Journal of Clinical Neuroscience xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

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

Case study

Posterior spinal cord shift does not affect surgical outcomes after muscle-preserving selective laminectomy

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ARTICLE INFO

Article history:
Received 18 October 2017
Accepted 18 January 2018
Available online xxxx

Keywords:
Cervical compressive myelopathy
Posterior spinal cord shift
Selective laminectomy
Surgical outcomes
Minimally invasive surgery

ABSTRACT

Postoperative posterior spinal cord shift (PSS) has been considered a required radiographic endpoint of posterior decompression procedures. To achieve PSS, laminoplasty for cervical compressive myelopathy (CCM) has been consecutively performed on four or more laminae (C2–C7, C3–C7, or C3–C6). However, the clinical significance of PSS remains controversial. By selecting the surgically treated laminae, selective laminectomy (SL) can achieve adequate decompression without disturbing the extensor musculature and facet joints. The clinical features and radiological findings from 162 patients with CCM whose decompression included C4/5 level were investigated. The postoperative C2–C7 angle, PSS at C4/5 level, and laminectomy width were measured. Radiologic factors affecting PSS and the relationship between PSS and functional outcome were analyzed. Smaller PSS was observed in cases involving two or fewer consecutive laminectomies than in cases involving three or more consecutive laminectomies. The number of consecutive laminae (CLs) surgically treated and the postoperative C2–C7 angle correlated with PSS. Multiple linear regression analyses showed that the number of surgically treated CLs was the greatest predictor of PSS. No correlation was observed between PSS and the recovery rate (RR) of the Japanese Orthopaedic Association (JOA) score; RR of the JOA score was not affected even in patients with no PSS. PSS was affected by the number of CLs surgically treated and the postoperative C2–C7 angle. The magnitude of PSS never affected the RR of JOA score after SL. Therefore, for patients with CCM, PSS is not mandatory to obtain satisfactory functional recovery.

1. Introduction

Posterior decompression surgeries are commonly performed for patients with cervical compressive myelopathy (CCM). These surgeries can remove posterior compressive factors like hypertrophied ligamentum flavum and compressive bones. Furthermore, it distances the spinal cord from anterior compressive factors.

Posterior spinal cord shift (PSS) has been considered a desired radiologic endpoint to achieve satisfactory surgical decompression [1,2]. Laminoplasty has been performed in extensive and consecutive laminae (CLs) such as C2–C7, C3–C7, or C3–C6 to obtain PSS [3,4]. However, the clinical significance of PSS after posterior surgeries remains controversial [2]. Although two previous studies demonstrated that PSS was correlated with successful surgical outcomes [5,6], other studies failed to show a correlation between them [1,7–9]. Most of those studies compared the PSS and surgical outcomes among patients who underwent extensive and consecutive decompression with or without fusion [1,5–7,9]. One study compared single-level muscle-preserving selective laminectomy (SL) and C3–C7 double-door laminoplasty, but did not include SLs that decompressed two or more consecutive levels [8]. Thus, no previous study has evaluated the relationship between PSS and the number of CLs surgically treated in the same procedure.

Our institute has used SL to decompress CCM for over 12 years. By selecting the decompression laminae without disturbing the deep extensor muscles (DEMs) or facet joints, SL can minimize the effect on posterior cervical structure and maintain cervical

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https://doi.org/10.1016/j.jocn.2018.01.067
0967-5868/

alignment [10–14]. This study focused on PSS at C4/5 level; only patients who underwent SL including those that included the C4/5 level were enrolled in this study. This study aimed to investigate the relationship between surgical or radiological factors (i.e., the number of CLs surgically treated, cervical alignment, and laminectomy width (LW)) and PSS and evaluate the clinical significance of PSS after SL.

2. Materials and methods

2.1. Subjects

The study participants included 198 consecutive patients with CCM who underwent SL at a single academic institution between April 2010 and March 2013. The inclusion criteria for SL were (1) local kyphosis of <20° [14], (2) spondylolisthesis with a displacement of <3.5 mm [15], and (3) occupying ratio of ossification of posterior longitudinal ligament (OPLL) of <60% [16]. Patients who required instrumented fixation, foraminotomy, or anterior and posterior combined surgery; those who presented with radiculopathy alone, tumors, infection, trauma, ankylosing spondylitis, and rheumatoid arthritis; or those who had previous cervical spine surgeries were excluded. Patients who underwent interlaminar decompression or nonconsecutive decompression, reported as "skip laminectomy" [11,12], were also excluded. All patients underwent preoperative cervical myelogram–computed tomography (CT), and for each patient, the presence and type of OPLL were identified. A total of 162 patients with CCM whose surgery included the C4/5 level were enrolled in this study (Table 1). This study focused on the C4/5 level for the following reasons: (1) the decompression cases most commonly included the C4/5 level; (2) as the C4/5 level tends to be at the apex of the cervical lordosis in most patients [17], the PSS around this level is the greatest following posterior decompression [7]; and (3) several previous studies reported that PSS was related to the incidence of C5 palsy [18–21]. In those studies, PSS was usually measured at the C4/5 level because of the course of the C5 nerve root [20–22]. To analyze the relationship between C5 palsy and PSS, we focused on the C4/5 level.

