Degenerative changes of the lumbar spine are an important cause of morbidity in adults. Changes include lumbar spinal stenosis with neurogenic claudication as well as lumbar disc herniation, both of which can lead to back pain, sciatica, and radiculopathy. It is estimated that at least 30% of people between 30 and 50 years of age will have some degree of disc degeneration, although not all will experience pain. In symptomatic patients, failure of nonoperative treatment usually leads to surgical intervention. Spinal stenosis, for example, is a condition that is one of the most frequent indications for spinal surgery in patients > 65 years of age.\(^2\) The first successful surgical treatment for lumbar disc herniation was reported in 1934.\(^12\) Surgical discectomy has become the standard operative technique for lumbar disc herniations and was established in the 1970s in Europe by Caspar\(^1\) and Yasargil\(^29\) and in the US by Williams\(^26\) and Wilson and Kenneth.\(^27\) In recent years the use of tubular retractors for microsurgical decompression of degenerative spinal disease is a safe and effective treatment modality. As with other techniques, minimally invasive procedures are associated with a significant learning curve. As surgeons become more comfortable with the procedure, its applications can be expanded to include, for example, spinal instrumentation and deformity correction.

**Object.** The authors present their clinical results and the learning curve associated with the use of tubular retractors for 1- and 2-level lumbar microscope-assisted discectomies and laminectomies.

**Methods.** The study involves a retrospective and prospective analysis of 230 patients who underwent noninstrumented minimally invasive procedures for degenerative lumbar spinal disease between 2004 and 2007. Data on patient demographic characteristics and operative results, including length of stay, blood loss, operative times, and surgical complications were collected. Clinical outcomes were assessed based on pre- and postoperative Visual Analog Scale scores, Oswestry Disability Index values, and the Macnab outcome scale scores.

**Results.** The results showed characteristic differences in blood loss and operating times between 1- and 2-level procedures and between discectomies and laminectomies. A significant learning curve was seen by a decrease in operating time for 1-level discectomies and 2-level laminectomies. Major complications were not observed.

**Conclusions.** The use of tubular retractors for microsurgical decompression of degenerative spinal disease is a safe and effective treatment modality. As with other techniques, minimally invasive procedures are associated with a significant learning curve. As surgeons become more comfortable with the procedure, its applications can be expanded to include, for example, spinal instrumentation and deformity correction.

(DOI: 10.3171/FOC/2008/25/8/E14)

**Key Words.** • laminectomy • microdiscectomy • minimally invasive surgery • spine • tubular retractor

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**Abbreviations used in this paper:** CSF = cerebrospinal fluid; EBL = estimated blood loss; LMD = lumbar microdiscectomy; LOS = length of hospital stay; ODI = Oswestry Disability Index; VAS = Visual Analog Scale.
TABLE 1
Demographic data in 230 patients with degenerative lumbar spine disease

<table>
<thead>
<tr>
<th>Factor</th>
<th>LMD</th>
<th>Laminectomy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-Level</td>
<td>2-Level</td>
</tr>
<tr>
<td>no. of patients</td>
<td>141</td>
<td>14</td>
</tr>
<tr>
<td>sex (M/F)</td>
<td>75.66</td>
<td>9.5</td>
</tr>
<tr>
<td>age in yrs mean ± SD</td>
<td>48.3 ± 13.1</td>
<td>43.4 ± 13.9</td>
</tr>
<tr>
<td>range</td>
<td>22–85</td>
<td>18–65</td>
</tr>
<tr>
<td>disc level (%)</td>
<td>L2–3</td>
<td>2 (1.4)</td>
</tr>
<tr>
<td></td>
<td>L3–4</td>
<td>8 (5.6)</td>
</tr>
<tr>
<td></td>
<td>L4–5</td>
<td>55 (39)</td>
</tr>
<tr>
<td></td>
<td>L5–S1</td>
<td>76 (54)</td>
</tr>
<tr>
<td></td>
<td>L2–3, L3–4</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>L3–4, L4–5</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>L4–5, L5–S1</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>L4–5, L1–2</td>
<td>NA</td>
</tr>
</tbody>
</table>

* NA = not applicable; SD = standard deviation.

