Endoscope-assisted spinal decompression surgery for lumbar spinal stenosis

Technical note

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Object. The authors undertook this study to document the clinical outcomes of microendoscopic laminotomy, a minimally invasive decompressive surgical technique using spinal endoscopy for lumbar decompression, in patients with lumbar spinal stenosis (LSS).

Methods. A total of 366 patients were enrolled in the study and underwent microendoscopic laminotomy between 2007 and 2010. Indications for surgery were single- or double-level LSS, persistent neurological symptoms, and failure of conservative treatment. Microendoscopy provided wide visualization through oblique lenses and allowed bilateral decompression via a unilateral approach, through partial resection of the base of the spinous process, thereby preserving the supraspinous and interspinous ligaments and contralateral musculature. Clinical symptoms and signs of low-back pain were evaluated prior to and following surgical intervention by applying the Japanese Orthopaedic Association (JOA) scoring system, Roland-Morris Disability Questionnaire (RMDQ), Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ), and 36-Item Short Form Health Survey (SF-36). These items were evaluated preoperatively and 2 years postoperatively.

Results. Effective circumferential decompression was achieved in all patients. The 2-year follow-up evaluation was completed for 310 patients (148 men and 162 women; mean age 68.7 years). The average recovery rate based on the JOA score was 61.3%. The overall results were excellent in 34.9% of the patients, good in 34.9%, fair in 21.7%, and poor in 8.5%. The mean RMDQ score significantly improved from 11.3 to 4.8 (p < 0.001). In all categories of both JOABPEQ and SF-36, scores at 2 years’ follow-up were significantly higher than those obtained before surgery (p < 0.001). Twelve surgery-related complications were identified: dural tear (6 cases [1.9%]), wrong-level operation (1 [0.3%]), transient neuralgia (4 [1.3%]), and infection (1 [0.3%]). All patients recovered, and there were no serious postoperative complications.

Conclusions. Microendoscopic laminotomy is a safe and very effective minimally invasive surgical technique for the treatment of degenerative LSS.

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Key words • clinical outcomes • endoscopic surgery • lumbar spinal stenosis • minimally invasive surgery
Microendoscopic laminotomy for lumbar spinal stenosis

in fusion technology, such as new internal fixation devices, interbody fusion cages, bone graft substitutes, and biological enhancement. However, degeneration may develop at mobile segments above or below a fused spinal segment; this phenomenon is known as adjacent-segment disease.14,22,31,32,34,42

Recently, minimally invasive surgical methods have been developed with a view to preserving the paraspinous muscles and the posterior elements—including the laminae, spinous processes, interspinous ligaments, and facet joints.14,22,31,32,34,42 Endoscopic surgery has been introduced for lumbar spinal disorders. However, there is a lack of detailed description of the procedures (for example, range of decompression achieved) that could help surgeons avoid dural tear or injury to neural tissue and the associated morbidity. In 1998, a minimally invasive laminotomy procedure using spinal endoscopy was developed and standardized to provide precise lumbar decompression. In this technique, called microendoscopic laminotomy, enlargement of the spinal canal provides safe relief of spinal nerve compression.42 It also allows maximal preservation of the facet joints, posterior ligament complex, and soft tissues. At least from our experience, microendoscopic laminotomy decreases the risk of some complications (for example, dural tear) and difficulties (for example, learning curve), which we otherwise associate with more invasive types of procedures. Here, we describe our use of microendoscopic laminotomy in the treatment of LSS and document our clinical outcomes in patients with this condition.

Methods

Microendoscopic Laminotomy for LSS

General endotracheal anesthesia is induced with adequate intravenous access and an intraarterial monitoring catheter. The patient is turned to the prone position on the Relton-Hall frame. The fluoroscopic C-arm is brought into the surgical field so that real-time posterior-anterior (PA) fluoroscopic images can be obtained. The disc level and interlaminar space are identified on the PA image, and the targeting point is marked on the side of approach (defined as the side with the most significant symptoms). The surgeon generally stands on the side of the approach and video monitors are placed opposite him or her. The approximate level of the incision is marked 1.0 to 2.0 cm off the midline at the approach side under PA fluoroscopic guidance. For spinal decompression, a skin incision of approximately 16 mm in length is made to target the interlaminar space. Serial tubal dilators of the METRx endoscopic system (Medtronic Sofamor Danek), which was developed by Smith and Foley for lumbar disc herniation, are inserted through the incision.34 A slightly medial angulation is desirable at this point to ensure optimal visualization of the interlaminar space and lateral recess during the procedure. The 16-mm final working channel is then passed over the dilators and secured to the flexible-arm METRx retractor mounted to the table side rail. Final fluoroscopic confirmation of the working channel position is obtained, and the serial dilators are removed. The endoscope is then attached to the tubular retractor. The precise localization is reconfirmed with PA fluoroscopy before the decompression procedure.

