Original Article

The new proposal of the relationship between axial pain and hinge fracture and facet involvement after open-door laminoplasty with titanium spacers

ABSTRACT

Study Design: This was a retrospective, observational study.

Objectives: Postoperative axial pain (AP) is a well-known complication of cervical posterior surgery. It can be caused by various reasons, but the etiology remains unclear. This study aimed to investigate risk factors for postoperative AP after open-door laminoplasty. A previous meta-analysis revealed muscle damage, female, age of <60 years, and longer collar application as possible risk factors for postoperative AP after cervical posterior procedures. However, the postoperative AP etiology, specifically for open-door laminoplasty, has been inconclusive and remains conflicting.

Methods: This retrospective study included 129 adult patients who underwent open-door cervical laminoplasty for degenerative diseases in our single institution from January 2015 to October 2021. Postoperative AP was defined as intolerable pain on the neck or shoulder that lasted for >1 month postoperatively. We compared the demographic and radiographic characteristics of AP and non-AP groups.

Results: Postoperative AP developed in 62 (48.1%) patients. Intraoperative hinge fracture (HF) and facet involvement by miniscrews were significantly greater in the AP group than in the non-AP group ($P < 0.05$). Using a logistic regression model, multivariate analysis revealed that HF was significantly associated with postoperative AP (odds ratio = 2.83, 95% confidence interval = 1.28–6.44, $P = 0.011$).

Conclusions: HF and facet involvement were risk factors for postoperative AP after open-door laminoplasty with titanium spacers. Careful surgical manipulation is required to prevent postoperative AP.

Keywords: Axial pain, cervical laminoplasty, facet involvement, hinge fracture, open door

INTRODUCTION

Open-door cervical laminoplasty (CLP) with internal fixation was proposed in 1983.[1] Researchers have developed this popular procedure with some modifications mainly for cervical degenerative diseases. Tani *et al*. designed a new titanium spacer (Laminoplasty Basket; Ammtec Co., Japan) in 2010.[2] This implant produces adequate decompression and high bone fusion rates and accomplishes clinically satisfactory outcomes with safety.[3] However, postoperative axial pain (AP) has been the most prevalent complaint after CLP, greatly affecting patients' quality of life.[4] Several studies have been reported on postoperative AP risk factors after cervical posterior decompression or fusion procedures.[5] However, the complex AP etiology after open-door CLP has been inconclusive and remains conflicting. Therefore, this retrospective study aimed to elucidate the radiographic and clinical risk factors of postoperative AP after open-door CLP with titanium

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spacer fixation for patients with degenerative diseases by board-certified surgeons in a single institution.

METHODS

Study population

This single-center study retrospectively reviewed 195 adult patients who underwent open-door CLP between C3–C6 levels for cervical radiculopathy or myelopathy caused by spondylosis, developmental spinal canal stenosis, and ossification of the posterior longitudinal ligament (OPLL) in our institution from January 2015 to October 2021. The exclusion criteria were (1) demyelinating diseases, trauma, hematoma, reoperation, and postinfection cases, (2) those operated by double-door CLP, (3) simultaneously performed foraminotomy, (4) unavailable preoperative X-rays or computed tomography (CT) images, and (5) follow-up period of <1 month. Finally, this study included 129 patients (94 males and 35 females) [Figure 1]. These patients were aged 25–86 (69.2 ± 10.2) years. The median follow-up periods were 22.4 ± 18.5 months. Informed consent requirement from individual patients was waived due to the retrospective nature of this study and the low risk of studying participants. Approval was obtained from our hospital institutional review board (No. 20221128-8).

Surgical technique

Several board-certified surgeons performed the following surgical steps: after exposing the bilateral laminae, gutters were made medial to the lateral mass on the open side by following the traditional open-door method. The ligamentum flavum was partially resected. In our institution, the open side was set on the left unless the patient's symptoms were right-side dominant. The outer cortical bone of the opposite lamina was drilled out. After laminar elevation, appropriate-sized titanium spacers (Basket 1 or Basket 2; 8, 10, or 12 mm in length; Ammtec Co., Tokyo, Japan; [Figure 2a and b]) filled with the artificial bone, consisting of hydroxyapatite and atelocollagen (ReFit; HOYA Technosurgical, Tokyo, Japan), were applied between the lateral mass and elevated lamina. One 5-mm miniscrew was inserted into the lateral mass, and one or two 4-mm miniscrews were applied through the spacer into the elevated lamina. Additional dome-shaped laminectomies were performed if required. All patients wore a soft cervical collar for 1 week postoperatively.

