Lumbar Spinous Process–Splitting Laminoplasty: A Novel Technique for Minimally Invasive Lumbar Decompression

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Minimally invasive posterior spinous process–splitting laminoplasty preserving the paraspinal musculature has been introduced to treat patients with lumbar spinal stenosis. Despite its theoretical advantage of limiting muscular trauma, additional efforts are required to evaluate patients’ clinical and functional results following this procedure. Between 2010 and 2012, 37 patients underwent spinous process–splitting laminoplasty for lumbar stenosis at a mean age of 68 years (range, 36-87 years) and were followed for minimum of 1 year (mean, 1.3 years). There were 22 (59%) men and 15 (41%) women. Mean number of levels treated with a spinous process–splitting laminoplasty was 2.2 (range, 1-6 levels). Patients had statistically significant improvements in their scores for all self-reported outcomes, including visual analog scale (VAS) for back and leg pain, Oswestry Disability Index (ODI), and Short Form 36 (SF-36) components. Mean VAS significantly decreased by 4.4±3.2 points for back pain and 3.9±3.7 points for leg pain (P<.0001). Mean ODI significantly decreased by 17.5±19.1 points (P<.0001), and mean SF-36 significantly increased by 29±30.4 points (P=.0017) for the physical component and 21.8±25.6 points (P=.0062) for the mental health component. Four (10.8%) patients had a dural tear requiring repair (3 were intraoperative), 3 (8%) had an epidural hematoma requiring evacuation, 1 (2.7%) had an infection requiring irrigation and debridement, and 2 (5%) had additional decompression for symptom recurrence secondary to instability. Lumbar spinous process–splitting laminoplasty is a novel minimally invasive technique that provides adequate decompression for the neuronal elements and may avoid extensive paraspinal muscular damage associated with conventional laminectomy. Patients demonstrated significant improvements in pain and overall health and function scores at a minimum 1-year follow-up. [Orthopedics. 2016; 39(5):e950-e956.]
to decompress the spine has been the gold standard for this condition. However, conventional decompression techniques have been associated with several complications.\(^5\,7\) It is theorized that some of the complications associated with traditional techniques are related to the detachment of the paraspinal muscles, specifically the multifidus,\(^8\) and the excessive dissection required for this technique.\(^5,7\) Several downsides have been described, including paraspinal muscle atrophy, epidural scarring, and iatrogenic instability.\(^5,7\) Due to these complications, various minimally invasive spine surgery techniques have been developed to try to accomplish the same surgical goals with less surgical morbidity. Although these techniques show promise, they generally require specialized equipment and more technical expertise and are associated with significant learning curves.\(^13\)

The spinous process–splitting laminoplasty described by Watanabe et al\(^14\,15\) as an alternative technique to decompress the lumbar spine has the advantage of a traditional midline approach that surgeons are familiar with. It also avoids the need for specialized tubular retractors. Preliminary results suggested excellent decompression with less muscular damage than both traditional and other tubular techniques to decompress the lumbar spine.\(^14\,25\) The current authors theorized that this would be similar in a group of North American patients and therefore set out to analyze the results of a cohort of patients undergoing this procedure at their institution. The central hypothesis of this study was that spinal process–splitting laminoplasty is effective for the treatment of lumbar canal stenosis. The authors sought to evaluate complications associated with this procedure, as well as clinical outcomes at a minimum 1-year follow-up.

**Materials and Methods**

Institutional review board approval was obtained for all aspects of the study. Patients were identified by conducting a comprehensive search of hospital medical and surgical databases, and those undergoing spinal process–splitting laminoplasty for lumbar spinal stenosis performed by the senior author (A.N.N.) at the authors’ institution were included. Between 2010 and 2012, 46 patients underwent lumbar spinal process–splitting laminoplasty at the authors’ institution. The medical records for all potential patients were reviewed. Thirty-seven (80%) patients were followed by the senior author at the outpatient spinal clinic for a minimum of 1 year, and these patients composed the study group.

**Patient Characteristics**

The cohort comprised 22 (59%) men and 15 (41%) women. Eight (22%) patients had undergone at least 1 prior spine surgery; of these, all except 1 had a single spine procedure. Four (11%) patients had a prior surgery involving the lumbar spine. All patients had both radiographs and either magnetic resonance imaging (MRI) or computed tomography (CT) myelography confirming a diagnosis of symptomatic lumbar spinal stenosis. In addition, 13 patients had spondylolisthesis at the symptomatic segment, 2 had retrolisthesis, and 6 had scoliotic deformity. Visual analog scale (VAS) pain scores were recorded preoperatively, with baseline back and leg pain means of 7±2.3 points and 6.4±3 points, respectively. Patients reported a mean preoperative Oswestry Disability Index (ODI) score of 40.2±15 points (n=35). Patients also reported mean scores of 29±13 points and 52.4±15 points for the physical and mental health components of the Short Form 36 (SF-36), respectively (n=16).

