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Clinical Study

Selective blocking laminoplasty in cervical laminectomy and fusion to prevent postoperative C5 palsy

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Abstract

BACKGROUND CONTEXT: Cervical laminectomy and fusion (CLF) is a common surgical option for multilevel cord compression. Postoperative C5 palsy occurrence after CLF has been a vexing problem for spine physicians. The posterior shift of the cord following laminectomy has been implicated as a major factor for postoperative C5 palsy, but attempts by spine surgeons to mitigate excessive shift while providing sufficient decompression have not been well reported.

PURPOSE: To compare the incidence of postoperative C5 palsy after performing selective blocking laminoplasty concurrently with CLF to those of conventional CLF.

STUDY DESIGN: A retrospective comparative study of prospectively collected data.

PATIENT SAMPLE: Of 116 cervical myelopathy patients with degenerative cervical myelopathy, ossification of the posterior longitudinal ligament, and multilevel disc herniation, 93 patients (69 in group A [CLF group] and 24 in group B [selective blocking laminoplasty with CLF, CLF-S group]) were included in the study.

OUTCOME MEASURES: The primary outcome measure was the occurrence of postoperative C5 palsy. Secondary end points included (1) clinical outcomes based on pain intensity, neck disability index (NDI), Japanese Orthopaedic Association (JOA) score, (2) radiologic outcomes including cervical alignment and fusion rate at 1 year and hardware complications, and (3) perioperative data (hospital stay, blood loss, and operative times).

METHODS: We compared the occurrence of postoperative C5 palsy, as well as clinical, radiologic, and surgical outcomes, between the two groups at 1-year follow-up.

RESULTS: The patients in both groups were statistically similar between the groups with respect to demographic characteristics such as age, sex, smoking status, body mass index, preoperative pathology, surgical segments, and the degree of the cervical lordosis. Postoperative C5 palsy developed in 9 of 61 patients (14%) in group A and in 0 of 24 patients (0%) in group B (CLF-S group) (p=.03). Postoperative neck pain, NDI, and JOA improvement were not significantly different between the two groups (p=.93, 0.90, and 0.79, respectively). Perioperative data did not differ significantly between the two groups.

CONCLUSIONS: This study showed that performing selective blocking laminoplasty might lead to reducing the incidence of postoperative C5 palsy in CLF surgery.

Keywords: Cervical spine; Laminectomy; Fusion; C5 palsy; Blocking; Selective laminoplasty.

FDA device/drug status: Approved (Vertex system, Medtronic Sofamor Danek, Memphis, TN).

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Introduction

Cervical laminectomy and fusion (CLF) with screw fixation is commonly used to treat multilevel compressive pathologies of the cervical spine [1–6]. However, several drawbacks of CLF have been pointed out, including a limited range of neck motion, surgical site infection, nonunion, and postoperative C5 palsy [7,8].

Among the drawbacks, postoperative C5 palsy has been a vexing problem for spine surgeons. Several studies have documented the pathophysiology and factors of postoperative C5 palsy after CLF [8–18]. One of these factors is excessive posterior shifting of the spinal cord, resulting in C5 nerve root tethering [19,20]. The posterior shifting phenomenon of the cervical cord following laminectomy has been well documented in several experimental and clinical studies [19–30]. However, attempts to mitigate excessive posterior shifting while providing sufficient decompression of the cervical cord have not been widely reported.

Considering the relationship between posterior spinal cord shifting and C5 palsy, the authors devised a surgical modification of CLF that includes selective blocking laminoplasty (CLF-S) to avoid excessive shifting. In the current study, we aimed to evaluate the outcomes of our modified technique (CLF-S) and compare them with those of conventional CLF.

Materials and methods

Patients

The study concept and procedure were approved by our institutional review board. This retrospective comparative study evaluated the impact of additional selective blocking laminoplasty in multilevel CLF on the postoperative outcomes, focusing on the occurrence of postoperative C5 palsy. We had initially intended to study the postoperative outcomes of multilevel CLF (CLF, group A) from January 2012. However, in May 2015, we altered the surgical technique to include a modified CLF (CLF-S, group B), which involved additional selective laminoplasty on the basis of a trial on some patients. Therefore, all consecutive patients who received CLF or CLF-S were enrolled and classified into two groups based on the date of surgical treatment, and their prospectively collected data were retrospectively reviewed.

Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) obvious findings of multilevel cervical pathologies on cervical radiograph, computed tomography (CT), and magnetic resonance imaging (MRI), including degenerative cervical myelopathy, ossification of the posterior longitudinal ligament, and multilevel soft disc herniation with cord compression which corresponded to the patient's myelopathic symptoms and/or signs; (2) pathology requiring posterior decompression and fusion; (3) surgical procedure conducted on ≥2 segments involving C4-5; (4) patient follow-up ≥1 year after surgery. The exclusion criteria were as follows: (1) history of infection, trauma, or tumor in the cervical spine; (2) concurrent anterior-approach surgery, such as anterior cervical discectomy and fusion or corpectomy; (3) cervical myelopathy with radiculopathy (cervical myeloradiculopathy) requiring cervical root decompression, such as anterior or posterior foraminotomy and uncinate process excision; (4) cervical deformity requiring corrective procedures, such as pedicle subtraction osteotomy; (5) surgery extended to the thoracic spine; (6) patient follow-up <1 year after surgery.

Surgical technique and postoperative protocol

All surgeries were conducted with same surgical procedures and techniques. The surgical segments were determined by an agreement of two spine surgeons on the basis of the patient's symptoms/signs and radiologic findings.

In CLF, total laminectomies with lateral mass screw fixations (Vertex system, Medtronic Sofamor Danek, Memphis, TN, USA) were performed simultaneously on the affected segments using matchstick-shaped surgical burr were performed. In CLF-S, selective blocking laminoplasty similar to the method of open-door laminoplasty was conducted at the middle level of the affected segments. After lifting the opening side of the lamina, a suture tie (2-0 Ethibond, Ethicon Inc., Somerville, NJ, USA) for maintaining spinal canal expansion, was placed from the base of spinous process to the neck of hinge-side lateral mass screw. For example, if CLF was planned to be performed at the C3-6 segments, laminectomy at C3 and C6, as well as selective laminoplasty at C4 and C5, were performed.

The patients were allowed to ambulate on the first day after surgery. All patients wore a Philadelphia cervical collar for 2 months, during which time sports activity was prohibited. Two months after surgery, the patients were allowed to gradually resume normal preoperative activities.

Outcome measures

The primary outcome measure was the occurrence of postoperative C5 palsy, defined as (1) a newly developed paralysis of the deltoid and/or biceps compared to preoperative motor power, without worsening myelopathy-related symptoms [9], and/or (2) pain or paresthesia or other sensory disturbance on the dermatomal area innervated from the C5 nerve root, especially at the lateral area of the upper arm. Identification of C5 palsy was described by a third party who was a junior spine surgeon and research coordinator for this study after full consideration and discussion as documented above, and finally confirmed by corresponding author's (GWL) diagnosis. Severity of motor weakness was graded using motor grade scale (grade 0–5) [31].

The secondary outcome measures were the clinical outcomes, radiologic outcomes, and surgical outcomes.

The clinical outcomes were assessed on the basis of the pain intensity using the 10-point visual analogue scale (VAS) score for neck pain, Neck Disability Index (NDI) score for functional status, 17-point Japanese Orthopedic Association (JOA) score for cervical myelopathy using Hirabayashi's method [32], and the recovery rate of JOA score was calculated as follows: (postoperative score−preoperative score)×100/(17−preoperative score). The enrolled patients regularly visited the outpatient clinic preoperatively and at 1, 3, 6, and 12 months postoperatively, and the questionnaire forms were completed by the patients themselves, with an aid of a research coordinator. For the radiologic outcomes, the 1-year fusion rate and mechanical complications, such as screw loosening and reclosure on the laminoplasty segment, were evaluated in detail using radiographs and CT images. Fusion status was evaluated 1 year after surgery based on (1) the Cobb angle difference <2° between flexion and extension lateral radiographs and (2) the presence of a fusion mass definitely connecting the operated segments on CT images. The presence of a continuous fusion mass on radiographs and CT scans was considered to be indefinite or inconclusive on radiographs and CT, or a difference of more than 2° in the Cobb angle, which was defined as a nonunion status. The lordosis of the cervical spine was measured between the lower end plate of C2 and the lower end plate of C7 preoperatively and postoperative 1 year, by a junior spine surgeon who was not participated in the study. The surgical outcomes, including the hospital stay duration, estimated blood loss, and operative times, were also assessed. Surgical procedure-related complications were also analyzed in detail. The questionnaires, chart data, clinical records, and radiologic images were analyzed by one surgeon who was not otherwise involved in this study.

