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A Propensity Score–matched Analysis of Clinical Outcomes Between Single-level and Multilevel Intervertebral Decompression for Cervical Radiculopathy

Masahito Oshina, MD,^a Naohiro Kawamura, MD, PhD,^b Nobuhiro Hara, MD, PhD,^c Akiro Higashikawa, MD, PhD,^d Takashi Ono, MD, PhD,^e Yujiro Takeshita, MD,^f Seiichi Azuma, MD, PhD,^g Masayoshi Fukushima, MD,^h Hiroki Iwai, MD, PhD,ⁱ Takeshi Kaneko, MD, PhD,^j Hirohiko Inanami, MD,^j and Yasushi Oshima, MD, PhD^k

Study Design. Retrospective multicenter study with propensity score matching.

Objective. To compare the clinical outcomes of single-level and multilevel intervertebral decompression for cervical degenerative radiculopathy.

Summary of Background Data. In patients with cervical radiculopathy, physical examination findings are sometimes inconsistent with imaging data. Multilevel decompression may be necessary for multiple foraminal stenosis. Additional decompression is more invasive yet expected to comprehensively decompress all suspected nerve root compression areas. However,

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Study protocols were approved by the institutional review board at our hospitals and informed consent was obtained from all patients.

The authors report no conflicts of interest.

Address correspondence and reprint requests to Masahito Oshina, MD, Department of Orthopedic Surgery, NTT Medical Center Tokyo, 5-9-22 Higashigotanda, Shinagawa-ku, Tokyo 141-8625, Japan; E-mail: oshinamasahito@gmail.com

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the surgical outcomes of this approach compared with that of single-level decompression remain unknown.

Materials and Methods. The data of patients with spinal surgery for pure cervical radiculopathy were collected. Patients were categorized into the single-level (SLDG) or multilevel (MLDG) intervertebral decompression group at C3/C4/C5/C6/C7/T1. Demographic data and patient-reported outcome scores, including the Neck Disability Index (NDI) and Numerical Rating Scale (NRS) scores for pain and numbness in the neck, upper back, and arms, were collected. The NDI improvement rates and changes in NRS scores were analyzed one year postoperatively at patient-reported outcome evaluation. Propensity score matching was performed to compare both groups after adjusting for baseline characteristics, including the preoperative NDI and NRS scores.

Results. Among the 357 patients in this study, SLDG and MLDG comprised 231 and 126 patients, respectively. Two groups (n = 112, each) were created by propensity score matching. Compared with the MLDG, the SLDG had a higher postoperative NDI improvement rate (P=0.029) and lower postoperative arm numbness NRS score (P=0.037). Other outcomes tended to be more favorable in the SLDG than in the MLDG, yet no statistical significance was detected.

Conclusions. In patients with cervical radiculopathy, the surgical outcomes of the SLDG showed better improvement in clinical outcomes than those of the MLDG. Numbness remained on the distal (arms) rather than the central (neck and upper back) areas in patients receiving multilevel decompression.

Key words: cervical radiculopathy, foraminal stenosis, clinical outcome, propensity score matching, NDI, NRS, single-level decompression, multilevel decompression, spine surgery, spine **Spine 2023;48:247–252**

n most patients with cervical degenerative radiculopathy, the identification of the nerve root compression site can be accomplished by the careful evaluation of clinical

From the ^aDepartment of Orthopedic Surgery, NTT Medical Center Tokyo, Tokyo, Japan; ^bDepartment of Spine and Orthopedic Surgery, Japanese Red Cross Medical Center, Tokyo, Japan; ^cDepartment of Orthopedic Surgery, Japanese Red Cross Musashino Hospital, Tokyo, Japan; ^dDepartment of Orthopedic Surgery, Japan Organization of Occupational Health and Safety Kanto Rosai Hospital, Kanagawa, Japan; ^eDepartment of Spinal Surgery, Japan Community Health-Care Organization Tokyo Shinjuku Medical Center, Tokyo, Japan; ^fDepartment of Orthopedic Surgery, Japan Organization of Occupational Health and Safety Yokohama Rosai Hospital, Kanagawa, Japan; ^BDepartment of Orthopedic Surgery, Saitama Red Cross Hospital, Saitama, Japan; ^hDepartment of Orthopedic Surgery, Toranomon Hospital, Tokyo, Japan; ¹Iwai Orthopedic Medical Hospital, Tokyo, Japan; ¹Inanami Spine and Joint Hospital, Tokyo, Japan; and ^kDepartment of Orthopedic Surgery, the University of Tokyo, Tokyo, Japan.

symptoms, physical examination findings, and imaging data.¹ However, if physical examination findings are not clearly consistent with imaging data and there is evidence of multi-level intervertebral stenosis multilevel decompression may be necessary.^{2–4} Moreover, physical examination findings often mismatch or overlap with the classical dermatome of each nerve root,⁵ resulting in a low correlation between subjective symptoms and objective imaging findings.⁶

When there is no diagnostic confidence regarding the site of the responsible lesion, electromyography (EMG) or selective nerve root block (SNRB) is sometimes used. However, these invasive techniques do not always provide an accurate diagnosis.^{7,8} Therefore, for patients with suspected cervical radiculopathy, whose physical and imaging findings do not match those of intervertebral stenosis, multilevel decompression may be required. This would be more invasive but is expected to comprehensively decompress all suspected nerve root compression areas, including those with polyradiculopathy. However, whether this approach provides the same surgical outcome as that of a single-level decompression remains unknown. This study aimed to compare the clinical outcomes between single-level and multilevel intervertebral decompression for cervical degenerative radiculopathy.

