Functional and clinical evaluation for the surgical treatment of degenerative stenosis of the lumbar spinal canal

Clinical article

BARİŞ YAŞAR, M.D.,1 SERKAN ŞİMŞEK, M.D., PH.D.,1 UYGUR ER, M.D.,1 KAZIM YİĞİTKANLI, M.D.,1 EMEL EKİSƏƏĞLU, M.D.,2 TIBET ALTUĞ, M.D.,3 DENİZ BELEN, M.D.,1 ZAFA H. KARS, M.D.,1 AND MURAD BAYBEK, M.D.1

1Second Neurosurgery, 2Physical Therapy, and 3Orthopedic Surgery Clinics, Dişkapı Yıldırım Beyazıt Training and Research Hospital, Ankara, Turkey

Object. This study was designed to evaluate the efficacy of decompressive surgery for degenerative lumbar spinal stenosis (LSS) on a functional and clinical basis.

Methods. A prospective analysis and follow-up of 125 consecutive patients with degenerative LSS between 2000 and 2006 were performed. All patients underwent surgery for lumbar stenosis. Functional evaluations of the patients were performed using a treadmill, the visual analog scale, and the Oswestry Disability Questionnaire (ODQ). These parameters were recorded before surgery and the 3rd month and 1st and 2nd years after treatment. The first symptom time (FST), maximal walking duration (MWD), and thecal sac cross-sectional area (CSA) before and after surgery were also recorded. Statistical relations between variables were calculated.

Results. As patient ages increased, the CSA of the thecal sac decreased. Decompressive surgery reached the target according to the difference between the preoperative and postoperative thecal sac CSA. A correlation between the CSA of the thecal sac and FST, and between the CSA of the thecal sac and MWD could not be established. There was a significant correlation between the FST and MWD, and a negative correlation could be established between the MWD and the ODQ score. Surgery led to significant decreases in the ODQ score. Maximal improvement was observed in the 3rd month after decompressive surgery.

Conclusions. The treatment for LSS should be decided using functional criteria; radiological criteria may not correlate with the severity of the disease. Improvements following lumbar decompression surgery continued within 1 year of treatment according to the ODQ and did not change significantly thereafter. (DOI: 10.3171/2009.3.SPINE08692)

KEY WORDS • decompression • functional measurement • surgery • lumbar spinal stenosis

Since the first description of LSS in 1911,7 one of the most useful definitions of this well-known entity is “a disproportion in the spinal canal between the size of the neural elements and the space available.”15 Compression of the thecal sac and its neural contents can cause pain and neural symptoms.10,17,23 The most common cause of the LSS is degenerative changes in the discs, facet joints, ligamentum flavum, or vertebral bodies.3,15 Lumbar stenosis results in part from hypertrophy of the ligamentum flavum. It is postulated that the hypertrophied ligamentum flavum may lose its elasticity and thus fold into the spinal canal, which leads to compression of the dural tube.2,3,5,15 Narrowing of the spinal canal can intensify if degenerative changes are superimposed on preexisting conditions.15,27 Any factor leading to additional narrowing of the spinal canal, such as axial loading and hyperextension bending, will typically worsen clinical symptoms.21,28 The clinical symptoms of spinal canal narrowing may not be accurately reflected on radiological studies. Despite significant spinal narrowing, some patients may have only minor symptoms—but the reverse situation is also common.3 Consequently, the long-term results of surgery are not well understood. This study was designed to evaluate the efficacy of decompressive surgery on a functional and clinical basis.

Methods

Patient Population

Adult patients with radiologically confirmed neurological claudication were included in the study; confir-
mation was based on the thecal sac CSA on axial CT. A thecal sac CSA < 100 mm² was considered to be narrowing of the spine. Walking for no more than 15 minutes without symptoms was regarded as neurological claudication.