The decompression is performed under the endoscope’s 25° viewing angle, using the tubular retractor system. An endoscopic bipolar cautery is then used to remove any residual muscular and soft tissues overlaying the lamina and facet joint in the tubular retractor, with the bony edges well visualized. The endoscope-assisted procedure also allows bilateral decompression via a unilateral approach, the so-called unilateral approach and bilateral decompression, to decompress the central canal and bilateral lateral recesses. To preserve the integrity of the facet joint to the maximum possible extent, we used a high-speed drill with a specially designed long curved endoscopic bit (Midas Rex Institute) (Fig. 1), curved Kerrison rongeurs, and a curved ultrasonic aspirator (Sonopet, Stryker Endoscopy) to undercut the facet joint. The base of the spinous process was drilled first to secure the contralateral surgical field (Fig. 2). To obtain a wide and clear surgical field, after the drilling the tubular retractor is tilted upward to the midline as much as possible. The scope is rotated to a lateral position to make use of its 25° viewing angle. As a result of these maneuvers, an excellent viewing angle of nearly 60°–75° is usually obtained with good contralateral visualization (Fig. 3). The laminotomy is performed by using a long curved high-speed drill to thin the lamina near the attachment of the ligamentum flavum (Fig. 4). After adequate drilling, endoscopic Kerrison rongeurs are used to continue the removal of the lamina. The superior attachment of the ligamentum flavum is exposed, and the procedure is then continued to the medial facet complex and inferior lamina. Decompression of the bilateral lateral recesses is achieved by the medial trumpet facetectomy. The integrity of the facet joint is preserved by use of the above-mentioned curved instruments. The inferior attachment of the ligamentum flavum is exposed by drilling of the inferior lamina until immediately before the ligament. It is important to undertake these procedures without removing the ligamentum flavum to protect the dura and spinal nerve root. When the surrounding undercut is completed, the flavum itself is floating; attention is then directed to removal of the ligamentum flavum. Indeed, when the flavum is split along the midline, it begins to float. A small angled curette, nerve hook, or endoscopic Kerrison rongeurs can be used to gently dissect the ligament and to identify the plane between the ligamentum flavum and the underlying dura. When the ligamentum flavum is completely removed, dural pulsation is observed. After identifying the spinal nerve roots, foraminotomy is performed bilaterally (Fig. 5).

The endoscopic technique offers a unique advantage in the decompression of lumbar stenosis. Because the endoscopic lens is angled at 25°, the visualization of lateral recesses and foramina are superior to what can be achieved with the surgical microscope (Fig. 6). The adequacy of decompression is determined by observing pulsation of the dural sac and probing the traversing nerve roots to ensure their mobility. When decompression surgery is needed at an adjacent vertebral level, the tubular retractor is inclined at the midpoint between the selected intervertebral disc levels. Then, the procedure is performed as described above.
A drain is placed at each level to prevent epidural hematoma after surgery. The tubular retractor and endoscope are removed, and the fascia and skin are closed using standard techniques. The drain is kept in place at the operative level(s) for 48 hours to prevent the epidural hematoma after surgery.

Patient Population and Outcome Measures

This study was approved by the institutional review board of Wakayama Medical University. A total of 366 patients were prospectively enrolled in the study and underwent microendoscopic laminotomy between January 2007 and December 2010. Inclusion criteria were as follows: neurogenic claudication or radicular leg pain with associated neurological signs referring to the LSS syndrome; moderate to severe spinal stenosis on cross-sectional MRI; and failure of conservative treatment for at least 3 months. Dynamic radiographs were routinely obtained at 6 months, 1 year, and 2 years after surgery. Exclusion criteria included spinal stenosis with more than 3 affected levels, tumor, trauma, degenerative disease of the knee or hip, rheuma-
Microendoscopic laminotomy for lumbar spinal stenosis