TABLE 2
Results in 230 patients treated with LMD or laminectomy

<table>
<thead>
<tr>
<th>Factor</th>
<th>LMD</th>
<th>Laminectomy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-Level</td>
<td>2-Level</td>
</tr>
<tr>
<td>no. of patients</td>
<td>141</td>
<td>14</td>
</tr>
<tr>
<td>mean LOS in days ± SD</td>
<td>1.0 ± 0.86</td>
<td>1.0 ± 0.63</td>
</tr>
<tr>
<td>mean EBL in ml ± SD</td>
<td>16.9 ± 37.0</td>
<td>16.9 ± 24.9</td>
</tr>
<tr>
<td>range</td>
<td>10–300</td>
<td>10–100</td>
</tr>
<tr>
<td>% of cases w/ minimal blood loss (≤10 ml)</td>
<td>94.1</td>
<td>92.3</td>
</tr>
<tr>
<td>mean op time in min ± SD</td>
<td>68.7 ± 25.9 (117)</td>
<td>104.1 ± 31.4 (14)</td>
</tr>
<tr>
<td>2004–2005</td>
<td>96.2 ± 29.4 (5; 5)</td>
<td>no cases</td>
</tr>
<tr>
<td>2005</td>
<td>77.5 ± 24.9 (39; 41)†</td>
<td>112.8 ± 39.7 (6; 6)</td>
</tr>
<tr>
<td>2006</td>
<td>65.4 ± 25.3 (44; 56)</td>
<td>97.5 ± 24.3 (8; 8)</td>
</tr>
<tr>
<td>2007</td>
<td>57.1 ± 20.6 (29; 39)</td>
<td>no cases</td>
</tr>
</tbody>
</table>

* The first number in parentheses denotes the number of cases in which data were available; the second number denotes the total number treated in that category.
† Significant versus 2007; p < 0.05.
‡ Significant versus 2005; p < 0.001.

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Surgical Technique

The microendoscopic tubular approach was originally described by Foley and colleagues in 1999. The operative technique used was a modification of what has been described previously. Briefly, patients were placed prone on a Wilson frame on a Jackson table. The operative level was identified using fluoroscopy. A small skin incision was made ~ 1 cm lateral to the midline on the side of the main disorder. A METRx tubular retractor (Medtronic Sofamor Danek, Inc.) was placed over serial dilators and fixed in place with a table-mounted arm. The surgeons used 14-, 16-, 18-, or 22-mm-diameter tubular retractors for these operations. The correct level was reconfirmed with fluoroscopy. An operating microscope (Carl Zeiss, Inc.) was used during these operations. The microscope was brought in and a laminotomy was performed using a 3-mm fluted curved matchstick bur (Anspach). For disc herniations, a standard microsurgical discectomy was performed. In patients with lumbar spinal stenosis, the tubular retractor was directed more medially, and bilateral laminectomies were performed by undercutting the spinous process using the matchstick bur and Kerrison rongeurs. Ipsilateral and contralateral decompression were achieved by resection of ligamentous hypertrophy in the lateral recesses. If a CSF leak was observed, it was covered with DuraSeal (Confluent Surgical, Inc.). At the conclusion of the procedure, the operative field was irrigated with antibiotic solution, the tubular retractor was removed, and every attempt was made to close the lumbosacral fascia before skin closure was done.

Patient Evaluation

Patients were divided into 4 groups: 1-level LMD, 2-level LMD, 1-level laminectomy, and 2-level laminectomy. The operative variables that were analyzed were the level and side of the procedure, the LOS, EBL, and operating time. The complication variables that were assessed included CSF leak rate, number of reoperations, infection rate, and neurological injury. Lastly, patient outcome was analyzed pre- and postoperatively based on the VAS, ODI, and the Macnab criteria outcome scale. In the Macnab scale, patient outcomes were classified as excellent, good, fair, or poor based on follow-up visits. Grading of patient outcomes that could not be obtained from a follow-up visit.
was done over the phone. These variables were obtained from patient medical records, operative and anesthesia reports, and clinical visits, which had been placed in a database for review.

Statistical evaluation was performed on EBL, operating time, and ODI and VAS scores. Statistical significance was measured using a one-way analysis of variance for EBL and operating time, with post-hoc tests of the Tukey test and Dunnet method, respectively. A Student t-test was used to assess statistical significance for ODI and VAS scores.

## Results

### Demographic Data

The majority of patients underwent either 1-level LMD or 1-level laminectomy (141 and 49 patients, respectively; see Table 1). Ten patients in the laminectomy group underwent surgery for decompression of a facet joint cyst, whereas all other patients presented with either herniated lumbar disc or degenerative spinal stenosis. Most patients underwent surgery for disorders at the L4–5 or L5–S1 levels. Other patient demographic data were not significant for any particular procedural group.