Patients who were able to walk for 15 minutes without any symptoms; who had a neurological, cardiovascular, or pulmonary disease; or who had critical stenosis of the aorta, uncontrolled hypertension, osteoarthrosis in the knee joint, osteoarthrosis in the hip joint, and peripheral arterial or nerve disease were not included in the study. Those who had a history of lumbar or lower extremity surgery or major lumbar trauma, whose MR images demonstrated fragmented or extruded disc herniations, or whose thecal sac CSA was > 100 mm² on axial CT also were not included in the study.

One hundred thirty-five consecutive patients with narrow spinal canals who had been surgically treated at the Dişkapı Yıldırım Beyazıt Training and Research Hospital, Ankara, Turkey, between 2001 and 2006 were included in this prospectively designed clinical study. Ten patients failed to report for follow-up; thus, the remaining 125 patients (73 women and 52 men) who could be followed up for 2 years made up our study sample. The institutional review and ethics board of the hospital reviewed this project and approved the protocol. Written informed consent was obtained from all the patients or their relatives.

Seventy-three women and 52 men had a mean age of 58 ± 11 years (range 36–79 years) at the time of surgery. The mean age of the women was 60.8 ± 11 years, and of the men 56.5 ± 10.7 years. The majority of patients were in the 6th or 7th decade of life. The mean weight of the patients was 77 ± 12 kg.

One hundred seventeen patients (93.6%) suffered from the leading symptom of low back pain. Other frequently observed symptoms included numbness of the lower extremities (98.4%), leg pain (90.4%), neurological claudication (95.2%), and weakness of the lower extremities (73.6%). Urinary incontinence as an initial symptom was seen in only 2 patients. The duration of symptoms had ranged from 0–2 years to 15–20 years (see Table 2). Most patients had been symptomatic for 0–2 or 3–5 years (38.4 and 30.4%, respectively). The medical history of 46 patients (36.8%) revealed an asymptomatic minor lumbar trauma before the operation.

Patient Assessments

Functional and clinical evaluations of the patients were performed before and after treatment by using a treadmill, the visual analog scale, and the ODQ. These parameters were recorded before surgery and the 3rd month and 1st and 2nd years after treatment (Table 1). Evaluation with the treadmill at a speed of 2 km/hour with a 0° slope was performed after 10 minutes of resting. The FST, the time it took for the first cardiovascular or claudication symptoms to appear during the treadmill test, and MWD, the maximum amount of time a patient could walk during the treadmill test, were recorded. The treadmill test was finished if the patient walked for 15 minutes or if cardiovascular symptoms appeared. The median preoperative FST (pre-FST) in patients on the treadmill was 172 ± 100 seconds (range 23–400 seconds). The median preoperative MWD (pre-MWD) on the treadmill was 410 ± 208 seconds (range 85–860 seconds). The patients who walked longer than 15 minutes were not included in this study according to the exclusion criteria. The median preoperative ODQ (pre-ODQ) score of the patients was 24 ± 6.4 (range 6.0–38.0; Table 1).

Neurological examination and radiological evaluation of the patients were performed, and the results were recorded in the patient charts by a single author (B.Y.). Preoperative neurological examination of the patients revealed that mechanical signs such as straight leg raising were positive in 39.2% of patients. Various motor deficits in the lower extremities were found in 74.4% of the entire study population. Hypesthesia and paresthesia in the lower extremities were detected in 90.4% of patients. Abnormalities of the deep tendon reflexes were assessed in 74.4% of the patients. Urinary incontinence in the 2 patients was confirmed with urodynamic studies.

Radiological assessments were performed in all patients before surgery by using dynamic plain radiographs, CT, and MR imaging. The area of the thecal sac was measured on axial CT scans, and the narrowest segment was taken into consideration. Postoperatively, the thecal sac was measured on axial CT scans obtained in all 125 patients in our study. The median preoperative thecal sac CSA (pre-CSA) was 57 ± 14.6 mm² (range 15–85 mm²) on axial CT (Table 1). Narrowing of the spinal canal occurred in 1 segment in 28% of patients, 2 segments in 54.4%, 3 segments in 16%, and 4 segments in 1.6%. In 13.2% of the patients unilateral lumbar discectomy was performed at the same time as the laminectomy, flavectomy, and bilateral foraminotomy.