Definition of axial pain

Postoperative AP is defined as intolerable pain on the neck or shoulder that lasts for over 1 month postoperatively. It is different from preoperative radicular pain. Moreover, the region of pain is apart from the wound. It was moderate-to-severe pain that interfered with patients' daily lives and was evaluated by the patients themselves.

Radiographic data measurements

Radiographic measurements were taken at each level using CT images with the picture archiving and communication system (ShadeQuest/Serv; FUJIFILM Medical Solutions Corporation, Tokyo, Japan). A 3-mm transverse slice image parallel to the end plates was used for preoperative and postoperative CT. Postoperative X-rays and CT images were performed the next day after CLP. "Laminoplasty number" and "Laminectomy number" are the numbers of operated laminae. The sagittal vertical axis (SVA) is measured as the distance from the line of the pedicle center of the C2 vertebra to the posterior superior corner of the C7 vertebra, along with X-ray studies in a standing position. We calculated the difference between the pre- and postoperative SVA as "SVA difference." C2–7 Cobb

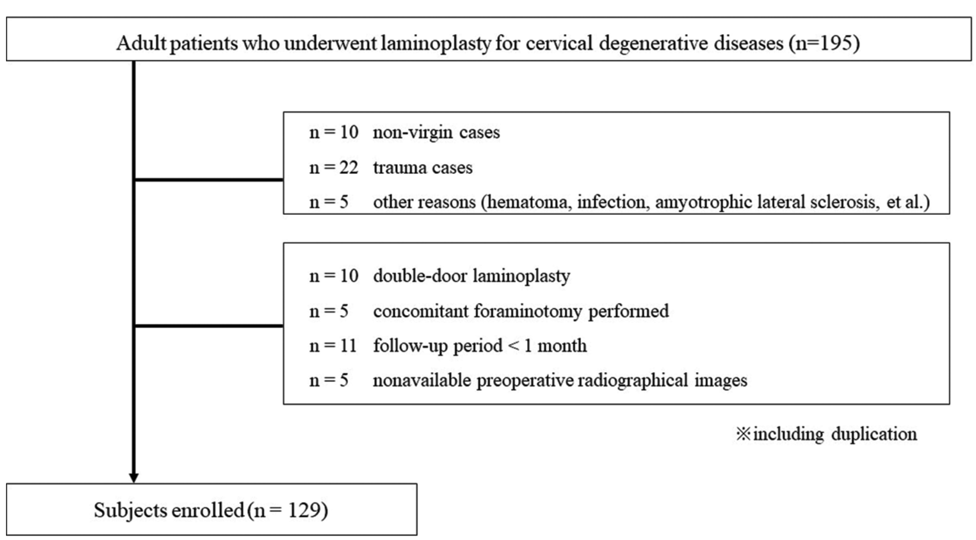

Figure 1: Flowchart of this study

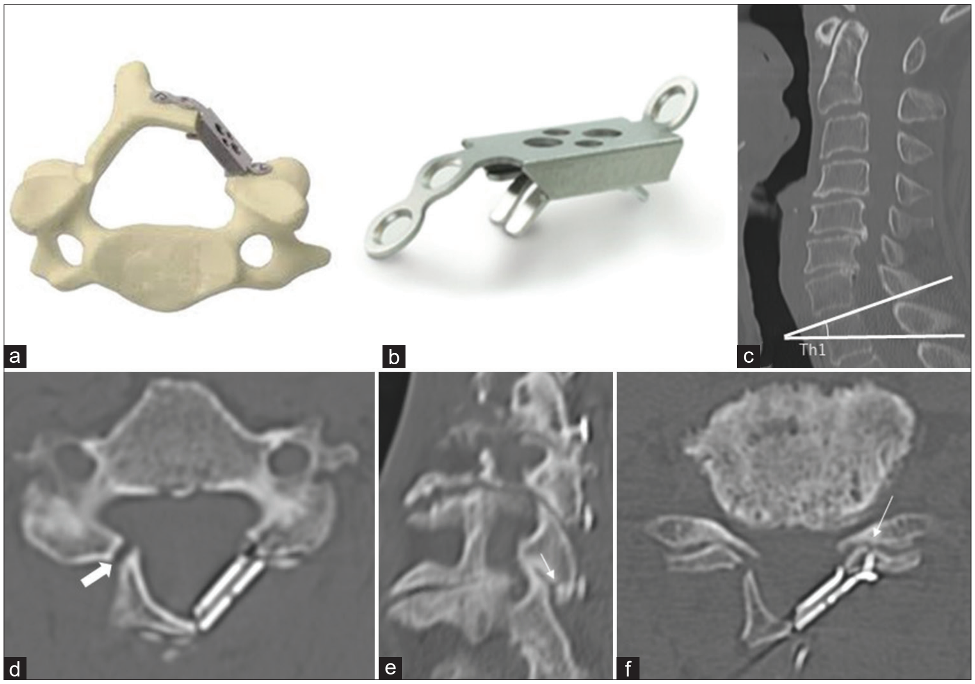

Figure 2: (a and b) Basket system images, (c) T1 slope on preoperative computed tomography image, (d) hinge fracture on the open side (white arrow), and (e and f) facet involvement (white arrows)

angle is the angle between C2 and C7 lower end plates of each vertebral body. We also calculated the difference between the pre- and postoperative C2–7 angles as "C2–7 Cobb angle difference." "T1 slope" is the angle that is formed between the horizontal plane and T1 superior end plate [Figure 2c]. Hinge fracture (HF) is defined as the completely disconnected lamina on the hinge side in postoperative CT scan studies the next day after CLP, when HF exists in one lamina [Figure 2d]. Facet involvement means penetration in the articular surface of the facet joints by miniscrews [Figure 2e and f]. "T2 high" is positive when a lesion in the spinal cord is high on preoperative T2-weighted magnetic resonance imaging.

Statistical analysis

We conducted the statistical analysis of the measurement data using the R version 4.1.2 software (Free Software Foundation's GNU General Public License, Boston, USA) and represented the data using the mean ± the standard deviation (SD) about the mean (X ± SD). The test was evaluated using an unpaired *t*-test or Wilcoxon rank sum exact test for continuous variables and the Chi-squared test or Fisher's exact test for categorical variables between the AP and non-AP groups. $P < 0.05$ indicated statistical significance in each analysis.

