Residual numbness of the upper extremity after cervical surgery in patients with cervical spondylotic myelopathy

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OBJECTIVE Although numbness is one of the chief complaints of patients with cervical spondylotic myelopathy (CSM), preoperative factors relating to residual numbness of the upper extremity (UE) and impact of the outcomes on cervical surgery are not well established. The authors hypothesized that severe preoperative UE numbness could be a risk factor for residual UE numbness after surgery and that the residual UE numbness could have a negative impact on postoperative outcomes. Therefore, this study aimed to identify the preoperative factors that are predictive of residual UE numbness after cervical surgery and demonstrate the effects of residual UE numbness on clinical scores and radiographic parameters.

METHODS The study design was a retrospective cohort study. The authors analyzed data of 103 patients who underwent cervical laminoplasty from January 2012 to December 2014 and were followed up for more than 2 years postoperatively. The patients were divided into two groups: the severe residual-numbness group (postoperative visual analog scale [VAS] score for UE numbness > 40 mm) and the no/mild residual-numbness group (VAS score ≤ 40 mm). The outcome measures were VAS score, Japanese Orthopaedic Association scores for cervical myelopathy, physical and mental component summaries of the 36-Item Short-Form Health Survey (SF-36), radiographic film parameters (C2–7 sagittal vertical axis, range of motion, C2–7 lordotic angle, and C7 slope), and MRI findings (severity of cervical canal stenosis, snake-eye appearance, severity of foraminal stenosis). Following univariate analysis, which compared the preoperative factors between groups, the variables with p values < 0.1 were included in the multivariate linear regression analysis. Additionally, the changes in clinical scores and radiographic parameters after 2 years of surgery were compared using a mixed-effects model.

RESULTS Among 103 patients, 42 (40.8%) had residual UE numbness. In the multivariate analysis, sex and preoperative UE pain were found to be independent variables correlating with residual UE numbness (p = 0.017 and 0.046, respectively). The severity of preoperative UE numbness did not relate to the residual UE numbness (p = 0.153). The improvement in neck pain VAS score and physical component summary of the SF-36 was significantly low in the severe residual-numbness group (p < 0.001 and 0.040, respectively).

CONCLUSIONS Forty-one percent of the CSM patients experienced residual UE numbness for at least 2 years after cervical posterior decompression surgery. Female sex and preoperative severe UE pain were the predictive factors for residual UE numbness. The patients with residual UE numbness showed less improvement of neck pain and lower physical status compared to the patients without numbness.

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KEYWORDS cervical spondylotic myelopathy; cervical surgery; residual numbness of the upper extremity; preoperative factor; outcome assessment; visual analog scale
symptoms can be critical factors that affect patients’ satisfaction after surgical treatment.6

Although numbness of the upper extremity (UE) is a common symptom of CSM,7,8 a clear definition for numbness is not well established. In general, “numbness” includes sensory disorders such as hypoesthesia, anesthesia, dysesthesia, paresthesia, and/or mild radicular pain. Due to its subjective nature and complexity, it is quite difficult to precisely define “numbness” in scientific studies. One potential method for measuring patients’ numbness is the visual analog scale (VAS) score, which is a patient-reported pain scale and frequently used to measure treatment outcomes, such as UE pain or numbness in patients with cervical spine disorders.

The relationship between low recovery of myelopathy and low satisfaction with surgery as well as low health-related quality of life (HRQOL) is well demonstrated.9 However, the impact of residual UE numbness on surgical outcomes is not well studied, although several studies have reported that UE numbness persists even after surgery.10 We hypothesized that preoperative severe UE numbness could be a risk factor for residual UE numbness after surgery. In addition, residual UE numbness could have a negative impact on postoperative outcomes. Therefore, the primary purpose of the present study was to identify the preoperative factors, including radiographic parameters, that are relevant in patients with severe residual UE numbness. In addition, we investigated the effects of residual UE numbness on improvements or changes in physician-assessed surgical outcomes, radiographic changes, and patient-oriented scores, including the assessment of HRQOL.