Surgical Technique

Operations were performed after inducing intrathecal general anesthesia in prone patients. A standard lumbar vertical median incision was used. A stenotic segment was confirmed with the aid of fluoroscopy. All patients underwent a posterior decompressive laminectomy, flavectomy, and bilateral foraminotomy with or without concomitant arthrodesis. If the adjacent facet joints were hypertrophic, one-third medial facetectomies were performed. Discectomies were performed in the patients who had degenerative intervertebral disc disease and same-side leg pain when indicated.

Statistical Analysis

Data analysis was performed using SPSS for Windows, version 11.5 (SPSS, Inc.). To determine whether the continuous variables were normally distributed, we applied the Shapiro-Wilk test. Continuous variables were shown as the median (25th–75th percentiles). The differences between the medians of 2 repeated measurements were tested using the Wilcoxon signed-rank test. Differences between the medians of more than 2 repeated measurements were evaluated using the Friedman test. When the probability value from the Friedman test was statistically significant, the Wilcoxon signed-rank test was used.
Lumbar spinal stenosis

TABLE 1: Summary of parameters evaluated before and after surgery for LSS*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preop</th>
<th>3rd Mo Postop</th>
<th>1st Yr Postop</th>
<th>2nd Yr Postop</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSA (mm²)</td>
<td>57 ± 14.6</td>
<td>121.4 ± 14</td>
<td>900 ± 195</td>
<td>8 ± 5.7</td>
</tr>
<tr>
<td>FST (sec)</td>
<td>172 ± 100</td>
<td>540 ± 209</td>
<td>900 ± 76</td>
<td>8 ± 5.1</td>
</tr>
<tr>
<td>MWD</td>
<td>410 ± 208</td>
<td>840 ± 155</td>
<td>900 ± 76</td>
<td>8 ± 5.1</td>
</tr>
<tr>
<td>ODQ score</td>
<td>24 ± 6.4</td>
<td>10 ± 5.7</td>
<td>8 ± 5.4</td>
<td>8 ± 5.1</td>
</tr>
</tbody>
</table>

* Values are expressed as the medians ± SDs.

to determine which measurement differed from the others. The degrees of associations between continuous variables were calculated with the Spearman Rho correlation coefficient. A p value < 0.05 was considered statistically significant. The Bonferroni adjustment was applied for all possible multiple comparison tests controlling for a Type I error. Values are expressed as the medians ± SDs. A public health department physician blinded to the patient identities performed the statistical analysis.

Results

Decompressive laminectomy and foraminotomy were performed for 1 segment in 28% of the patients, 2 segments in 54.4%, 3 segments in 16%, and 4 segments in 1.6%.

Results at 3 Months

The first postoperative neurological, radiological, and functional assessment of the patients was performed 3 months after surgery by using the treadmill (3-mo FST and 3-mo MWD), thecal sac CSA (3-mo CSA), and ODQ (3-mo ODQ) score. The median CSA, FST, MWD, and ODQ score at 3 postoperative months were 121 ± 14 mm² (range 76–147 mm²), 540 ± 209 seconds (range 68–900 seconds), 840 ± 155 seconds (range 223–900 seconds), and 10 ± 5.7 (range 1.0–22.0), respectively (Table 1).

Results at 1 Year

The second postoperative assessment of patients was performed 1 year after surgery based on 3 parameters: 1-yr FST, 1-yr MWD, and 1-yr ODQ score. The median values for these parameters were 900 ± 195 seconds (range 198–900 seconds), 900 ± 76.2 seconds (range 468–900 seconds), and 8 ± 5.5 (range 1.0–22.0), respectively (Table 1).

Results at 2 Years

The third and last postoperative assessment was performed 2 years after surgery by using only the ODQ (2-yr ODQ). The 2-yr median ODQ score was 8 ± 5.1 (range 1.0–23.0; Table 1).