In this cohort, mean age at the time of the procedure was 68.4 years (range, 36-87 years). Mean body mass index was 27.7±5.1 kg/m\(^2\). Mean number of levels split was 2.2 (range, 1-6 levels). Twelve patients had a 1-level split, 12 had a 2-level split, 9 had a 3-level split, 3 had a 4-level split, and 1 had a 6-level split. Five (14%) patients had posterior spine fusion at the index procedure; 3 patients had a noninstrumented in situ fusion and 2 had an instrumented posterior fusion at the index procedure.

**Surgical Technique**

Templating, which is performed preoperatively, consists of identifying the anteroposterior axis of the spinal process and measuring its shortest depth to understand the spine anatomy for each patient and avoid overpenetration of the osteotomy into the spinal canal. The maximum anteroposterior depth of the spinal process above the spinal process junction with the dorsal lamina is chosen as the depth of the osteotomy. Using fluoroscopy, the spinal process to be osteotomized is identified and the skin is marked (Figure 1). The spinal process to be split is always superior to the interspace to be decompressed (eg, for an L3-4 decompression, the L3 spinal process would be split).

A midline skin incision is made, and the subcutaneous tissue is dissected until the thoracolumbar fascia is reached (Figure 2). A radiograph in the anteroposterior and lateral position is performed as a secondary pause with a spinal needle in the spinous process(es) to verify the level(s) to be split. The dorsal aspect of the cortical bone of the spinous process is then decorticated using a 2-mm round burr, and a #15 blade is used to incise the supraspinous and interspinous ligaments in...
line with the midsubstance of their fibers above and below the level to be split (Figure 3). The spinous process is then divided in 2 halves with a thin osteotome and detached from the spinous process lamina junction at the predetermined depth (Figure 4). All muscular attachments remain intact and attached to the lateral walls of each spinous process. A working space is made available by inserting a self-retaining retractor between the split halves of the spinous process until the medial edges of the facet joints are identified laterally (Figure 5).

Decompression is then performed under microscope or loupe magnification by removing the distal aspect of the superior lamina as well as the proximal aspect of the inferior lamina. The ligamentum flavum is resected, and lateral recess decompression is performed by undercutting the facet on both sides through a traditional midline approach (Figure 6). Bleeding is controlled with bipolar coagulation and hemostatic agents. Once decompression is achieved, a deep drain is placed, and the split spinous processes are approximated using transosseous restorable sutures (Figure 7). The supraspinous and interspinous ligaments are repaired with interrupted sutures.

Postoperatively, all patients are placed into a soft abdominal binder for comfort and activities are restricted to walking without trunk flexion/extension for 6 weeks. The procedure can be performed at multiple segments using a similar approach (Figure 8). In cases of fusion, fixation can be achieved through the same or paramedian incisions using the interval between the multifidus and the other paraspinal muscles.

Clinical Follow-up

Complications and reoperations were recorded from the medical records. All patients included in the study had a minimum 1-year follow-up. The follow-up duration was calculated until each patient’s latest clinical assessment. At the most recent evaluation, all patients were examined during their in-person visit to the outpatient clinic by the treating surgeon. Mean follow-up was 1.3 years (range, 1-2.4 years). In addition, patients completed a self-evaluation questionnaire containing components of the VAS for back pain and leg pain, ODI, and SF-36 assessment tools. Outcomes were measured using these assessment tools. The possible range of the VAS is 0 to 10 points, with higher scores indicating...
an increased pain severity. The possible range of the ODI is 0 to 100 points, with lower scores indicating better results. The possible range of the physical and mental health components of the SF-36 is 0 to 100 points, with higher scores indicating better results.

Statistical Analysis
Unless otherwise specified, continuous variables are presented as means±SD, and categorical variables are presented as numbers with proportions. Measured outcome values obtained at most recent follow-up were compared with their corresponding preoperative measured values using either paired t tests or Wilcoxon signed rank tests as appropriate. All statistical tests were 2-sided, and P values less than .05 were considered to be statistically significant. Statistical analyses were performed using JMP version 10.0.0 statistical software (SAS Institute Inc, Cary, North Carolina).

RESULTS
At a minimum 1-year follow-up (mean, 1.3 years; range, 1-2.4 years), patients experienced substantial improvements in pain and overall health and function after lumbar decompression with the use of the spinous process–splitting laminoplasty technique. There were statistically significant improvements in all collected patient-reported outcome scores. Mean VAS for back pain significantly improved from 6.8±2.3 points to 3±3 points at most recent follow-up (P<.0001) (n=37). Likewise, mean VAS for leg pain significantly improved from 6.4±2.6 points to 3±3 points at most recent follow-up (P<.0001) (n=37). In addition, mean ODI significantly decreased by 17.5±19.1 points (P<.0001) (n=35). At most recent follow-up, the ODI was graded as minimal disability (0-20 points) for 17 (46%) patients, moderate disability (21-40 points) for 14 (38%) patients, and crippling or severe disability (>40 points) for the remaining 6 (16%) patients. Mean SF-36 showed statistically significant improvement by 29±30.4 points (P=.0017) for the physical component and 21.8±25.6 points (P=.0062) for the mental health component (n=17) (Table).

