Clinical Neurology and Neurosurgery 162 (2017) 108–114

Contents lists available at ScienceDirect

Clinical Neurology and Neurosurgery

journal homepage: www.elsevier.com/locate/clineuro

Full Length Article

Surgical outcomes after laminoplasty for cervical spondylotic myelopathy: A focus on the dynamic factors and signal intensity changes in the intramedullary spinal cord on MRI

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ARTICLE INFO

Keyword:
Cervical spondylotic myelopathy
Dynamic factors
MRI
Surgical outcome
Laminoplasty

ABSTRACT

Objective: We aimed to analyze the relationship between the dynamic factors and signal intensity changes in the intramedullary spinal cord on MRI, and surgical outcomes, following double-door laminoplasty for cervical spondylotic myelopathy (CSM).

Patients and methods: This retrospective study included 100 consecutive patients who underwent double-door laminoplasty for CSM. The following factors were analyzed: JOA score recovery rate, age, duration from onset to surgery, intraoperative bleeding, signal intensity changes in the intramedullary spinal cord on MRI, pre and postoperative C2-7 lordotic angle (LA), changes in C2-7 LA, pre and postoperative C2-7 range of motion (ROM), and pre and postoperative segmental ROM. The Charlson Comorbidity Index (CCI) was also used for the assessment of complications.

Results: Age, CCI, preoperative segmental ROM, and pre and postoperative MRI grade significantly correlated with JOA score recovery rate ($P < 0.01$), whereas number of expanded laminae, duration from onset to surgery, surgery time, intraoperative bleeding, preoperative and postoperative C2-7 LA, change in C2-7 LA, and preoperative C2-7 ROM did not. Multivariate analysis showed that the preoperative segmental ROM (OR = −0.988, P = 0.017) and preoperative MRI grade (OR = −7.170, P = 0.042) were significantly associated with JOA score recovery rate.

Conclusion: Considering the dynamic factors, there was no correlation with C2-7 ROM and surgical outcome, but preoperative segmental ROM and a change in signal intensity of the intramedullary spinal cord on MRI were negatively correlated with surgical outcome. From these results, we suggest that preoperative segmental ROM is possibly associated with spinal cord damage due to repeated minor trauma and affects surgical outcome of laminoplasty.

1. Introduction

In the previous literatures, surgical outcomes in cervical spondylotic myelopathy (CSM) are reportedly associated with multiple factors, including preoperative neurologic symptoms, disease duration, and the age at the time of surgery [1–3]. The pathophysiology of CSM is related to static spinal cord compression and dynamic factors such as instability of the vertebral column, and preoperative instability induces dynamic compression of the spinal cord [4,5]. Additionally, cervical anterolisthesis is a predictor of poor outcomes after laminoplasty in patients with CSM [6,7], and increased segmental hyperextension curvature and range of motion (ROM) are also risk factors for high-intensity lesions on T2-weighted MRI in these patients [8]. Some studies have demonstrated signal intensity changes in the spinal cord in patients with CSM on magnetic resonance imaging (MRI), but the physiological role of this intramedullary signal intensity change is still controversial [9–11]. Thus, there are few reports that have analyzed the association between dynamic factors, signal intensity changes in the intramedullary spinal cord on MRI, and surgical outcomes.

The purpose of the present study was to analyze the relationship between surgical outcomes after double-door laminoplasty for CSM with a focus on the dynamic factors and signal intensity changes in the intramedullary spinal cord on MRI.

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http://dx.doi.org/10.1016/j.clineuro.2017.10.003
Received 2 August 2017; Received in revised form 18 September 2017; Accepted 1 October 2017
Available online 04 October 2017
0303-8467/

2. Materials and methods

2.1. Patient population

We retrospectively reviewed the medical records of 100 consecutive patients (61 male, 39 female) with CSM who underwent double-door laminoplasty between August 2006 and September 2014 at our hospital. The mean age at the time of surgery was 72.3 years (range 45–88 years) and the mean follow up period was 34 months (range 12–105 months).

The modified kyphosis line (the modified K-line), which is the line connecting the midpoints of the spinal cord at C2 and C7 on preoperative T1-weighted sagittal magnetic resonance images, is used while making decisions regarding the surgical approach for patients with CSM. The minimum interval between the modified K-line and the anterior compression factor on midsagittal images is defined as the INT min [12]. The parameter "INT min" correlated with the occurrence of postoperative residual anterior compression of the spinal cord. A cutoff point of 4.0 mm is most appropriate for alerting spine surgeons to a high likelihood of postoperative residual anterior compression of the spinal cord. Therefore, the indication of double-door laminoplasty for CSM was INT min > 4.0 mm in the present study.