Methods

Study Design and Ethics

In this retrospective analysis, we prospectively collected the data of patients who underwent cervical posterior decompression surgery for CSM. All study participants provided written informed consent and the study protocol was approved by the IRB of our institution.

Patient Population

This study included 120 patients with CSM who underwent open-door C3–6 laminoplasty at our institution between January 2012 and December 2014 and were followed up for more than 2 years postoperatively. The patients were excluded if they had cervical surgery in the past (n = 5), they were > 20 years old (n = 3), or the quality of their data was not reliably sufficient for adequate analysis (n = 9). Finally, a total of 103 patients were included in the analysis (65 males, 38 females; mean age at the time of surgery 65.5 ± 12.2 years; Fig. 1).

Surgical Procedure

Cervical posterior decompression surgery was performed using the open-door technique as previously described.11 In most patients, the surgery was extended from C3 to C6, and the C2 and C7 spinous processes were preserved. Hydroxyapatite spacers were placed at every level for holding the laminae open.12 The day after surgery, all patients were allowed to sit up with a soft neck collar and, if possible, to stand and walk. Brace removal was allowed 1 week after the operation. The patients were then encouraged to start exercises to strengthen the isometric muscles and improve range of motion (ROM) in the neck muscles as soon as possible. All patients were treated with the same postoperative rehabilitation protocol, including in-hospital physical therapy for 2 weeks after surgery.

Clinical Evaluation

Physician-assessed and patient-oriented clinical scores were recorded preoperatively and 2 years postoperatively. As a physician-assessed score for myelopathy, we recorded the Japanese Orthopaedic Association (JOA) score to evaluate the severity of cervical myelopathy.13 The visual analog scale (VAS) score for UE numbness,14 and the 36-Item Short-Form Health Survey (SF-36) results were recorded as components of the patient-oriented score.15 The VAS scores were evaluated using a 10-cm-long horizontal line with extremes indicated as “no symptoms” and “worst symptoms imaginable.” The scores of the SF-36 were summarized as physical component summaries (PCSs) and mental component summaries (MCSs), both according to formulae previously described.15 Based on previous reports, we defined the minimal clinically important difference (MCID) for the JOA score as 2.5 points, the MCID for the VAS score of neck pain and UE pain as 25 mm, and the MCID of the SF-36 PCS and MCS as 4 points.9,10,16–18

Definition of Residual UE Numbness After Surgery

Based on the VAS score for UE numbness 2 years postoperatively, the patients were divided into two groups: the severe residual-numbness group and no/mild residual-numbness group. The severe residual-numbness group included patients with a VAS score of UE numbness > 40 mm; this cutoff value was defined according to previous studies.19,20

Radiographic Evaluation: Plain Radiographs

Plain cervical radiographs were obtained preoperatively and 2 years postoperatively, with the patient sitting in the neutral cervical position. The parameters of cervical sagittal balance and alignment were defined as 1) C2–7 sagittal vertical axis (cSVA), the horizontal distance between the center of C2 and the posterosuperior corner of the C7 vertebral body;21 2) C7 slope, the angle between a horizontal line and the C7 upper endplate;22 3) C2–7 lordotic angle, the lordotic angle between the tangent lines of the lower endplates of C2 and lower endplates of the C7 vertebral body; and 4) cervical ROM, the differences of the C2–7 lordotic angle between flexion and extension positions. Observers reviewed the images and measured the parameters using Synapse (Fujifilm).