RESULTS

Postoperative AP occurred in 62 of 129 (48.1%) patients. Postoperative AP lasted for 2.27 ± 1.49 and 0.39 ± 0.20 months in AP and non-AP groups. Table 1 shows the baseline demographic and radiographical characteristics of each group. Demographics and preoperative radiographical findings were not statistically significantly different between these groups, and the change of C2–7 Cobb angle and SVA did not differ between them. However, the occurrence (48.4% vs. 26.9%) and the number (0.68 ± 0.83 vs. 0.39 ± 0.72) of intraoperative HF (48.4% vs. 26.9%) and facet involvement by miniscrews (25.8% vs. 10.4%) were significantly greater in AP group than non-AP group ($P < 0.05$). Among them, multivariate analysis using a logistic regression model revealed that HF was significantly associated with postoperative AP (odds ratio = 2.83, 95% confidence interval = 1.28–6.44, $P = 0.011$) [Table 2].

DISCUSSION

Etiology and risk factors of axial pain from previous literature

The diagnostic criteria for postoperative AP are various and inconsistent;[5] however, we used the most adopted definition such as Zhang's report.[6] The incidence of postoperative AP has been reported to range from 30% to 60% in patients who underwent CLP.[7] Previously reported risk factors of postoperative AP included female sex,[5] lamina open-door angles of >30°,[8] age of ≦63 years,[5] neck muscles and structures damage,[5,7,9] OPLL,[10] longer external cervical immobilization,[5,6,11] T1 slope,[12] C2–7 SVA,[6,12] change of cervical range of motion,[4] facet joint disturbance,[4]

Table 1: Patient demographics and radiographical characteristics of non-AP and AP groups

Variables	Non-AP (n=67)	AP (n=62)	P
Age	69.84±9.76	67.42±13.42	0.242
Sex (Male, %)	46 (68.7)	48 (77.4)	0.357
OPLL (%)	23 (34.3)	15 (24.2)	0.285
T2 high (%)	22 (32.8)	25 (40.3)	0.484
Anterolisthesis (%)	6 (9.0)	8 (12.9)	0.662
Pre SVA (degrees)	32.30±18.73	33.70±18.35	0.669
Post SVA (degrees)	35.24±18.36	37.61±21.03	0.497
SVA difference (degrees)	2.95±10.87	3.91±15.01	0.676
Pre C2–7 Cobb angle (degrees)	13.35±9.38	13.45±9.49	0.954
Post C2–7 Cobb angle (degrees)	12.57±9.00	11.23±8.61	0.391
C2–7 Cobb angle difference (degrees)	−0.79±6.08	−2.22±8.47	0.269
Pre T1 slope (degrees)	18.74±9.56	19.58±9.67	0.628
Postoperative AP duration (months)	0.39±0.20	2.27±1.49	<0.001
Laminoplasty number	2.67±0.66	2.84±0.58	0.13
Laminectomy number	1.60±0.55	1.58±0.62	0.874
Hinge fracture (%)	18 (26.9)	30 (48.4)	0.019
Number of hinge fracture	0.39 (0.72)	0.68 (0.83)	0.035
Facet involvement (%)	7 (10.4)	16 (25.8)	0.041

