Efficacy of Laminoplasty in Improving Sensory Disturbances in Patients with Cervical Spondylotic Myelopathy: A Prospective Study

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OBJECTIVE: **Upper extremity sensory disturbances are primary symptoms that affect the quality of life (QOL) of patients with cervical spondylotic myelopathy. Although laminoplasty is 1 of the surgical options, its effects on sensory disturbances have remained unclear. We aimed to determine whether surgical intervention would improve the sensory disturbances of patients with cervical spondylotic myelopathy.**

METHODS: **We conducted a prospective clinical trial of 101 patients who had undergone open door laminoplasty. For an objective sensory assessment, we measured the current perception thresholds (CPTs) in the patients' forearms and palms using PainVision PS-2100. For a subjective sensory assessment, numbness in the upper extremities was rated using a visual analog scale (VAS). Using the VAS scores, the patients were divided into those with improvement and without improvement. Their self-reported 36-item short-form health survey and Japanese Orthopaedic Association cervical myelopathy evaluation questionnaire scores were compared.**

RESULTS: **The postoperative CPTs in relationship to the preoperative CPTs at 3, 6, and 12 months was 99.3%, 98.1%, and 93.8% in the forearm and 93.6%, 90.6%, and 87.8% in the palm, respectively. The corresponding postoperative numbness VAS scores were 63.8%, 50.5%, and 48.0%. At 12 months postoperatively, the 36-item short-form health survey physical and role component summary scores, cervical spine function effectiveness rates, upper and lower extremity function, and QOL items in the Japanese Orthopaedic Association cervical myelopathy evaluation questionnaire were significantly higher in the improvement group.**

CONCLUSIONS: **Our findings have indicated that improvement in postoperative subjective sensory disturbances will occur relatively earlier and will be significantly greater than the improvement in objective sensory disturbances. Furthermore, improvement in the subjective sensory disturbances contributes to functional spinal cord recovery and patients' health-related QOL.**

INTRODUCTION

Cervical spondylotic myelopathy (CSM) is 1 of the most common neurologic disorders among geriatric populations. It is a progressive degenerative disease characterized by cervical spinal cord dysfunction. The common CSM symptoms include sensory disturbances of the extremities,

Key words
- Cervical spondylotic myelopathy
- JOACMEQ
- Laminoplasty
- Numbness
- PainVision
- Sensory disturbance
- SF-36

Abbreviations and Acronyms
CI: Confidence interval
CPT: Current perception threshold
CSM: Cervical spondylotic myelopathy
GH: General health
IQR: Interquartile range
JOA: Japanese Orthopaedic Association
JOACMEQ: Japanese Orthopaedic Association cervical myelopathy evaluation questionnaire
OPLL: Ossification of the posterior longitudinal ligament
OR: Odds ratio
PCS: Physical component summary
PF: Physical functioning
QOL: Quality of life
RCS: Role/social component summary
RE: Role limitations due to emotional problems
RP: Role limitations due to physical health problems
SF-36: 36-Item short-form health survey
VAS: Visual analog scale

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clumsiness of the hands, gait abnormalities, and urinary dysfunction.[1] The treatment options include decompression surgery, and several studies have demonstrated that cervical laminoplasty will provide satisfactory results.[2-7] Sensory disturbances, such as numbness, will often present as the initial CSM symptoms and will often be localized in the upper limbs.[8] However, because it is difficult to quantitatively assess sensory disturbances, few data on their postoperative changes are available. Although the Japanese Orthopaedic Association[9] (JOA) and modified JOA[10] scores have been commonly used in the clinical assessment of CSM, the objective and quantitative evaluation of sensory disturbances using the JOA score has been challenging, and the pre- and postoperative differences cannot be assessed effectively. However, sensory disturbances will frequently persist after surgery, affecting patients' activities of daily living and quality of life (QOL). Thus, the assessment of sensory disturbances is vital.

The present study's aims were to prospectively examine the postoperative improvements in subjective and objective sensory disturbances in patients with CSM after laminoplasty. In addition, we aimed to prospectively evaluate the effect of sensory disturbance improvement on patient satisfaction, physical disability, and general health.

