Spine

SPINE Volume 46, Number 18, pp E966–E975

CLINICAL CASE SERIES

Relief of Low Back Pain After Posterior Decompression for Lumbar Spinal Stenosis

Masaaki Kakiuchi, MD, PhD,[a] Eiji Wada, MD, PhD,[b] Takeo Harada, MD,[c] Ryoji Yamasaki, MD, PhD,[b] and Wakaba Fukushima, MD, PhD[d]

Study Design. A retrospective study.

Objective. The aim of this study was to confirm that decompression for lumbar spinal stenosis (LSS) relieves low back pain (LBP) as adequately as it relieves leg pain and to identify predictors for inadequate LBP relief.

Summary of Background Data. Although decompression for LSS is generally thought to yield worse results for LBP than for leg pain, some studies have reported similar improvements in pain scores between LBP and leg pain. To treat LBP or take measures to prevent inadequate LBP relief, reliable predictors for LBP relief should be identified.

Methods. We retrospectively reviewed 175 patients who underwent posterior element-preserving decompression and evaluated the relief of LBP and leg pain using numeric rating scales (NRSs). Associations between demographic, clinical, or imaging parameters and LBP relief at 1 and 4 years were analyzed by stepwise linear regression analyses. The imaging parameters included Modic change type 1, disc degeneration, foraminal stenosis, vertebral slipping (within Grade 1), scoliosis ($<15°$) and lordosis.

Results. The mean improvements in LBP and leg pain NRS scores from baseline were 5.22 and 4.70 points ($P = 0.064$, paired t test) at 1 year and 5.12 and 4.62 points ($P = 0.068$) at 4 years, respectively. Poor LBP scores at 4 years were significantly associated with long-lasting LBP (beta $= 0.31$, $P < 0.0001$) and moderate or severe arm symptoms with cervical spinal cord compression or intramedullary hyperintense signal on T2-weighted MRI (beta $= 0.22$, $P = 0.0014$). The imaging parameters of the lumbar spine failed to show clear associations with poor LBP scores at 4 years, although Modic change type 1 showed a significant association with poor LBP scores at 1 year (beta $= 0.28$, $P < 0.0001$).

Conclusion. Posterior decompression relieves LBP as well as leg pain. Long-lasting LBP and concurrent symptomatic cervical myelopathy are important predictors for inadequate LBP relief. There were no reliable imaging parameters predictive of inadequate LBP relief.

Key words: arm symptom, cervical myelopathy, decompression, disc degeneration, duration of LBP, foraminal stenosis, leg pain, low back pain, lumbar spinal stenosis, Modic change Type 1, numeric rating scale, predictor, spinous process–splitting approach, suspension laminoplasty.

Level of Evidence: 4

Spine 2021;46:E966–E975

Lumbar spinal stenosis (LSS) is typically characterized by leg symptoms, but the clinical presentations frequently include low back pain (LBP). For patients who are refractory to conservative care, surgery is occasionally indicated. The most frequently performed procedure is posterior decompression, with the primary aim of relieving leg symptoms. Although LBP also often decreases after surgery,[1,2] decompression is generally thought to yield worse results for LBP than for leg pain and is suggested for patients with leg predominant symptoms.[3] However, some studies have reported similar improvements in pain scores between LBP and leg pain.[4–7] To include LBP in therapeutic targets or to take measures to prevent inadequate LBP relief, reliable predictors for LBP relief should be identified. Knowledge of the predictors might aid surgeons in choosing optimal treatments for each patient. Several factors have been shown to be associated with inadequate LBP relief, including narcotic usage,[8] compensation claims,[8] high degrees of apical vertebral rotation,[9] and high Cobb angles.[10] However, many other factors still remain to be studied. The purposes of this study were to confirm whether

From the [a]Department of Orthopedic Surgery, Iseikai Hospital, Osaka-fu, Japan; [b]The Spine and Spinal Cord Center, Osaka Police Hospital, Osaka, Japan; [c]Department of Rehabilitation Medicine, North Osaka Housenka Hospital, Osaka-fu, Japan; and [d]Department of Public Health, Osaka City University Graduate School of Medicine, Osaka, Japan.

Acknowledgment date: October 7, 2020. First revision date: December 8, 2020. Acceptance date: January 4, 2021.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work.

Relevant financial activities outside the submitted work: payment for lecture.

Address correspondence and reprint requests to Masaaki Kakiuchi, MD, PhD, The Department of Orthopedic Surgery, Iseikai Hospital, 6-2-25 Sugahara, Higashiyodogawa-ku, Osaka-shi, Osaka-fu 533-0022, Japan; E-mail: kakiuchi@sutv.zaq.ne.jp

DOI: 10.1097/BRS.0000000000004006

decompression for LSS relieves LBP as adequately as it relieves leg pain and to identify predictors for inadequate LBP relief. Demographic, clinical, and imaging parameters, including those related to the cervical spine, were evaluated using numeric rating scales (NRSs) for symptoms at 1 and 4 years.

MATERIALS AND METHODS

Patients

This was a retrospective, observational, single-institution case series study based on a database review and imaging data. All study patients provided informed consent. The institutional review board approved this study. The patients completed an outcome questionnaire independently from the surgeon before each medical examination. The patients who did not visit on the scheduled day were sent a follow-up questionnaire. The information on the patients was recorded in a database. Data on consecutive patients who were treated by the first author from September 2004 to January 2015 were retrieved from the database.

The inclusion criterion for this study was LSS treated by expansive suspension laminoplasty using a spinous process-splitting approach[11] (n = 347). We included patients from a previous study,[11] which did not address the issues of the present study. The indication for this procedure was multilevel stenosis with or without Grade 1 degenerative spondylolisthesis and narrowing of the spinal canal throughout the disc and vertebral body levels. The exclusion criteria were a herniated lumbar disc (n = 13), lumbar scoliosis $\geq 15^{\circ}$ (n = 16), urgent surgery (n = 6), a pacemaker (n = 5), Parkinson's disease (n = 3), a rheumatic disease (n = 7), a vertebral fracture at the decompression level (n = 13), and previous lumbar spine surgery at the decompression level (n = 1). Of the remaining 283 patients, 22 patients were unable to or declined to answer the questionnaire (Figure 1).

