A New Grading of Epidural Hematoma or Scar Formation after Posterior Cervical Spine Surgery: Evaluation of Perioperative Related Factors, Distributions, and Clinical Outcomes after Surgery

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Abstract:

Introduction: The purpose of this study was to evaluate surgical outcomes using a new grading of postoperative epidural hematoma (EH) or epidural scar formation after posterior cervical spine surgery.

Methods: Postoperative EH or epidural scar formation after cervical laminoplasty (LP) or posterior decompression and fusion (PDF) were graded into Grades 1-5 by magnetic resonance imaging at 24 hours, 2 weeks, 6 months, and one year after surgery. The patients were divided into the Mild group (Grades 1-3) and the Severe group (Grades 4, 5). Perioperative factors were compared between the two groups at 24 hours after surgery. Distribution of EH or scar formation was investigated according to two surgeries. The recovery rate of Japanese Orthopedic Association (JOA) scores and the improvements of neck disability index (NDI) were compared between the two groups at one year postoperatively.

Results: Of the postoperative factors, posterior shift of the cervical spinal cord at C4 and C7 significantly differed between the two groups. Patients in the Severe group at 24 hours after surgery (17%) increased to 41% at 2 weeks and subsequently decreased to 16% at 6 months after LP. After PDF, 3% in the Severe group at 24 hours after surgery increased to 15% at 2 weeks and then decreased to 3% at 6 months postoperatively. Only one (3%) patient remained in the Severe group at 1 year after PDF. The recovery rate of JOA score (47.5%) of the patients in the Mild group showed trend larger than that of the Severe group (34.7%) after LP. Preoperative NDI (15.6 points) significantly improved postoperatively to 12.1 points in only the Mild group after LP.

Conclusions: The patterns of distribution of EH or scar formation did not differ between the two surgical methods. The severity of postoperative scar formation related to surgical outcomes after LP.

Keywords:

Epidural hematoma, Scar formation, Grading, Cervical laminoplasty, Posterior fusion, Postlaminectomy membrane, Ossification of the posterior longitudinal ligament, Cervical spondylotic myelopathy

Spine Surg Relat Res 2019; 3(4): 285-294
dx.doi.org/10.22603/ssrr.2019-0015

Introduction

Postoperative hematoma after cervical spinal surgery often causes serious complications. For example, postoperative retropharyngeal hematoma is especially well known to occur after anterior cervical spine surgery[1]. A previous study identified the risk factors of postoperative retropharyngeal hematoma as (1) diffuse idiopathic skeletal hyperostosis, (2) ossification of the posterior longitudinal ligament (OPLL), (3) therapeutic heparin use, (4) longer operative time, and (5) greater number of surgical levels[1]. On the contrary, after posterior cervical spine surgery, postoperative epidural hematoma (EH) can cause various symptoms including paralysis[2,3] and intolerable neck pain[4,5], with urgent surgical removal of the hematoma sometimes needed[6]. It remains unclear what risk factors are associated with postoperative EH

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Received: March 6, 2019, Accepted: May 10, 2019, Advance Publication: May 31, 2019

after posterior cervical spine surgery.

It has been hypothesized that, in some cases, postoperative epidural scar formation, so-called postlaminectomy membrane, may cause late neurological deterioration after cervical laminectomy[7]. In the literature, postlaminectomy membrane formation is thought to occur as part of the postoperative healing process or in association with EH formation[8-10]. Therefore, postoperative scar formation after cervical laminoplasty (LP) may also be associated with EH. Indeed, one case report presented remarkable epidural scar formation that compressed the cervical spinal cord after LP with hydroxyapatite spacers[11].

Because postlaminectomy membrane formation often causes late neurological deterioration due to postoperative movements of the cervical spine, postoperative epidural scar formation might similarly lead to poor neurological improvements after LP. On the other hand, one group reported no postoperative fibrosis after LP with fusion[12]. To our knowledge, there are no detailed reports on the relationships between postoperative EH and postoperative epidural scar formation, or postoperative clinical outcomes after posterior cervical spine surgery, including LP and posterior decompression and fusion (PDF).

