Predictors for Surgical Outcome of Laminoplasty for Cervical Spondylotic Myelopathy

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■ BACKGROUND: **There were no precise researches showing which parameters with regard to degree of cervical stenosis and sagittal cervical alignment are the most crucial for surgical outcomes after laminoplasty for cervical spondylotic myelopathy (CSM). The objectives of this study were to investigate to what extent the preoperative parameters may have a direct influence on postoperative neurologic recovery, and to determine the crucial determinants of prognosis.**

■ METHODS: **A retrospective review of 83 patients with CSM after laminoplasty was conducted. Magnetic resonance imaging parameters evaluation included presence/absence of signal change on T1 and T2 and anatomic measurements, including cervical canal compromise and cervical alignment. Data analysis involved logistic regressions and Spearman rank correlation coefficients. Receiver operator characteristic (ROC) curves were computed to evaluate the contribution of the original model.**

■ RESULTS: **Univariate logistic regression showed that age (odds ratio = 0.822; 95% confidence interval, 0.729–0.927; *P* = 0.001), baseline Japanese Orthopedic Association (JOA) score (odds ratio = 1.700; 95% confidence interval, 1.158–2.496; *P* = 0.007), cervical curvature index (Ishihara) score (CCI) (odds ratio = 1.123; 95% confidence interval, 1.030–1.225; *P* = 0.008), maximum canal compromise (MCC) (odds ratio = 0.940; 95% confidence interval, 0.885–0.998; *P* = 0.041), and signal intensity (odds ratio = 0.139; 95% confidence interval, 0.033–0.580; *P* = 0.007) were independent prognostic indicators after laminoplasty. A ROC curve was computed based on the probability of the five predictors, with an area under the curve of 0.929 ± 0.028.**

■ CONCLUSIONS: **Age and baseline JOA scores were crucial clinical predictors of outcome after laminoplasty for patients with CSM. Regarding the predictive value, CCI, MCC, and patterns of signal intensity changes on T1-/T2-weighted images were crucial determinants of prognosis of neurologic outcome.**

INTRODUCTION

Cervical laminoplasty, originally developed to treat ossification of the posterior longitudinal ligament, has been now used as an effective and relatively safe method of treating multisegmental cervical spondylotic myelopathy (CSM),[1-3] and the clinical results can be achieved with greater consistency even after long follow-up periods.[4,5] However, apart from great risks associated with surgery of the cervical spine, cervical laminoplasty does not always result in a perfect outcome. How to predict neurologic outcomes after surgery is therefore of great importance because surgeons can use this information to discuss with patients the prognosis after surgical intervention and to manage their expectations. Potential prognostic indicators after expansive laminoplasty for CSM have been identified, including age of patient, duration of preoperative symptoms, severity of myelopathy (baseline Japanese Orthopedic Association [JOA] score), pathologic changes of the spinal cord (T2 and/or T1 signal intensity [SI]), change on magnetic resonance imaging (MRI), degree of cervical stenosis, and sagittal alignment of the cervical spine.[6-11] Although there are several parameters to evaluate every

Key words
- Cervical spondylotic myelopathy
- Laminoplasty
- Predictor
- Signal intensity

Abbreviations and Acronyms
CCI: cervical curvature index (Ishihara)
CSM: cervical spondylotic myelopathy
JOA: Japanese Orthopedic Association
MCC: maximum canal compromise
MRI: magnetic resonance imaging
MSCC: maximum spinal cord compression
SI: signal intensity
TA: transverse area

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Citation: World Neurosurg. (2016) 94:89-96.
http://dx.doi.org/10.1016/j.wneu.2016.06.092

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

prognostic indicator associated with postoperative neurologic improvement, especially degree of cervical stenosis and sagittal cervical alignment, there have been no precise researches showing which parameters are the most crucial for surgical outcomes and to what extent they may have a direct influence on the surgical outcomes, which may correlate with clinical decision-making or patient counseling. Moreover, there have been no researches to evaluate the predictive performance of a model based on the aforementioned parameters for predicting functional outcomes after laminoplasty to date. In our study, we have focused on building a model based on clinical and MRI prognostic indicators. The objectives of this study were to determine the crucial determinants of prognosis, and to improve the validity of the clinical prediction model using statistical measures.

MATERIAL AND METHODS

Patients and Methods

We conducted a retrospective review of 83 patients with CSM who had undergone expansive laminoplasty in our institution from January 1, 2009, to January 1, 2013. Approval to conduct this study was obtained from our institutional review board, and informed consent was obtained from each patient. Patients with cervical myelopathy caused by multisegmental spondylosis were enrolled in this study. Patients with obvious cervical kyphosis, asymptomatic cervical cord compression, prior surgical intervention for CSM, infection, neoplastic disease, rheumatoid arthritis, ankylosing spondylitis, recent or prior neurologic trauma, cerebrovascular accident, and concomitant symptomatic lumbar spinal stenosis were excluded from the study.