All the patients were symptomatic and presented with MRI and CT myelography findings consistent with myelopathy secondary to spinal cord compression. The exclusion criteria of the present study were 1) severe multiple stenosis case that the neuropathology could not decide the one level as the cause of myelopathy 2) rheumatoid arthritis, cerebral palsy, ossification of the posterior longitudinal ligament, and other spinal diseases. All patients were followed up for more than 12 months and clinical and radiographic assessments were performed preoperatively and 12 months postoperatively.

2.2. Surgical technique for double-door laminoplasty

In this study, double-door laminoplasty was performed according to Kurokawa's method, with some modifications [13]. Specifically, the laminae were expanded one above and one below the compression level, typically at levels C3-6. For level C2, dome-shaped undercutting of the axis was performed. For levels C6/7, the superior lamina at C7 was fenestrated, with complete preservation of the deep extensor musculature insertion in C2 and C7. The spinous processes between C3 and C6 were resected at their bases, and the center of the laminae was cut using a thread-wire saw. Bilateral gutters were created as hinges at the border of laminae and facets. After the halves of laminae were elevated, hydroxyapatite spinous process spacers were tied to bridge the edges of the laminae.

2.3. Postoperative considerations

After the surgery, all patients were allowed to sit up and walk on the second postoperative day while wearing a soft collar. The collars were used for all patients and were removed 10 days after the surgery. Subsequently, early cervical ROM exercises were performed during rehabilitation.

2.4. Clinical assessment

We used the Japanese Orthopaedic Association (JOA) score (Table 1) to evaluate the severity of myelopathy preoperatively and postoperatively. Postoperative evaluations were performed 12 months after the surgery. Postoperative improvement was evaluated in terms of JOA score recovery rate, calculated using the Hirabayashi method as (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score) × 100%, with a recovery rate of 100% indicating the best postoperative improvement [14]. The multifactorial effects of variables such as duration from onset to surgery, Charlson Comorbidity Index (CCI), [15] which is used for assessment of complications (Table 2), surgery time, and intraoperative bleeding, were also studied.

Table 1
The modified JOA score.

I. Motor function of the upper extremity
- 0. Impossible to eat with chopsticks or spoon
- 1. Possible to eat with spoon but not with chopsticks
- 2. Possible to eat with chopsticks, but inadequate
- 3. Possible to eat with chopsticks, awkward
- 4. Normal

II. Motor function of the lower extremity
- 0. Impossible to walk
- 1. Needs cane or aid on flat ground
- 2. Needs cane or aid only on stairs
- 3. Possible to walk without cane or aid but slowly
- 4. Normal

III. Sensory function
- A. Upper extremity
  - 0. Apparent sensory loss
  - 1. Minimal sensory loss
  - 2. Normal
- B. Lower extremity
  - 0. Apparent sensory loss
  - 1. Minimal sensory loss
  - 2. Normal
- C. Trunk
  - 0. Apparent sensory loss
  - 1. Minimal sensory loss
  - 2. Normal

IV. Bladder function
- 0. Complete retention
- 1. Severe disturbance (sense of retention, dribbling, incomplete continence)
- 2. Mild disturbance (urinary frequency, urinary hesitancy)
- 3. Normal

2.5. Radiological assessment

All patients underwent lateral X-ray in the flexion and extension positions, and MRI in the prone position by using a 1.5-T Sigma MRI unit (Symphony; Siemens Medical Solutions, Erlangen, Germany) preoperatively and 12 months postoperatively. Lateral X-rays were taken in the following position. With each patient in a standing posture, neck flexion and extension were actively performed. The same amount of flexion and extension is performed in all the 3 positions (40° flexion, 0° neutral, and 20° extension positions). Cervical alignment was assessed in terms of the C2–C7 Cobb lordotic angle (LA), which was defined as the angle formed by the inferior end plates of C2 and C7 on standing lateral radiographs (Fig. 1A). The C2–C7 range of motion (ROM) was calculated with the following formula: C2–C7 ROM (°) = (extension C2–C7 Cobb LA) − (flexion C2–C7 Cobb LA) on flexion and extension lateral radiographs. We also calculated segmental ROM at the level of cervical myelopathy. Determination of the level of myelopathy was comprehensively assessed using 1) clinical examinations, where in neuropathology was expected to be the most common cause of myelopathy and 2) blocked level, observed on myelography, and level of the changes in the signal intensity in the spinal cord on MRI [16]. Segmental ROM was calculated with the following formula: Segmental ROM (°) = (extension Segmental angle) − (flexion Segmental angle) on flexion and extension lateral radiographs. Segmental angles were measured between the lines drawn from the inferior margin of the upper vertebral body and the superior margin of the lower vertebral body on flexion and extension lateral radiographs (Fig. 1B). Three independent observers measured each parameter on images generated using a DICOM viewer on a DICOM workstation. The measurements were obtained using electronic calipers. In the present study, we investigated the reliability of the measurement techniques and found