The present study aimed to clarify the perioperative factors, the distribution of EH or scar formation, and the clinical outcomes of postoperative scar formation after posterior cervical spine surgery (LP and PDF) using a new grading system to determine the severity of the postoperative mass posterior to the dural sac by magnetic resonance imaging (MRI).

Materials and Methods

Subjects

One-hundred and two patients with cervical myelopathy underwent posterior cervical spine surgery at our institution and were included in the present study. All patients who completed 1 year of follow-up were included (follow-up rate, 93%). The average age at the time of surgery was 66 years (range, 27-87 years). Sixty-nine consecutive patients underwent LP as follows: 47 patients had cervical spondylotic myelopathy (CSM) and 22 had OPLL. All patients with OPLL who underwent LP had K-line (+) OPLL. Thirty-three consecutive patients underwent PDF as follows: nine patients had CSM and 24 had OPLL. PDF was used for patients with K-line (−) OPLL in the neck-flexed position[13], or CSM with malalignment.

Operative technique and postoperative treatment

Both LP and PDF groups underwent C3 laminectomy with complete preservation of the semispinalis cervicis (Sc) insertion at C2[14]. Spinous process-splitting laminoplasty was performed, with hydroxyapatite spinous process spacers placed at C4 to C7. During PDF procedure, pedicle screws were first inserted bilaterally into C2, C7, and T1 pedicles. Lateral mass screws at C4 to C6 or C5 pedicle screws were used as mid-cervical anchors. For C2 pedicle screw insertion, the interval between the obliquus capitis inferior and Sc insertion points was exposed using a spatula and medical scissors to preserve the muscles[15]. Bilateral rods were passed under the Sc. Local bone grafting was performed from C2/C3 to C7/T1 in all patients. Finally, 2 or 3 suction drainage tubes for postoperative bleeding were put on the hydroxyapatite spinous process spacers, and between the unilateral or bilateral opened laminae and deep muscles.

MRI was performed at 24 hours after surgery, and the suction drainage tubes were removed 2 or 3 days after surgery. None of the patients required postoperative immobilization with a collar. The patients were permitted to sit up or walk within 1 week postoperatively, and exercise was resumed within 1 week postoperatively.

Grading of epidural hematoma or scar formation posterior to the dural sac after posterior cervical spine surgery

The severity of postoperative EH or scar formation was graded using T1-weighted and T2-weighted mid-sagittal MRI (Fig. 1). Images were taken using XTREX VIEW (J-MAC System, Sapporo, Japan). Grading was determined by the degree of compression of the dorsal dural sac space and the cervical spinal cord, as shown in Table 1 and Fig. 1. The grading was performed at 24 hours and 2 weeks postsurgery. The degree of epidural scar formation was also assessed at 6 months and 1 year after surgery. Patients were divided into two groups based on the grading results: "Mild group," comprising Grades 1, 2, and 3; or "Severe group," comprising Grades 4 and 5.

Relationship between postoperative epidural hematoma and perioperative factors

Perioperative factors, including pre-, intra-, and postoperative factors, are described in Table 2. All of the perioperative factors were compared between the Mild and Severe groups by grading at 24 hours after surgery. The longitudinal distance index was defined as the length of a straight line drawn between the posteroinferior edges of C2 and C7 divided by the anteroposterior diameter of C4 on lateral neutral radiographs[16]. Preoperative lordotic angles and range of motion (ROM) at C2-C7 were measured on lateral radiographs of the cervical spine using the posterior tangents of the C2 and the C7 vertebral bodies. The preoperative cross-sectional areas of the cervical posterior muscles, including the trapezius, splenius capitis, semispinalis capitis, Sc, and multifidus muscles, were measured on axial T2-weighted magnetic resonance (MR) images at the level of C4/C5 according to the method of Takeuchi et al. (Fig. 2)[15]. Prophylactic bilateral C4/5 foraminotomy[17] was adopted in 71 patients (LP: 52 cases; PDF: 19 cases). The average and maximum systolic blood pressure were measured up to 24 hours after surgery. C5 palsy (19 patients) was defined as new deterioration of muscle strength of the deltoid and/or the biceps brachii[18]. The width between bilateral gutters and the