Radiological Evaluation: MRI

Cervical canal stenosis from C2–3 to C7–T1 was classified into four groups according to the grading system reported by Kang et al. using T2-weighted sagittal MR images.23 Grade 0 refers to the absence of central canal
stenosis; grade 1 refers to obliteration exceeding 50% of the subarachnoid space, without signs of cord deformity; grade 2 refers to central canal stenosis with cord deformity, but without spinal cord signal change; and grade 3 refers to the presence of spinal cord signal change near the compressed level. Observers recorded each patient’s maximum stenosis level as the stenosis severity in the patient. A snake-eye appearance was defined as a lateral or bilateral small, round, high-signal-intensity lesion in the central gray matter near the ventrolateral posterior column. Foraminal stenosis at each level from C3–4 to C7–T1 was categorized into three groups using a T2-weighted axial image according to Kim et al.: grade 0 refers to the absence of foraminal stenosis; grade 1 refers to mild foraminal stenosis, including the narrowest width of the neural foramen the same or less than (but > 50% of) the extraforaminal nerve root width; and grade 2 refers to severe foraminal stenosis, including the narrowest width of the neural foramen ≤ 50% of the extraforaminal nerve root width. Any differences in the evaluation were settled by consensus of the two observers.

**Statistical Analyses**

The inter- and intraobserver reliabilities of every parameter were calculated using interclass correlation coefficients for continuous variables and kappa values for categorical variables. To calculate the reliability, two observers (M.I. and K.T.) measured all parameters twice at an interval of 2 weeks in between.

After dividing the overall patients into the severe and no/mild residual-numbness groups, the basic demographics were compared between the two groups using the Mann-Whitney U-test or chi-square test. In addition, the change in the UE numbness from preoperatively to 2-year postoperatively was compared between the two groups using a mixed-effects model.

To demonstrate the predictive factors, the preoperative clinical score and radiographic parameters were compared between the severe and no/mild residual-numbness groups using the Mann-Whitney U-test or chi-square test. Subsequently, the variables with a significance of p < 0.10 in univariate analysis were included in the multivariate linear regression model. In this analysis, the VAS score for residual numbness (continuous value) was set as a dependent variable, and age and sex were included as independent variables to adjust for these variables. Unstandardized partial regression coefficients (β), p values, and 95% confidence intervals (CIs) were calculated.

Finally, the improvements in clinical scores and changes in radiographic parameters 2 years after surgery were compared between the severe and no/mild residual-numbness groups using a mixed-effects model. In addition, the ratio of the patients who achieved the clinical score improvement more than the MCID were compared between the severe and no/mild residual-numbness groups using the chi-square test. All analyses were performed using SPSS Statistics software (version 23, IBM Corp.). A p value < 0.05 was considered statistically significant.

**Results**

The inter- and intraobserver reliabilities of all variables, including plain radiograph parameters and MRI findings, were fair to excellent (Table 1).

**Demographics of the Severe and No/Mild Residual-Numbness Groups**

Demographic data in this study are summarized in Table 2. The severe residual-numbness group included 42 patients (23 male, average age 67.5 ± 11.3 years) and the no/mild residual-numbness group included 61 patients (42 male, average age 65.1 ± 12.7 years). There were no significant differences between the two groups regarding sex and average age, while there was a significant difference in VAS score for UE numbness 2 years after surgery (Fig. 2). There was a significant difference in the change in VAS score for UE numbness between the groups: the UE numbness improved over time in the no/mild residual-numbness group, whereas UE numbness deteriorated in the severe residual-numbness group (p < 0.001; Fig. 2).
Univariate Analysis of Preoperative Clinical Scores

The summary of preoperative clinical scores is shown in Table 3. The VAS score for preoperative UE numbness showed no significant differences between the groups (p = 0.153). The severe residual-numbness group showed significantly higher preoperative VAS scores for UE pain than in the no/mild residual-numbness group (46.7 vs 26.6, p = 0.028). The other preoperative clinical scores, including JOA score, VAS score for neck pain, and SF-36 PCS and MCS, showed no significant differences.

Univariate Analysis of Preoperative Radiographic Parameters

In the comparison between the preoperative radiographic parameters, the p values of the C7 slope and C2–7 lordotic angle ranged from 0.05 to 0.10 (p = 0.091 and p = 0.054, respectively; Table 4), although there were no significant differences between the two groups. Based on our definitions, those two parameters were included in the multivariate analysis. Other preoperative parameters, including cSVA, ROM, degree of canal stenosis, presence of snake-eye appearance, and foraminal stenosis, showed no significant differences between the two groups.

