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Surgical outcomes of decompressive laminoplasty with spinous process osteotomy to treat lumbar spinal stenosis

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ABSTRACT

Decompressive laminoplasty with spinous process osteotomy (LSPO) was developed as a less invasive procedure for lumbar decompression by Weiner et al. There are few reports extensively highlighting the surgical outcomes of LSPO. The purpose of this study was to evaluate the surgical outcomes of LSPO for lumbar spinal stenosis (LSS). In total, 23 patients with LSS were studied. All patients were followed up for more than 2 years. The Japanese Orthopedic Association (JOA) scores, the recovery rate (RR) of JOA scores, Visual analog scale (VAS) scores, responses to the JOA Back Pain Evaluation Questionnaire (JOABPEQ), sagittal alignment and segmental motion following LSPO were assessed preoperatively and 2 years postoperatively. Postoperative paravertebral muscle atrophy and bone union rates between the spinous process and the residual laminae were assessed. Preoperative and 2-year postoperative JOA scores were 13.0 points and 24.7 points, respectively ($p<0.001$). With respect to JOABPEQ, significant improvements were observed in pain-related disorders ($p<0.05$), walking ability ($p<0.01$), social life function ($p<0.05$), and mental health ($p<0.05$) dimensions. There were no significant differences between preoperative and 2-year postoperative sagittal alignment and range of motion. The degree of the paravertebral muscle atrophy at 2 years postoperatively was 23.0 % at spread side and 9.6 % at nonspread side ($p<0.01$). The fusion rate of the spinous process with the arcus vertebrae was 87%. This result reveals that LSPO could acquire the reconstruction of posterior supporting structures. We demonstrated that LSPO could be a one of the surgical options for LSS.

Keywords: decompressive laminoplasty with spinous process osteotomy, lumbar spinal stenosis, a less invasive procedure, surgical outcome

INTRODUCTION

There are several surgical approaches to correct lumbar spinal stenosis (LSS), with each procedure possibly having good and poor surgical outcomes. While an accustomed procedure is recommended, it is important to postoperatively preserve the posterior supporting structures

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because surgical damage to these important stabilizing structures may lead to postoperative segmental malalignment, instability, and subsequently failed back surgery syndrome. Weiner et al[1] developed decompressive laminoplasty with spinous process osteotomy (LSPO) as a less invasive procedure for lumbar decompression. In LSPO, unilateral limited takedown of the multifidus is undertaken and the spinous processes with the attached interspinous/supraspinous ligaments are retracted. In the original procedure, the multifidus of non-approach side was taken down from lamina for fenestration. In this study, we slightly modified the LSPO procedure. In our procedure, the lamina is removed from the center to the spread side without removing these muscles from non-approach side lamina. After decompressing nerve tissues, the retracted spinous process is replaced for bone unions between the spinous process and the residual laminae. However, in a previous report[1], follow-up duration was short (9 months), and bone fusion rate and paravertebral muscle (PVM) atrophy were not recorded.

There are few other reports of surgical outcomes of LSPO for patients with LSS. The purpose of this study was to evaluate the 2-year postoperative surgical outcomes and the usefulness of LSPO in LSS patients.

MATERIALS AND METHODS

Patients

Patient inclusion criteria were as follows: consecutive 2 levels LSS, no degenerative lumbar spondylolisthesis, no degenerative lumbar scoliosis, and no previous history of lumbar surgery. From January 2011 to March 2014, 27 eligible patients underwent stenosis decompression. In total, 23 patients were followed up for more than 2 years (mean follow-up duration was 27.4 months). We evaluated the outcomes of 23 patients (13 men and 10 women, mean age: 69.1 years, range: 36–87 years) who underwent LSPO. LSPO procedure was performed at L2 in one patients, L3 in three patients, L4 in 17 patients and L5 in two patients (table 1). This study was approved by the Institutional Review Board of Chutoen General Medical Center.

Table 1 Clinical data of 23 patients with LSS

Variable	
Sex	
Male	13
Female	10
Mean age (range)	69.1 (36–87)
Mean follow-up month (range)	27.4 (24–46)
Operation levels (case)	
L2	1
L3	3
L4	17
L5	2
Mean surgical duration ± SD (min)	128.0 ± 30.4
Mean intraop blood loss ± SD (ml)	115.5 ± 90.6

SD, standard deviation

Surgical procedures

A total of 23 patients underwent LSPO in the prone position. In this procedure, a posterior midline skin incision was made between the L3 and L5 spinous processes to expose the top of the L4 spinous process (if L3–4 and L4–5 decompressions were predetermined). Unilateral limited takedown of the multifidus was undertaken, followed by L4 spinous process osteotomies at the involved level [Figure 1(a)]. The L4 spinous processes with the attached interspinous/supraspinous ligaments were retracted, and the L4 lamina was removed from center to spread side. A complete trumpeted decompression was then undertaken at both L3–L4 and L4–L5 levels under the microscope [Figure 1(b),2]. After decompressing nerve tissues, the retracted L4 spinous process was replaced using a strong suture.