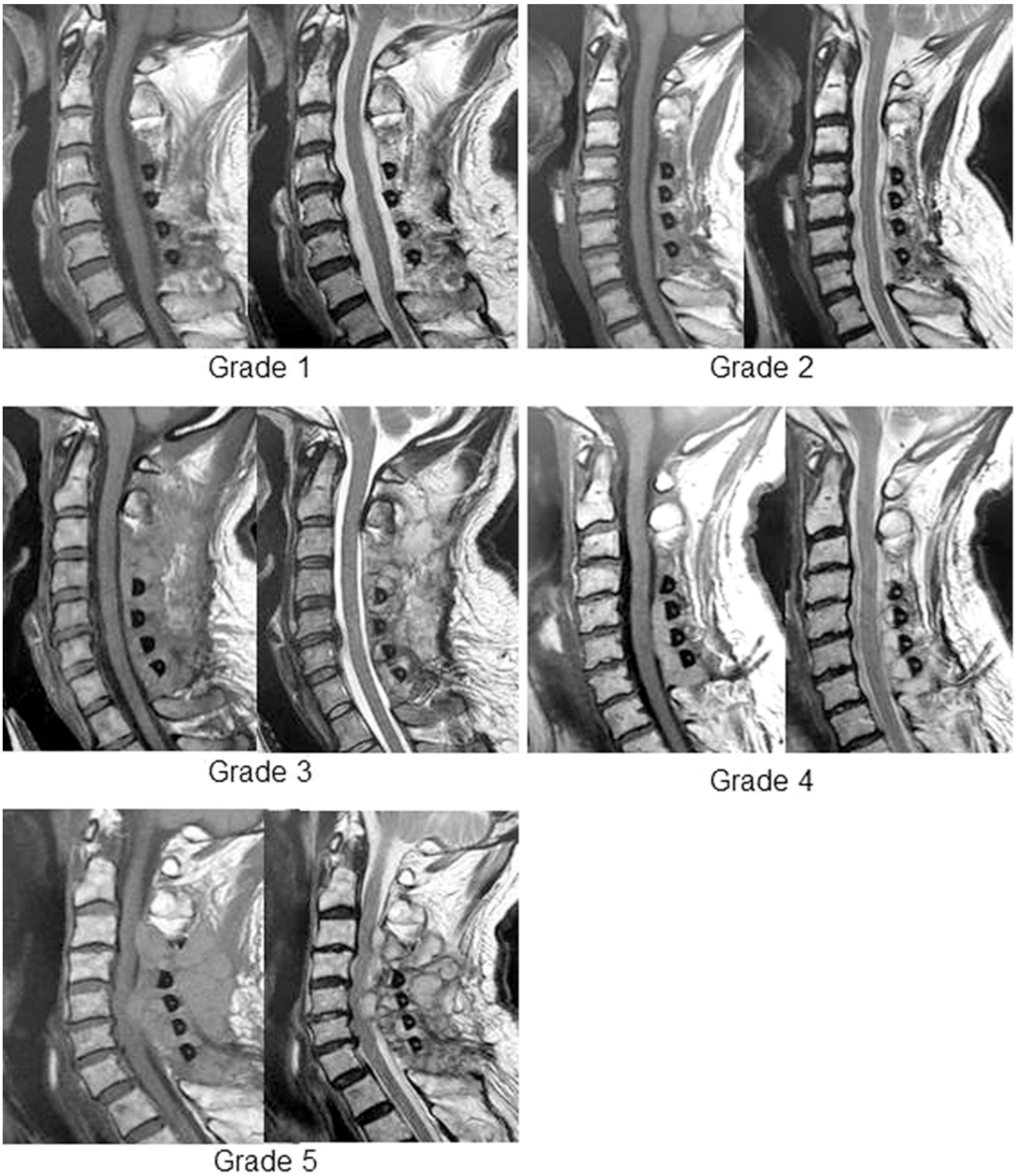

Figure 1. Grading of the mass posterior to the dural sac using magnetic resonance (MR) imaging. T1-weighted (left) and T2-weighted (right) mid-sagittal MR images are shown for each grade. Grade 1: Dorsal dural sac space (DDS) is expanded without any compression by the mass. Grade 2: DDS is expanded with partial compression by the mass. Grade 3: DDS has a linear shape with the entire area compressed by the mass. Grade 4: DDS disappears without compression of the spinal cord by the mass. Grade 5: The spinal cord is compressed by the mass.

Table 1. Grading of the Mass Posterior to the Dural Sac after Posterior Cervical Spine Surgery.

Grade 1	DDS is expanded without any compression by mass
Grade 2	DDS is expanded with partial compression by mass
Grade 3	DDS has a linear shape with the entire area compressed by mass
Grade 4	DDS disappears without compression of the spinal cord by mass
Grade 5	Spinal cord is compressed by mass

DDS: dorsal dural sac space

inclination angle of the lamina was measured using postoperative computed tomography (CT) at 2 weeks after surgery. The gutter position was defined as the proportion of the distance between the gutters and the distance of the transverse

Table 2. Relationships between Perioperative Factors in the Two Groups by Grading at 24 Hours after Surgery.

	Mild group (*n*=89)	Severe group (*n*=13)	*P* value
Preoperative factors			
Age (years old)	66.0±12.7	68.3±13.1	0.3687
Gender (M/F; *n*)	56/33	9/4	0.7468
Disease (CSM/OPLL; *n*)	46/43	10/3	0.1350
Operative methods (LP/PDF; *n*)	57/32	12/1	0.0561
Merger of hypertension (*n*)	29	4	>0.9999
Merger of diabetes (*n*)	22	2	0.7277
Anti-platelet drugs/anticoagulants (*n*)	19	2	>0.9999