Overall, 4 (10.8%) patients had a dural tear requiring repair, 3 (8%) developed neurological symptoms resulting from a compressive epidural hematoma requiring evacuation during the index hospital stay, 1 (2.7%) underwent irrigation and debridement for infection, and 2 (5%) underwent an additional decompression procedure for symptom recurrence secondary to instability. Intraoperatively, 3 patients had dural tears, which were repaired without incident during the same operative setting. Postoperatively, 5 (14%) patients underwent 1 or more reoperations, including 2 (5%) requiring further decompression. Of these 5 patients, 2 had hematoma evacuation during index hospital stay and 1 had late pseudomeningocele repair. The remaining 2 patients were reoperated twice. The first patient who underwent L4 spinous process–splitting laminoplasty for canal stenosis and spondylolisthesis had a hematoma evacuation during the index hospital stay, and then required a revision decompression of L3-S1 with posterior instrumentation and transfominal interbody fusion of L4-L5 for recurrent stenosis and worsening of preexisting instability at that segment with foraminal stenosis (after 0.77 years). The second patient who underwent L4 spinous process–splitting laminoplasty for canal stenosis underwent irrigation and debridement followed by a revision decompression of L4-L5 with posterior instrumentation and transfominal interbody fusion of L4-L5 for recurrent stenosis with spondylolisthesis and radiculopathy symptoms secondary to foraminal stenosis (after 1.82 years).

DISCUSSION
Spinous process–splitting laminoplasty is a recently reported technique to decompress the lumbar spine in a minimally invasive fashion. The rationale is to preserve the paraspinal muscles with
the assumption that this will result in quicker recovery and better long-term function in these patients (Figure 9). The current study cannot address all of these questions; however, it demonstrates that this procedure can be used safely to decompress the spine in a North American cohort of patients with spinal stenosis. In this study, patients demonstrated improvements in all key outcomes for pain and health-related quality of life measures at a minimum 1-year follow-up with complications that are comparable with those reported with conventional and other minimally invasive spine surgery techniques.26-29

In the current study, 4 (10.8%) patients had a dural tear with repair, 3 (8%) had a hematoma evacuation, 1 (2.7%) underwent irrigation and debridement for infection, and 2 (5%) required additional decompression with posterior fusion for persistent symptoms secondary to worsening instability. The reported number of dural tears is consistent with previous studies.27-29 Wang et al29 reported approximately 14% of patients with dural tears in a cohort of 641 patients who underwent lumbar spine surgery. Tsutsumimoto et al28 reported that approximately 5% of patients sustained dural tears in a cohort of 555 patients who underwent a microscopic lumbar decompressive procedure. Although the development of symptomatic epidural hematoma is infrequent after lumbar decompression surgery,26 the rate of postoperative hematoma requiring evacuation was high in the current study cohort (8%). The authors theorize that this is due to some continued bleeding postoperatively from the cut edges of the spinous process. This was a complication encountered early, before routine drain placement, and therefore it is likely

<table>
<thead>
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<th>Variable</th>
<th>Mean±SD</th>
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<tr>
<td>Hospital length of stay, d</td>
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<td>Intraoperative total blood loss,a mL</td>
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<td>Preoperative</td>
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<td>Last follow-up</td>
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<td>ODI score</td>
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<tr>
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<td>Last follow-up</td>
<td>71±20.3</td>
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Abbreviations: ODI, Oswestry Disability Index; SF-36, Short Form 36; VAS, visual analog scale.

aFor patients who did not have posterior fusion.
bFor all patients included in the study.
cData were missing for 2 patients.
dData were missing for 21 patients.

Figure 9: Preoperative axial T2-weighted magnetic resonance image of a 45-year-old man with a severe spinal canal stenosis at L2-L3 showing severe spinal canal stenosis (A). Postoperative axial T2-weighted magnetic resonance image showing adequate decompression with healed spinous process (arrow) and preserved paraspinal muscle bulk and signal without evidence of atrophy (B).
preventable. Subsequent to routine drain placement, no epidural hematomas were encountered.