Statistical analysis

The paired or Student's *t* test, Wilcoxon rank test, and analysis of variance were used for continuous variables, and the Fisher's exact test was used for proportional variables. GraphPad Prism program (version 7.01 Graph Pad Software, Inc., San Diego, CA, USA) was used for all statistical analyses, and a two-sided p value <.05 was considered statistically significant. Numerical values were expressed as means±standard deviations.

Results

Patient characteristics

Of 116 consecutive patients, 93 patients (69 in group A and 24 in group B) were enrolled in the study (Fig. 1). The patients were statistically similar between the groups with respect to demographic characteristics such as age, sex, smoking status, body mass index, preoperative pathology, surgical segments, and the degree of the cervical lordosis (Table 1).

Primary outcome measure (postoperative C5 palsy)

Clinically, postoperative C5 palsy developed in 9 of 61 patients (14.7%) in group A (CLF group), and in 0 of 24 patients (0%) in group B (CLF-S group). There was a significant difference between the two groups (p=.03). Among the nine patients who had postoperative C5 palsy in

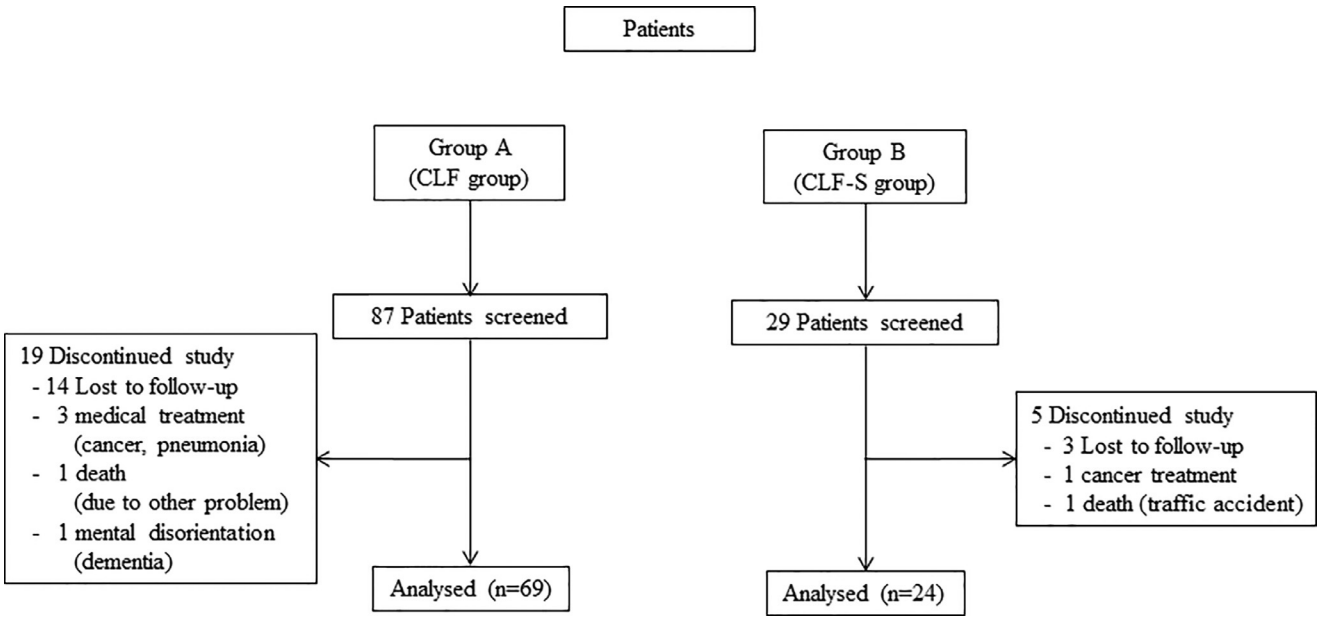

Fig. 1. Flow diagram for enrolled patients.