AP: axial pain; OPLL: the ossification of the posterior longitudinal ligament; SVA: sagittal vertical axis

Table 2: Risk factors of postoperative axial pain in multivariable logistic regression analysis

Variables	Odds Ratio	95% Confidence Interval		P
Age	0.97	0.93	1	0.072
Sex (Reference: Female)	1.65	0.72	3.94	0.243
Hinge fracture	2.83	1.28	6.44	0.011
Facet involvement	2.71	2.15	5.26	0.057

anterolisthesis,[13] current smoking,[13] preoperative neck pain,[13] and lower Short Form-36 survey score.[13] These variables, among those we researched, were not significantly different except for facet involvement. The etiology and pathomechanism for postoperative AP are multifactorial; thus, a uniform understanding of the consensus remains lacking.[11] Ultimately, this study indicates that numerous clinical factors, including patient factors, surgical indications, surgical procedures, applied implants, and postoperative management, were associated with postoperative AP complicatedly. Therefore, concluding that some particular factors are responsible for postoperative and AP is extremely difficult.

Facet involvement and axial pain

Cohen's neurophysiologic study on facet joints reported nociceptors activated by capsule stretch could cause persistent neck pain.[14] Resection, necrosis, and scarring around facet joints might be related to postoperative AP.[11] Inflammatory reactions spread toward nerve roots when inflammation was induced in a lumbar facet joint in the rat model; radiculopathy was induced by chemical factors such as tumor necrosis factor-alpha immunoreactive cells.[15] Facet joint destruction might cause cervical instability and induce nonbacterial inflammation, resulting in postoperative AP.[4]

The number of involved facet joints on the open side of the postoperative AP group was statistically higher than the non-AP group.[4] In addition, the rate of disturbed facet joints by miniscrews was 30.6%,[4] which was higher than our reports (16/62; 25.8% in AP and 7/67; 10.4% in non-AP groups). Miniplates were anchored to the lateral mass by two 7-mm miniscrews in their cases, whereas titanium spacers were fixed by one 5-mm miniscrew in our cases. Thus, the risk of penetrating facet joints is theoretically decreased using shorter miniscrews. No studies have reported postoperative AP after open-door CLP using the basket system. This implant can produce firm stability with safety as aforementioned.[3]

Relationship between hinge fracture and axial pain

Nuchal muscle damage, shoulder muscle spasm, facet joint destruction, and nerve root irritation were the main mechanisms of postoperative AP;[16] however, they could not explain why postoperative AP persisted, even on the delayed timing, and could not be decreased, although CLP procedures have been modified. Studies have reported that HF might be related to chronic neck pain or palsy.[17] Patients with ≧3 delayed HFs experienced significant worsening of both Visual Analog Scales (VASs) and neck disability index (NDI) scores 12 months after CLP.[18] To the best of our knowledge, this is the first report on the relationship between intraoperative HF and postoperative AP. Intraoperative deformed hinge might cause HF on the delayed timing, but we did not evaluate postoperative AP in the delayed phase of approximately 3–6 months. At least, intraoperative HF might affect postoperative AP and interfere obviously with the patient's daily activities in our study. Therefore, it could be concluded that factors in preoperative patients did not affect postoperative AP in our study. Careful surgical manipulation for CLP must be required to prevent postoperative AP as adverse events.

Limitations to the study

This study has two major limitations. First, this study was retrospectively performed; the scale of postoperative AP was not standardized such as VAS or NDI scales. Second, the number of patients enrolled in the study is relatively low, and further research should include more patients. A more comprehensive nationwide study is required to draw solid conclusions.

CONCLUSIONS

Intraoperative HF and facet involvement by miniscrews were risk factors for postoperative AP after open-door CLP. In particular, multivariate analysis using a logistic regression model revealed that HF was significantly associated with postoperative AP. Careful surgical manipulation must be required to prevent postoperative AP.

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Conflicts of interest

There are no conflicts of interest.

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