METHODS

Subjects

A total of 101 patients with CSM (78 men and 23 women; mean age, 65.5±12.8 years), who had undergone open door laminoplasty from May 2009 to November 2016 at our medical center, were enrolled in the present study (Figure 1). Patients with both single- and multiple-level spinal cord compression lesions were included. Patients with a history of cervical surgery, cerebral palsy, thoracic myelopathy, ossification of the posterior longitudinal ligament (OPLL), cervical disc herniation, cervical radiculopathy, spinal cord tumor, spinal cord injury, or spinal fusion surgery were excluded from the present study.

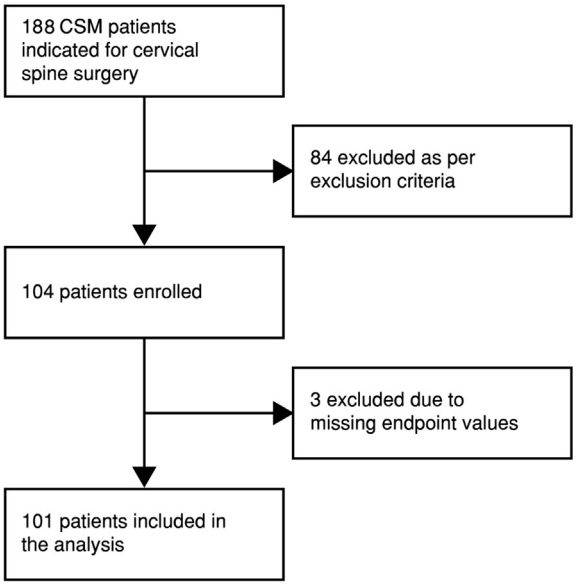

Figure 1. Flow chart showing the number of patients enrolled and excluded from the present study. CSM, cervical spondylotic myelopathy.

Surgical Technique for Modified Open Door Laminoplasty

A single surgeon performed modified open door laminoplasty as initially described by Itoh and Tsuji.[11] In brief, the head was elevated at a 20°–30° angle with a Mayfield cranial stabilizing device to attain mild flexion of the cervical spine. A posterior midline incision was made, followed by an incision of the ligamentum nuchae. The muscles from the C3 to C6 spinous processes were detached, and the muscles attached to C2 and C7 were preserved. Muscle detachment was performed slightly lateral to the lamina–facet junction. Gutters were created on the inner edges of the facet joints on both the open and the hinge sides. A dome-shaped partial laminectomy was performed on the caudal side of C3 and cranial side of C7 on a case-by-case basis. Once the gutters had been completed, the lamina was opened, and the ligamentum flavum and the epidural adhesion tissue on the open side were severed as necessary. A small burr hole was created on the open side, sutures were passed through, and a hydroxyapatite spacer was placed to preserve an open laminal position. A closed drain was installed, and the wound was closed by suturing the ligamentum nuchae.

On postoperative day 2, the patient was permitted to sit, stand, and walk. In principle, a cervical collar was not used. Cervical spine range of motion training and isometric muscle strengthening were initiated during the early postoperative period.

Assessment of Sensory Disturbances

PainVision PS-2100 (Nipro, Osaka, Japan; Figure 2) was used to perform an objective sensory assessment by selectively stimulating sensory nerves with a pulsed current (Aβ and Aδ

Figure 2. Photograph of the PainVision PS-2100 unit used to calculate the current perception threshold.

Figure 3. Photography of the measurement sites for the PainVision unit. Proximomedial sections of the flexion side of the bilateral forearms and palms were used to calculate the current perception threshold.

fibers). The PainVision PS-2100 device (Nipro) includes an electrical stimulation system and a control system and can measure both the perception threshold and the pain intensity. The current perception threshold (CPT) mode was used for objective sensory assessment. The CPT measures the minimum perceived current by generating a weak stimulating current, which gradually increases. When the stimulating current is perceived for the first time, the subject uses a stop switch button to end the measurement. The point at which a current has initially been perceived represents the CPT. In the present study, PainVision was used to measure the CPT in the proximomedial flexion side sections of the bilateral forearms and palms. The CPT test sites were identical for all the patients. A weak electrical current was applied to the skin via an electrode. CPT was defined as the minimum threshold that could be perceived as a stimulus. PainVision generated a superficial pulsed current (50 Hz; 0–150 μA; pulse amplitude, 0.3 ms) that gradually increased in intensity and measured the participant's electrical stimulation threshold (Figure 3). We measured the CPT 3 times in each section and calculated the bilateral average.