Multivariate Analysis of Preoperative Factors

Based on the results of the univariate analysis, age, sex, VAS score for preoperative UE pain, preoperative C7 slope, and preoperative C2–7 lordotic angle were included in the multivariate analysis. As a result, sex (p = 0.017) and preoperative UE pain (p = 0.046) were determined to be the independent variables significantly related to the residual UE numbness (Table 5); women tended to have residual UE numbness after surgery, and patients with preoperative severe UE pain showed high residual UE numbness. Age, C7 slope, and C2–7 lordotic angle were not significant variables.

Improvement in Clinical Score After Surgery

The JOA score, VAS score for UE pain, and SF-36 MCS improved significantly in both groups (p < 0.05), but there was no significant difference in the degree of improvement between the groups (Fig. 3). The improvement in neck pain VAS score and SF-36 PCS showed significant differences between groups (p < 0.001 and 0.040, respectively; Fig. 3). In terms of the ratio of patients who achieved an improvement > MCID, more than half of the patients with CSM achieved the MCID for the JOA score and SF-36 PCS and MCS, while 23% and 33% of patients achieved the MCID in the VAS score for neck pain and UE pain, respectively. There was no significant difference in the ratio of achievement of MCID between the two groups (Table 6), except for UE numbness.

Changes in Radiographic Parameters After Surgery

The change of cervical balance parameters including cSVA, C7 slope, C2–7 lordotic angle, and ROM showed no significant differences between the groups (Fig. 3).

Discussion

Numbness is one of the most frequent complaints of patients with CSM, and Machino et al. reported that approximately 50% of sensory disorders, including UE numbness, persisted after cervical surgery, which is consistent with our results. Therefore, spine surgeons should recognize residual numbness in patients with CSM.

In the present study, we found that as many as 40% of the patients who underwent cervical surgery experienced UE numbness, with a VAS score > 40 mm 2 years postoperatively. Female sex and preoperative severe UE pain were the predictive factors of residual UE numbness in these patients. Interestingly, the severity of preoperative UE numbness and preoperative intensity changes in the spinal cord were not related to residual UE numbness after surgery.
In addition, we found that patients with residual UE numbness showed minimal improvements in neck pain and physical status postoperatively.

To the best of our knowledge, the current study is the first to evaluate the preoperative factors for residual UE numbness after cervical surgery. We revealed that severe preoperative UE pain was a predictive factor of severe residual UE numbness. Three possible reasons for this phenomenon were postulated. First, residual UE numbness could be a form of mild radicular pain. Because the definition of numbness in our study is based on a patient’s complaints, patients may record weak pain as numbness. Second, patients with CSM with severe preoperative UE pain could underestimate the degree of preoperative UE numbness because radicular pain masked UE numbness. Lastly, preoperative UE pain may potentially change into residual UE numbness because of changes in conditions of the spinal cord, such as local reperfusion or decompression itself. However, these reasons are just hypotheses because the definitions and causes of numbness and pain are multifactorial. Therefore, we need to verify in more detail why severe UE pain preoperatively was a predictive factor of severe residual UE numbness.

Other findings of the current study were that there was no relationship between residual UE numbness and other factors, including foraminal stenosis, intensity of cord change, severity of canal stenosis, and cervical alignment. As all patients in this study underwent cervical laminoplasty, cervical degenerative changes such as segmental instability, spondylolisthesis, disc degeneration, and facet degeneration were left as they were. Although the current study could not find a significant relationship between residual UE numbness and findings on radiography or MRI, a further study should be performed to help surgeons establish an adequate surgical strategy for laminoplasty and other procedures with fusion techniques.