Table 1
Demographic data

	Group A (n=69)	Group B (n=24)	p
Age (y)	62.1±9.8	66.3±7.2	.58
Gender (male: female)	45: 24	15: 9	.61
Height (cm)	166.3±17.1	168.2±14.3	.83
Weight (kg)	68.2±9.9	66.4±8.1	.74
BMI (kg/m^2)	24.0±4.3	23.4±3.9	.86
Smoking status			.67
Smoker	22 (32%)	5 (21%)	
Nonsmoker	47 (68%)	19 (79%)	
Surgical level			.53
C4–C6	31 (45%)	8 (33%)	
C3–C5	19 (28%)	6 (25%)	
C3–C6	14 (20%)	9 (38%)	
Others	5 (7%)	1 (4%)	
Cervical lordosis*			
Preoperative	9.3±6.8	8.1±7.2	.82
Postoperative 1 y	11.9±7.7	11.6±6.3	.99
Pathology			.70
OPLL	29 (42%)	9 (38%)	
CSM	25 (36%)	8 (33%)	
Multilevel disc herniation	7 (10%)	2 (8%)	
Mixed	8 (12%)	5 (21%)	

Group A, CLF; Group B, CLF-S.

All surgical levels were performed with both total laminectomy and lateral mass screw fixations, and blocking laminoplasty at the middle level of the affected segments was added in the group B.

Values in data cells represent mean±SD (standard deviation) or number (percentage).

BMI, body mass index; OPLL, ossification of posterior longitudinal ligament; CSM, cervical spondylotic myelopathy

* The lordosis of the cervical spine was measured between the lower end plate of C2 and the lower end plate of C7 preoperatively and postoperative 1 y.

Table 2
Surgical outcomes

Variables	Group A (n=69)	Group B (n=24)	p
Surgical time (h)	2.2±0.3	2.3±0.4	.92
Incision length (mm)	96.7±15	103.2±19	.97
Blood loss (mL)	281.9±93	295.6±78	.96
Hospital stay (d)	3.9±0.3	3.7±0.2	.99

Group A, CLF; Group B, CLF-S.

Values in data cells represent mean±SD (standard deviation).

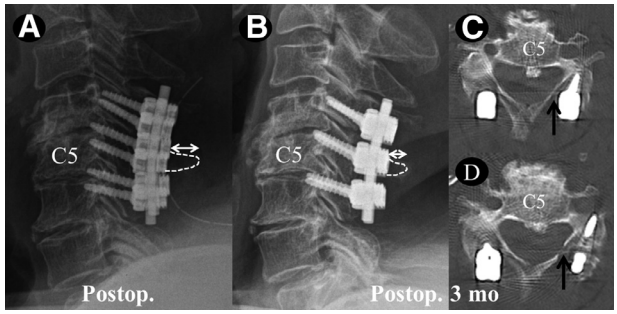

Fig. 2. A case of reclosure after cervical laminectomy and fusion with blocking selective laminoplasty. (A) Immediate postoperatively, height of C5 posterior bony arch from screw head was 12.7 mm at lateral radiograph of the cervical spine. (B) Three months postoperatively, the height was 3.1 mm at lateral radiograph of the cervical spine, which was significantly decreased. (C and D) CT images revealed that opening site for the selective laminoplasty was reclosed (black arrow).

group A, five patients had motor weakness of shoulder abduction with or without elbow flexion, and the remaining four patients had sensory disturbance and pain at the C5 dermatomal distribution. All patients, except for one patient with motor weakness, fully recovered their newly developed C5 palsy-related symptoms within 1 year postoperatively. The one patient with motor weakness had persistent motor weakness of motor grade 2 at 1-year follow-up.

