stated: "We seldom do fusion even if all the posterior stability has been lost. Olisthesis will rarely occur where the disease process is degenerative disk disease."[10] The challenge of balancing an adequate decompression without needlessly destabilizing the spine continues in the present era.

2. What is instability?

Spinal instability is a nebulous concept. In the biomechanical realm, spinal instability has been defined as excessive motion, pathologic motion— both increased or decreased—any motion causing abnormal load distribution, or loss of normal coupling patterns.[11,12] One of the most well known definitions of clinical spinal instability comes from White and Panjabi who defined it as a loss of the spine's ability to maintain its patterns of displacement under physiologic loads without neurologic deficit, deformity, or incapacitating pain.[11]

In 1982, Kirkaldy–Willis and Farfan defined clinical spinal instability as a patient who is able to function normally but is at high risk of becoming incapacitated by a relatively minor stimulus due to abnormal increased motion of a damaged

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joint.[13] They divided the clinical course of a patient with a degenerative spine into three stages: temporary dysfunction phase, unstable phase, and stabilization phase. A patient in the unstable phase may complain of recurrent low back pain with radiculopathy and dramatic, albeit temporary, alleviation of symptoms with mobilization or manipulation. Forward bending tends to increase pain and a painful "catching" sensation can occur when the patient transitions from flexion to extension. The authors note that a large number of patients in the unstable phases have had previous spine surgery. Characteristic radiographic findings of patients in the unstable phase include gas in the disc, traction spurs, annular fissuring, and increased or asymmetric motion on bending radiographs. The stabilization phase is characterized by loss of disc height and approximation of the vertebral bodies and anterior osteophytes. The patient's "phase" can help guide surgical treatment with decompression alone appropriate for patients in the stabilization phase and decompression with fusion indicated for patients in the unstable phase.

There is a wide range of radiological parameters that define spinal instability. In many cases, there is a poor correlation between radiological instability and patient symptoms.[6] In 1944, Knutsson defined radiological instability as vertebral body motion of at least 3 mm on flexion-extension views, spondylolisthesis, vacuum disc (i.e. Knuttsson's sign), reactive vertebral body changes, or disc space narrowing.[14] Definitions for anterolisthesis deemed to be indicative of instability have ranged from greater than 2–4 mm, or 6% in translation on static radiographs.[6,15] On lateral flexion-extension radiographs, anterolisthesis with greater than 2–5 mm or 5–8% of translation or greater than 5–15% of angulation have been deemed unstable.[15] A scoring system designed to help surgeons predict the stability of the lumbar spine, that took into account biomechanical parameters, radiologic findings, neurologic damage, and anticipated loading on the spine, was developed by Panjabi and colleagues but its clinical utility appears limited.[6,11] Anteroposterior lateral bending films can demonstrate abnormal motion in the form of asymmetric tilting of the vertebral bodies, misalignment of the spinous processes, or lateral translation of the vertebral bodies.[13] Dynamic CT involving rotating a patient's lower lumbar spine and pelvis with a bump can demonstrate widening of the facet joint on the elevated side.[13] A recent dynamic imaging study found that a subset of patients with spondylolisthesis exhibit aberrant intervertebral motion at mid-range of flexion, suggesting that standard flexion-extension radiographs may underestimate the amount of spinal stability.[16]

3. Biomechanics

Stability of the spinal column relies on the interplay between the spinal column components (disc, ligaments, and facet joints), the paraspinal muscles, and the neural control unit.[11] The spinal column acts as a load bearer and transducer, relaying information regarding load, motion, and position to the neural control unit that in turn activates the appropriate spinal muscles to keep the spinal column within physiological normal parameters.