toid arthritis, arterial insufficiency of the leg, polyneuropathy, pyogenic spondylitis, destructive spondyloarthropathy, other combined spinal lesions, or previous back surgery. The functional outcome assessment tools applied before surgical intervention and at the 2-year postoperative visit were the Japanese Orthopaedic Association (JOA) scoring system (maximum score 29 points),27,39 Roland-Morris Disability Questionnaire (RMDQ),4,12,21 and 36-Item Short Form Health Survey (SF-36).7 These scoring systems were applied only after consent for surgery was obtained. The results were recorded in the patient’s chart and did not form the basis for any decision-making. At the end of the study period of 2 years plus an additional year for collection of outcome information from the latest patients enrolled, the results were collated and analyzed. The clinical outcomes were based on the recovery rates, which were calculated following examination with the criteria proposed by the JOA score. The recovery rate was calculated as follows: recovery rate = 100 × (postoperative JOA score – preoperative JOA score)/(29 – preoperative JOA score).

The clinical results were classified into 4 grades according to improvement rate: excellent (75% and over), good (50%–74%), fair (25%–49%), and poor (< 25%). Treatment success was defined by an improvement of more than 25% in JOA score.

The data regarding intraoperative, perioperative, and postoperative complications were retrieved from the medical charts.

Statistical Analysis

All parameters were analyzed statistically. The Student t-test was used to compare pre- and postoperative JOA scores, recovery rates, and scores on the RMDQ, JOABPEQ, and SF-36. A p value of less than 0.05 was considered significant. The operating surgeon was not involved in the statistical analysis.

Fig. 4. Photograph obtained during microendoscopic laminotomy. The drilling is carried out with one hand. To protect the surgical site against mechanical vibration, the drill is held by the thumb and index and middle fingers; the middle or ring finger is placed on the tubular retractor; and the little finger is positioned against the skin.

Fig. 5. Intraoperative endoscopic photographs obtained during microendoscopic laminotomy. It is possible to confirm the interlaminar space by drilling a part of the lamina and medial facet complex (A). The contralateral surgical field can be accessed by partially resecting the base of the spinous process. A trumpet facetectomy is achieved by use of curved instruments (high-speed drill or Kerrison rongeurs) (B). When the undercut of the attachment of the ligamentum flavum is completed, the ligament itself floats. The flavum is split along the midline and floats like open wings (C). After identifying the plane between the ligamentum flavum and the underlying dura, the hypertrophied ligament is gently removed (D). Dural pulsation is observed on removing the ligamentum flavum. After identifying the spinal nerve roots, the lateral recesses are bilaterally decompressed (E). The adequacy of decompression is determined by observing pulsation of the dural sac and probing the traversing nerve roots to ensure their mobility (F). In all panels, left is cranial and right is caudal.
Results

We enrolled 366 patients who met the selection criteria. The 2-year follow-up evaluation was completed in 310 of the 366 patients (follow-up rate 84.7%; 148 men and 162 women). The analysis is based on data from these 310 cases. The patients’ mean age at surgery was 68.7 years (range 47–88 years). One hundred thirty-nine patients had degenerative LSS without degenerative spondylolisthesis or scoliosis, 143 patients had LSS and degenerative spondylolisthesis, and 28 patients had LSS and degenerative scoliosis. In total, 415 levels were decompressed in 310 patients. Two hundred five patients (66.1%) had single-level decompression and 105 (33.9%) had double-level decompression, all through a single surgical incision. The most frequently involved level was L4–5 (258 levels decompressed), followed by L3–4 (136 levels), L2–3 (12 levels), and L5–S1 (9 levels) (Table 1). Level determination depended on findings of plain radiography of the lumbar spine, which was performed in flexion and extension positions in the lateral view, as well as on MRI, myelography, and CT performed after myelography.