For the subjective sensory assessment, numbness in the upper extremities was rated by the patients using a visual analog scale (VAS) for numbness with a score from 0 mm (no pain/numbness) to 100 mm (most intense pain/numbness imaginable). The CPT and VAS numbness were measured preoperatively and at 3, 6, and 12 months postoperatively. Using the change in the VAS numbness score at 12 months postoperatively, the patients were divided into an improvement group ($n = 64$) and a nonimprovement group ($n = 36$). In accordance with the findings from a previous study,[11] the improvement group included patients who had had either 1) a ≥20-mm decrease in the postoperative VAS numbness score compared with the preoperative VAS numbness score or 2) a preoperative VAS numbness score of ≥10 mm with a postoperative VAS numbness score was <10 mm. One patient was excluded from the analysis because both the pre- and the postoperative VAS scores were ≤10 mm.

Assessment According to Patient Perspectives

The assessments were performed using the Japanese Orthopaedic Association cervical myelopathy evaluation questionnaire (JOACMEQ)[12] and the 36-item short-form health survey (SF-36).[13] The JOACMEQ is a patient-based assessment method, in which the patients answer 24 questions related to their QOL and their cervical, upper extremity, lower extremity, and bladder function. Each item was scored from 0 to 100, after which the assessments were performed. The effectiveness rate was determined by comparing the pre- and postoperative JOACMEQ scores for each item. The surgical intervention was considered effective if the score had increased by ≥20 points or if the preoperative score had been <90 points and the postoperative score was ≥90 points.[12]

We obtained scores for the 8 SF-36 subscales (physical functioning [PF], role limitations due to physical health problems [RP], bodily pain [BP], general health [GH], vitality [VT], social functioning [SF], role limitations due to emotional problems [RE], and mental health [MH]) and the summary scores of the three components (physical component summary [PCS], mental component summary [MCS], and role/social component summary [RCS]).[13] Both the JOACMEQ and SF-36 were used as self-assessment tools preoperatively and at 3, 6, and 12 months postoperatively.

Statistical Analysis

Statistical analyses were performed using SPSS, version 22.0, for Windows (IBM Japan, Tokyo, Japan). All data are presented as mean ± standard deviation or the median and interquartile range (IQR). The Mann-Whitney U test and χ^2 test were used to analyze the differences between the 2 groups. Repeated measures analyses of variance were performed in the same group using the Wilcoxon signed rank test. We performed logistic regression analysis to identify the preoperative factors associated with nonimprovement in numbness. Univariate logistic regression analysis was performed, followed by multivariate logistic regression analysis including the variables with $P < 0.2$ in the univariate analysis (forward selection method, likelihood ratio). The 95% confidence intervals (CIs) of odds ratios (ORs) were estimated, and risk ratios <5% were considered significant.

Table 1. Current Perception Threshold and Visual Analog Scale Score for Numbness at Each Assessment Point*

Variable	Preoperatively	Postoperatively		
		3 Months	6 Months	12 Months
Objective sensory assessment				
Forearm CPT (μA)	14.6 (7.2)	13.8 (5.7)	14.5 (5.7)	13.4 (8.3)
Postoperative versus preoperative CPT (%)	NA	99.3 (49.8)	98.1 (40.8)	93.8 (43.2)
Palm CPT (μA)	31.6 (15.5)	29.4 (16.6)	29.9 (14.3)	28.7 (12.2)
Postoperative versus preoperative CPT (%)	NA	93.6 (35.9)	90.6 (33.8)	87.8 (33.8)
Subjective sensory assessment				
VAS score for numbness (mm)	77 (48)	43 (50)	36 (56)	33 (54)
Postoperative versus preoperative VAS (%)	NA	63.8 (55.2)	50.5 (71.3)	48.0 (72.6)

Data presented as median (interquartile range).
CPT, current perception threshold; NA, not applicable; VAS, visual analog scale.
*The comparison of the postoperative CPT in relation to the preoperative CPT at 3, 6, and 12 months in the forearm and in the palm with the postoperative VAS score for numbness in relation to the preoperative VAS score at 3, 6, and 12 months using the Mann-Whitney *U* test revealed *P* values of <0.001 for all measurement points.