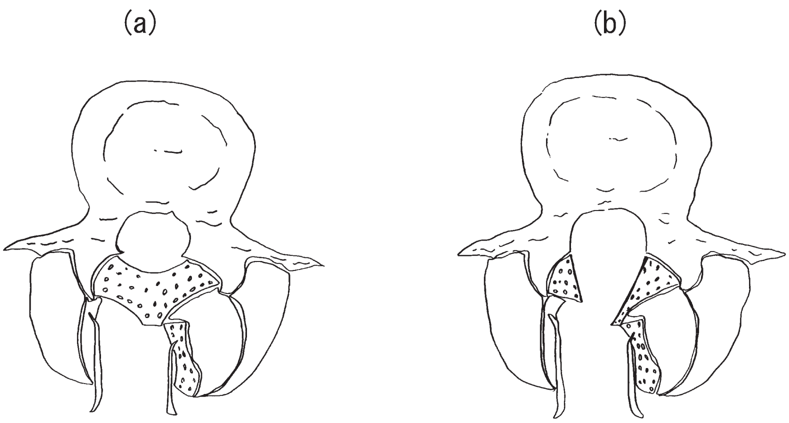

Fig. 1 (a) Illustration showing that unilateral limited takedown of the multifidus is undertaken, followed by L4 spinous process osteotomies. (b) Illustration showing that a complete trumpeted decompression, leaving L4 lamina on the nonapproach side.

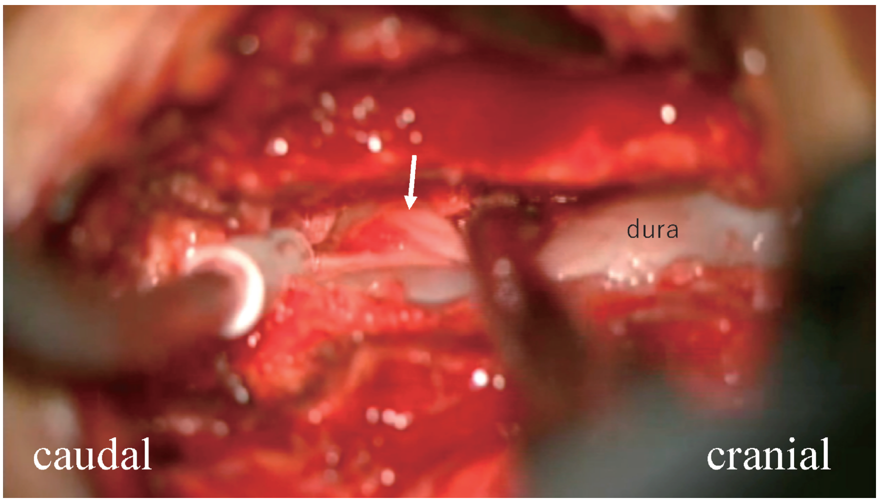

Fig. 2 This patient underwent L4 LSPO right side approach for LSS (L3-4,4-5 stenosis). White arrow pointed the left L5 root.

Evaluation of outcomes

All clinical charts and radiological data of the patients were retrospectively reviewed. The low-back pain Japanese Orthopedic Association (JOA) scores[6)] were used to assess parameters preoperatively and 2 years postoperatively. Further, the recovery rate (RR) of JOA score was evaluated using the Hirabayashi method[7)]. Visual analog scale (VAS) scores for lower extremity (L/E) numbness, L/E pain, and low back pain (LBP) and responses to the JOA Back Pain Evaluation Questionnaire (JOABPEQ) were assessed preoperatively and 2 years postoperatively. Preoperative and 2-year postoperative sagittal alignment and segmental motion in both L1-S and surgical levels following LSPO were evaluated (Figure 3). The segmental motions were determined using the following formulae:

1. Pre- and post-operative flexion ROM (L1-S, above and below level) = pre- and post-operative lordotic angle (L1-S, above and below level) in neutral position – pre-and post-operative lordotic angle (L1-S, above and below level) in flexion
2. Pre- and post-operative extension ROM (L1-S, above and below level) = pre- and post-operative lordotic angle (L1-S, above and below level) in extension – pre- and post-operative lordotic angle (L1-S, above and below level) in neutral position

The surgical duration and intraoperative blood loss for each level were analyzed. To evaluate the magnitude of surgical damage to PVMs, we measured the cross-sectional PVM areas on preoperative and 2-year postoperative T2-weighted axial magnetic resonance imaging (MRI), which were obtained at the lowest operating intervertebral level. Measurement was performed twice on each image, and the mean of the cross-sectional area of PVM was calculated for each

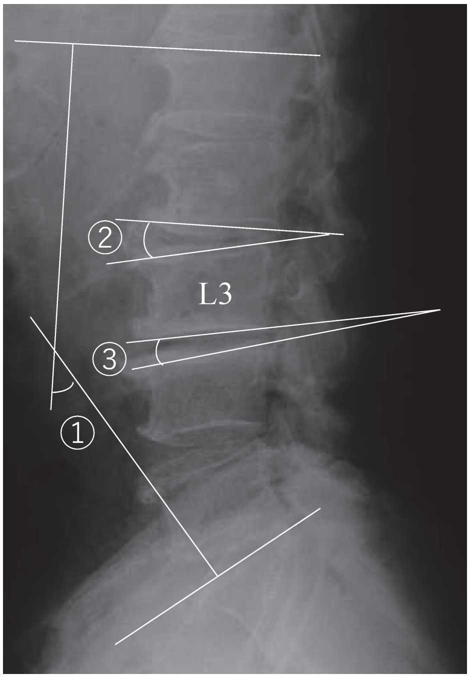

Fig. 3 This patient underwent L3 decompressive laminoplasty with spinous process osteotomy. By subtracting the value of the angle (1: L1-S sagittal angle, 2: above level angle, 3: below level angle) in the neutral position from those at maximal flexion and extension positions, the range of motion in flexion and extension could be measured, respectively.

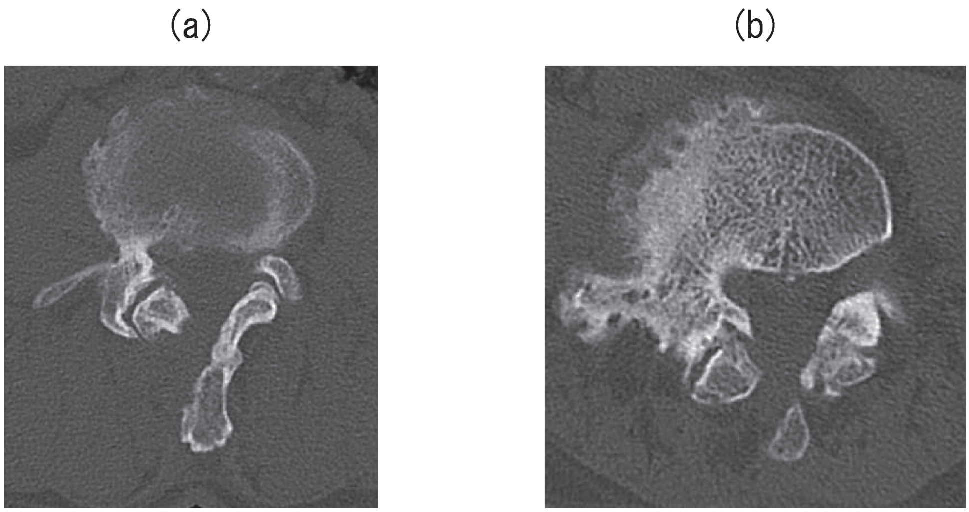

Fig. 4 (a) Bone union between the spinous process and the residual lamina was revealed. (b) The spinous process did not connect the residual lamina.

patient. The rate of muscle atrophy was calculated using the following formula: atrophy rate (%) = (1 − total postoperative area/total preoperative area) × 100.[3] Bone union rates between the spinous process and the residual laminae were also examined using computed tomography (CT) at 1 year and 2 years postoperatively. If the residual lamina was fused with the spinous process, we deemed bone fusion successful (Fig. 4).

Statistical Analysis

The data are presented as means ± standard deviations. Statistical differences in preoperative and 2-year postoperative clinical and radiographic parameters after LSPO were compared using Student's t-test. A p value of <0.05 was considered to be statistically significant.