Biomechanical studies have demonstrated the importance of the posterior spinal elements in imparting stability to the spine. Abumi et al. concluded that facetectomy, unilateral or bilateral, destabilized the spine to an unacceptable degree and recommended that the pars and at least 50% of the facet bilaterally be preserved.[17] Cadaveric lumbar segments treated with facet sparing laminectomy showed significantly less angular motion in flexion, lateral bending, and axial rotation compared to those treated with laminectomy and bilateral facetectomy (i.e. Christmas tree laminectomy).[18] The study also found a disproportionately larger increase in instability in the "Christmas tree laminectomy" group when a subsequent discectomy was performed. Lee et al. observed less spinal mobility and improved stiffness in cadavers with bilateral laminotomy, where the spinous process, interspinous, and supraspinous ligaments are preserved, compared to those with laminectomies.[19] These biomechanical findings have been borne out in the clinical realm.

4. Incidence

Not all laminectomies are created equal. During the era of the radical or "Christmas tree laminectomy," the incidence of postoperative anterolisthesis ranged from 43% to 55%.[6,9] In cases where facet-sparing laminectomies were performed, the incidence of spondylolisthesis ranges from 0–43%.[6,20–24] A systematic review of 24 studies detailing the incidence of postoperative instability following decompression for LSS found a 5.5% incidence of new or worsening spondylolisthesis. The reoperation rate for instability was 1.8% for all examined studies and 4.1% in patients who underwent open laminectomy.[15] The incidence of spondylolisthesis progression was twice as high in patients with a preexisting spondylolisthesis compared to patients with stenosis alone and were ten times more likely require a subsequent stabilization procedure.[15] When stratifying studies by type of approach, the authors found higher rates of radiographic instability and need for reoperation in the open laminectomy group, 12.0% and 4.1%, compared to the minimally invasive surgery (MIS) group, 2.6% and 0.81%.[15] As our decompression techniques have evolved to minimize the amount of disruption to stabilizing structures, the incidence of iatrogenic instability has decreased. Identifying risk factors for iatrogenic instability can aid surgeons in choosing the optimal procedure for their patients.

5. Patient and radiographic risk factors

A variety of patient, radiographic, and surgical risk factors associated with instability following laminectomy have been identified. Multilevel laminectomies tend to be more destabilizing than single level laminectomies.[20,25] The female sex has been associated with higher rates of both degenerative spondylolisthesis and postoperative spondylolisthesis.[9,26] Increased ligamentous laxity and decreased bone mineral density are thought to be contributing factors to the increased instability seen in females.[9,27] Low bone density was found to be an independent risk factor for post-operative instability in a cadaveric lumbar spine laminectomy model.[28]

Preoperative spondylolisthesis is one of the strongest preoperative risk factors associated with post-laminectomy instability.[6,15,22,29–31] In a series of 124 patients with LSS

treated with laminectomy, Fox et al. found preoperative anterolisthesis to be the most important factor in predicting instability.[6] Increased anterior translation occurred in 73% of patients with a preoperative spondylolisthesis compared to 31% in patients who had no preoperative spondylolisthesis. In Herkowitz and Kurz's landmark paper comparing laminectomy alone to laminectomy and intertransverse-process arthrodesis in patients with degenerative lumbar spondylolisthesis and spinal stenosis, 96% of patients in the laminectomy alone group had progression of their spondylolisthesis compared to 28% in the arthrodesis group.[32]

Loss of L4-5 disc height and the presence of anterior osteophytes have been suggested as being protective against instability.[6,22,26] In 1971, Macnab proposed that the presence of a "traction spur"—a horizontally oriented anterior osteophyte originating 2mm caudal or cephalad from the disc margin—was an indicator of segmental instability.[33] He contrasted the "traction spur" with the marginal or "claw" osteophyte that is commonly seen in a degenerative spine. While the morphology of the osteophytes was not detailed in the studies that identified osteophytes as being protective against instability, we can surmise that they were the marginal type.