### TABLE 3. Univariate analysis of preoperative clinical scores

<table>
<thead>
<tr>
<th>Clinical Score</th>
<th>Residual Numbness*</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Severe (n = 42)</td>
<td>No/Mild (n = 61)</td>
</tr>
<tr>
<td>JOA score</td>
<td>9.5 ± 3.3</td>
<td>10.1 ± 3.1</td>
</tr>
<tr>
<td>VAS score for UE numbness</td>
<td>56.9 ± 29.9</td>
<td>45.7 ± 31.6</td>
</tr>
<tr>
<td>VAS score for UE pain</td>
<td>46.7 ± 35.2</td>
<td>26.6 ± 32.8</td>
</tr>
<tr>
<td>VAS score for neck pain</td>
<td>24.4 ± 29.0</td>
<td>17.1 ± 22.3</td>
</tr>
<tr>
<td>SF-36 PCS</td>
<td>23.4 ± 13.3</td>
<td>24.7 ± 13.8</td>
</tr>
<tr>
<td>SF-36 MCS</td>
<td>39.7 ± 15.3</td>
<td>40.1 ± 13.4</td>
</tr>
</tbody>
</table>

* Data are given as mean ± SD.

### TABLE 4. Univariate analysis of preoperative radiological evaluation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Residual Numbness</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Severe (n = 42)</td>
<td>No/Mild (n = 61)</td>
</tr>
<tr>
<td>Plain film</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cSVA (mm)</td>
<td>25.5 ± 14.8</td>
<td>26.9 ± 14.4</td>
</tr>
<tr>
<td>C7 slope (°)</td>
<td>25.9 ± 16.8</td>
<td>31.6 ± 14.5</td>
</tr>
<tr>
<td>C2–7 lordotic angle (°)</td>
<td>7.0 ± 16.0</td>
<td>13.5 ± 15.7</td>
</tr>
<tr>
<td>ROM (°)</td>
<td>31.3 ± 15.5</td>
<td>33.8 ± 15.1</td>
</tr>
<tr>
<td>MRI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max grade of central stenosis</td>
<td>0.800</td>
<td></td>
</tr>
<tr>
<td>Grade 0 or 1</td>
<td>20 (47.6%)</td>
<td>25 (41.0%)</td>
</tr>
<tr>
<td>Grade 2</td>
<td>14 (33.3%)</td>
<td>23 (37.7%)</td>
</tr>
<tr>
<td>Grade 3</td>
<td>8 (19.0%)</td>
<td>13 (21.3%)</td>
</tr>
<tr>
<td>Snake-eye appearance (+)</td>
<td>20 (47.6%)</td>
<td>20 (32.8%)</td>
</tr>
<tr>
<td>Max grade of foraminal stenosis</td>
<td>0.258</td>
<td></td>
</tr>
<tr>
<td>Grade 0</td>
<td>2 (4.8%)</td>
<td>3 (4.9%)</td>
</tr>
<tr>
<td>Grade 1</td>
<td>8 (19.0%)</td>
<td>15 (24.6%)</td>
</tr>
<tr>
<td>Grade 2</td>
<td>32 (76.2%)</td>
<td>43 (70.5%)</td>
</tr>
</tbody>
</table>

FIG. 2. Line graph showing the change of the VAS score for UE numbness at each time point. There was a significant difference in the improvement of UE numbness between the groups (p < 0.001, mixed-effects model).
The results of our current study potentially help improve the patient’s satisfaction after surgery and prevent residual UE numbness. Kong et al. emphasized that patient satisfaction depended on precise preoperative explanation.26 The current results can aid surgeons in explaining changes in symptoms after surgery, which can result in higher satisfaction in patients. Additionally, our results may suggest potential solutions of residual UE numbness, such as detecting the responsible nerve by examining the nerve conduction study preoperatively and adding posterior fixation at the responsible levels, or change surgical procedures such as ACDF or disc arthroplasty.