A few studies have been published on lumbar spinous process–splitting laminoplasty or slight variations of this technique. These have included a brief description of the technique and reports on the clinical outcomes in patients with lumbar canal stenosis.\(^1\)\(^4\)\(^-\)\(^1\)\(^5\) Watanabe et al\(^1\)\(^4\) compared the clinical outcomes at a minimum of 2 years between 18 patients treated with spinous process–splitting laminectomy and 20 patients treated with conventional laminectomy for lumbar canal stenosis. They concluded that comparable clinical results can be achieved for both techniques based on the Japanese Orthopaedic Association (JOA) score. They also demonstrated significantly less muscular atrophy and fatty infiltration of the paraspinal muscles in patients undergoing spinous process–splitting laminectomy compared with traditional decompression based on postoperative MRI.\(^1\)\(^4\)

Cho et al\(^1\)\(^6\) compared the results of 40 patients undergoing a spinous process–splitting laminoplasty technique (Marmot technique) with 30 patients undergoing conventional laminectomy. They reported significant clinical improvements at 1 year favoring patients undergoing spinous process–splitting laminoplasty. They used the JOA score for low back disorders, theVAS for back pain, and the Prolo scale for function and employment status. They also noted that patients undergoing the spinous process–splitting laminoplasty had significantly lower creatine phosphokinase–muscular-type isoenzyme levels during the early postoperative period, indicating less muscle trauma with this technique.\(^1\)\(^6\)

Watanabe et al\(^1\)\(^5\) noted a significant improvement in wound pain during the early recovery period with no difference in activities of daily living in patients undergoing spinous process–splitting laminoplasty compared with those undergoing conventional laminectomy. They also noted that patients undergoing spinous process–splitting laminoplasty had significantly lower rates of atrophy of the paraspinal muscles on axial MRI 1 month postoperatively.\(^1\)\(^5\)

Rajasekaran et al\(^2\)\(^2\) conducted a randomized, controlled trail and compared outcomes at a minimum of 1 year (mean, 14.2 months) between 28 patients undergoing lumbar spinous process–splitting laminoplasty and 23 patients undergoing conventional decompression. They found no difference between the groups in number of decompressed levels, operative time, intraoperative blood loss, and length of hospital stay. They also reported no difference in clinical outcomes between patients based on JOA score, neurogenic claudication outcome score, VAS for back pain, and VAS for neurogenic claudication. Furthermore, there was no difference between patients in C-reactive protein and creatine phosphokinase–muscular-type isoenzyme levels on postoperative days 1 and 3. Thus, they could not establish the advantage of lumbar spinous process–splitting laminoplasty vs conventional decompression.\(^2\)\(^2\)

Although many studies focusing on the potential benefits of minimally invasive spine surgery to preserve the posterior musculature have failed to show long-term benefit over conventional techniques, several studies demonstrate some potential advantages to these techniques, including saving the paraspinal muscles, avoiding the detachment of tendons, and minimizing tissue retraction.\(^5\)\(^-\)\(^1\)\(^1\)\(^3\)\(^\)\(^0\) Gejo et al\(^3\)\(^0\) assessed postoperative back muscle injury in rats and reported that 2-hour retraction resulted in a high signal intensity for the multifidus muscles 21 days postoperatively. Histologically, these were also associated with small-diameter and large extracellular fluid space for the regenerating muscle fibers. Kim et al\(^9\) evaluated trunk extensor muscle strength following open vs minimally invasive spinal fusion and demonstrated a significantly better extension strength in the minimally invasive spinal fusion group. Kim et al\(^1\)\(^1\) studied serum skeletal muscle tissue injury markers and inflammatory cytokines in patients undergoing conventional posterior lumbar decompression and fusion vs patients undergoing a mini-open approach using tubular retractors. They found that patients who underwent the conventional technique had significantly higher levels of serum creatinine kinase, aldolase, pro-inflammatory cytokines (interleukin [IL]-6, IL-8), and anti-inflammatory cytokines (IL-10, IL-1 receptor antagonist) during the early postoperative period.\(^1\)\(^1\) Nevertheless, more studies are required to evaluate the potential benefits of this procedure on clinical outcomes and functional recovery in the long term.

The current study has some limitations, including its retrospective nature and the limited number of patients who underwent the proposed technique; thus, further analysis of the factors associated with the outcomes in these patients was difficult. Several patients were lost to follow-up, possibly due to a poor outcome, and therefore the complication rate may be underrepresented.

Despite these limitations, a strength of this study is that all patients were treated with the same technique performed by a single surgeon. This cohort also included all cases since adopting the technique, including early cases during the learning curve, which presumably may have a higher complication rate. To the authors’ knowledge, this series is the first to report the use of spinous process–splitting laminoplasty on a North American cohort of patients, demonstrating that this technique may be suited to this population.

**Conclusion**

Spinous process–splitting laminoplasty for the treatment of lumbar canal stenosis has favorable clinical outcomes with the potential advantage of avoiding extensive damage of the posterior spinal musculature. Future research using different study designs and comparing the
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