MATERIALS AND METHODS

Patient Samples

We retrospectively extracted data from 509 patients who underwent cervical spinal surgery for cervical radiculopathy registered in 11 hospitals participating in this prospective multicenter study between 2017 and 2020. The inclusion criteria were degenerative cervical radiculopathy without cervical myelopathy and myeloradiculopathy. Each patient had a cervical radiculopathy diagnosis on their preoperative surveillance record, which included other demographic data. Among the aforementioned patients, those with complete demographic data and patient-oriented questionnaires preoperatively and one year postoperatively were included. Patients with a diagnosis of spinal tumors, rheumatoid arthritis, congenital abnormalities, infection, or trauma were excluded. Patients were divided into two groups single-level (SLDG) or multilevel (MLDG) intervertebral decompression between C3/C4, C4/C5, C5/C6, C6/C7, and C7/T1.

Data Collection

Demographic data, including age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status classification, diabetes mellitus (DM), smoking status, history of disk herniation or osteoarthritis, surgical procedure, and number of intervertebral decompression levels, were collected. Radiculopathy diagnosis, surgical indication, surgical procedure, and number of decompression levels were decided by surgeons at each institute. Surgical procedures for patients were classified into anterior

decompression and fusion, posterior decompression, and posterior decompression and fusion.

Clinical Outcomes

Patient-reported outcome (PRO) scores were collected preoperatively with questionnaires, including the Neck Disability Index (NDI) and Numerical Rating Scale (NRS) for pain and numbness in the neck, upper back, and arms (Figure 1). At the one-year follow-up, patients were encouraged to complete the same questionnaires for postoperative PRO. In addition, the NDI improvement rate, defined as (postoperative NDI score-preoperative NDI score)/(preoperative NDI score) × 100, and changes in NRS scores, defined as preoperative NRS score-postoperative NRS score, were analyzed.

Statistical Analyses

Demographic data and preoperative and postoperative PRO scores were compared between SLDG and MLDG using an unpaired t test or Mann-Whitney U test for continuous variables and a χ^2 test for categorical variables, as appropriate. To adjust for preoperative background factors, propensity score matching was performed. Propensity scores were calculated from logistic regression models. In the present study, demographic data, including age, sex, BMI, ASA classification, DM, smoking status, history of disk herniation or osteoarthritis, surgical procedure, and the number of decompressed spinal levels, as well as preoperative PRO scores, including NDI scores, NRS scores for pain (neck, upper back, and arms), and NRS scores for numbness in these sites, were used for one-to-one propensity score matching between SLDG and MLDG. R statistical software, version 2.8.1 (The R Foundation for Statistical

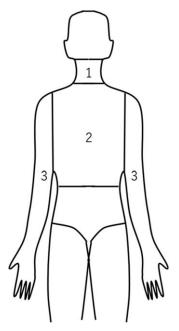


Figure 1. Areas of pain and numbness were divided into the neck (1), upper back (2), and arms (3). Pain and numbness intensity were measured using Numerical Rating Scale.

Computing) was used for statistical analyses. A P value <0.05 was considered statistically significant.

RESULTS

Comparison of Preoperative Characteristics

Of the 509 patients who underwent surgery for pure cervical radiculopathy and did not have myelopathy or myeloradiculopathy diagnoses, 357 patients (288 males and 69 females; mean age at surgery, 55.4 yr) with complete demographic data as well as preoperative and one-year postoperative PROs were included. Among these patients, 231 and 126 received single-level and multilevel intervertebral decompressions between C3/C4 and C7/T1, respectively.

Multilevel decompression was performed between two intervertebral segments in 89 cases, between three intervertebral segments in 24 cases, between four intervertebral segments in 12 cases, and between five intervertebral segments in one case (Table 1). For single-level decompression, the anterior method with 100% fusion surgery was used in 28% of cases, while the posterior method with 2% fusion surgery was used in 72% of cases. For multilevel decompression, the anterior method with 100% fusion surgery was used in 23% of cases, while the posterior method with 5% fusion surgery was used in 77% of cases.

Comparison of Unmatched Preoperative and Postoperative Data

MLDG included patients who were older (P = 0.02), those who had a higher ASA grade (P = 0.012), and fewer patients with a history of disk herniation (P < 0.001) than SLDG. The preoperative NRS scores for pain in the neck (P = 0.002) and arms (P = 0.041) were significantly higher in SLDG than in MLDG. Other parameters, including the NDI score; NRS scores for upper back pain; and NRS scores for numbness in the neck, upper back, and arms, tended to be worse in the SLDG than in MLDG; however, the difference was not statistically significant.

Before propensity matching, the postoperative NDI improvement rate (P = 0.001); changes in NRS scores for pain in the neck (P = 0.003), upper back (P = 0.040), and arms (P = 0.028); and changes in NRS scores for arm numbness (P = 0.025) were better in the SLDG than in MLDG. The postoperative NRS scores for arm numbness (P = 0.006) were lower in SLDG than in MLDG (Table 2).

Comparison of Demographic Data and Clinical Outcomes With Propensity Score Matching

Preoperative age, sex, BMI, ASA classification, DM, smoking status, history of disk herniation or osteoarthritis, surgical technique, NDI scores, and NRS scores for pain and numbness in the neck, upper back, and arms were matched by propensity scores, resulting in 112 matched pairs of patients in SLDG and MLDG, respectively. Post-operatively, SLDG had a better NDI improvement rate (P = 0.029) and lower NRS score for arm numbness (P = 0.037) than the MLDG. The postoperative NDI scores and other NRS scores tended to be better in SLDG than in MLDG; however, there was no statistically significant difference (Table 3).