Longitudinal distance index	4.7±1.6	4.9±0.5	0.6018
C2-C7 lordotic angle (degrees)	13.8±13.2	14.9±13.2	0.5438
C2-C7 range of motion (degrees)	43.7±14.8	40.7±12.5	0.4547
Cross-sectional area at C4/5 (mm^2)	3507.5±751.1	3524.5±693.6	0.9720
Preoperative JOA score (points)	10.1±2.8	10.5±2.5	0.7174
Intraoperative factors			
Prophylactic C4/5 foraminotomy (*n*)	60	11	0.3343
Surgical time (min)	262.4±115.0	207.5±61.3	0.2696
Surgical bleeding (mL)	274.7±255.1	203.1±91.1	0.6470
Number of drainage tube	2.7±0.5	2.5±0.5	0.1359
Postoperative factors			
Discharge of drainage tube (mL)	615.8±316.5	521.9±249.1	0.4456
Average systolic blood pressure (mmHg)	129.3±16.7	140.2±25.4	0.1210
Maximum systolic blood pressure (mmHg)	151.1±20.4	159.8±26.3	0.1483
C5 palsy (*n*)	16	3	0.7049
Gutter position at C3	0.84±0.07	0.81±0.06	0.0690
Gutter position at C4	0.80±0.08	0.78±0.05	0.2871
Gutter position at C5	0.81±0.08	0.81±0.05	0.6513
Gutter position at C6	0.79±0.07	0.80±0.07	0.4484
Gutter position at C7	0.75±0.09	0.73±0.09	0.4306
Inclination angle of the lamina at C4 (degrees)	58.9±5.8	59.6±3.8	0.4201
Inclination angle of the lamina at C5 (degrees)	59.5±5.7	58.5±2.8	0.6844
Inclination angle of the lamina at C6 (degrees)	59.1±6.1	57.2±5.1	0.4638
Inclination angle of the lamina at C7 (degrees)	58.4±5.9	56.5±4.6	0.3665
Posterior shift of the spinal cord at C3 (mm)	1.7±1.1	0.9±1.2	0.2563
Posterior shift of the spinal cord at C4 (mm)	3.4±1.4	2.2±1.5	**0.0187**
Posterior shift of the spinal cord at C5 (mm)	4.1±1.6	2.7±2.3	0.0651
Posterior shift of the spinal cord at C6 (mm)	4.2±1.7	2.2±1.6	**0.0008**
Posterior shift of the spinal cord at C7 (mm)	3.2±1.6	2.4±1.3	0.0509
Recovery rates of JOA score (%)	43.3±32.7	53.5±26.6	0.4337