There are several limitations to the present study. First, its retrospective nature makes it difficult to exclude selection bias, especially regarding referral for a certain type of surgery, or particular surgical techniques applied. Second, the relatively small sample size could affect the statistical results in our study. Third, additional follow-ups (besides a 2-year postoperative follow-up) should have been performed to evaluate the progress of the residual UE numbness and to identify the causal relationship between shoulder changes and residual UE numbness. Fourth, this study included patients who underwent cervical laminoplasty, but did not include patients with other surgical procedures, such as ACDF and cervical laminectomy and fusion. Therefore, different results might have been obtained if the study included patients who underwent ACDF or cervical laminectomy and fusion. Fifth, this study could not enroll consecutive patients because we excluded patients whose VAS score data of UE numbness were missed preoperatively or 2 years postoperatively. Finally, there might be inconsistency in the severe residual-numbness group, as we used patient-reported “numbness” as an outcome for selecting the groups and the score was determined based on the patients’ own judgment. In addition, the definition of specific numbers, such as 40 mm, varied in each patient.

<table>
<thead>
<tr>
<th>Variable</th>
<th>β</th>
<th>p Value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.62</td>
<td>0.074</td>
<td>-0.06 1.31</td>
</tr>
<tr>
<td>Sex</td>
<td>19.30</td>
<td>0.017</td>
<td>3.56 35.06</td>
</tr>
<tr>
<td>Preop VAS score for UE pain</td>
<td>0.218</td>
<td>0.046</td>
<td>0.01 0.43</td>
</tr>
<tr>
<td>C7 slope</td>
<td>0.052</td>
<td>0.830</td>
<td>-0.43 0.54</td>
</tr>
<tr>
<td>C2–7 lordotic angle</td>
<td>-0.429</td>
<td>0.078</td>
<td>-0.91 0.05</td>
</tr>
</tbody>
</table>

The VAS score for residual UE numbness (continuous value) was set as a dependent variable.

### TABLE 6. Ratio of the patients with improvement greater than the MCID

<table>
<thead>
<tr>
<th>Clinical Score</th>
<th>Overall (%)</th>
<th>Residual Numbness (%)</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>JOA score</td>
<td>59.4</td>
<td>56.4 61.4</td>
<td>0.781</td>
</tr>
<tr>
<td>VAS score for UE numbness</td>
<td>40.6 15.4 55.8</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>VAS score for UE pain</td>
<td>33.3 24.0 40.0</td>
<td>0.317</td>
<td></td>
</tr>
<tr>
<td>VAS score for neck pain</td>
<td>23.2 25.0 22.0</td>
<td>0.997</td>
<td></td>
</tr>
<tr>
<td>SF-36 PCS</td>
<td>62.1 54.8 67.2</td>
<td>0.283</td>
<td></td>
</tr>
<tr>
<td>SF-36 MCS</td>
<td>52.4 47.6 55.7</td>
<td>0.542</td>
<td></td>
</tr>
</tbody>
</table>

*The p value represents the value after comparison between the severe and no/mild residual-numbness groups.

**FIG. 3.** Mixed-effects models comparing the improvements in clinical scores and radiographic changes. The improvement in neck pain VAS score and SF-36 PCS showed significant differences between groups. post = postoperative; pre = preoperative.
tient. Therefore, to identify the exact effect of residual UE numbness on surgical outcomes after cervical surgery, a further prospective study with a longer follow-up period (e.g., > 10 years) with a larger sample size is required. Nevertheless, this study was conducted using multiple clinical scores and radiographic parameters collected prospectively, and the number of patients was also sufficient for analysis. Therefore, regardless of these limitations, we believe that the current study findings can help physicians predict poor surgical outcomes in patients preoperatively.

Conclusions

In the current study, approximately 40% of patients with CSM had residual UE numbness 2 years after cervical surgery. We demonstrated that female sex and preoperative severe pain of the UE were independent predictors of residual UE numbness. The patients with residual UE numbness showed less improvement in neck pain and lower physical status compared to patients without residual UE numbness. These results may help provide physicians with adequate information for patients with CSM and also help surgeons predict patients with poor surgical outcomes preoperatively.

Acknowledgments

We thank the individuals who contributed to the study or manuscript preparation but do not fulfill all the criteria of authorship.

References


Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Tamai, Iwamae, Ohyama, Hori, Yabu. Acquisition of data: Tamai, Iwamae, Takahashi, Hori, Yabu.

Supplemental Information
Previous Presentations
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