DISCUSSION

Despite propensity score matching for preoperative physical status and disability, the surgical outcomes in SLDG regarding the NDI improvement rate instead of the NDI score itself and the postoperative NRS scores for arm numbness were better than those undergoing MLDG. To the best of our knowledge, this study is the first to assess the effect of the number of decompression levels on the clinical outcomes of pure cervical radiculopathy in a multicenter cohort using propensity score matching.

In pure cervical radiculopathy, outcome comparison based on different surgical levels has not been previously performed. However, in a previous systematic review, the

TABLE 1. Preoperative Demographic Data							
		Mean (SD)					
	Total	Single-level	Multilevel	Р			
N (2, 3, 4, 5 levels)	357	231	126 (89, 24, 12, 1)				
Age (yr)	55.4 (10.8)	54.4 (10.6)	57.2 (11.0)	0.020			
Sex: male (%)	80.7	80.1	81.7	0.780			
BMI (kg/m ²)	24.1 (3.6)	23.86 (3.6)	24.55 (3.7)	0.084			
ASA grade (grade 1:2:3:4) (%)	1.7 (0.5)	36:60:4:0	21:72:6:0	0.012			
Diabetes mellitus (%)	12.9	11.7	15.1	0.409			
Current smoker (%)	16.8	13.9	22.2	0.054			
Disk herniation (%)	27.7	34.6	15.1	< 0.001			
Surgical procedure (PD:ADF:PDF) (%)	71:26:3	70:28:2	72:23:5	0.256			
	•	•	•	•			

Bold values indicate P < 0.05.

ADF indicates anterior decompression and fusion; ASA, American Society of Anesthesiologists Classification; BMI, body mass index; PD, posterior decompression; PDF, posterior decompression and fusion.

Single VS Multi Decompression for	Cervical Radiculopathy Oshina et al
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c Data

Analysis

Р

0.628 >0.999 0.688

0.768

> 0.999 0.730 0.856 0.613

> 0.804 0.589 0.485 0.745 0.681

0.475

0.691

0.411

0.029

0.214

0.149

0.296 0.185

0.187

0.540

0.731

0.547

0.614

0.373

0.037

0.185

2.6(3.3)

3.2 (3.5)

ADF indicates anterior decompression and fusion; ASA, American Society of

Anesthesiologists Classification; BMI, body mass index; NDI, Neck Disability Index; NRS, Numerical Rating Scale; PD, posterior decompression; PDF, posterior decompression and fusion; PRO, patient-reported outcome.

Change in NRS scores

Bold values indicate P < 0.05.