Secondary outcome measures

The mean VAS scores for posterior neck pain indicated that the 1-year postoperative pain levels were significantly lower than the preoperative levels in both groups, with the mean scores decreasing from 4.1±1.1 preoperatively to 2.0±0.8 at 1 year postoperatively in group A and from 4.9±1.4 to 2.2±0.5 in group B (p=.93). There was no significant difference between the groups. Further, there was no significant difference in the pain intensity at the regular follow-up after surgery.

The mean JOA score improved from 11.9±3.2 preoperatively to 16.3±2.1 at 1 year after surgery in group A, and from 12.3±3.8 preoperatively to 16.7±1.8 at 1 year after surgery in group B. The mean recovery rate of JOA score at the final follow-up was 69.7%±15.3% in group A and 68.4%±16.7% in group B, and there was no statistically significant difference between groups (p=.90).

The mean NDI also improved from 36.5±10.1 preoperatively to 18.0±4.7 at 1 year postoperatively in group A and from 35.1±9.7 preoperatively to 15.1±3.8 at 1 year after surgery in group B. There was no significant difference between both groups (p=.79).

Perioperative outcomes, including estimated blood loss, operative time, hospital stay duration, and incision length, are described in Table 2. There were no significant differences between the two groups. One patient in group B had reclosure of the selective laminoplasty segment (Fig. 2). However, the patient's myelopathic symptoms and signs and other clinical symptoms did not worsen. There were no other complications such as fever, swelling, or deep infection in any patient. However, there was one case of superficial infection at the surgical site in group A. Infection was resolved with antibiotics administration.

Discussion

Various hypotheses regarding postoperative C5 palsy after cervical spine surgery have been described. However, a consensus regarding the etiology has yet to be reached.

Offered theories include inadvertent injury to the nerve root during surgery, nerve root traction caused by consecutive posterior spinal cord shifting following decompression surgery, spinal cord ischemia due to decreased blood supply from the radicular arteries, segmental spinal cord disorder, and reperfusion injury of the spinal cord [33]. Among them, excessive posterior spinal cord shifting has been presumed by many researchers to be a major factor [15,16,34–36]. However, there has been no attempt to reduce the excessive posterior shifting of the cervical cord. To our knowledge, this is the first surgical trial to show a reduction in the incidence of postoperative C5 palsy by controlling posterior spinal cord shifting with selective blocking laminoplasty during multilevel CLF.

Multilevel cervical laminectomy results in posterior expansion of the thecal sac and posterior shifting of the spinal cord. In previous reports, the amount of cord shifting after posterior laminectomy and fusion was 2.4 mm to 4 mm on average [19,22,23]. A greater number of laminectomy segments and excessive cervical lordosis after surgery might be an important risk factor for posterior spinal cord shifting. Excessive posterior spinal cord shifting increases the distance from the spinal nerve root. Thus, a stretch force between the spinal cord and the nerve root could occur. Yamashita et al. reported that the posterior spinal cord drift averaged 5 mm in patients with C5 palsy, and this was significantly higher than that in patients without palsy [37]. Radcliff et al. also reported that the mean postoperative cord shifting in patients with C5 palsy was 5.1 mm and 5.2 mm at the C5 and C6 levels, respectively [19]. In addition, the coexistence of neural foraminal stenosis could reduce the mobility of the nerve root and might increase the possibility of axonal injury of the nerve root by accelerating the stretch force between the spinal cord and the nerve root.

The C5 segment is usually at the apex of the posterior decompression and the greatest extent of posterior shifting [33,37–39]. Considering this background, we presumed that performing selective blocking laminoplasty in the middle portion of the entire laminectomy segment might adjust spinal canal widening in the corresponding segment and control the amount of thecal sac expansion and cord shifting in the middle portion without development of C5 palsy. In addition, CLF-S not only directly removes the cause of soft tissue cord compression through the resection of the ligamentum flavum but also allows appropriate indirect spinal cord decompression through laminoplasty. In the present study, the addition of blocking laminoplasty decreased the incidence of postoperative C5 palsy, with a significant difference between the groups.