Patients with mild pain and those with moderate or severe pain should not be included in the same model because clinically meaningful improvement in function requires different magnitudes of decrease in the NRS score for the different levels of pain.[12] We selected an NRS score of 4 points as the lower limit for moderate pain or numbness because the commonly recommended lower limits for moderate pain are 4 points[13,14] and 5 points.[12,15] Therefore, 38 patients with a preoperative LBP NRS score (LBP score) ≤ 3 points were excluded (Figure 1).

During the 4-year follow-up period, 44 patients dropped out, and four patients died. Consequently, complete follow-up data at 1 and 4 years postoperatively were available for 175 patients (Figure 1). The baseline characteristics, except for lumbar scoliosis, were similar between the 175 study patients and the remaining 48 patients (Table 1). The postoperative events are listed in Table 2.

Radiographic Measures

The preoperative radiographic data included anterior or posterior vertebral slipping, lumbar lordosis (between the upper endplates of L1 and S1) and lumbar scoliosis (as measured using the Cobb method) on standing plain lumbar radiographs as well as disc degeneration,[16] Modic change (MC) type 1[17] and foraminal stenosis[18] on sagittal lumbar magnetic resonance imaging (MRI) scans. Patients with suspected cervical disorders were encouraged to undergo cervical spine MRI scans before lumbar surgery. Cervical cord pathology (*i.e.*, cervical spinal cord compression[19] and intramedullary signal hyperintensity[20]) was detected on sagittal cervical MRI scans. The MRI findings were assessed

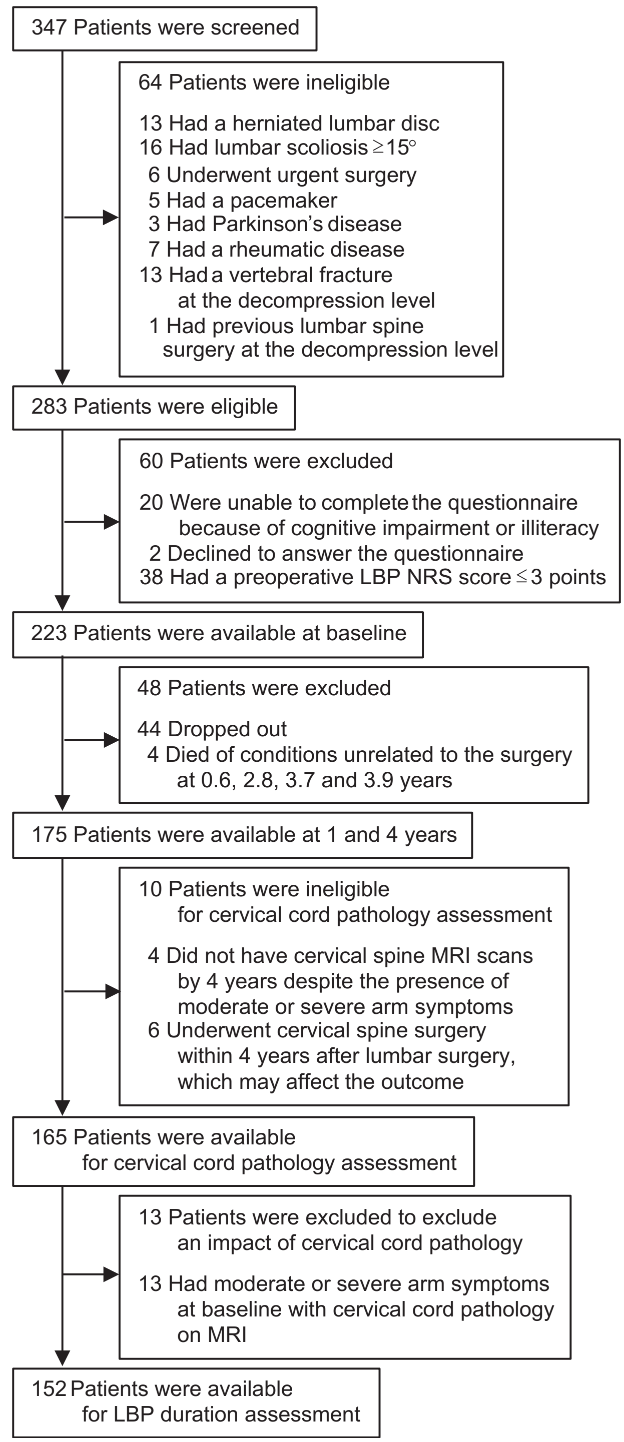

Figure 1. Patient selection flow diagram.

TABLE 1. Baseline Characteristics of the Patients*

Characteristic	Study Patients (N = 175)	Dropouts and Deceased (N = 48)	P†
Female, no. (%)	66 (37.7)	21 (43.8)	0.51
Age at the time of the operation, y	69.1 ± 8.2	69.2 ± 11.3	0.92
Body mass index, kg/m^2	24.8 ± 3.1	24.8 ± 3.6	0.98
Diabetes, no. (%)	39 (22.3)	14 (29.2)	0.34
Heart disease, no. (%)	52 (29.7)	15 (31.3)	0.86
Brinkman Index (cigarettes/day times years)	539 ± 714	440 ± 586	0.38
Dominant location of LBP, no. (%)			
The lumbar area	67 (38.3)	19 (39.6)	0.62
The buttock area	99 (56.6)	25 (52.1)	
Equally painful in both areas	9 (5.1)	4 (8.3)	
Distribution of LBP, unilateral, no. (%)	73 (41.7)	16 (33.3)	0.32
Duration of LBP, y	5.7 ± 8.6	5.4 ± 8.4	0.85
Duration of leg symptoms, y	3.3 ± 5.1	3.8 ± 7.0	0.55
Previous spine surgery, lumbar, other levels, no. (%)	6 (3.4)	1 (2.1)	1.00
Previous spine surgery, nonlumbar (cervical or thoracic), no. (%)	24 (13.7)	7 (14.6)	0.82
Disc levels decompressed (no.)	2.8 ± 0.8	2.9 ± 0.8	0.41
Lumbar spondylolysis, no. (%)	2 (1.1)	1 (2.1)	0.52
Lumbar scoliosis (°)	6.2 ± 3.0	7.7 ± 3.6	**0.0043**
Lumbar lordosis (°)	34.3 ± 14.4	33.8 ± 13.9	0.81
Maximum anterior or posterior vertebral slipping‡ (%)	8.2 ± 8.7	7.1 ± 7.7	0.44
Disc degeneration, no. (%)			
Presence of Grade 3 degeneration	152 (86.9)	42 (87.5)	1.00
Presence of Grade 4 degeneration	166 (94.9)	44 (91.7)	0.48
Presence of Grade 5 degeneration	53 (30.3)	16 (33.3)	0.73
Modic change type 1, no. (%)			
Overall, TH12-L1 to L5–S	15 (8.6)	5 (10.4)	0.78
L2–L3	3 (1.7)	2 (4.2)	0.29
L3–L4	1 (0.6)	1 (2.1)	0.38
L4–L5	10 (5.7)	1 (2.1)	0.46
L5–S	1 (0.6)	1 (2.1)	0.38
Marked or advanced foraminal stenosis, no. (%)	139 (79.4)	37 (77.1)	0.69
Symptom scale score§ (points)			
NRS score for LBP	7.6 ± 1.8	7.1 ± 1.8	0.11
NRS score for leg pain	6.9 ± 2.8	6.5 ± 3.1	0.35
NRS score for leg numbness	6.2 ± 3.1	6.3 ± 2.7	0.84
NRS score for arm symptoms (pain or numbness)	1.9 ± 2.7	2.1 ± 2.8	0.61
Moderate or severe arm symptoms,‖ no. (%)	44 (25.1)	11 (22.9)	0.85
Oswestry Disability Index score¶ (points)	49.0 ± 15.2	51.8 ± 12.1	0.24