RESULTS

No major surgery-related complications occurred following LSPO. The mean surgical duration and intraoperative blood loss were 128.4 ± 30.4 minutes and 115.5 ± 90.6 mL, respectively (Table 1). The mean preoperative and 2-year postoperative JOA scores were 13.0 ± 2.1 and 24.7 ± 3.8 in LSPO, respectively, indicating that the JOA scores significantly improved postoperatively. RR at 2 years postoperatively was 73.7% ± 23.2% in LSPO. With respect to JOABPEQ, significant improvements were observed in pain-related disorders ($p<0.05$), walking ability ($p<0.01$), social life function ($p<0.05$), and mental health ($p<0.05$) dimensions, but there was no significant difference between preoperative and 2-year postoperative lumbar function. VAS scores for L/E pain and LBP had significantly improved 2 years postoperatively ($p<0.05$) (Table 2). There were no significant differences between preoperative and 2-year postoperative sagittal alignment at L1-S and ROM (L1-S, above and below operation levels) (Table 3 and Figure 3). The PVM atrophy rates at 1 and 2 years postoperatively were 19.1% ± 13.7% and 23.0% ± 12.1% in the approach side and 6.7% ± 9.2% and 9.6% ± 8.8% in the nonapproach side, respectively (Table 4). The bone union rates between the spinous process and the residual laminae at 1 and 2 years postoperatively were 82.6% (19/23 cases) and 87.0% (20/23 cases), respectively (Table 4).

Table 2 Surgical outcomes

Variables	preop	postop 2 yrs	p
Mean JOA score ± SD (point)	13.0 ± 2.1	24.7 ± 3.8	<0.001
RR at 2 yrs (%)		73.7 ± 23.2	
Mean JOABPEQ score ± SD			
Pain-related disorders	44.4 ± 29.7	77.7 ± 24.8	0.033
Lumbar function	55.4 ± 34.3	71.7 ± 14.2	0.26
Walking ability	28.4 ± 20.9	75.4 ± 37.1	0.002
Social life function	41.7 ± 8.8	62.7 ± 23.2	0.03
Mental health	39.0 ± 13.1	56.3 ± 19.3	0.017
VAS (cm)			
L/E pain	6.0 ± 2.7	2.8 ± 3.1	0.02
L/E numbness	6.1 ± 2.9	3.5 ± 3.5	0.104
LBP	4.9 ± 3.0	2.1 ± 1.6	0.049

JOA, Japanese Orthopedic Association; RR, recovery rate; JOABPEQ, JOA Back Pain Evaluation Questionnaire; SD, standard deviation; VAS, visual analog scale; L/E, low extremity; LBP, low back pain

Table 3 Radiological evaluation

Variables	preop	postop 2 yrs	p
L1-S (°)			
Sagittal alignment ± SD	42.9 ± 13.1	42.4 ± 16.9	0.86
Flexion ROM ± SD	22.8 ± 11.4	17.8 ± 13.2	0.196
Extension ROM ± SD	11.3 ± 10.2	9.6 ± 14.6	0.7
Decompression levels (°)			
above level flexion ROM ± SD	5.7 ± 3.8	4.7 ± 3.9	0.334
above level extension ROM ± SD	2.6 ± 2.9	2.9 ± 2.4	0.68
below level flexion ROM ± SD	5.2 ± 3.8	5.5 ± 4.4	0.772
below level extension ROM ± SD	2.1 ± 3.6	3.4 ± 3.4	0.219

ROM, range of motion; SD, standard deviation

Table 4 PVM atrophy rate and bone union rate

	post op 1 yr	post op 2 yrs
PVM atrophy rate (%) ± SD		
Approach side	19.1% ± 13.7%	23.0% ± 12.1%
Non-approach side	6.7% ± 9.2%	9.6% ± 8.8%
Bone union rate (%)	82.6%	87%

PVM, paravertebral muscle; SD, standard deviation

DISCUSSION

The LSPO procedure allows for better decompression of intraspinal nerve tissues as well as reconstruction and minimizing damage to posterior supporting structures. JOA scores, RR of JOA scores, and the four items (pain-related disorders, walking ability, social life function, and mental health) in JOABPEQ were significantly improved postoperatively. Our findings demonstrated that the PVM atrophy rate at the nonsurgical side was significantly lower than that at the surgical side. In addition, the bone fusion rate at 1 and 2 years was 82.6% and 87.0%, respectively. Therefore, using the LSPO procedure, we could reconstruct the posterior supporting structures postoperatively and achieve better long-term spinal stability than other procedures for LSS.