Meanwhile, there was no difference in the clinical scores (JOA, NDI, and VAS), radiologic outcomes, and surgical outcomes between the patients with and without blocking laminoplasty. The postoperative outcomes of the myelopathic symptoms using the JOA score did not differ significantly. This outcome indicates that performing selective laminoplasty at the middle segment, instead of total laminectomy, does not compromise the decompression of the spinal cord. Moreover, there were no differences in the other clinical parameters, such as pain and neck function, and surgical factors such as operative time, hospital stay duration, and estimated blood loss between the two groups. Considering the primary and secondary outcome measures, additional selective laminoplasty at the middle segment in multilevel CLF may reduce the incidence of postoperative C5 palsy, but may not lead to other problems related to the surgical procedure itself.

There were some technical issues in conducting selective laminoplasty during CLF in our study, and one of them is the use of the suture technique for selective laminoplasty. Open-door laminoplasty using the suture technique has been reported to be more likely to cause reclosure than that using the laminoplasty plate and screw system. As depicted on Fig. 2, one patient in group B had reclosure of the laminoplasty segment 3 months after surgery, but fortunately had no aggravated myelopathic symptoms and signs. The authors believed that the reclosure problem was not associated with the selective laminoplasty procedure itself but with the limited availability of a firm instrumentation, such as screw-plate implant, in our country. It was technically challenging to fix the lateral mass screw and conventional laminoplasty plate simultaneously in one lateral mass. Therefore, we used suture technique despite of the possibility of the reclosure [40,41]. Accordingly, we think that such a reclosure issue can be addressed by the use of a firm implant for selective laminoplasty.

The present study has several limitations. First, we did not directly measure the posterior spinal cord shifting after surgery. Because of their financial burden on patients, imaging studies, such as magnetic resonance imaging, to evaluate the postoperative spinal cord status, could not be performed. However, the expansion of the thecal sac, which was visually confirmed during surgery, might be smaller in the blocking laminoplasty group. In addition, by adding selective blocking laminoplasty, which could be effective in limiting excessive spinal cord shifting, the incidence of C5 palsy significantly decreased. Second, excessive posterior spinal cord shifting is not the only cause of C5 palsy. Additionally, CLF-S cannot be applied to anterior cervical surgery. However, since the incidence of C5 palsy after CLF only was relatively higher than that after laminoplasty or anterior surgery, this study focused on the development of preventive surgery for C5 palsy applicable to laminectomy with fusion [14–18,33]. Third, the number of enrolled patients and patients with C5 palsy was relatively small because of the relatively short duration of the study and because the procedures were conducted by one surgeon in a single institution. However, research by a single institution and one surgeon can be expected to reduce performance and selective bias by introducing consistency in the surgical technique or perioperative management. Moreover, the incidence of C5

palsy after CLF confirmed in this study is similar to that reported in other previous studies [14–18,33].

Conclusions

This study revealed that performing selective blocking laminoplasty in CLF could significantly reduce the incidence of postoperative C5 palsy in comparison with performing only CLF in patients with cervical myelopathy. To better establish the efficacy and safety of selective blocking laminoplasty in multilevel CLF, more studies should be performed that use a larger sample size, an extended follow-up period, and a prospective-randomized study design.