LBP indicates low back pain; NRS, numeric rating scale. Boldface type indicates significance.
**Plus-minus values are means ± standard deviations.*
†Fisher exact test or Student t test.
‡Both the anterior and posterior slips are expressed as positive values.
§Scale from 0 to 10.
‖Moderate or severe arm symptoms = NRS scores of ≥4 points for arm pain or numbness.
¶Scale from 0 to 100.

by two spine surgeons. When they disagreed, a consensus opinion was reached by discussion.

Outcome Measures and Symptom Scales

The primary outcome measure was the NRS for LBP. The secondary outcome measures were the NRSs for leg pain and leg numbness and the Oswestry disability index (ODI).[21] The ODI omitted a question relating to sex life because of a poor response rate; the results are expressed as percentages of the maximum possible score. Arm symptoms were defined to be moderate or severe when the NRS score for arm pain or numbness was ≥4 points.

TABLE 2. Outcomes at 1 and 4 Years and Postoperative Events in 175 Patients

Outcome Scale or Event	Outcome Scale Score or No. of Patients
Mean improvement from baseline, points (95% CI)	
LBP NRS score*	
1 y	5.22 (4.81 to 5.62)
4 y	5.12 (4.72 to 5.52)
Leg pain NRS score*	
1 y	4.70 (4.18 to 5.22)
4 y	4.62 (4.09 to 5.15)
Leg numbness NRS score*	
1 y	3.47 (2.96 to 3.99)
4 y	3.71 (3.20 to 4.21)
Oswestry Disability Index score†	
1 y	27.3 (24.9 to 29.6)
4 y	27.6 (25.0 to 30.1)
Mean difference in the improvements from baseline between LBP and leg pain NRS scores,* points (95% CI])	
1 y	0.52 (−0.03 to 1.07)
4 y	0.50 (−0.04 to 1.03)
Additional spine surgery, no. (%)	
Lumbar, the same levels	2 (1.14)
Lumbar, another level	1 (0.57)
Cervical	6 (3.43)
Thoracic	1 (0.57)
Deep wound infection (no.)	0
Symptomatic wound hematoma (no.)	0

CI indicates confidence interval; LBP, low back pain; NRS, numeric rating scale.
**Scale from 0 to 10.*
†Scale from 0 to 100.

Location of LBP

The low back was defined as the area between the costal margin and the inferior gluteal folds and divided into the lumbar and buttock areas at the level of the posterior superior iliac spine, which is discernible to the patients' own touch, although there are no clear definitions of the two anatomical sites.[22]

Statistical Analysis

Analyses were performed to determine the factors influencing the outcomes (*i.e.*, LBP scores at 1 and 4 years) using JMP 12.2.0 (SAS Institute Inc., Cary, NC). In the primary analyses (Table 3), linear regression models were used to assess the association of each factor with outcomes while adjusting for baseline outcome scores. Baseline LBP scores, sex, age and factors associated with each outcome with $P < 0.10$ in the primary analyses were included in the forward and backward stepwise linear regression models that maintained a P value of 0.25 for entry and exit; baseline LBP scores were locked into the model to ensure that it withstood stepwise selection (Table 4). This model produced a multivariate model of factors associated with the outcome while adjusting for baseline outcome scores. Statistical tests were two-tailed, and a P value of <0.05 was significant.

We evaluated the correlation between each pair of 25 factors listed in Table 3. A correlation coefficient (R) of >0.4 was found between the Brinkman Index and sex ($R = 0.50$, $P < 0.0001$) and between leg symptom duration and LBP duration ($R = 0.46$, $P < 0.0001$); therefore, the Brinkman Index and leg symptom duration were excluded from the stepwise selection.

To identify the duration range associated with the outcomes, LBP duration before lumbar surgery was divided into four categories (A1 through A4, Figure 2), with the same number of patients in each category. LBP duration before the onset of leg symptoms was divided into four categories (B1 through B4), in which a similar number of patients were included in each category after the patients who developed LBP and leg symptoms on the same day were separated into one category (B2). In these analyses, 23 patients related to cervical cord pathology assessment were excluded (Figure 1). The remaining 152 patients were dichotomized into a category of interest and a reference category (*i.e.*, "yes" for either A2, A3, or A4 and "no" for A1; "yes" for either B1, B3, or B4 and "no" for B2), with patients in the remaining category being excluded (*e.g.*, A2 and A3 were excluded when A4 corresponded to "yes"). The association between each category and the outcomes was determined by multivariate linear regression analysis while adjusting for baseline LBP scores and significant predictors identified in

TABLE 3. Primary Linear Regression Models for the Association Between Baseline Characteristics and LBP NRS Scores at 1 and 4 Years While Adjusting for LBP NRS Scores at Baseline