Table 2. Baseline Data for Improvement and Nonimprovement Groups

Variable	Improvement	Nonimprovement	*P* Value*
Patients	64	36	
Sex			0.8
Male	50	27	
Female	14	9	
Age (years)	65.3 ± 14.1	65.5 ± 10.2	0.73
Preoperative forearm CPT (μA)	16.8 ± 10.9	17.3 ± 10	0.48
Preoperative palm CPT (μA)	36.3 ± 12.1	32.2 ± 12.6	0.085
Preoperative VAS score for numbness in upper extremity (mm)	75.3 ± 24	60.8 ± 30.3	0.019
Preoperative VAS score for numbness in lower extremity (mm)	40.6 ± 36.4	41.9 ± 32.1	0.82

Data presented as n or mean ± standard deviation.
CPT, current perception threshold; VAS, visual analog scale.
*Mann-Whitney *U* test.

RESULTS

The preoperative median CPT was 14.6 μA (IQR, 7.2 μA) in the forearm and 31.6 μA (IQR, 15.5 μA) in the palm. The preoperative median VAS score for numbness was 77 mm (IQR, 48 mm). The postoperative median CPT at 3, 6, and 12 months in relationship to the preoperative CPT was 99.3% (IQR, 49.8%), 98.1% (IQR, 40.8%), and 93.8% (IQR, 43.2%) in the forearm and 93.6% (IQR, 35.9%), 90.6% (IQR, 33.8%), and 87.8% (IQR, 33.8%) in the palm, respectively. In contrast, the postoperative median VAS score for numbness at 3, 6, and 12 months in relationship to the preoperative VAS for numbness was 63.8% (IQR, 55.2%), 50.5% (IQR, 71.3%), and 48.0% (IQR, 72.6%), respectively. By comparing the objective and subjective assessments, we noted that the subjective symptoms scores had improved to a greater extent compared with the objective CPT values at all measurement points (Table 1).

According to the VAS scores for numbness at 12 months, the patients were divided into an improvement group (n = 64) and nonimprovement group (n = 36). The SF-36 and JOACMEQ scores were compared between the 2 groups. Although the preoperative VAS scores for numbness in the upper extremities were greater in the improvement group than in the nonimprovement group, no statistically significant differences were found between the 2 groups in terms of sex, age, preoperative forearm and palm CPT, and VAS scores for numbness in the lower extremities (Table 2). When the preoperative SF-36 subscale scores were compared between the 2 groups, the GH score was significantly greater in the improvement group than in the nonimprovement group (Table 3). The postoperative PCS and RCS scores were also significantly greater in the improvement group than in the nonimprovement group at all assessment points. Additionally, although all subscale scores in the improvement group at 12 months postoperatively were greater than the preoperative scores, the increase in the nonimprovement group was limited to PF, RP, and RE (Table 3). The preoperative JOACMEQ item scores did not differ between the 2 groups. The effectiveness rate at 6 and 12 months postoperatively were significantly greater in the improvement group than in the nonimprovement group for upper extremity function, QOL items (at all assessment points), cervical spine function, and lower extremity function (Table 4).

Univariate and multivariate analyses were used to analyze the preoperative factors contributing to the differences between the 2 groups. Age, sex, forearm and palm CPT, VAS scores for numbness in the upper and lower extremities, SF-36 score, 3-component SF-36 summary scores, JOACMEQ score, and the duration of the symptoms before surgery were set as independent variables. Multivariate analysis indicated that greater preoperative VAS scores in the upper extremities were associated with a lower proportion of the nonimprovement group (OR, 0.977; 95% CI, 0.961–0.994; P = 0.007), and greater preoperative SF-36 RE scores were associated with a lower proportion of the nonimprovement group (OR, 0.941; 95% CI, 0.898–0.986; P = 0.011; Table 5).