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References

[1] Kumar VG, Rea GL, Mervis LJ, McGregor JM. Cervical spondylotic myelopathy: functional and radiographic long-term outcome after laminectomy and posterior fusion. Neurosurgery 1999;44:771–8.
[2] Gok B, McLoughlin GS, Sciubba DM, McGirt MJ, Chaichana KL, Wolinsky JP, et al. Surgical management of cervical spondylotic myelopathy with laminectomy and instrumented fusion. Neurol Res 2009;31:1097–101.
[3] van Geest S, de Vormer AM, Arts MP, Peul WC, Vleggeert-Lankamp CL. Long-term follow-up of clinical and radiological outcome after cervical laminectomy. Eur Spine J 2015;24(Suppl 2):229–35.
[4] Klineberg E. Cervical spondylotic myelopathy: a review of the evidence. Orthop Clin North Am 2010;41:193–202.
[5] Cunningham MR, Hershman S, Bendo J. Systematic review of cohort studies comparing surgical treatments for cervical spondylotic myelopathy. Spine 2010;35:537–43.
[6] Anderson PA, Matz PG, Groff MW, Heary RF, Holly LT, Kaiser MG. Laminectomy and fusion for the treatment of cervical degenerative myelopathy. J Neurosurg Spine 2009;11:150–6.
[7] Nassr A, Eck JC, Ponnappan RK, Zanoun RR, Donaldson WF 3rd, Kang JD. The incidence of C5 palsy after multilevel cervical decompression procedures: a review of 750 consecutive cases. Spine 2012;37:174–8.
[8] Sakaura H, Hosono N, Mukai Y, Ishii T, Yoshikawa H. C5 palsy after decompression surgery for cervical myelopathy: review of the literature. Spine 2003;28:2447–51.
[9] Katsumi K, Yamazaki A, Watanabe K, Ohashi M, Shoji H. Analysis of C5 Palsy After Cervical Open-door Laminoplasty: Relationship Between C5 Palsy and Foraminal stenosis. J Spinal Disord Tech 2013;26:177–82.
[10] Epstein NE. Hollingsworth R. C5 Nerve root palsies following cervical spine surgery: A review. Surg Neurol Int 2015;6:S154–63.
[11] Basaran R, Kaner T. C5 nerve root palsy following decompression of cervical spine with anterior versus posterior types of procedures in patients with cervical myelopathy. Eur Spine J 2016;25:2050–9.
[12] Guzman JZ, Baird EO, Fields AC, McAnany SJ, Qureshi SA, Hecht AC, et al. C5 nerve root palsy following decompression of the cervical spine. a systematic evaluation of the literature. Bone Joint J 2014;96-B:950–5.
[13] Klement MR, Kleeman LT, Blizzard DJ, Gallizzi MA, Eure M, Brown CR. C5 palsy after cervical laminectomy and fusion: does width of laminectomy matter? Spine J 2016;16:462-7.
[14] Imagama S, Matsuyama Y, Yukawa Y, Kawakami N, Kamiya M, Kanemura T, et al. C5 palsy after cervical laminoplasty: a multicentre study. J Bone Joint Surg Br 2010;92:393–400.
[15] Tsuzuki N, Abe R, Saiki K, Okai K. Paralysis of the arm after posterior decompression of the cervical spinal cord. II. Analyses of clinical findings. Eur Spine J 1993;2:197–202.
[16] Uematsu Y, Tokuhashi Y, Matsuzaki H. Radiculopathy after laminoplasty of the cervical spine. Spine 1998;23:2057–62.
[17] Chiba K, Toyama Y, Matsumoto M, Maruiwa H, Watanabe M, Hirabayashi K. Segmental motor paralysis after expansive open-door laminoplasty. Spine 2002;27:2108–15.
[18] Hasegawa K, Homma T, Chiba Y. Upper extremity palsy following cervical decompression surgery results from a transient spinal cord lesion. Spine 2007;32:E197–202.
[19] Radcliff KE, Limthongkul W, Kepler CK, Sidhu GD, Anderson DG, Rihn JA, et al. Cervical Laminectomy Width and Spinal Cord Drift Are Risk Factors for Postoperative C5 Palsy. Clin Spine Surg 2014;27:86–92.
[20] Denaro V, Longo UG, Berton A, Salvatore G, Denaro L. Cervical spondylotic myelopathy: the relevance of the spinal cord back shift after posterior multilevel decompression. A systematic review. Eur Spine J 2015;24:832–41.
[21] Du W, Zhang P, Shen Y, Zhang YZ, Ding WY, Ren LX. Enlarged laminectomy and lateral mass screw fixation for multilevel cervical degenerative myelopathy associated with kyphosis. Spine J 2014;14:57–64.
[22] Tashjian VS, Kohan E, McArthur DL, Holly LT. The relationship between preoperative cervical alignment and postoperative spinal cord drift after decompressive laminectomy and arthrodesis for cervical spondylotic myelopathy. Surg Neurol 2009;72:112–7.
[23] Lee JY, Sharan A, Baron EM, Lim MR, Grossman E, Albert TJ, et al. Quantitative prediction of spinal cord drift after cervical laminectomy and arthrodesis. Spine 2006;31:1795–8.
[24] Xia G, Tian R, Xu T, Li H, Zhang X. Spinal posterior movement after posterior cervical decompression surgery: clinical findings and factors affecting postoperative functional recovery. Orthopedics 2011;34:e911–8.
[25] Shiozaki T, Otsuka H, Nakata Y, Yokoyama T, Takeuchi K, Ono A, et al. Spinal cord shift on magnetic resonance imaging at 24 hours after cervical laminoplasty. Spine 2009;34:274–9.
[26] Hatta Y, Shiraishi T, Hase H, Yato Y, Ueda S, Mikami Y, et al. Is posterior spinal cord shifting by extensive posterior decompression clinically significant for multisegmental cervical spondylotic myelopathy? Spine 2005;30:2414–9.
[27] Sodeyama T, Goto S, Mochizuki M, Takahashi J, Moriya H, et al. Effect of decompression enlargement laminoplasty for posterior shifting of the spinal cord. Spine 1999;24:1527–32.
[28] Fujimura Y, Nishi Y, Nakamura M. Dorsal shift and expansion of the spinal cord after expansive open-door laminoplasty. J Spinal Disord 1997;10:282–7.
[29] Aita I, Hayashi K, Wadano Y, Yabuki T. Posterior movement and enlargement of the spinal cord after cervical laminoplasty. J Bone Joint Surg Br 1998;80:33–7.
[30] Baba H, Uchida K, Maezawa Y, Furusawa N, Azuchi M, Imura S. Lordotic alignment and posterior migration of the spinal cord following en bloc open-door laminoplasty for cervical myelopathy: a magnetic resonance imaging study. J Neurol 1996;243:626–32.
[31] Rathe R. Neurologic Examination at First Year Medical Curriculum at University of Florida College of Medicine. 2nd ed. 2000.
[32] Hirabayashi K, Miyakawa J, Satomi K, Maruyama T, Wakano K. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. Spine 1981;6:354–64.
[33] Sakaura H, Hosono N, Mukai Y, Ishii T, Yoshikawa H. C5 Palsy after Decompression Surgery for Cervical Myelopathy: Review of the Literature. Spine 2003;28:2447–51.
[34] Hirabayashi K, Toyama Y, Chiba K. Expansive laminoplasty for myelopathy in ossification of the longitudinal ligament. Clin Orthop Relat Res 1999;359:35–48.