Baseline Characteristics	LBP NRS Score					
	1 Year		4 Years			
	(N = 175)		(N = 175)		(N = 165)*	
	Beta	*P*	Beta	*P*	Beta	*P*
Sex (female *vs.* male)	0.098	0.18	0.093	0.21	0.061	0.42
Age at the time of the operation	0.131	**0.076**	0.185	**0.012**	0.197	**0.0093**
Body mass index	−0.015	0.84	−0.017	0.82	0.015	0.85
Diabetes (yes *vs.* no)	0.039	0.61	0.067	0.37	0.063	0.41
Heart disease (yes *vs.* no)	0.044	0.55	0.151	**0.041**	0.188	**0.013**
Brinkman Index (cigarettes/day multiplied by years)	−0.003	0.97	−0.160	**0.031**	−0.129	**0.088**
Dominant location of LBP (buttock area *vs.* no)	−0.194	**0.0081**	−0.219	**0.0028**	−0.223	**0.0029**
Distribution of LBP (unilateral *vs.* bilateral)	−0.056	0.45	−0.012	0.87	−0.006	0.94
Duration of LBP	0.319	**<0.0001**	0.349	**<0.0001**	0.357	**<0.0001**
Duration of leg symptoms	0.127	**0.085**	0.170	**0.021**	0.174	**0.021**
Previous spine surgery, lumbar, other levels (yes *vs.* no)	−0.039	0.60	0.068	0.36	0.070	0.35
Previous spine surgery, nonlumbar (yes *vs.* no)	0.175	**0.017**	0.156	**0.034**	0.163	**0.031**
No. of disc levels decompressed	0.091	0.22	0.023	0.76	0.052	0.49
Lumbar spondylolysis (yes *vs.* no)	0.027	0.72	0.069	0.36	0.070	0.36
Lumbar scoliosis	0.191	**0.0092**	0.169	**0.022**	0.190	**0.012**
Lumbar lordosis	−0.063	0.40	−0.118	0.11	−0.162	**0.032**
Maximum anterior or posterior vertebral slipping†	0.079	0.29	−0.086	0.25	−0.061	0.43
Disc degeneration, Grade 4 (yes *vs.* no)	0.120	0.10	0.037	0.62	0.037	0.63
Disc degeneration, Grade 5 (yes *vs.* no)	0.141	**0.059**	0.109	0.14	0.144	**0.060**
Modic change type 1 (yes *vs.* no)	0.276	**0.0001**	0.145	**0.048**	0.151	**0.046**
Marked or advanced foraminal stenosis (yes *vs.* no)	0.060	0.42	0.115	0.12	0.105	0.17
Leg pain NRS score	0.053	0.48	0.081	0.28	0.045	0.56
Leg numbness NRS score	0.152	**0.039**	0.135	**0.068**	0.155	**0.041**
Oswestry Disability Index score	0.178	**0.023**	0.165	**0.035**	0.166	**0.039**
Arm symptom (pain or numbness) NRS score	0.265	**0.0003**	0.225	**0.0021**	0.218	**0.0037**
Moderate or severe arm symptoms‡ (yes *vs.* no)						
With cervical cord pathology on MRI					0.196	**0.0092**
Without cervical cord pathology on MRI					0.069	0.36

Beta indicates standardized regression coefficient; LBP, low back pain; NRS, numeric rating scale.

Cervical cord pathology = spinal cord compression or intramedullary signal hyperintensity on T2-weighted sagittal MRI.

Boldface type indicates P value <0.1. Factors related to each outcome (P < 0.10) were included in the subsequent, stepwise linear regression models as well as sex, age, and the baseline LBP scores.

Ten patients were ineligible for cervical cord pathology assessment (4 patients did not have cervical spine MRI scans by 4 years despite the presence of moderate or severe arm symptoms at baseline, and 6 patients underwent cervical spine surgery within 4 years after lumbar surgery. Figure 1).

†*Both anterior and posterior slips are expressed as positive values.*

‡*Moderate or severe arm symptoms = NRS scores of ≥4 points for arm pain or numbness.*

the multivariate analysis for 175 patients (*i.e.*, sex and MC type 1 for the 1-year outcome; sex for the 4-year outcome). Cervical cord pathology-related factors (*i.e.*, previous nonlumbar spine surgery and arm symptom NRS scores) were not included.

RESULTS

The mean improvements in LBP and leg pain NRS scores from baseline were 5.22 and 4.70 points ($P = 0.064$, paired *t* test) at 1 year and 5.12 and 4.62 points ($P = 0.068$) at 4 years, respectively (Table 2). In the primary analyses for 175 patients (Table 3), the predictors closely associated with outcomes (beta > 0.20) were LBP duration, arm symptom NRS scores and MC type 1 for the 1-year outcome, and LBP duration, arm symptom NRS scores and dominant location of LBP for the 4-year outcome.

In the multivariate analyses of 175 patients (Table 4), LBP duration and arm symptom NRS scores were significant predictors of both 1- and 4-year outcomes, and MC type 1 was significant for only the 1-year outcome. Sex and previous nonlumbar spine surgery were also significant predictors, but the associations were weak (beta < 0.20).

In the additional multivariate analysis for 165 patients (Table 4), two nominal variables instead of the "arm

TABLE 4. Stepwise Linear Regression Models for the Association Between Baseline Characteristics and LBP NRS Scores at 1 and 4 Years While Adjusting for LBP NRS Scores at Baseline

Baseline Characteristics	LBP NRS Score					
	1 Y		4 Y			
	(N = 175)		(N = 175)		(N = 165)*	
	Beta	*P*	Beta	*P*	Beta	*P*
LBP NRS score†	0.199	**0.0038**	0.194	**0.0061**	0.234	**0.0005**
Sex (female *vs.* male)	0.159	**0.014**	0.150	**0.025**	0.163	**0.018**
Age at the time of the operation	0.089	0.17	0.123	0.074	0.135	**0.0497**
Heart disease (yes *vs.* no)	—	—	0.115	0.089	0.160	**0.019**
Dominant location of LBP (buttock area *vs.* no)	−0.112	0.095	−0.099	0.16	−0.122	0.089
Duration of LBP	0.231	**0.0005**	0.305	**<0.0001**	0.311	**<0.0001**
Previous nonlumbar spine surgery (yes *vs.* no)	0.130	**0.046**	0.120	0.076		
Lumbar lordosis	—	—	—	—	−0.165	**0.017**
Modic change type 1 (yes *vs.* no)	0.283	**<0.0001**	0.125	0.063	0.104	0.13
Oswestry Disability Index score	0.116	0.091	0.100	0.16	—	—
Arm symptom (pain or numbness) NRS score	0.224	**0.0008**	0.160	**0.019**		
Moderate or severe arm symptoms‡ (yes *vs.* no)						
With cervical cord pathology on MRI†					0.220	**0.0014**
Without cervical cord pathology on MRI†					0.021	0.75
Adjusted R^2	0.331		0.286		0.315	

Beta indicates standardized regression coefficient; LBP, low back pain; NRS, numeric rating scale.