The average JOA score was 14.1 ± 4.2 points preoperatively and 22.6 ± 4.5 points at 2 years’ follow-up. The average JOA score recovery rate was 61.3% ± 24.3%. The overall results were excellent in 34.9% of the patients, good in 34.9%, fair in 21.7%, and poor in 8.5%. The preoperative JOA scores were lowest in patients with poor clinical outcome (p < 0.01). The average RMDQ score significantly improved from 11.3 ± 4.9 points preoperatively to 4.8 ± 5.4 points at 2 years’ follow-up (p < 0.001) (Table 2). In all 5 categories (low-back pain, lumbar function, walking ability, social life function, and mental health) of the JOABPEQ, scores at 2 years’ follow-up were significantly higher than those before surgery (p < 0.001) (Fig. 7). For the SF-36, scores on all subscales (physical functioning, role physical, bodily pain, social functioning, general health perceptions, vitality, role emo-

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**TABLE 1: Summary of demographic and clinical characteristics in 310 patients**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>sex</td>
<td></td>
</tr>
<tr>
<td>male</td>
<td>148</td>
</tr>
<tr>
<td>female</td>
<td>162</td>
</tr>
<tr>
<td>age in yrs</td>
<td></td>
</tr>
<tr>
<td>mean</td>
<td>68.7</td>
</tr>
<tr>
<td>range</td>
<td>47–88</td>
</tr>
<tr>
<td>coexisting disease</td>
<td></td>
</tr>
<tr>
<td>LSS alone</td>
<td>139</td>
</tr>
<tr>
<td>LSS + spondylolisthesis</td>
<td>143</td>
</tr>
<tr>
<td>LSS + scoliosis</td>
<td>28</td>
</tr>
<tr>
<td>level of decompression (no. of levels)</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>415</td>
</tr>
<tr>
<td>L2–3</td>
<td>12</td>
</tr>
<tr>
<td>L3–4</td>
<td>136</td>
</tr>
<tr>
<td>L4–5</td>
<td>258</td>
</tr>
<tr>
<td>L5–S1</td>
<td>9</td>
</tr>
<tr>
<td>single-level surgery</td>
<td>205 (66.1)</td>
</tr>
<tr>
<td>2-level surgery</td>
<td>105 (33.9)</td>
</tr>
</tbody>
</table>

* Data are reported for the 310 patients who completed 2-years’ follow-up (84.7% of the 366 originally enrolled in the study). Values represent numbers of patients (%) except in the category “level of decompression.”

**TABLE 2: Outcomes of functional evaluation in 310 patients**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>JOA score</td>
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<tr>
<td>preop</td>
<td>14.1 ± 4.2</td>
</tr>
<tr>
<td>2-yr follow-up</td>
<td>22.6 ± 4.5</td>
</tr>
<tr>
<td>recovery rate (%)</td>
<td>61.3 ± 24.3</td>
</tr>
<tr>
<td>excellent</td>
<td>34.9</td>
</tr>
<tr>
<td>good</td>
<td>34.9</td>
</tr>
<tr>
<td>fair</td>
<td>21.7</td>
</tr>
<tr>
<td>poor</td>
<td>8.5</td>
</tr>
<tr>
<td>RMDQ score</td>
<td></td>
</tr>
<tr>
<td>preop</td>
<td>11.3 ± 4.9</td>
</tr>
<tr>
<td>2-yr follow-up</td>
<td>4.8 ± 5.4</td>
</tr>
</tbody>
</table>
Microendoscopic laminotomy for lumbar spinal stenosis

tional, and mental health) were significantly increased at 2 years' follow-up as compared with preoperative scores (p < 0.001) (Fig. 8). There were no significant differences in improvement in JOA score, RMDQ, JOABPEQ, or SF-36 among patients with LSS alone, those with coexisting degenerative spondylolisthesis, or those with coexisting degenerative scoliosis. In total, 12 surgery-related complications were identified: dural tear (6 cases [1.9%]), wrong-level operation (1 [0.3%]), transient neuralgia (4 [1.3%]), and infection (1 [0.3%]). In the 2 cases of dural tear, the dura was endoscopically sutured; in the other 4 cases, the dura was repaired by patch technique using a polyglactin sheet. All neurological symptoms improved with conservative treatment. There was no progression of preexisting spondylolisthesis or scoliosis (Fig. 9). The average rate of slip in patients with coexisting degenerative spondylolisthesis was 16.3% ± 6.9% preoperatively and 17.3% ± 6.8% at the 2-year follow-up evaluation. The average Cobb angle (L-1 to L-4) in patients with coexisting degenerative scoliosis was 30.7° ± 16.4° preoperatively and 33.3° ± 15.7° at the 2-year follow-up visit. However, increased bulging of the intervertebral disc and progression of spinal instability was observed at the affected levels in 4 and 3 patients, respectively. The 3 patients who had progression of instability underwent an additional spinal fusion (transforaminal lumbar interbody fusion [TLIF]). All consecutive patients who had 1) single- or double-level degenerative lumbar spondylolisthesis and 2) evidence of associated spinal stenosis were enrolled in this study. These included, on the basis of preoperative flexion-extension dynamic radiographs, 18 patients with more than 25% slippage, 58 patients with more than 5% slippage instability, and 16 patients with more than 10° of posterior opening spinal instability. Their average recovery rate was 62.5%. The overall result was poor in 12%. Of the 3 patients who underwent an additional spinal fusion (TLIF), one had 3 of the above-mentioned spinal instability elements (more than 25% slippage, more than 5% slippage instability, and more than 10° of posterior opening spinal instability, and the other 2 patients each had 2 of the 3 spinal instability elements.