of arm numbness

NDI scores 15.2 (7.9) 0.005 Nole kopain 4.3 (2.9) 3.3 (3.1) 0.002 Neck pain 4.3 (2.9) 3.3 (3.1) 0.002 Margin 3.3 (3.3) 2.7 (3.1) 0.116 Margin 5.3 (3.1) 4.6 (3.4) 0.041 Neck numbness 1.6 (2.7) 1.6 (2.7) 0.840 Numbness 1.3 (3.5) 1.1 (2.2) 0.605 Arm numbness 5.5 (3.1) 5.4 (3.1) 0.997 Postoperative PRO (NDL and NRS scores) Null scores 8.0 (7.5) 8.3 (6.6) 0.721 NDI scores 8.0 (7.5) 8.3 (6.6) 0.721 Null scores 15.6 (8.2) 15.3 (7) NDI scores 8.0 (7.5) 8.3 (6.6) 0.721 Null scores 15.6 (8.2) 15.3 (7) NDI scores 1.8 (2.4) 1.8 (2.2) 0.909 Null scores 1.6 (2.7) 1.5 (3.0) Change in NRS 2.1 (3.3) 1.3 (3.7) 0.404 Neck numbness 1.3 (3.2) 2.8 (3 Arm pain 1.9 (2.5) 2.1 (2.5) 0.559 NDI scores 7.2 (7.4) 8.0 (6		Mean (SD)			Propensity Score-matched		
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Upper back numbness 1.3 (3.5) 1.1 (2.2) 0.605 Arm numbness 5.5 (3.1) 5.4 (3.1) 0.997 Disbetes mellitus (%) 15.2 17.0 Properative PRO (NDI and NRS scores) NDI scores 8.0 (7.5) 8.3 (6.6) 0.721 NDI scores 8.0 (7.5) 8.3 (6.6) 0.721 Output for the scores NDI scores 15.6 (8.2) 15.3 (7.5) NDI scores of neck pain 1.8 (2.4) 1.8 (2.2) 0.909 Output for the scores 15.6 (8.2) 15.3 (7.5) Change in NRS scores of neck pain 1.2 (2.0) 1.5 (2.4) 0.351 Output for the scores 1.8 (2.8) 1.6 (2.8)	Neck numbness	1.6 (2.7)	1.6 (2.7)	0.840		22:73:5:0	24:70:
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Disk periative PRO (NDI and NRS scores) Disk herniation (%) 15.2 17.7 NDI scores 8.0 (7.5) 8.3 (6.6) 0.721 Surgical procedure (PD: ADDI and NRS scores) 73.22 NDI miprovement rate (%) 1.8 (2.4) 1.8 (2.2) 0.909 Preoperative PRO (NDI and NRS scores) 73.22 Change in NRS scores of neck pain 2.5 (3.0) 1.5 (2.4) 0.351 NDI scores 15.6 (8.2) 15.3 (7 Change in NRS scores of neck pain 1.2 (2.0) 1.5 (2.4) 0.351 Neck pain 3.7 (3.1) 3.5 (3 Arm pain 1.9 (2.5) 2.1 (2.5) 0.559 NDI scores 7.2 (7.4) 8.0 (6 NDI mporement pain 1.9 (2.5) 2.1 (2.5) 0.559 NDI scores 7.2 (7.4) 8.0 (6 NDI mponement pain 0.9 (2.8) 0.8 (2.8) 0.785 NDI scores 7.2 (7.4) 8.0 (6 NDI mponement scores of arm pain 0.9 (3.6) 0.5 (2.7) 0.375 NDI scores 1.5 (2.2) 1.8 (2 Change in NRS scores of arm numbness 2.1 (2.6) 2.9 (2.8) 0.006 Neck num		5.5 (3.1)	5.4 (3.1)	0.997	Current smoker (%)	17.0	19.6
NDI scores 8.0 (7.5) 8.3 (6.6) 0.721 NDI improvement rate (%) 50.0 (44.6) 26.4 (91.2) 0.001 Neck pain 1.8 (2.4) 1.8 (2.2) 0.909 Change in NRS scores of neck pain 2.5 (3.0) 1.5 (3.0) 0.003 Upper back pain 1.2 (2.0) 1.5 (2.4) 0.351 Change in NRS scores of upper back pain 2.1 (3.3) 1.3 (3.7) 0.040 Neck numbness 1.9 (2.5) 2.1 (2.5) 0.559 Change in NRS scores of arm pain 3.4 (3.67) 2.5 (3.5) 0.028 NDI scores 7.2 (7.4) 8.0 (6 NDI improvement scores of arm pain 1.9 (2.8) 0.8 (1.8) 0.910 Change in NRS scores of neck numbness 0.9 (2.8) 0.8 (2.8) 0.785 Upper back numbness 0.9 (3.6) 0.5 (2.7) 0.375 Change in NRS scores of arm numbness 2.1 (2.6) 2.9 (2.8) 0.0026 Arm numbness 2.1 (2.6) 2.9 (2.8) 0.0026 Change in NRS scores of arm numbness 3.0 (3.4) 2.5 (3.2) 0.227				0.007		15.2	17.0
NDI improvement rate (%) 50.0 (44.6) 26.4 (91.2) 0.001 Neck pain 1.8 (2.4) 1.8 (2.2) 0.909 Change in NRS scores of neck pain 2.5 (3.0) 1.5 (3.0) 0.003 Upper back pain 1.2 (2.0) 1.5 (2.4) 0.351 Change in NRS scores of upper back pain 2.1 (3.3) 1.3 (3.7) 0.040 Arm pain 1.9 (2.5) 2.1 (2.5) 0.559 Change in NRS scores of arm pain 3.4 (3.67) 2.5 (3.5) 0.028 Neck numbness 0.7 (1.9) 0.8 (1.8) 0.910 Change in NRS scores of neck numbness 0.9 (2.8) 0.8 (2.8) 0.785 Upper back numbness 0.9 (3.6) 0.5 (2.7) 0.375 Change in NRS scores of upper back numbness 0.9 (3.6) 0.5 (2.7) 0.375 Oth indicate $P < 0.05$. 0.9 (3.6) 0.5 (2.7) 0.375 Nold uses indicate $P < 0.05$. 0.9 (3.6) 0.5 (2.7) 0.375 Old values indicate $P < 0.05$. 0.9 (3.6) 0.5 (2.7) 0.375 Nold uscores of arm numbness 3.3 (3.4)				0.721		71:27:3	73:22