Weiner et al[1)] reported that the use of LSPO in lumbar decompressive surgery provides excellent visualization and room to work while minimizing resection and injury to tissues not directly involved in the pathologic process. In their report, the PVM atrophy rate, bone fusion rate, and radiological evaluation were not recorded. In our study, 2-year postoperative surgical outcomes and the usefulness of LSPO were evaluated. Other decompression procedures for LSS that preserve the posterior supporting structures of the lumbar spine have been developed[2-4,8,9)]. Watanabe et al[3)] reported that the lumbar spinous process-splitting laminectomy (LSPSL) procedure for LSS allows for better visualization and a wider working space while minimizing damage to posterior lumbar supporting structures. However, in this procedure, postoperative bone fusion between the spinous processes and the lamina was not expected. The postoperative reconstruction of posterior structures, for example, bone union between the spinous process and the residual laminae, might be very important to achieve positive, long-term surgical outcomes, likewise inhibiting postoperative atrophy of paraspinal muscles. Sihvonen et al[9)] reported that striking denervation atrophy of low back muscles occurs in injured segments, leading to loss of functional muscle support and disturbed segmental mobility. Kakiuchi et al[2)] reported that osseous continuity between the spinous processes and the lamina after posterior decompression of the lumbar spine is important for maintaining positive surgical outcomes. Deleterious effects of osseous discontinuity on patient outcomes were obvious 10–12 years later. We previously reported on a modified LSPSL procedure[4)]. This procedure was less invasive to the PVMs and was considered to be laminoplasty. However, acquiring bone fusion was not easy and the bone fusion rate between the spinous processes and the lamina in modified LSPSL was 81.3%, which was lower than that in the LSPO procedure.

In addition, Abumi et al[10)] reported that the division of supraspinous and interspinous ligaments did not affect ROM. However, Bresnehan[5)] reported that removal of posterior elements for treatment of stenosis at L3-L4 and L4-L5 results in increased flexion-extension and axial rotation at the surgical site. Removal of the spinous process and supra- and interspinous ligaments in the complete laminectomy (OPEN) model produced almost twice as much flexion motion compared with that generated when these elements remained intact in microendoscopic decompression of stenosis (MEDS) and bilateral interlaminar laminotomies (IL). The greatest effect on motion as a result of posterior element removal occurred in extension. The motion generated in both the OPEN and the IL models was four times greater than the intact. The MEDS motion also increased; however, it was slightly less than twice the intact. In LSPO, the sagittal alignment and segmental motion at L1-S, above and below surgical levels, were not significantly different preoperatively and 2 years postoperatively. In LSPO, all patients underwent spinous process osteotomy. On the other hand, in the MED model, bilateral decompression was done without spinous process osteotomy, followed unilateral limited takedown of the multifidus. Therefore, preservation of interspinous/supraspinous ligaments and bone union between the spinous process and the residual laminae may be more effective for sagittal alignment than PVM preservation.

Moreover, there were several reports[11-13] that stated microscopic bilateral decompression via a unilateral approach is a minimally invasive technique. Dohzono et al[12] reported achievement of good decompression along with preservation of the interspinous /supraspinous ligament complexes and contralateral paraspinal muscles, thus minimizing postoperative spinal instability. However, sometimes it might be difficult for these procedures to achieve complete root decompression at the approach side when there is a huge facet and/or bulging of the spinous process. LSPO is not affected by bone deformities.

The PVM atrophy rate at the nonsurgical side in LSPO might approximately be the same compared with the LSPSL procedure. However, the PVM atrophy rate at the surgical side in LSPO was higher than that in the LSPSL procedure. Two years postoperatively, VAS scores for LBP significantly improved in the LSPO procedure. In this study, it was unclear how much PVM atrophy affected LSPO surgical outcomes. Therefore, a longer follow-up period is required to assess the association between long-term surgical outcomes and PVM atrophy.

This study had some limitations. First, our study was performed at a single institution and we could not compare the outcomes of LSPO procedure with that of other procedures. Second, this study showed only single-level LSPO surgical outcomes. In our future study, we will evaluate multilevel LSPO surgical outcomes.

CONCLUSIONS

Postoperative surgical outcomes of LSPO were good in LSS patients. The LSPO procedure allowed bone union between the spinous process and the residual lamina postoperatively in many cases. We have illustrated LSPO could be a one of the surgical options for LSS.

CONFLICT OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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