Table 3. Scores for the 36-Item Short-Form Health Survey Subscales in the Improvement and Nonimprovement Groups

	Group		*P* Value		
SF-36 Score	Improvement	Nonimprovement	A*	B†	C‡
PF			NA	<0.001	0.033
Preoperatively	19.2 ± 24.0	12.5 ± 21.6	0.23		
12 Months postoperatively	37.2 ± 20.9	19.7 ± 19.1	<0.001		
RP			NA	<0.001	0.027
Preoperatively	23.8 ± 18.3	19.5 ± 14.0	0.35		
12 Months postoperatively	42.0 ± 15.9	25.5 ± 16.0	<0.001		
BP			NA	<0.001	0.79
Preoperatively	38.5 ± 10.8	36.8 ± 12.8	0.28		
12 Months postoperatively	46.9 ± 11.3	36.9 ± 10.2	<0.001		
GH			NA	<0.001	0.42
Preoperatively	44.6 ± 9.3	39.6 ± 10.5	0.031		
12 Months postoperatively	49.1 ± 10.9	38.9 ± 10.8	<0.001		
VT			NA	<0.001	0.15
Preoperatively	41.2 ±11.7	38.3 ± 10.6	0.21		
12 Months postoperatively	49.6 ± 12.8	40.6 ± 12.3	0.0015		
SF			NA	<0.001	0.64
Preoperatively	34.7 ± 17.4	33.6 ± 14.2	0.77		
12 Months postoperatively	47.0 ± 14.0	35.0 ± 15.0	<0.001		
RE			NA	<0.001	0.012
Preoperatively	30.7 ± 18.6	23.7 ± 15.3	0.076		
12 Months postoperatively	45.3 ± 15.9	30.5 ± 15.3	<0.001		
MH			NA	<0.001	0.083
Preoperatively	40.9 ± 12.1	38.2 ± 10.7	0.24		
12 Months postoperatively	49.5 ± 14.1	42.1 ± 13.0	0.0097		
PCS			NA	<0.001	0.19
Preoperatively	27.8 ± 16.3	23.0 ± 17.5	0.16		
3 Months postoperatively	38.4 ± 13.5	30.4 ± 15.2	0.0095		
6 Months postoperatively	40.1 ± 13.1	27.4 ± 12.9	<0.001		
12 Months postoperatively	39.5 ± 15.2	26.1 ± 15.0	<0.001		
MCS			NA	0.54	0.29
Preoperatively	53.9 ± 11.0	52.8 ± 11.7	0.53		
3 Months postoperatively	54.3 ± 11.3	53.3 ± 12.0	0.82		
6 Months postoperatively	54.1 ± 10.6	52.1 ± 13.1	0.45		
12 Months postoperatively	53.9 ± 11.1	50.9 ± 13.0	0.25		
RCS			NA	<0.001	0.012
Preoperatively	28.6 ± 20.1	25.9 ± 13.8	0.54		
3 Months postoperatively	35.7 ± 16.3	25.6 ± 16.7	0.0059		
6 Months postoperatively	40.2 ± 14.8	30.6 ± 18.2	0.0097		
12 Months postoperatively	44.4 ± 14.5	32.4 ± 16.2	<0.001		

SF-36, 36-Item short-form health survey; PF, physical function; NA, not applicable; RP, role limitations due to physical health problems; BP, bodily pain; GH, general health; VT, vitality; SF, social functioning; RE, role limitations due to emotional problems; MH, mental health; PCS, physical component summary; MCS, mental component summary; RCS, role component summary.

**P* values from comparison between the improvement and nonimprovement group scores at each assessment point using the Mann-Whitney *U* test.

†*P* values from comparison between the preoperative and 12-month postoperative scores in the improvement group using the Wilcoxon test.

‡*P* values from comparison of the preoperative and 12-month postoperative scores in the nonimprovement group using the Wilcoxon test.

DISCUSSION

In the present study, we performed an objective assessment of the pre- and postoperative differences in sensory disturbances using PainVision combined with a subjective assessment of numbness using a VAS. We included only patients with CSM (excluding cervical disc herniation and OPLL) who had undergone the same surgical procedure performed by a single surgeon at the same facility. The assessment focused on the patients' sensory disturbances. We found that the subjective sensory assessment had improved more than had the objective sensory assessment.