### Operative Results

Data on LOS, EBL, and operating times are given in Table 2. The mean LOS was between 1 and 1.4 days. The mean EBL for each LMD and each laminectomy procedure was similar. The EBL was higher in laminectomy compared with LMD procedures. There was no statistical significance across procedures and over the time period of 2004–2007 for blood loss, probably because of high standard deviations (data not shown). The mean operating time between 2004 and 2007 increased with the complexity of the procedure; it was 68.7 minutes for 1-level LMD and 134.9 minutes for 2-level laminectomy. There was a learning curve resulting in shorter operating times for all procedures between 2004 and 2007 (see also Fig. 1). Significance was seen between 2004 and 2005 in comparison to 2007 (p < 0.05) in 1-level LMD and between 2006 and 2007 compared to 2005 in 2-level laminectomy (p < 0.001). In the majority of cases 16- and 18-mm-diameter tubular retractors were used for microdiscectomies, and 18- and 22-mm retractors were used for laminectomies.

### Surgery-Related Complications

There were no serious complications in this patient population. Intraoperative dural tears were observed in 12 patients who underwent LMD and in 7 who underwent laminectomy (Table 3). Based on our analysis, the incidence of dural tears appeared to be increased when operating from the left side. There were no postoperative complications attributable to durotomy, including pseudomeningocele or infection. Intraoperatively, all leaks were covered with a thin layer of DuraSeal. An attempt was always made to close the lumbodorsal muscle fascia and patients were kept flat for ~12 hours after surgery.

One patient developed a superficial wound infection that required drainage and treatment with intravenous antibiotics. A total of 8 patients required a second operation for a recurrent disc herniation. The patients requiring another operation in the laminectomy group had originally undergone a discectomy in addition to removal of the lamina.

One patient had new onset of dorsiflexion weakness after resection of a L4–5 facet joint cyst, although his preoperative radicular pain completely resolved. At the most recent follow-up his weakness had resolved and he was classified under “good outcome” on the Macnab outcome criteria. No other neurological or medical complications were seen in this patient population.

### Clinical Results

A total of 198 patients was available for outcome assessment performed using the Macnab criteria, with a mean follow-up time of 5.8 months (range 0.25–36 months). Of these patients, 78 had ≥3 months of follow-up, with a mean follow-up duration of 9 months, as depicted in Fig. 2. According to the Macnab criteria, each bar is divided into 4 outcome categories: excellent, good, fair, or poor. In 78 patients, 15% had excellent, 51.8% had good, 25.5% had fair, and 7.5% had poor outcome. In the overall group of 198 patients, these outcome results were very similar (20.8, 51.8, 25.5, and 7.5% respectively).

---

**TABLE 3**

Complications in 230 patients with degenerative lumbar spine disease

<table>
<thead>
<tr>
<th>Factor</th>
<th>LMD 1-Level</th>
<th>LMD 2-Level</th>
<th>Laminectomy 1-Level</th>
<th>Laminectomy 2-Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of patients</td>
<td>141</td>
<td>14</td>
<td>49</td>
<td>26</td>
</tr>
<tr>
<td>CSF leak rate</td>
<td>12 (8.5%)</td>
<td>0</td>
<td>5 (10.2%)</td>
<td>2 (7.7%)</td>
</tr>
<tr>
<td>no. w/ lt/rt approach to CSF leak</td>
<td>10/2</td>
<td>NA</td>
<td>3/2</td>
<td>1/1</td>
</tr>
<tr>
<td>infection requiring IVA</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>reops (% of total cases)</td>
<td>4 (2.8%)</td>
<td>2 (14.3%)</td>
<td>1 (2.0%)</td>
<td>1 (3.8%)</td>
</tr>
</tbody>
</table>

* IVA = intravenous antibiotics.
Six patients presented preoperatively as surgical emergencies with a cauda equina syndrome; 5 of these underwent laminectomies. All of these patients improved clinically after surgery, with all classified under “good” based on the Macnab criteria.

Of the total number of surgically treated patients in this group, 60 provided information on VAS- and ODI-assessed outcome follow-up data pre- and postoperatively. We demonstrated a statistically significant improvement in VAS-reported back pain (preoperative VAS Score 7.17, postoperative Score 2.64) and leg pain (preoperative Score 8.26, postoperative Score 2.83) (Fig. 3). The mean ODI value improved from 56 to 26.4 postoperatively (range 1–24 months; p < 0.001) (Fig. 4).