Facet joint morphology and amount of resection are important factors in postsurgical instability. Sagittally oriented facet joints, greater than 50 degrees, are a risk factor for instability.[20,26] Robertson et al. suggested that the coronal dimension and sagittal orientation of the joints were better predictors of instability than amount of joint resected, as resecting 50% of a small, sagittally oriented joint is more destabilizing to anterior shear stress that resecting 50% of a large, coronally oriented joint[26] (Fig. 1). The presence of a facet joint effusion has been associated with a mobile spondylolisthesis[34,35] (Fig. 2). It is now widely accepted that facetectomy and fracture of the pars is a strong risk factor for progressive spondylolisthesis.[9,20,25,31]

6. Surgical risk factors

Surgical techniques have evolved over time to allow for an adequate decompression while minimizing the disruption to surrounding stabilizing structures. The conventional laminectomy involves removal of the spinous process, supraspinous ligament, interspinous ligament, lamina, and portion of the facet joints. The laminotomy was developed in an attempt to preserve the midline structures and can be performed bilaterally, or unilaterally with bilateral decompression (ULBD).

Thome et al. randomized 120 patients with LSS to laminectomy, unilateral laminotomy, or ULBD.[36] At a mean follow up of 16 months, significant improvement in disability, symptoms, and quality of life was noted in all three groups with a reoperation rate for instability of 5% in the ULBD group and 9% in the laminectomy group. A case series of ULBD in 29 patients (37 levels) resulted in an excellent or good outcome in 88% of patients and no evidence of instability despite 21% of patients in the series having a preoperative spondylolisthesis at the surgical level.[37]

Various surgical techniques involving osteotomies of the spinous process have been developed that purport to provide better visualization and decreased muscle denervation. The lumbar spinous process–splitting laminectomy (LSPSL) was developed by Watanabe in 2001 and involves splitting the spinous process longitudinally, cutting the base of the spinous process, and retracting each split spinous process laterally with its respective paraspinal musculature.[38] Following adequate decompression, the split spinous process is reapproximated with suture. The study compared 18 patients who underwent LSPSL to 20 patients undergoing conventional laminectomy. At 2 years, clinical outcomes were similar in both groups, with significantly less paravertebral muscle atrophy seen in the LSPSL group compared to the laminectomy group, 5% and 24% respectively. A series of 39 patients (118 levels) treated with LSPSL yielded a good or excellent result in 77% of patients with no cases of instability at mean of follow up of seven months despite more than a third of patients having a preoperative anterolisthesis.[39]

Hermansen et al, published a series of 56 laminarthrectomy cases that involved unilateral stripping of the multifidus, osteotomy of the spinous process base, laminotomy of the inferior portion of the cephalad lamina and superior portion of the caudal lamina, partial medial facetectomy, then allowing the osteotomized portion of the spinous process to fall into place following decompression.[40] Eighty three percent of patients reported symptom improvements and no cases of instability were reported. There was a positive correlation between symptom relief and amount of decompression as measured by the change in dural sac cross sectional area before and after surgery.

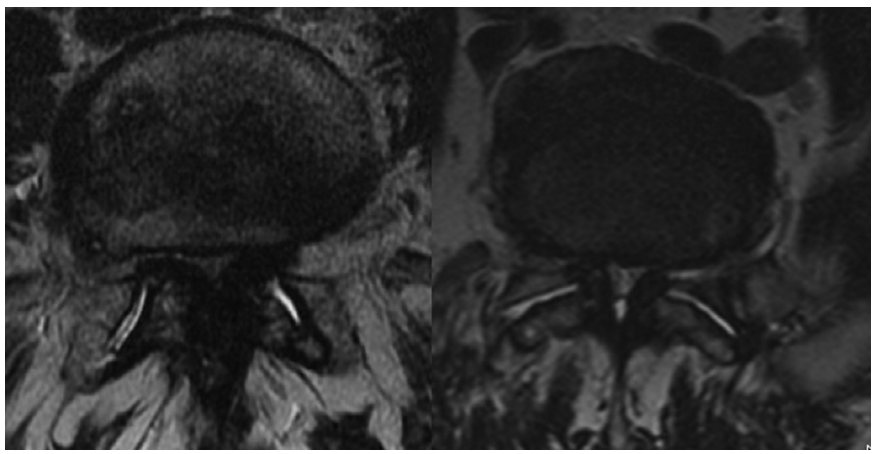

Fig. 1 – Axial T2 MRI images of the lumbar spine with sagitally (left) and coronally (right) oriented facets.