rate (%) Preoperative PRO (NDI and NRS scores) Neck pain 1.8 (2.4) 1.8 (2.2) 0.909 Change in NRS scores of neck pain 2.5 (3.0) 1.5 (3.0) 0.003 Upper back pain 1.2 (2.0) 1.5 (2.4) 0.351 Change in NRS scores of upper back pain 2.1 (3.3) 1.3 (3.7) 0.040 Arm pain 1.9 (2.5) 2.1 (2.5) 0.559 Change in NRS scores of arm pain 3.4 (3.67) 2.5 (3.5) 0.028 Neck numbness 0.7 (1.9) 0.8 (1.8) 0.910 Change in NRS scores of neck numbness 0.9 (2.8) 0.8 (2.8) 0.785 Upper back 0.4 (1.2) 0.6 (1.6) 0.332 Upper back numbness 0.9 (3.6) 0.5 (2.7) 0.375 Change in NRS scores of arm numbness 3.3 (3.4) 2.5 (3.2) 0.025 Of arm pain 1.7 (2.4) 2.1 (2.6) 2.9 (2.8) 0.006 NDI improvement numbness 0.9 (3.6) 0.5 (2.7) 0.375 0.4 (3.0) 1.7 (2.4) 2.2 (2 Change in NRS scores of upper back nain		. ,					
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Change in NRS scores of neck pain 2.5 (3.0) 1.5 (3.0) 0.003 Upper back pain 1.2 (2.0) 1.5 (2.4) 0.351 Change in NRS scores of upper back pain 2.1 (3.3) 1.3 (3.7) 0.040 Arm pain 1.9 (2.5) 2.1 (2.5) 0.559 Change in NRS scores of arm pain 3.4 (3.67) 2.5 (3.5) 0.028 Neck numbness 0.7 (1.9) 0.8 (1.8) 0.910 Change in NRS scores of neck numbness 0.7 (1.9) 0.8 (1.8) 0.910 Change in NRS scores of neck numbness 0.9 (2.8) 0.8 (2.8) 0.785 Change in NRS scores of upper back numbness 0.9 (3.6) 0.5 (2.7) 0.375 Change in NRS scores of upper back numbness 0.9 (3.6) 0.5 (2.7) 0.375 Change in NRS scores of upper back numbness 3.3 (3.4) 2.5 (3.2) 0.025 Change in NRS scores of arm numbness 3.3 (3.4) 2.5 (3.2) 0.025 Did values indicate P < 0.05. WDI indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, atient-reported outcome. 0.5 (1.3) 0.6 (1.6) DU indicates Neck Disability Index; NRS, Numerical Rating S		1.8 (2.4)	1.8 (2.2)	0.909			
scores of neck pain Upper back pain 3.1 (3.2) 2.8 (3) Upper back pain 1.2 (2.0) 1.5 (2.4) 0.351 Arm pain 4.7 (3.2) 4.8 (3) Change in NRS scores of upper back pain 2.1 (3.3) 1.3 (3.7) 0.040 Neck numbness 1.6 (2) Change in NRS scores of arm pain 1.9 (2.5) 2.1 (2.5) 0.559 O.028 Arm numbness 5.3 (3.3) 5.5 (3.2) Neck numbness 0.7 (1.9) 0.8 (1.8) 0.910 Onge in NRS scores of neck numbness 0.9 (2.8) 0.8 (2.8) 0.785 Change in NRS scores of neck numbness 0.9 (3.6) 0.5 (2.7) 0.375 O.026 Arm numbness 0.9 (3.6) 0.5 (2.7) 0.375 O.026 Change in NRS scores 1.9 (3.2) 1.3 (3.0) Arm numbness 2.1 (2.6) 2.9 (2.8) 0.0006 Change in NRS scores 1.0 (4.3) 0.7 (1.7) 0.7 (1.7) Dupper back numbness 2.1 (2.6) 2.9 (2.8) 0.0026 Neck numbness 0.7 (1.7) 0.7 (1.7) Duback numbness 3.3 (3.4) 2.5 (3.2) <td></td> <td>2.5 (3.0)</td> <td></td> <td></td> <td></td> <td></td> <td></td>		2.5 (3.0)					
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Change in NRS scores of upper back pain 2.1 (3.3) 1.3 (3.7) 0.040 Arm pain 1.9 (2.5) 2.1 (2.5) 0.559 Change in NRS scores of arm pain 3.4 (3.67) 2.5 (3.5) 0.028 Neck numbness 0.7 (1.9) 0.8 (1.8) 0.910 Change in NRS scores of neck numbness 0.7 (1.9) 0.8 (1.8) 0.910 Change in NRS scores of neck numbness 0.9 (2.8) 0.8 (2.8) 0.785 Upper back numbness 0.9 (3.6) 0.5 (2.7) 0.375 Change in NRS scores of arm numbness 2.1 (2.6) 2.9 (2.8) 0.006 Arm numbness 2.1 (2.6) 2.9 (2.8) 0.0025 Arm numbness 3.3 (3.4) 2.5 (3.2) 0.025 told values indicate $P < 0.05$. 0.9 (2.6) 0.9 (2.8) 0.006 Change in NRS scores of upper back numbness 3.3 (3.4) 2.5 (3.2) 0.025 told values indicate $P < 0.05$. 0.1 (2.6) 2.9 (2.8) 0.006 told values indicate $P < 0.05$. 0.1 (2.6) 2.9 (2.8) 0.0025 told values indicate $P < 0.05$. 0.1 (2.6) 2.9 (2.8) 0.0025 told						4.7 (3.2)	4.8 (3
scores of upper back pain1.9 (2.5)2.1 (2.5)0.559Arm pain1.9 (2.5)2.1 (2.5)0.559Change in NRS scores of arm pain3.4 (3.67)2.5 (3.5)0.028Neck numbness0.7 (1.9)0.8 (1.8)0.910Neck numbness0.7 (1.9)0.8 (2.8)0.785Change in NRS scores of neck numbness0.9 (2.8)0.8 (2.8)0.785Upper back numbness0.4 (1.2)0.6 (1.6)0.332Change in NRS scores of upper back numbness0.9 (3.6)0.5 (2.7)0.375Change in NRS scores of arm numbness2.1 (2.6)2.9 (2.8)0.006Change in NRS scores of arm numbness3.3 (3.4)2.5 (3.2)0.025Bold values indicate $P < 0.05$.0.050.025Neck numbnessBold values indicate $P < 0.05$.0.050.025Neck numbnessBold values indicate $P < 0.05$.0.050.025Neck numbnessInical outcomes of different surgical procedures for the0.5 (1.3)0.6 (1.6)Arm numbness2.1 (2.6)2.9 (2.8)0.006Bold values indicate $P < 0.05$.0.07 (1.7)0.7 (1.7)Bold values indicate $P < 0.05$.0.0050.025Bold values of different surgical procedures for the0.5 (1.3)0.6 (1.6)Change in NRS scores of upper back numbness0.5 (1.3)0.6 (1.6)Change in NRS scores of neck numbness0.5 (1.3)0.6 (1.6)Bold values indicate $P < 0.05$.0.0060.006Bo				0.351		1.8 (2.8)	1.6 (2