Discussion

Advances in the management of LSS have been slow in coming. Nevertheless, an increasing number of patients are requiring surgical treatment. Here, we demonstrate that the endoscope-assisted spinal decompression procedure known as microendoscopic laminotomy is a safe and very effective minimally invasive surgical technique for degenerative LSS. The microendoscopic decompression technique for lumbar disorders involves bilateral decompression surgery using the unilateral approach, and the procedure has been gradually and successfully applied to the treatment of LSS. However, the surgical procedure has not yet been established internationally. Because of a lack of standardization, the rate of perioperative complications and the surgical results vary, hindering recognition of microendoscopic spinal surgery as a standard surgery. One of the main barriers to this is the skill level of a surgeon. We have worked and improved microendoscopic spinal surgery since 1998, and herein describe it in detail. Briefly, this surgical method involves resecting the bilateral laminae from the base of the spinous process using a special air-tome. The procedure decreases perioperative complications and increases postoperative stability. Moreover, it is possible to completely preserve the contralateral facet joint. In our previous investigation on facet joint resection rate after microendoscopic decompression surgery for lumbar spinal stenosis, we found that about 70% of the facet joints were preserved in the side of the approach and more than 95% were preserved in the contralateral side (unpublished data). However, maximal preservation of the facet joints is important for preventing the progression of spinal instability after surgery. In the present study, the most commonly encountered surgery-related complication was durotomy, which has been reported elsewhere in approximately 8% of all cases of microendoscopic decompression surgery. The incidence was comparable with and even lower than the reported incidence of 18% in most series of open laminectomy for LSS. However, it
is possible that dural tear is associated with the surgeon’s learning curve, surgical approach, and severity of stenosis, because most cases occurred during the early development of the technique, in patients undergoing unilateral laminotomy for bilateral decompression or in patients with severe stenosis. As shown in this study, improvement of the technique has resulted in an excellent viewing angle with good contralateral visualization. Hence, even in patients with severe stenosis, a dorsal space was first made by the bony procedure, and the spinal decompression could be carried out more easily. Consequently, the incidence of dural tear complications has decreased. In addition, the ligamentum flavum is preserved as a protective barrier for the dura mater until completion of the bony procedure. Gentle manipulation of the neural tissues and extensive surgical experience and skill of the surgeon may alleviate the risk of such complications.

Our study has 2 major limitations: 1) it lacks a control group for comparison and 2) the follow-up period is too short to establish long-term benefits. Longer studies performed in the future should also focus on the duration of symptom relief, risk of postoperative instability and re-stenosis, and incidence of reoperation.

Conclusions

Microendoscopic laminotomy, a minimally invasive surgical technique using spinal endoscopy, is a safe procedure and could be the standard surgical treatment for LSS.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Minamide. Acquisition of data: Maio, Tsutsui. Analysis and interpretation of data: Hashizume. Drafting the article: Nakagawa, Iwasaki. Critically revising the article: Minamide, Yoshida, Yamada, Nakagawa, Maio, Hashizume, Iwasaki, Tsutsui. Reviewed submitted version of manuscript: Minamide, Yoshida, Yamada, Nakagawa, Maio, Hashizume, Iwasaki, Tsutsui. Approved the final version of the manuscript on behalf of all authors: Minamide. Statistical analysis: Hashizume. Administrative/technical/material support: Yoshida, Kawai. Study supervision: Yoshida.

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Microendoscopic laminotomy for lumbar spinal stenosis


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