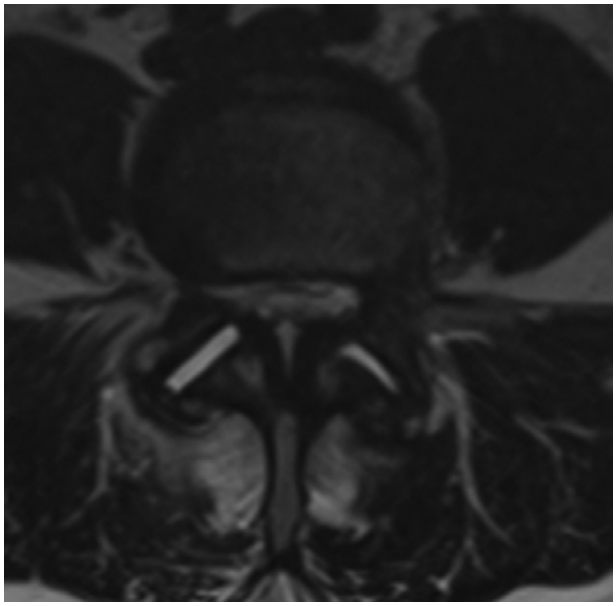

Fig. 2 – Axial T2 MRI image demonstrating facet gapping and effusion, often suggestive of a spondylolisthesis on upright radiographic films.

A randomized comparison of laminectomy, bilateral laminotomy, and trumpet laminectomy through a spinous process splitting approach resulted in significant improvement of symptoms in all groups.[41] Significantly greater patient satisfaction at 12–18 months was seen in the bilateral laminotomy group. There were no reoperations for instability in the bilateral laminotomy group compared to 8% in the laminectomy group and 5% in the trumpet laminectomy group. Arai et al. compared the two-year outcomes of patients treated with ULBD and muscle preserving interlaminar decompression (MILD).[23] Briefly, the supraspinous ligament was divided longitudinally and the inferior portion of the cephalad spinous process and superior portion of the caudal spinous process were osteotomized allowing for removal of the upper third of the caudal lamina and inferior portion of the cephalad lamina to the insertion of ligamentum flavum. The single level ULBD group had equivalently good outcomes to the single level MILD group. This stands in contrast to patients undergoing multilevel surgery where improved pain and function was reported in the ULBD group compared to the multilevel MILD group. Increase in sagittal translation was seen in 11% of the MILD group and 0% in the ULBD group. The authors noted that the patients who had increased sagittal translation had greater lumbar lordosis and theorized that removal of the spinous process resulted in aggravation of the lordosis and altered the posterior elements ability to transmit load.

Overdest et al. performed a systematic review of various midline preserving posterior decompression techniques for LSS compared to laminectomy.[42] Ten randomized controlled studies (four high-quality studies, six low-quality studies) were included in the analysis that grouped midline-preserving procedures into three categories: ULBD, bilateral laminotomy, and split spinous process laminotomy. There were fewer cases of iatrogenic instability in the ULBD and bilateral laminotomy groups compared to laminectomy. However, given the poor methodology and reporting of outcome measures, the authors stated that the proposed advantage of midline preserving procedures in lowering the incidence of iatrogenic instability was plausible but not conclusive.

7. Conclusion

Decompression, stabilization, and deformity correction are the three surgical means by which spine surgeons can help their patients. Out of concern for late deterioration of results following laminectomy for LSS, thought to be due in part to iatrogenic instability, our surgical techniques have evolved over the last century to feature procedures that allow for removal of a minimum of the stabilizing structures while still achieving an adequate decompression. While a variety of patient, radiographic, and surgical risk factors relating to iatrogenic instability have been discovered, the debate over when stabilization is indicated continues. Future research is needed to identify which combination of factors elevates the risk of iatrogenic instability to a level where a patient with LSS would benefit from a decompression with concomitant stabilization.

8. Disclosures

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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