Arm pain $1.9 (2.5)$ $2.1 (2.5)$ 0.559 Change in NRS scores of arm pain $3.4 (3.67)$ $2.5 (3.5)$ 0.028 Neck numbness $0.7 (1.9)$ $0.8 (1.8)$ 0.910 Change in NRS scores of neck numbness $0.9 (2.8)$ $0.8 (2.8)$ 0.785 Upper back numbness $0.4 (1.2)$ $0.6 (1.6)$ 0.332 Change in NRS scores of upper back numbness $0.9 (3.6)$ $0.5 (2.7)$ 0.375 Change in NRS scores of arm numbness $2.1 (2.6)$ $2.9 (2.8)$ 0.006 Change in NRS scores of arm numbness $3.3 (3.4)$ $2.5 (3.2)$ 0.025 Kold values indicate $P < 0.05$. UD indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, attent-reported outcome. $0.5 (1.3)$ $0.5 (2.7)$ $0.7 (1.7)$ Inical outcomes of different surgical procedures for the $0.5 (1.3)$ $0.5 (2.7)$ 0.25	scores of upper	2.1 (3.3)	1.3 (3.7)	0.040		1.5 (4.4)	1.1 (2
Change in NRS scores of arm pain $3.4 (3.67)$ $2.5 (3.5)$ 0.028 Postoperative PRO (NDI and NRS scores)Neck numbness $0.7 (1.9)$ $0.8 (1.8)$ 0.910 NDI scores $7.2 (7.4)$ $8.0 (6)$ Neck numbness $0.7 (1.9)$ $0.8 (1.8)$ 0.910 NDI scores $7.2 (7.4)$ $8.0 (6)$ Change in NRS $0.9 (2.8)$ $0.8 (2.8)$ 0.785 NDI scores $2.2 (3.0)$ $1.7 (3)$ Upper back numbness $0.4 (1.2)$ $0.6 (1.6)$ 0.332 Neck pain $1.2 (2.1)$ $1.5 (2.2)$ $1.8 (2)$ Change in NRS scores of upper back numbness $0.9 (3.6)$ $0.5 (2.7)$ 0.375 O.475Change in NRS scores $1.9 (3.2)$ $1.3 (3)$ Change in NRS scores of arm numbness $2.1 (2.6)$ $2.9 (2.8)$ 0.006 O.025O.025Change in NRS scores $3.0 (3.6)$ $2.7 (3)$ Sold values indicate $P < 0.05$. NDI indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, atient-reported outcome. $1.1 (3.0)$ $0.9 (2)$ $0.5 (2)$ Inical outcomes of different surgical procedures for the Arm numbness $1.1 (3.0)$ $0.5 (2)$ Inical outcomes of different surgical procedures for the Arm numbness $2.1 (2.7)$ $2.9 (2)$				0.550	Arm numbness	5.3 (3.3)	5.5 (3
Change in NRS scores of arm pain $3.4 (3.67)$ $2.5 (3.5)$ 0.028 NDI scores $7.2 (7.4)$ $8.0 (6$ NDI scores $0.7 (1.9)$ $0.8 (1.8)$ 0.910 NDI improvement rate (%) $50.5 (47.1)$ $28.8 (9$ Neck numbness $0.9 (2.8)$ $0.8 (2.8)$ 0.785 Neck pain $1.5 (2.2)$ $1.8 (2)$ Upper back numbness $0.4 (1.2)$ $0.6 (1.6)$ 0.332 Neck pain $1.2 (2.1)$ $1.5 (2)$ $1.3 (2)$ Change in NRS scores of upper back numbness $0.9 (3.6)$ $0.5 (2.7)$ 0.375 O.375O.477 (1.7) $0.7 (1.7)$ $0.7 (1.7)$ Change in NRS scores of upper back numbness $2.1 (2.6)$ $2.9 (2.8)$ 0.006 O.025O.025O.025O.9 (3.6) $0.5 (2.7)$ 0.375 Mrm numbness $2.1 (2.6)$ $2.9 (2.8)$ 0.0025 O.025O.025O.7 (1.7) $0.7 (1.7)$ $0.7 (1.7)$ Noticates Neck Disability Index; NRS, Numerical Rating Scale; PRO, ratient-reported outcome. $0.5 (1.3)$ $0.6 (1.3)$ $0.5 (2.7)$ Inical outcomes of different surgical procedures for the $0.7 (1.7)$ $0.7 (1.7)$ $0.7 (1.7)$ $0.7 (1.7)$	-				Postoperative PRO (NDI	and NRS scores	5)
painNDI improvement rate (%) $50.5 (47.1)$ $28.8 (9)$ Neck numbness0.7 (1.9)0.8 (1.8)0.910Neck pain $1.5 (2.2)$ $1.8 (2)$ Change in NRS scores of neck numbness0.4 (1.2)0.6 (1.6)0.332Neck pain $1.2 (2.1)$ $1.5 (2.2)$ $1.8 (2)$ Upper back numbness0.4 (1.2)0.6 (1.6)0.332Neck pain $1.2 (2.1)$ $1.5 (2.2)$ $1.3 (3)$ Change in NRS scores of upper back numbness0.9 (3.6)0.5 (2.7) 0.375 Change in NRS scores of upper back pain $1.7 (2.4)$ $2.2 (2)$ Change in NRS scores of arm numbness $2.1 (2.6)$ $2.9 (2.8)$ 0.006 $Arm pain$ $1.7 (2.4)$ $2.2 (2)$ Change in NRS scores of arm numbness $3.3 (3.4)$ $2.5 (3.2)$ 0.025 $Neck numbness$ $0.7 (1.7)$ $0.7 (1)$ Bold values indicate P < 0.05. valuent-reported outcome. $Neck numbness$ $0.5 (1.3)$ $0.6 (1)$ Inical outcomes of different surgical procedures for the $Arm numbness$ $2.1 (2.7)$ $2.9 (2)$		3.4 (3.67)	2.5 (3.5)	0.028			