2.2. Surgical procedure

An operating microscope was used throughout the SL surgery [10–13]. Prior to the surgery, decompression levels were established via complete obstruction of the subarachnoid space using preoperative cervical myelogram–CT with each patient's neck in a neutral and extended position. Decompression of the two adjacent intervertebral levels was achieved using selective monolaminectomy [10].

Table 1
Summary of surgical procedure in the 162 patients.

Number of CLs surgically treated	Surgically treated laminae	Decompressed intervertebral levels	No. of patients
1	C5	C4/5-C5/6	3
2	C3-C4	C2/3-C4/5	2
	C4-C5	C3/4-C5/6	23
	C5-C6	C4/5-C6/7	35
3	C3-C5	C2/3-C5/6	10
	C4-C6	C3/4-C6/7	48
	C5-C7	C4/5-C7/T1	1
4	C3-C6	C2/3-C6/7	32
	C4-C7	C3/4-C7/T1	6
5	C3-C7	C2/3-C7/T1	2

CLs, consecutive laminae.

The surgical technique used for C4–C5 SL was as follows. The nuchal fascia was divided in line with the midline skin incision. Subsequently, the C3/4, C4/5, and C5/6 interlaminar spaces were exposed [10,11]. Using a high-speed drill, the C4 and C5 spinous processes were split longitudinally and were divided at the base without disturbing the bilateral DEMs. The C4 and C5 laminae, upper half of the C6 lamina, and yellow ligament of the ventral aspect of the C3 lamina were removed. Decompression was thus accomplished in the adjacent three levels (C3/4, C4/5, and C5/6) [10]. The split fragments of the C4 and C5 spinous processes were subsequently tied together with a nonabsorbable suture.

The decompression levels were identified via complete obstruction of the subarachnoid space on preoperative myelogram–CT with the patient's neck in a neutral and extended position. Subsequently, all measurements of the width of the spinal cord were performed at the upper edge of each lamina using axial myelogram–CT to determine the LW. During SL, the LW was no more than 2–3 mm wider than the spinal cord width [14,21]. The LW was normally between 15 and 19 mm, and the bilateral facet joints were never exposed or affected during surgery.

2.3. Evaluation of clinical outcome

The patients' clinical characteristics, including age, sex, diagnosis, and operative level, were recorded. To evaluate the clinical outcome, the Japanese Orthopaedic Association (JOA) score system was used for cervical myelopathy at both the preoperative stage and the final follow-up (at least 1 year after surgery). To calculate the recovery rate (RR) of the JOA score, Hirabayashi's method was applied [23].

2.4. Radiological evaluation

The postoperative C2–C7 angle was obtained by measuring the angle between the tangential lines along the posterior borders of the C2 and C7 vertebral bodies with a standing lateral cervical radiograph of the neutral position (Fig. 1a). The distances between the posterior margin of the compression factor (PMCF) at the C4/5 level and the nearest point of the anterior margin of the spinal cord (AMSC), PMCF–AMSC (Fig. 1b), were measured pre- and postoperatively using T2-weighted midsagittal magnetic resonance imaging (MRI) [20,21]. The following formula was used to calculate PSS: P SS = postoperative PMCF–AMSC – preoperative PMCF–AMSC. The LW was measured from the middle of each lamina via postoperative T2-weighted axial MRI, and the average LW was used in further analyses [21]. Postoperative radiographs and MRI were performed at least one month after the surgery. Analyses of the images were performed by two independent spine surgeons using a DICOM viewer (RadiAnt version 3.2.3, Meixant, Poznan, Poland, or SYNAPSE version 4.1.0, Fujifilm Medical, Tokyo, Japan). The inter-rater reliabilities analyzed by the interclass correlation coefficient (ICC) (2, 1) showed strong correlations (ICC (2, 1) >0.8) in each radiological measurement.

2.5. Statistical analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) (version 22.0, IBM Corporation, Armonk, NY, USA). Mean ± standard deviations were used to describe continuous variables. A comparison of each independent variable between the groups with ≤2 CLs, 3 CLs, and <4 CLs surgically treated was analyzed using ANOVA. Either the Tukey–HSD or Games–Howell post hoc tests were used for continuous variables, whereas the chi-square test or Kruskal–Wallis test was used for discrete variables. The correlation of PSS with clinical and radiological factors was analyzed using Pearson's correlation coefficient for

Please cite this article in press as: Nori S et al. Posterior spinal cord shift does not affect surgical outcomes after muscle-preserving selective laminectomy. J Clin Neurosci (2018), https://doi.org/10.1016/j.jocn.2018.01.067