Boldface type indicates significance.

Cervical cord pathology = spinal cord compression or intramedullary signal hyperintensity on T2-weighted sagittal MRI.

**Ten patients were ineligible for cervical cord pathology assessment (Figure 1). The nominal variable "previous nonlumbar spine surgery" was excluded (of the 13 patients who had moderate or severe arm symptoms at baseline with cervical cord pathology on MRI, five patients underwent cervical spine surgery before lumbar surgery, Table 5).*

†These variables were locked into the model to ensure that it withstood stepwise selection.

‡Moderate or severe arm symptoms = NRS scores of ≥4 points for arm pain or numbness.

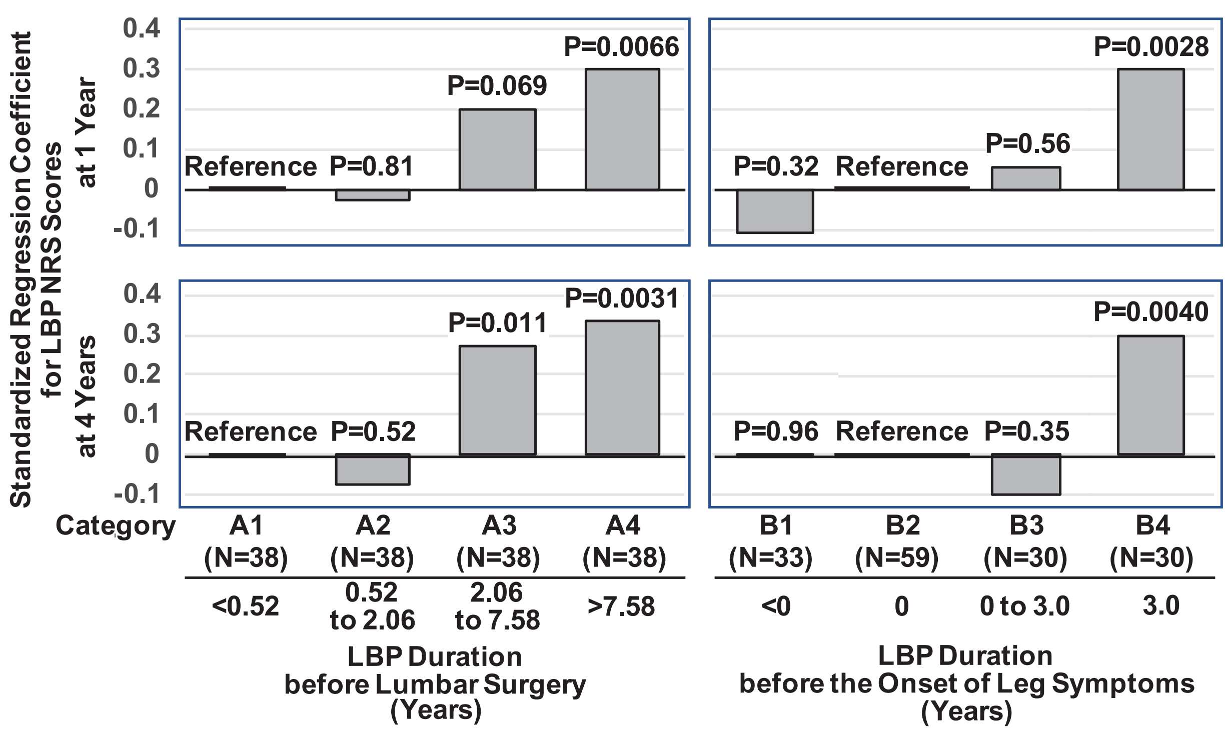

Figure 2. Standardized regression coefficients for the associations between each category of LBP duration and LBP NRS scores at 1 and 4 years were determined by multivariate linear regression analyses. Patients were dichotomized into each category of interest and a reference category. The duration was expressed as a negative value when LBP occurred after the onset of leg symptoms.

TABLE 5. Patients Included in the Stepwise Linear Regression Analysis of Cervical Cord Pathology

Findings and Scan Timing of Cervical Spine MRI	Cervical Spine Surgery: Not Done (N = 143)	Cervical Spine Surgery: Done Before Lumbar Surgery (N = 22)	Overall (N = 165)	No. of Patients Dichotomized: Yes	No. of Patients Dichotomized: No
Patients who had no or mild arm symptoms at baseline* (no.)	112	15	127		
Patients who had Moderate or severe arm symptoms at baseline† (no.)					
Without cervical cord pathology on MRI‡	23 (5)	2	25 (5)	25	140
With cervical cord pathology on MRI‡	8	5 (1)	13 (1)	13	152
Spinal cord compression only	7	1	8		
Intramedullary signal hyperintensity only	0	4 (1)	4 (1)		
Presence of both findings	1	0	1		
Period between MRI scanning and lumbar surgery					
For MRI taken before lumbar surgery (range, years before lumbar surgery)	0.02–1.68	0.05–0.30	0.02–1.68		
For MRI taken within 4 y after lumbar surgery (range, years after lumbar surgery)	0.30–1.93	0.75	0.30–1.93		

MRI indicates magnetic resonance imaging.

No or mild arm symptoms = NRS scores of ≤3 points for arm pain or numbness.