To the best of our knowledge, no previous prospective studies have assessed sensory disturbances using an objective approach, including detailed analyses. The quantitative assessment of sensory disturbances can be difficult, and previous assessments have used the patients' subjective experiences (i.e., VAS, numerical rating scale). We observed improvement in the 8 SF-36 subscale scores at 12 months postoperatively compared with the preoperative scores in the improvement group. In addition, the effectiveness rates for all items of the JOACMEQ, except for bladder function, were

Table 4. Preoperative Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire Scores and Efficacy Rates Stratified by Group

	Group		*P* Value	
Variable	**Improvement**	**Nonimprovement**	**A***	**B†**
Cervical spine function				
Preoperatively	72.0 ± 23.7	63.6 ± 26.7	0.13	
3 Months postoperatively (%)	43.4	27.3		0.13
6 Months postoperatively (%)	56.9	21.9		0.0017
12 Months postoperatively (%)	61.7	37.1		0.028
Upper extremity function				
Preoperatively	65.2 ± 28.0	59.0 ± 24.2	0.19	
3 Months postoperatively (%)	68.6	41.2		0.012
6 Months postoperatively (%)	71.7	39.4		0.0030
12 Months postoperatively (%)	69.2	33.3		0.0012
Lower extremity function				
Preoperatively	47.4 ± 34.0	43.6 ± 27.9	0.56	
3 Months postoperatively (%)	56.6	50.0		0.55
6 Months postoperatively (%)	65.5	36.4		0.0080
12 Months postoperatively (%)	64.2	32.4		0.0037
Bladder function				
Preoperatively	67.0 ± 26.3	70.3 ± 21.5	0.77	
3 Months postoperatively (%)	45.3	24.2		0.050
6 Months postoperatively (%)	45.8	27.6		0.10
12 Months postoperatively (%)	40.0	29.4		0.31
QOL				
Preoperatively	41.5 ± 19.5	38.7 ± 16.4	0.52	
3 Months postoperatively (%)	40.6	19.4		0.031
6 Months postoperatively (%)	43.8	20.0		0.018
12 Months postoperatively (%)	44.3	11.1		<0.001

QOL, quality of life.

**P* values from comparison of the preoperative Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire item scores between the improvement and nonimprovement groups using the Mann-Whitney *U* test.

†*P* values from comparison of the efficacy rates of each Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire item between the improvement and nonimprovement groups using the $\chi 2$ test.

significantly greater in the improvement group than in the nonimprovement group. Furthermore, the PCS and RCS scores in the SF-36 were significantly greater at all assessment points in the improvement group compared with those in the nonimprovement group, as were the effectiveness rates for upper extremity function in the JOACMEQ scores and QOL items. Compared with the nonimprovement group, those in the improvement group had greater cervical spine and lower extremity function at 6 and 12 months postoperatively. To the best of our knowledge, no previous study has performed assessments as frequently as those in the present study (i.e., preoperatively and 3, 6, and 12 months postoperatively).[3,4,14,15] Thus, we consider our data valuable. These results suggest that the superiority or inferiority of the improvement in sensory disturbances could be an index of neural viability. Furthermore, the sensory disturbance itself could influence the patients' health-related QOL.

The ascending sensory tracts in the spinal cord include the lateral spinothalamic tract (which transmits pain and temperature), ventral spinothalamic tract (tactile sensations), and posterior funiculus (epicritic and deep sensations—the sense of vibration and position).[16] Detailed examination of these tracts will effectively identify the cross-sectional spread of the lesion into the spinal cord. Seichi et al.[17] reported that the distribution of sensory disturbances in the upper extremities is more reliable for a neurological level diagnosis than muscle weakness and the deep tendon reflexes. PainVision can selectively stimulate the Aβ and Aδ fibers.[18,19] The minimum perceivable stimulus (i.e., pain, temperature, tactile sensation) current was considered the CPT.[20] The benefit of this test compared with conventional methods is that sensory disturbances can be noninvasively and painlessly quantified, enhancing patients' understanding of the

Table 5. Multivariate Analysis Results*

Variable	OR	95% CI	*P* Value
VAS score for numbness in upper extremity	0.977	0.961—0.994	0.007
SF-36 RE	0.941	0.898—0.986	0.011

OR, odds ratio; CI, confidence interval; VAS, visual analog scale; SF-36, 36-item short-form health survey; RE, role limitations due to emotional problems.
*Only observation items with $P \leq 0.2$ on univariate analysis were included as independent variables in the multivariate analysis.

