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

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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, 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

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

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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.

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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

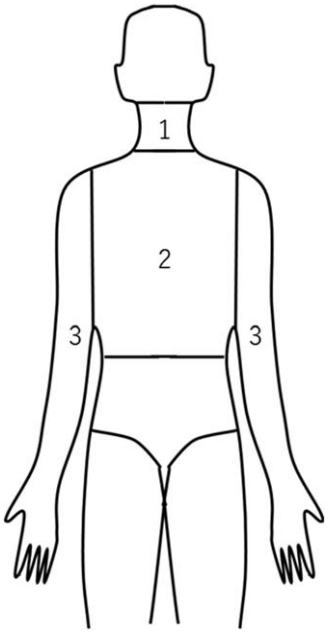

Figure 1. Areas of pain and numbness were divided into the neck (1), upper back (2), and arms (3). Pain and numbness intensity were measured using Numerical Rating Scale.

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. Postoperatively, 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)			*P*
	Total	**Single-level**	**Multilevel**	
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.

TABLE 2. Comparison of Unmatched Preoperative and Postoperative Data

	Mean (SD)		
	Single-level	Multilevel	*P*
Preoperative PRO (NDI and NRS scores)			
NDI scores	16.9 (8.0)	15.2 (7.9)	0.065
Neck pain	4.3 (2.9)	3.3 (3.1)	**0.002**
Upper back pain	3.3 (3.3)	2.7 (3.1)	0.116
Arm pain	5.3 (3.1)	4.6 (3.4)	**0.041**
Neck numbness	1.6 (2.7)	1.6 (2.7)	0.840
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
Postoperative PRO (NDI and NRS scores)			
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**
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
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, patient-reported outcome.

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

TABLE 3. Comparison of Demographic Data and Clinical Outcomes With Propensity Score–matched Analysis

	Mean (SD)		
	Single-level	Multilevel	*P*
N	112	112	
Age (yr)	57.5 (11.2)	56.6 (10.9)	0.628
Sex: male (%)	80.4	81.2	> 0.999
BMI (kg/m^2)	24.5 (3.6)	24.3 (3.5)	0.688
ASA grade (grade 1:2:3:4)	22:73:5:0	24:70:6:0	0.768
Diabetes mellitus (%)	15.2	15.2	> 0.999
Current smoker (%)	17.0	19.6	0.730
Disk herniation (%)	15.2	17.0	0.856
Surgical procedure (PD: ADF:PDF) (%)	71:27:3	73:22:5	0.613
Preoperative PRO (NDI and NRS scores)			
NDI scores	15.6 (8.2)	15.3 (7.9)	0.804
Neck pain	3.7 (3.1)	3.5 (3.1)	0.589
Upper back pain	3.1 (3.2)	2.8 (3.1)	0.485
Arm pain	4.7 (3.2)	4.8 (3.3)	0.745
Neck numbness	1.8 (2.8)	1.6 (2.8)	0.681
Upper back numbness	1.5 (4.4)	1.1 (2.2)	0.475
Arm numbness	5.3 (3.3)	5.5 (3.1)	0.691
Postoperative PRO (NDI and NRS scores)			
NDI scores	7.2 (7.4)	8.0 (6.4)	0.411
NDI improvement rate (%)	50.5 (47.1)	28.8 (93.0)	**0.029**
Neck pain	1.5 (2.2)	1.8 (2.2)	0.214
Change in NRS scores of neck pain	2.2 (3.0)	1.7 (3.1)	0.149
Upper back pain	1.2 (2.1)	1.5 (2.5)	0.296
Change in NRS scores of upper back pain	1.9 (3.2)	1.3 (3.7)	0.185
Arm pain	1.7 (2.4)	2.2 (2.5)	0.187
Change in NRS scores of arm pain	3.0 (3.6)	2.7 (3.6)	0.540
Neck numbness	0.7 (1.7)	0.7 (1.8)	0.731
Change in NRS scores of neck numbness	1.1 (3.0)	0.9 (2.8)	0.547
Upper back numbness	0.5 (1.3)	0.6 (1.6)	0.614
Change in NRS scores of upper back numbness	1.0 (4.3)	0.5 (2.6)	0.373
Arm numbness	2.1 (2.7)	2.9 (2.8)	**0.037**
Change in NRS scores of arm numbness	3.2 (3.5)	2.6 (3.3)	0.185

Bold values indicate P < 0.05.

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.

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 survey collection rate due to missing data and potentially a surveillance bias.

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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