**Discussion**

Open microsurgical decompression for lumbar spinal stenosis and disc herniations are among the most successful and satisfying operations in spinal surgery.\(^1,3,7,15,26\) The effectiveness of lumbar microdiscectomy to treat patients with disc herniations has recently been documented in a number of prospective randomized trials in which open surgery was compared to conservative treatment.\(^17,25\) Not too long after the introduction of microsurgery in the 1970s, interest grew among surgeons to minimize further the tissue trauma associated with the access to the disease. In 1993, Mayer and Brock\(^11\) mentioned the use of the endoscope for a percutaneous approach to the lumbar disc. Subsequently, the microendoscopic tubular approach was described by Foley and colleagues in 1999.\(^4\) In 1998, they presented results for their first 100 patients (Smith MM et al., unpublished data). They used a tubular retractor combined with the endoscope to perform a laminotomy, medial facetectomy, foraminotomy, and discectomy. Microendoscopic discectomy and open discectomy have subsequently been found to be equally effective for the treatment of lumbar disc herniations.\(^8,18,19,28\) Only a few surgeons are familiar with use of the endoscope, and therefore standard microscopic techniques have been adopted to perform the same operation as with the endoscope.\(^14,21\) In addition, microscopic compatibility affords the surgeon 3D visualization of the surgical anatomy. Operating through tubes has evolved as a promising alternative that seems to be associated with decreased muscle trauma. Measuring various serum markers of tissue trauma such as C-reactive protein and systemic cytokines after microendoscopic versus open lumbar discectomy and decompression procedures demonstrates that microendoscopic surgery is associated with a lower level of inflammatory parameters, suggesting decreased invasiveness.\(^5,13,22,23\)

Since 2004, we have exclusively used tubular retractors for 1- and 2-level microscope-assisted decompressive surgery in the lumbar spine. In this study, we summarized our clinical results in 230 consecutive patients treated for lumbar disc herniations, lumbar spinal stenosis, and lumbar facet joint cysts.

**Operative Results**

Our data on operating time, EBL, and LOS compare
favorably to published results on open microsurgery as well as endoscope- or microscope-assisted tubular surgery.\textsuperscript{8,18,19,21,29} As depicted in Tables 4 and 5, in experienced hands, operating times for endoscope- and microscope-assisted tubular surgery are comparable to open microsurgery, whereas blood loss is frequently reduced with tubular approaches.

Learning Curve

As with all new operative techniques, there is a learning curve associated with tubular microsurgery that has to be taken into consideration. Wu et al.\textsuperscript{28} compared their data on operating times, blood loss, and pain scores in endoscope-assisted tubular surgery for lumbar disc herniation to standard open microsurgery. Over the course of 3 years they documented a significant improvement in the first 2 parameters. Similar findings were reported by Perez-Cruet et al.,\textsuperscript{16} and this is also reflected in our results; over the course of 4 years a significant decrease in operating times when using the tubular retractors was observed (Table 2 and Fig. 1).

Surgery-Related Complications

Except for 1 patient who experienced transient foot weakness after decompression for a facet joint cyst, we observed no neurological complications. This compares favorably to the literature, in which neurological complications after microendoscopic decompression have been reported in up to 10.5\% of cases.\textsuperscript{6,13} Our overall reoperation rate was 5.7\%, and all reoperations were for recurrent disc herniations. This rate was similar to Palmer’s\textsuperscript{13} series of 135 patients undergoing tubular surgery for lumbar disc herniations, and it compares favorably to the rates reported by others, which were between 3 and 14\%.\textsuperscript{1,6,15,18,26} Our overall CSF leak rate of 6.6\% was comparable to data recorded in the literature (Tables 4 and 5). None of our patients required bed rest for 12 hours and there were no delayed adverse consequences of intraoperative dural tears. We attribute the benign course of CSF leaks to the fact that the muscle-splitting approach with tubular retractors results in minimal dead space after removal of the retractor, which seals the epidural space and prevents formation of an epidural CSF collection.

Study Limitations

There are a number of limitations to this study. First, the retrospective nature of the study made it difficult to obtain reliable outcome information on all patients. There was a limited number of patients who could be analyzed for pre- and postoperative VAS and ODI scores. Prospective data collection including standardized outcome parameters is currently underway. Second, our data do not include information on intraoperative fractures of the pars, which may occur, especially at the beginning of the learning curve with tubular surgery, during which orientation within the limited surgical field may be difficult. This was reported in 2.6\% of cases in the series presented by Ikuta et al.\textsuperscript{6} We did not record this in our database, but we recognize this phenomenon as a potential risk. We did not see any postoperative instability in our patients requiring fusion that would have initiated further workup.

Conclusions

The results of this study point out the learning curve associated with microscope-assisted tubular spinal surgery. Operating time decreased over the study period. Overall,
our results indicate that minimally invasive surgery in which tubular retractors are used for muscle-sparing access to spinal degenerative disorders is safe and effective. We consider these techniques essential as an initial step toward using minimally invasive surgery for other procedures, such as spinal fusion and deformity correction.

Disclaimer

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

Acknowledgments

We thank Robby Bowles and Sydni Meyrowitz for their help in developing the database and with statistical analysis. We also thank Synthes Spine for the educational grant, which supports Dr. Tomasiño’s Spine Research Fellowship.

References


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