†*Moderate or severe arm symptoms = NRS scores of ≥4 points for arm pain or numbness.*

‡*Findings on sagittal T2-weighted cervical spine MRI performed before lumbar surgery or within 4 years after lumbar surgery. The values in parentheses are the numbers of the patients who had cervical spine MRI scans within 4 years after lumbar surgery; these six patients were included to maximize the sample size.*

Ten patients were ineligible for cervical cord pathology assessment and excluded from the 175 patients (Figure 1). The remaining 165 patients were dichotomized (i.e., "yes" for patients having moderate or severe arm symptoms at baseline without cervical cord pathology on MRI and "no" for the remaining patients; or "yes" for patients having moderate or severe arm symptoms at baseline with cervical cord pathology on MRI and "no" for the remaining patients).

No patients underwent cervical spine surgery both before and after lumbar surgery.

symptom NRS score at baseline" were analyzed, namely, "moderate or severe arm symptoms at baseline with cervical cord pathology on MRI" and "moderate or severe arm symptoms at baseline without cervical cord pathology on MRI." The former variable was used to reflect symptomatic cervical myelopathy. Both variables were also locked into the model through stepwise selection. In this model, 10 patients were ineligible for cervical cord pathology assessment (Figure 1), and the remaining 165 patients were dichotomized to yes/no groups for each of the two variables (Table 5). Consequently, a significant association between moderate or severe arm symptoms and poor LBP scores at 4 years was detected in the patients with cervical cord pathology on MRI but not in the patients who did not have such images. Sex, age, heart disease, and lumbar lordosis were also significant predictors, but the associations were weak (absolute values of beta < 0.20).

LBP duration before lumbar surgery exhibited duration-dependent positive associations with 1- and 4-year outcomes. Duration ranges of <2.06 years before lumbar surgery and <3.0 years before the onset of leg symptoms did not exhibit significant associations with outcomes (Figure 2).

DISCUSSION

The present investigation was a 1- and 4-year follow-up study of LBP relief after posterior decompression for LSS. We found that significant differences were not demonstrated between the magnitudes of LBP relief and leg pain relief; moderate or severe arm symptoms with cervical cord pathology on MRI (*i.e.*, a parameter related to symptomatic cervical myelopathy) and long-lasting LBP were significantly associated with poor LBP scores at 4 years; and there were no imaging findings that showed clear associations at 4 years, although MC type 1 was associated with poor LBP scores at 1 year only.

The decompression procedure performed was suspension laminoplasty using a spinous process-splitting approach, which is characterized by spinal canal expansion throughout the disc and vertebral body levels and the preservation of the spinous processes and laminae without disrupting the origin of the multifidus muscle at the spinous process. This procedure aims to maintain adequate spinal canal decompression with long-term preserved stability from posterior elements.[11] Minimally invasive decompression might yield similar results to those of our procedure. Decompression with less preservation of the posterior elements may induce instability or recurrent stenosis, which affects the outcome, and imaging factors suggesting segmental instability may stand out as predictors. Additional studies that consider the differences in surgical approaches are needed.

Imaging findings of spine degeneration are present in many asymptomatic individuals, increasing with age. Many imaging-based degenerative features are likely part of normal aging and unassociated with pain.[23] Moreover, there is insufficient evidence for or against imaging findings correlating with the presence of LBP.[24] MC type 1 has been reported to be associated with chronic LBP,[25–29] poor surgical outcomes for LBP in patients undergoing discectomy for intervertebral disc herniation[30,31] and segmental instability.[32] MC type 1 indicates an ongoing active degenerative process[17] and is likely to be indicated for arthrodesis. As a natural course, however, conversion to a type 2 pattern, which is related to a stable and chronic process, has been observed after 14 months to 3 years.[17] MC type 1 may be a temporary state toward stabilization without additional procedures. Actually, the association between MC type 1 and poor LBP scores, which was seen at 1 year in our study, became nonsignificant at 4 years.

Degenerative findings in the lumbar and cervical spine occur in tandem,[33] and the prevalence increases with age.[34,35] The association between arm symptoms with cervical cord pathology on MRI and poor LBP scores observed in our study might be a sequence of manifestation of tandem degenerative changes in the lumbar and cervical spine. However, lumbar disc degeneration was not significantly associated with LBP relief in our study. Another possible reason is that cervical spinal cord compression can cause pain that is referred to the low back,[36,37] although the underlying pathophysiology remains unclear. Cervical myelopathy surgery occasionally provides long-term relief of LBP.[38–40] Accordingly, cervical decompression preceding lumbar surgery may be beneficial for patients with tandem spinal stenosis presenting primarily with LBP. However, treatment targets are difficult to identify because the clinical features of cervical pathology-related LBP remain unclear. Our study also failed to identify specific features; moderate or severe arm symptoms with cervical cord pathology on MRI were weakly associated with the longitudinal distribution of LBP but not with other baseline characteristics (data not reported here).

Previous comparative studies between shorter- and longer-LBP-duration cohorts of patients without stenosis showed that LBP duration is predictive of the prognosis of LBP; the threshold distinguishing the two cohorts was set as 0.25 years or slightly longer.[41,42] In our analysis, long-lasting LBP was most strongly associated with poor LBP scores. However, significant associations were seen only in the duration range of >2.06 years before lumbar surgery or >3.0 years before the onset of leg symptoms. This long LBP duration finding suggests that the patients have more chronic pain conditions extraneous to LSS and that the refractory nature is different from that of LBP that is generally classified as chronic, although the mechanism remains unclear. Decompression may promise adequate LBP relief, unless LBP has persisted for such long durations, although the sample size is too small to determine the exact threshold.

Lifestyle risk factors, including physical inactivity, are associated with LBP.[43–46] Physical inactivity due to heart disease may contribute to the burden of LBP. Heart disease might be a candidate for an important predictor of longer-term outcome.

There are several limitations to the present study. First, this was a retrospective, observational investigation with loss to follow-up, which limits conclusions regarding durability. Second, a single surgeon performed all the surgeries and postoperative follow-ups in a nonblinded fashion, although the patients completed the questionnaire independently from the surgeon before each medical examination. Conversely, no intersurgeon differences in operative performance existed. Third, we cannot exclude potential selection bias as a result of undetermined differences between our patients and the general population with LSS. Fourth, we considered the common confounding factors listed in Table 1 by making statistical adjustments, but there may still be important factors that have not been taken into account. Specifically, psychosocial and psychological factors may be important, as it has been reported that adverse psychological factors are associated with poor outcomes or prognoses for LBP[47,48] and cause serious LBP in various combinations with physical factors[49] and that psychosocial factors are more important predictors of future LBP disability than structural factors on MRI or discography.[50] There may be unknown factors that could independently affect the outcomes. Fifth, the parameter related to cervical myelopathy was based on patient-reported arm symptoms, although cervical spine MRI findings were taken into consideration; the parameter should include arm symptoms extraneous to myelopathy. The use of diagnosis by independent spine physicians would make the parameter more reliable. Finally, this was a noncontrolled study and improvements in pain and function could represent regression to the mean bias.