Interpretation of the Results

As the age of patients increased, the thecal sac CSA on axial CT decreased (p < 0.05); thus, patient age was one of the significant factors associated with narrowing of the spinal canal. There was a statistically significant difference between the pre-CSA and 3-mo CSA (p < 0.005), proving that decompressive surgery reached its target (Fig. 1). A correlation between pre-CSA and pre-FST, and between pre-CSA and pre-MWD could not be established (p > 0.5). Similarly, there was no correlation between the 3-mo CSA and 3-mo FST, and 3-mo MWD, and 1-yr FST, and 1-yr MWD (p > 0.5).

There was a significant correlation between the pre-FST and pre-MWD (p < 0.005). No correlation could be established between pre-MWD and pre-ODQ score (p = 0.42).

There was no negative or positive correlation between the duration of symptoms and FST, MWD, or ODQ score.

Maximal improvement after decompressive surgery was observed in the 3rd postoperative month based on the ODQ. The ODQ score decreased from 24 ± 6.4 to 10 ± 5.7 at 3 months postoperatively (p < 0.05). The 1-yr ODQ score decreased to 8 ± 5.5, a clinically significant decrease compared with the 3-mo ODQ score (p < 0.05). Surgery led to a significant decrease in the ODQ score at the 1st-year follow-up (p < 0.05). Further improvements after 1 year of surgery did not significantly increase the ODQ score (p = 0.75; Fig. 2).

According to the treadmill variables (FST and MWD), continuing improvement was observed at both 3 months and 1 year after surgery. The FST increased from 172 ± 100 to 540 ± 209 seconds after 3 months (p < 0.05) and to 900 ± 195 seconds at the 1st-year follow-up (p < 0.05; Fig. 3). The MWD also increased from 410 ± 208 seconds to 840 ± 155 seconds in the 3rd postoperative month (p < 0.05) and to 900 ± 76 seconds in the 1st postoperative year (p < 0.05; Fig. 4).

Discussion

Degenerative LSS is the most common diagnosis leading to spinal surgery in adults older than 65 years.
of age.\(^9\) The results of the surgical procedure for lumbar stenosis remain unknown, and the standardization of therapeutic interventions has not been achieved until today. Although the literature on this topic is contradictory,\(^{27}\) there have been several studies documenting 71% perfect clinical results after surgery.\(^{16,19}\) The sources of the contradiction may be the differences in study designs or baseline characteristics of the patients. Another possible explanation for the contrary results is patient selection; for example, surgery is more beneficial to patients with severe stenosis than those with mild stenosis.\(^5\) In the current study we evaluated the patients on a functional basis because LSS limits function. One of the important findings in the study is the absent correlation between the pre-CSA and pre-FST, and between the 3-mo CSA and 3-mo FST (p > 0.5) despite the fact that surgery widens the canal. Given that there is no correlation between the 3-mo CSA and 3-mo FST, one may question why the canal should be widened. This confusion may arise if one considers the radiological assessment more than the functional evaluation of a patient.

Surgery can help to improve function. Disability indexes help surgeons monitor their patients’ status. In this study we obtained functional measurements both pre- and postoperatively. As a result, we can say that surgery led to functional recovery until the 1st year after treatment according to the ODQ. Further improvements > 1 year after surgery did not significantly change the ODQ score. A comparison of the early results of surgery and conservative management in patients with LSS has revealed that the surgical results are better especially in the 3rd postoperative month.\(^4\) The longer the follow-up time, the better the results of conservative management become; but if the follow-up time is extended even more, a number of patients will proceed to surgery. Four-year outcomes of lumbar stenosis have revealed that 70% of major symptoms are improved in the surgery group. This improvement is only 52% in the conservative management group. Note that 22.1% of the patients in the conservative management group have proceeded to surgery during this same follow-up period.\(^2,5,6\)

The signs and symptoms of degenerative LSS can be attributed to radiculopathy or neurogenic claudication.\(^10\) Intermittent neurogenic claudication is the result of a central narrowing of the spinal canal and thecal compression.\(^8\) It is also well known that intermittent neurogenic claudication is a posture-dependent condition.\(^26\) Thus, it is expected that the more the canal is widened, the better the relief of symptoms. To attain this goal many procedures have been developed by spinal surgeons.