test, and does not require unique skills.[18] In the present study, we observed some differences in the postoperative improvement of the objective and subjective assessments of sensory disturbances, which we attributed to differences between the 2 sensory pathways and differences in spinal plasticity.[16] Furthermore, our findings were in line with a previous study, which detected faster improvement of the subjective than the objective outcome measures after lumbar spine surgery.[21]

Laminoplasty has been reported as an important option for the treatment of CSM in numerous studies[3-7] and has been used more frequently in Japan than elsewhere owing to the greater incidence of OPLL. Furthermore, the suitability of laminoplasty for single-level stenosis has continued to be debated. Chiba et al.[3] conducted a minimum 10-year follow-up survey of 80 patients (CSM, 27 patients; OPLL, 53 patients) after open door laminoplasty and reported a CSM improvement rate using the JOA scores of 57.9% at 3 years postoperatively and 55.7% in the final survey, demonstrating favorable maintenance of the results. For the patients with OPLL, the improvement rates were 63.3% and 47.9% at 3 years postoperatively and at the final survey, respectively, demonstrating a reduction in improvement over time. A study by Seichi et al.[4] reported the long-term results (≥10 years) after double-door laminoplasty. They had excluded cases complicated by athetoid cerebral palsy.[4] They reported that long-term stability was maintained in 78% of the 35 patients with OPLL and nearly 100% of the 25 patients with CSM. However, these assessments had only included the physician's subjective evaluation using JOA scores.

The assessment systems for cervical disorders can be grouped into single-item and comprehensive assessment systems. The scoring systems with a single item include the VAS and the Nurick scale.[22,23] Comprehensive scoring systems include the JOA scale, modified JOA scale, and SF-36. The JOA scale was created by a deep understanding of cervical myelopathy, and the assessment was implemented by a medical practitioner.[9] However, recently, more emphasis has been given to patient-based evaluation or value-based medicine. Thus, the JOACMEQ,[12] a patient-based evaluation method, has been proposed, with mean scores determined from healthy individuals stratified by age and sex.[24] The SF-36 has been the most widely used self-reported health status survey in the world.[14,25] It was carefully constructed from a psychometric aspect and is an internationally accepted measure of health status owing to its proven scientific reliability and validity. A recent prospective study using the JOACMEQ and SF-36, by Fujiwara et al.,[14] reported no significant differences in the surgical treatment outcomes or functional recovery prognosis between the CSM and the OPLL groups. The study also reported a negative correlation between axial neck pain and JOACMEQ-assessed cervical spine function.[14] Zhou et al.[15] compared the patient-based SF-36 assessment with the physician-implemented modified JOA assessment score and found that improved modified JOA scores correlated with improvements in PF, RP, and SF at 1 year postoperatively. The present study has demonstrated that for patients who have exhibited postoperative improvement in the upper extremity VAS score for numbness, neurological recovery will also have been achieved at a relatively early stage after surgery. Moreover, the multivariate analysis results indicated that the preoperative SF-36 RE scores (i.e., psychological factors in daily life before surgery) contributed to the postoperative improvement in numbness. Previous investigations have shown an association between psychological factors and surgery outcomes in other settings. Thus, Visser et al.[26] have demonstrated a correlation between depression and poorer preoperative and postoperative total knee arthroplasty scores. Furthermore, Flanigan et al.[27] have observed an association between psychological distress, fear-avoidance behavior, poor perceived self-efficacy, or pessimistic personality traits and elective orthopedic surgery outcomes. The reasons for these correlations have not yet been definitively elucidated. However, they might be related to differences in the motivation for treatment, active participation in therapeutic activities, pain perception, and discrepancies between expectations for the surgical outcome and actual recovery. However, the findings of a correlation between psychological factors and postoperative numbness improvement should be discussed critically and examined in further studies for confirmation.

The present study had several limitations. Although we used PainVision as an objective sensory test for pain, temperature, and tactile sensation, we did not examine the correlation between the PainVision results and the results of conventional objective sensory tests.

CONCLUSIONS

Our findings have indicated that patients exhibiting postoperative improvement in upper extremity numbness can also achieve spinal cord function recovery relatively early in the postoperative period. These data could greatly contribute to medical professionals' understanding of CSM and help them provide better explanations to their patients.

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