The treated pathology of the spinal canal accounts for a significant proportion of LBP relief after decompression. Decompression is a promising means of relieving LBP as well as leg pain. However, a proportion of patients did not experience LBP relief from decompression. All imaging findings of the lumbar spine failed to show clear associations with LBP relief, although MC type 1 was associated with poor LBP scores at 1 year; thus, there seemed to be no imaging parameter that is helpful in selecting candidates for additional spinal arthrodesis as a preventive measure against LBP. Alternatively, long-lasting LBP and concurrent symptomatic cervical myelopathy were important predictors of inadequate LBP relief.

➢ Key Points

- ❑ We retrospectively reviewed 175 patients who underwent posterior element-preserving decompression and assessed LBP relief at 1 and 4 years using NRSs.
- ❑ Significant differences were not demonstrated between the magnitudes of LBP relief and leg pain relief.

- Long-lasting LBP and concurrent symptomatic cervical myelopathy were important predictors for the inadequate LBP relief at 4 years.
- The imaging findings (disc degeneration, foraminal stenosis, vertebral slipping within Grade 1, scoliosis <15° and lordosis) were not clearly associated with LBP relief, although Modic change type 1 was associated with inadequate LBP relief at 1 year.

Acknowledgments

The authors thank Professor Emeritus Keiro Ono, MD, PhD, for his extensive advice and Professor Nobuyuki Shimizu, MD, PhD, for his advice regarding the Oswestry disability index.

References

1. Garfin SR, Glover M, Booth RE, et al. Laminectomy: a review of the Pennsylvania hospital experience. *J Spinal Disord* 1988;1:116–33.
2. Garfin SR, Herkowitz HN, Mirkovic S. Instructional course lectures, the American Academy of Orthopaedic Surgeons—spinal stenosis. *J Bone Joint Surg Am* 1999;81:572–86.
3. Kreiner DS, Shaffer WO, Baisden JL, et al., North American Spine Society. *Evidence-Based Clinical Guidelines for Multidisciplinary Spine Care: Diagnosis and Treatment of Degenerative Lumbar Spinal Stenosis (revised)*. Burr Ridge: North American Spine Society; 2011.
4. Kakiuchi M, Fukushima W. Impact of spinous process integrity on ten to twelve-year outcomes after posterior decompression for lumbar spinal stenosis: study of open-door laminoplasty using a spinous process-splitting approach. *J Bone Joint Surg Am* 2015; 97:1667–77.
5. Crawford CH 3rd, Glassman SD, Mummaneni PV, et al. Back pain improvement after decompression without fusion or stabilization in patients with lumbar spinal stenosis and clinically significant preoperative back pain. *J Neurosurg Spine* 2016;25:596–601.
6. Jones AD, Wafai AM, Easterbrook AL. Improvement in low back pain following spinal decompression: observational study of 119 patients. *Eur Spine J* 2014;23:135–41.
7. Weinstein JN, Tosteson TD, Lurie JD, et al. Surgical versus nonsurgical therapy for lumbar spinal stenosis. *N Engl J Med* 2008;358:794–810.
8. Srinivas S, Paquet J, Bailey C, et al. Effect of spinal decompression on back pain in lumbar spinal stenosis: a Canadian Spine Outcomes Research Network (CSORN) study. *Spine J* 2019; 19:1001–8.
9. Tsutsui S, Kagotani R, Yamada H, et al. Can decompression surgery relieve low back pain in patients with lumbar spinal stenosis combined with degenerative lumbar scoliosis?. *Eur Spine J* 2013;22:2010–4.
10. Oba H, Takahashi J, Tsutsumimoto T, et al. Predictors of improvement in low back pain after lumbar decompression surgery: prospective study of 140 patients. *J Orthop Sci* 2017;22:641–6.
11. Kakiuchi M, Wada E, Harada T, et al. Expansive suspension laminoplasty using a spinous process-splitting approach for lumbar spinal stenosis: surgical technique and outcomes over 8 years of follow-up. *J Am Acad Orthop Surg Glob Res Rev* 2018;2:e008.
12. Turner JA, Franklin G, Heagerty PJ, et al. The association between pain and disability. *Pain* 2004;112:307–14.
13. Zelman DC, Dukes E, Brandenburg N, et al. Identification of cut-points for mild, moderate and severe pain due to diabetic peripheral neuropathy. *Pain* 2005;115:29–36.
14. Krebs EE, Carey TS, Weinberger M. Accuracy of the pain numeric rating scale as a screening test in primary care. *J Gen Intern Med* 2007;22:1453–8.
15. Serlin RC, Mendoza TR, Nakamura Y, et al. When is cancer pain mild, moderate or severe? Grading pain severity by its interference with function. *Pain* 1995;61:277–84.
16. Pfirrmann CW, Metzdorf A, Zanetti M, et al. Magnetic resonance classification of lumbar intervertebral disc degeneration. *Spine (Phila Pa 1976)* 2001;26:1873–8.
17. Modic MT, Steinberg PM, Ross JS, et al. Degenerative disk disease: assessment of changes in vertebral body marrow with MR imaging. *Radiology* 1988;166:193–9.
18. Wildermuth S, Zanetti M, Duewell S, et al. Lumbar spine: quantitative and qualitative assessment of positional (upright flexion and extension) MR imaging and myelography. *Radiology* 1998;207:391–8.
19. Fehlings MG, Rao SC, Tator CH, et al. The optimal radiologic method for assessing spinal canal compromise and cord compression in patients with cervical spinal cord injury. Part II: Results of a multicenter study. *Spine (Phila Pa 1976)* 1999;24:605–13.
20. Yukawa Y, Kato F, Yoshihara H, et al. MR T2 image classification in cervical compression myelopathy: predictor of surgical outcomes. *Spine (Phila Pa 1976)* 2007;32:1675–8.
21. Fairbank JC, Pynsent PB. The Oswestry disability Index. *Spine (Phila Pa 1976)* 2000;25:2940–52.
22. Mannion AF, Mutter UM, Fekete TF, et al. Validity of a single-item measure to assess leg or back pain as the predominant symptom in patients with degenerative disorders of the lumbar spine. *Eur Spine J* 2014;23:882–7.
23. Brinjikji W, Luetmer PH, Comstock B, et al. Systematic literature review of imaging features of spinal degeneration in asymptomatic populations. *AJNR Am J Neuroradiol* 2015;36:811–6.
24. North American Spine Society. *Evidence-Based Clinical Guidelines for Multidisciplinary Spine Care: Diagnosis & Treatment of Low Back Pain*. Burr Ridge: North American Spine Society; 2020
25. Jensen RK, Leboeuf-Yde C, Wedderkopp N, et al. Is the development of Modic changes associated with clinical symptoms? A 14-month cohort study with MRI. *Eur Spine J* 2012;21:2271–9.
26. Kjaer P, Leboeuf-Yde C, Korsholm L, et al. Magnetic resonance imaging and low back pain in adults: a diagnostic imaging study of 40-year-old men and women. *Spine (Phila Pa 1976)* 2005;30:1173–80.
27. Kuisma M, Karppinen J, Niinimäki J, et al. Modic changes in endplates of lumbar vertebral bodies: prevalence and association with low back and sciatic pain among middle-aged male workers. *Spine (Phila Pa 1976)* 2007;32:1116–22.
28. Brinjikji W, Diehn FE, Jarvik JG, et al. MRI findings of disc degeneration are more prevalent in adults with low back pain than in asymptomatic controls: a systematic review and meta-analysis. *AJNR Am J Neuroradiol* 2015;36:2394–9.
29. Järvinen J, Karppinen J, Niinimäki J, et al. Association between changes in lumbar Modic changes and low back symptoms over a two-year period. *BMC Musculoskelet Disord* 2015;16:98.
30. Lurie JD, Moses RA, Tosteson AN, et al. Magnetic resonance imaging predictors of surgical outcome in patients with lumbar intervertebral disc herniation. *Spine (Phila Pa 1976)* 2013; 38:1216–25.
31. Sørlie A, Moholdt V, Kvistad KA, et al. Modic type I changes and recovery of back pain after lumbar microdiscectomy. *Eur Spine J* 2012;21:2252–8.
32. Rahme R, Moussa R. The Modic vertebral endplate and marrow changes: pathologic significance and relation to low back pain and segmental instability of the lumbar spine. *Am J Neuroradiol* 2008; 29:838–42.
33. Matsumoto M, Okada E, Toyama Y, et al. Tandem age-related lumbar and cervical intervertebral disc changes in asymptomatic subjects. *Eur Spine J* 2013;22:708–13.
34. Matsumoto M, Fujimura Y, Suzuki N, et al. MRI of cervical intervertebral discs in asymptomatic subjects. *J Bone Joint Surg Br* 1998;80:19–24.
35. Cheung KM, Karppinen J, Chan D, et al. Prevalence and pattern of lumbar magnetic resonance imaging changes in a population study