Fig. 2. Bar graph demonstrating improvements in the ODQ score. ODQ\(_1\) = pre-ODQ; ODQ\(_2\) = 3-mo ODQ; ODQ\(_3\) = 1-yr ODQ; ODQ\(_4\) = 2-yr ODQ.

Fig. 3. Bar graph showing improvements in the FST on the treadmill. FST\(_1\) = pre-FST; FST\(_2\) = 3-mo FST; FST\(_3\) = 1-yr FST.

Fig. 4. Bar graph showing the improvements in the MWD on the treadmill. MWD\(_1\) = pre-MWD; MWD\(_2\) = 3-mo MWD; MWD\(_3\) = 1-yr MWD.
regrowth of the excised posterior elements. Such an occurrence is more likely when limited decompression is performed.\textsuperscript{18}

The indication for fusion after decompression continues to be debated.\textsuperscript{13} It is well known that iatrogenic lumbar instability can contribute to canal compromise, disc herniation, facet fracture, and pain.\textsuperscript{10} Preserving stability is of paramount importance; however, the incidence of radiographically demonstrated instability after laminectomy is difficult to determine because researchers’ methods of choosing patients and interpreting radiographs have varied.\textsuperscript{25} Many investigators have attempted to define lumbar spinal instability.\textsuperscript{1,12} In the literature, unilateral decompression and contralateral bony fusion are considered to avoid postoperative instability.\textsuperscript{10} The fusion rate in the present series depends on the selected decompressive procedure. Laminectomy should be extended until the emerging roots can be seen. Laminotomy and laminectomy are also comparable with regard to postoperative listhesis, and there is no statistically significant difference between them.\textsuperscript{22} In contrast, there is a study showing that selective laminotomy lowers the incidence of postoperative instability.\textsuperscript{20}

Preoperative listhesis, abnormal motion on dynamic radiographs, patient sex, the presence of a degenerated disc, and lateral lumbar curvature may be the preoperative predictive factors for postoperative instability. In addition, slippage was more likely to develop in patients with > 1 decompressed level than in those with only 1 decompressed level. The rate of a second operation for postlaminectomy instability is 17\% in the literature.\textsuperscript{14} The incidence of a second operation in the present series was 2.7\%.

**Conclusions**

The ideal treatment for LSS should address the major symptoms without causing morbidity or complications. Initial treatment should be decided using the functional criteria explained above. Later, either conservative management or surgical interventions should be chosen. Radiological criteria may not correlate with the true severity of the disease. Furthermore, the CSA of the thecal sac is not the single factor determining the diagnosis of, and treatment for, degenerative lumbar stenosis. The function of a patient rather than radiological data should be considered when a surgeon is making a treatment decision. Improvements in lumbar decompression continued in our patients within 1 year of surgery according to the ODQ, FST, and MWD. Further improvements after 1 year did not significantly increase the ODQ score.

**Disclaimer**

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

**References**


**TABLE 2: Duration of symptoms in 125 patients with LSS**

<table>
<thead>
<tr>
<th>Duration of Symptoms (yrs)</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2</td>
<td>48 (38.4)</td>
</tr>
<tr>
<td>3–5</td>
<td>38 (30.4)</td>
</tr>
<tr>
<td>6–10</td>
<td>23 (18.4)</td>
</tr>
<tr>
<td>11–15</td>
<td>12 (9.6)</td>
</tr>
<tr>
<td>16–20</td>
<td>4 (3.2)</td>
</tr>
</tbody>
</table>

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Address correspondence to: Uygur Er, M.D., Söğütözü C., 4th Sk., No. 22/7, 06510, Çankaya, Ankara, Turkey. email: uygurer@gmail.com.