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Change in NRS scores of neck numbness $0.4 (1.2)$ $0.6 (1.6)$ 0.332 Upper back numbness $0.4 (1.2)$ $0.6 (1.6)$ 0.332 Change in NRS scores of upper back numbness $0.9 (3.6)$ $0.5 (2.7)$ 0.375 Arm numbness $0.9 (3.6)$ $0.5 (2.7)$ 0.375 Arm numbness $2.1 (2.6)$ $2.9 (2.8)$ 0.006 Change in NRS scores of arm numbness $3.3 (3.4)$ $2.5 (3.2)$ 0.025 Old values indicate $P < 0.05$. WDI indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, matient-reported outcome. $0.5 (1.3)$ $0.6 (1.6)$ Inical outcomes of different surgical procedures for the $0.7 (1.7)$ $0.7 (1.2)$ $0.5 (2.7)$ $0.7 (12)$ $0.5 (2.7)$ 0.025 0.025 0.0025 0.025 0.025 0.025 0.0125 0.025 0.025 0.025 0.0125 0.025 0.025 0.025 0.0125 0.025 0.025 0.025 0.0125 0.025 $0.5 (1.3)$ $0.6 (1.2)$ 0.0125 0.025 0.025 $0.5 (1.3)$ $0.6 (1.2)$ 0.0125 0.025 0.025 0.025 0.025 0.0125 0.025 0.025 0.025 0.025 0.0125 0.025 0.025 0.025 0.0125 0.025 0.025 0.025 0.0125 0.025 0.025 0.025 0.0125 0.025 0.025 0.025 0.0125 0.025 0.02						15(22)	18(2
Upper back numbness0.4 (1.2)0.6 (1.6)0.332Change in NRS scores of upper back numbness0.9 (3.6)0.5 (2.7)0.375Arm numbness0.9 (3.6)0.5 (2.7)0.375Arm numbness2.1 (2.6)2.9 (2.8)0.006Change in NRS scores of arm numbness3.3 (3.4)2.5 (3.2)0.025Bold values indicate P < 0.05. NDI indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, patient-reported outcome.0.5 (1.3)0.6 (1Inical outcomes of different surgical procedures for the0.5 (2.7)0.3750.375	scores of neck	0.9 (2.8)	0.8 (2.8)	0.785	Change in NRS scores		
numbness0.9 (3.6)0.5 (2.7)0.375Scores of upper back numbness0.9 (3.6)0.5 (2.7)0.375Arm numbness2.1 (2.6)2.9 (2.8)0.006Change in NRS scores of arm numbness3.3 (3.4)2.5 (3.2)0.025Bold values indicate P < 0.05. WD1 indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, batient-reported outcome.0.5 (1.3)0.6 (1 numbnessInical outcomes of different surgical procedures for the0.5 (2.7)0.3750.025		0.4 (1.2)	0.6 (1.6)	0.332	Upper back pain	1.2 (2.1)	1.5 (2
scores of upper back numbness2.1 (2.6)2.9 (2.8)0.006Arm numbness2.1 (2.6)2.9 (2.8)0.006Change in NRS scores of arm numbness3.3 (3.4)2.5 (3.2)0.025Sold values indicate P < 0.05. NDL indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, intical outcomes of different surgical procedures for theNeck numbness0.5 (1.3)0.6 (1.3)Change in NRS scores of neck numbness0.5 (1.3)0.6 (1.3)0.6 (1.3)0.5 (2.3)Change in NRS scores of neck numbness1.0 (4.3)0.5 (2.3)Change in NRS scores of upper back numbness1.0 (4.3)0.5 (2.3)Change in NRS scores of upper back numbness1.0 (4.3)0.5 (2.3)Arm numbness2.1 (2.7)2.9 (2.3)	numbness				Change in NRS scores of upper back pain	1.9 (3.2)	1.3 (3
back numbness2.1 (2.6)2.9 (2.8)0.006Change in NRS scores of arm numbness3.3 (3.4)2.5 (3.2)0.025Sold values indicate P < 0.05. NDL indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, 		0.9 (3.0)	0.3 (2.7)	0.575		1.7 (2.4)	2.2 (2
Arm numbness 2.1 (2.6) 2.9 (2.8) 0.006 Change in NRS scores of arm numbness 3.3 (3.4) 2.5 (3.2) 0.025 Bold values indicate P < 0.05. NDI indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, batient-reported outcome. Neck numbness 0.7 (1.7) 0.7 (1.7) Upper back numbness 0.5 (1.3) 0.6 (1) Change in NRS scores of upper back numbness 0.5 (1.3) 0.6 (1) Change in NRS scores of upper back numbness 1.0 (4.3) 0.5 (2) Change in NRS scores of upper back numbness 1.0 (4.3) 0.5 (2)	back numbness						
scores of arm numbness Change in NRS scores of neck numbness 1.1 (3.0) 0.9 (2) Bold values indicate P < 0.05.	Arm numbness	2.1 (2.6)	2.9 (2.8)	0.006		× /	, i
numbness 1.1 (3.0) 0.9 (2) Bold values indicate P < 0.05.		3.3 (3.4)	2.5 (3.2)	0.025	Neck numbness	0.7 (1.7)	0.7 (1
NDL indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, indicates Neck Disability Index; NRS, Numerical Rating Scale; PRO, i						1.1 (3.0)	0.9 (2
inical outcomes of different surgical procedures for the Arm numbress 2 1 (2 7) 2 9 (2	NDI indicates Neck Disabi		imerical Rating Sc	cale; PRO,		0.5 (1.3)	0.6 (1
inical outcomes of different surgical procedures for the Arm numbress 2 1 (2 7) 2 9 (2					of upper back	1.0 (4.3)	0.5 (2
mited symptoms of cervical radiculopathy showed no		0	-		Arm numbness	2.1 (2.7)	2.9 (2