Procedures and Outcome Measures

Cervical laminoplasty as described by Tsuji[1] and Hirabayashi et al.[2] was performed by the same surgeon (Y.-M.L.).[3] Patients were instructed to wear a soft collar for at least 3 weeks postoperatively. Data collection was performed by 2 of the authors (L-Q.S., Y-M.L.) and externally monitored to ensure integrity and completeness. The criterion proposed by the JOA was used to assess neurologic status pre- and postoperatively,[12] and functional recovery rate was calculated by the method of Hirabayashi et al.[13] This criterion is an 17-point clinical scale that separately evaluates motor function of the upper and lower extremities, sensation, and sphincter disturbance. The severity of myelopathy is calculated by summating scores of dysfunction in each category, with a lower score indicating greater functional deficit. According to previous reports, poor clinical outcome was defined as a recovery rate <50%, and good outcome was a recovery rate >50%.[14,15]

$$\text{Recovery rate} = \frac{\text{Postoperative JOA score} - \text{preoperative JOA score}}{17(\text{full score}) - \text{preoperative JOA score}} \times 100$$

Radiologic Evaluations

MRI images were anonymous and were analyzed blindly by an experienced neuroradiologist. MRI was performed just before surgery in all patients. All patients performed high-resolution MRI with a 1.5-T imager (Signa [GE Medical Systems, Milwaukee, WI, USA]). Sagittal T1-weighted image views were obtained using a spin echo sequence system, whereas sagittal T2-weighted image views were achieved by a fast spin echo sequence system. Slice width was 3 mm, and the acquisition matrix was 512 × 512. Sequence parameters were repetition time of 1892 milliseconds and echo time of 10.1 milliseconds for T1-weighted images and repetition time of 2700 milliseconds and echo time of 123 milliseconds for T2-weighted images. Window width and level were set differently in each patient by the magnetic resonance operators so that the optimal contrast between each tissue could be obtained. The transverse area (TA) of the spinal cord at the site of maximal compression were measured on the same axial T2-weighted images (Figure 1). Measurement of maximum spinal cord compression (MSCC) was evaluated on midsagittal T2-weighted images (Figure 2), whereas the maximum canal compromise (MCC) was evaluated on midsagittal T1-weighted images (Figure 3).[16,17] Preoperative cervical alignment was evaluated by the Cobb angle (C2-7) (Figure 4) and the cervical curvature index (CCI) (Ishihara) (Figure 5) as described by Ishihara on radiographs.[18] The presence/absence of signal change on T1- and T2-weighted images was evaluated on sagittal and axial magnetic resonance images. Based on previous researches, 3 types of cord SI changes on T1-weighted sequences/T2-weighted sequences were defined as follows: normal/normal, normal/high-SI changes, and low-signal/high-SI changes.[19]

Statistical Analysis

Descriptive statistics were used for all variables with distributions assessed for normality. The paired *t* tests were conducted to compare pre- and postoperative changes of the JOA scores. An analysis of variance was used to investigate the statistical differences of JOA scores among groups. Association between MRI parameters and clinical outcomes was determined using

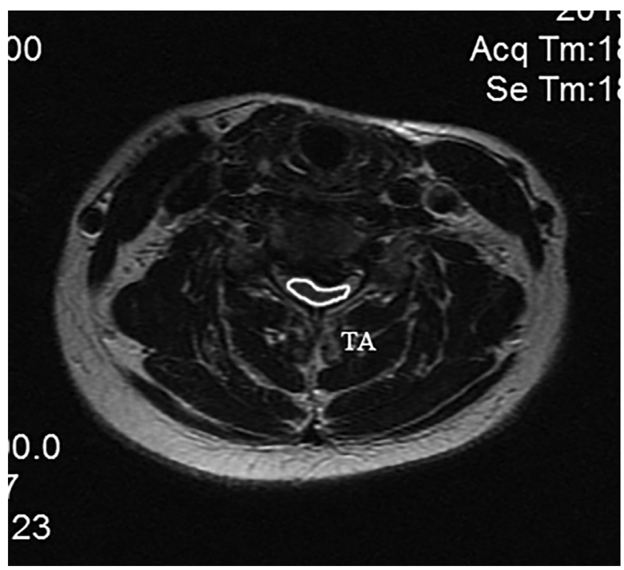

Figure 1. Measurements of the transverse area of the spinal cord at the site of maximal compression using axial T2-weighted magnetic resonance imaging. TA, transverse area.