of one thousand forty-three individuals. *Spine (Phila Pa 1976)* 2009;34:934–40.
36. Langfitt TW, Elliott FA. Pain in the back and legs caused by cervical spinal cord compression. *JAMA* 1967;200:382–5.
37. Ito T, Homma T, Uchiyama S. Sciatica caused by cervical and thoracic spinal cord compression. *Spine (Phila Pa 1976)* 1999;24:1265–7.
38. Kim CH, Chung CK, Lee U, et al. Postoperative changes in moderate to severe nonspecific low back pain after cervical myelopathy surgery. *World Neurosurg* 2018;116:e429–35.
39. Felbaum DR, Fayed I, Stewart JJ, et al. Relief of lumbar symptoms after cervical decompression in patients with tandem spinal stenosis presenting with primarily lumbar pain. *Cureus* 2016;8:e940.
40. Kawakita E, Kasai Y, Uchida A. Low back pain and cervical spondylotic myelopathy. *J Orthop Surg (Hong Kong)* 2009; 17:187–9.
41. da C, Menezes Costa L, Maher CG, et al. The prognosis of acute and persistent low-back pain: a meta-analysis. *CMAJ* 2012; 184:E613–24.
42. Hayashi K, Arai YC, Ikemoto T, et al. Predictive factors for the outcome of multidisciplinary treatments in chronic low back pain at the first multidisciplinary pain center of Japan. *J Phys Ther Sci* 2015;27:2901–5.
43. Lin CW, McAuley JH, Macedo L, et al. Relationship between physical activity and disability in low back pain: a systematic review and meta-analysis. *Pain* 2011;152:607–13.
44. Heneweer H, Vanhees L, Picavet HS. Physical activity and low back pain: a U-shaped relation?. *Pain* 2009;143:21–5.
45. Shiri R, Falah-Hassani K. Does leisure time physical activity protect against low back pain? Systematic review and meta-analysis of 36 prospective cohort studies. *Br J Sports Med* 2017;51:1410–8.
46. Robson EK, Kamper SJ, Davidson S, et al. Healthy Lifestyle Program (HeLP) for low back pain: protocol for a randomised controlled trial. *BMJ Open* 2019;9:e029290.
47. Thomas E, Silman AJ, Croft PR, et al. Predicting who develops chronic low back pain in primary care: a prospective study. *BMJ* 1999;318:1662–7.
48. Pincus T, Burton AK, Vogel S, et al. A systematic review of psychological factors as predictors of chronicity/disability in prospective cohorts of low back pain. *Spine (Phila Pa 1976)* 2002;27:E109–20.
49. Adams MA, Mannion AF, Dolan P. Personal risk factors for first-time low back pain. *Spine (Phila Pa 1976)* 1999;24:2497–505.
50. Carragee EJ, Alamin TF, Miller JL, et al. Discographic, MRI and psychosocial determinants of low back pain disability and remission: a prospective study in subjects with benign persistent back pain. *Spine J* 2005;5:24–35.