[35] Tsuzuki N, Abe R, Saiki K, Zhongshi L. Extradural tethering effect as one mechanism of radiculopathy complicating posterior decompression of the cervical spinal cord. Spine 1996;21:203–11.

[36] Yonenobu K, Hosono N, Iwasaki M, Asano M, Ono K. Neurologic complications of surgery for cervical compression myelopathy. Spine 1991;16:1277–82.

[37] Yamashita T, Yokogusu K, Yokozawa H. C5 nerve palsy after cervical laminoplasty: an analysis of three cases. Seikei Geka 1996;47:1365–9.

[38] Sasai K. Prevention and pathogenesis of C5 palsy after laminoplasty. J Jpn Spine Res Soc 2002;13:230.

[39] Tsuzuki N, Tanaka H, Abe R, Okai K. Cervical radiculopathy occurring after the posterior decompression of the cervical spinal cord. Rinsho Seikei Geka 1991;26:525–34.

[40] Chen H, Deng Y, Li T, Gong Q, Song Y, Liu H. Clinical and radiography results of mini-plate fixation compared to suture suspensory fixation in cervical laminoplasty: A five-year follow-up study. Clin Neurol Neurosurg 2015;138:188–95.

[41] Hu W, Shen X, Sun T, Zhang X, Cui Z, Wan J. Laminar reclosure after single open-door laminoplasty using titanium miniplates versus suture anchors. Orthopedics 2014;37:e71–8.