clinical outcomes of different surgical procedures for the limited symptoms of cervical radiculopathy showed no significant differences.⁹ Basques *et al*¹⁰ previously reported no significant differences in the NDI and Visual Analog Scale scores for pain in the neck and arms between one or two and three or four levels of intervertebral decompression. Similar results were reported by Choi *et al*¹¹ regarding anterior cervical discectomy and fusion using

stand-alone cages. And with respect to cervical laminoplasty by Hatta *et al.*¹²

In contrast to these prior reports, multilevel decompression for cervical degenerative radiculopathy did not result in equivalent clinical outcome to that of single-level decompression in our study. This discrepancy could be explained by more severe degenerative process in the multilevel group and consequent difficulties decompressing the intervertebral foramen. In addition, since it takes many years for degeneration to extend to multiple intervertebral levels or distal to the intervertebral foramen, irreversible damage to the nerve roots may occur due to chronic nerve root compression. Furthermore, since the imaging evaluation of the intervertebral foramen for cervical radiculopathy is sometimes mismatched with physical findings,^{6,14} the imaging of multilevel intervertebral stenosis for a definitive diagnosis of the responsible levels may be difficult.

The significant difference in residual numbness in the distal body regions (eg, the arms), rather than the proximal (neck and upper back) areas suggests that residual nerve damage symptoms might be present distally. In fact, the length-dependent pattern of nerve axonopathy suggested that numbness in the distal area was more likely to occur in the distal part of the nerve,¹⁹ which might explain the extent of numbness in the distal regions between the SLDG and MLDG in between the SLDG and MLDG in this study. Residual symptoms after cervical radiculopathy surgery are not infrequent, with estimations as high as 26%.²⁰

Our study has several limitations. First, determinations regarding the diagnosis, the surgical technique, the surgical site of the intervertebral level, and the number of decompressed intervertebral levels were surgeon-dependent, and anesthetic care as well as rehabilitation were center dependent, with no uniformity in treatment criteria. The decision to include SNRBs or EMGs as diagnostic tools was based on the surgeon's discretion, and these diagnostic tools may contribute to diagnostic accuracy. Second, while the duration of preoperative symptoms might be associated with surgical outcomes, this parameter was not matched in this study among the 11 centers because the data were from a prospective multicenter study group, and the retrospective addition of data on morbidity duration from medical records may reduce data reliability, including data interpretation and handling of recurrent or additional symptoms. However, there were no significant differences in surgical outcomes in our subset analysis of patients with different symptom durations. Further, given that there are some conflicting reports regarding the association between surgical outcomes and symptom duration, we decided that matching on this parameter was not ideal. Third, the follow-up period of one year postoperatively was relatively short. This time window was used not only to compare clinical outcomes but also to determine whether the diagnosis at the intervertebral level was correct. However, it is conceivable that long-term outcomes might differ from the present findings. Finally, the study was a surveillance-based retrospective multicenter study, with a decline in the

CONCLUSIONS

In patients with cervical radiculopathy, those receiving single-level intervertebral decompression demonstrated greater improvement in clinical outcomes than those undergoing multilevel decompressions. Numbness persisted to a greater degree in distal body regions (eg, the arms; as opposed to the neck and upper back) in patients receiving multilevel intervertebral decompression. In cases of widespread degeneration requiring multiple intervertebral decompressions, the possibility of poor postoperative symptomatic improvement and residual numbness in the upper extremities should be considered.

> Key Points

- □ A retrospective multicenter cohort study with propensity score matching was performed in patients with pure cervical radiculopathy to compare the clinical outcomes of single-level (SLD) and multilevel (MLD) intervertebral decompression after adjusting for baseline characteristics, including the preoperative scores of the NDI and NRS for pain and numbness in the neck, upper back, and arms.
- □ The surgical outcomes of SLD showed greater improvement in clinical outcomes than those of MLD. SLD demonstrated worse preoperative NDI scores and higher preoperative NRS scores than MLD. However, SLD yielded a higher postoperative NDI improvement rate (P = 0.029) and lower postoperative NRS score for arm numbness (P = 0.037) compared with MLD.
- Other outcomes, including postoperative NDI scores, tended to be more favorable in the SLD than in the MLDG, yet no statistically significant difference was detected.
- □ The numbness remained in the distal (arms) areas rather than the central (neck and upper back) areas in the MLDG.

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