Bold indicates a significant *P* value

M: male; F: female; CSM: cervical spondylotic myelopathy; OPLL: ossification of the longitudinal ligament; LP: laminoplasty; PDF: posterior decompression and fusion; JOA: Japanese Orthopedic Association

diameter of the spinal canal (Fig. 3)[19]. The average inclination angle of the lamina on both sides was measured as the angle by a line running between the bilateral facet joints and a line between the rising point of the inside of the lamina and the inside corner of the lamina of the spacer side (Fig. 3)[19]. The distance from the posterior edge of the center of each vertebra to the center of the spinal cord was measured at C3-C7. Posterior shifts of the cervical spinal cord at C3-C7 were determined by calculating the difference between the distance measured on T2-weighted mid-sagittal magnetic resonance images before and after surgery, according to the following formula: posterior shift (mm) = distance at 24 hours − distance before surgery[18]. All of the perioperative factors were compared between the Mild and Severe groups by grading at 24 hours after surgery.

Changes in distribution of postoperative epidural hematoma or scar formation

The changes in distribution of postoperative EH or scar formation were investigated. Surgery-specific distributions were examined from 24 hours to 1 year after surgery.

Postoperative outcome evaluations

The pre- and postoperative Japanese Orthopedic Association (JOA) scores and the recovery rate (%) of the JOA score were investigated in all patients. The recovery rates of the JOA score at 1 year after surgery was calculated as: recovery rate (%) = (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score) × 100. The surgery-specific recovery rates of the JOA score were compared between the Mild and Severe groups at 1 year after surgery. The pre- and postoperative (1 year after surgery) neck disability index (NDI) values were evaluated. The surgery-specific improvements of NDI values were evaluated in both the Mild and Severe groups at 1 year after surgery.

Postoperative radiological parameters

Radiological parameters, including the C2-C7 lordotic angle and the ROM at C2-C7, were measured on lateral radiographs of the cervical spine using the posterior tangents of the C2 and C7 vertebral bodies at 6 months and 1 year after LP. The relationships between the grouping at 6 months and 1 year and the radiological parameters at 6 months and 1 year after LP were examined.

After LP, the patients were divided into two groups based on the changes that took place from 2 weeks to 6 months postoperatively as follows: "S-M subgroup," comprising the patients whose grouping changed from severe at 2 weeks to mild at 6 months postoperatively; and "S-S subgroup," comprising the patients whose grouping was unchanged, i.e., severe at 2 weeks and severe at 6 months postoperatively. The relationships between these two subgroups and the radiological parameters at 6 months and 1 year postoperatively were investigated after LP. The changes in the radiological parameters from 6 months to 1 year postoperatively were also investigated in each subgroup after LP.

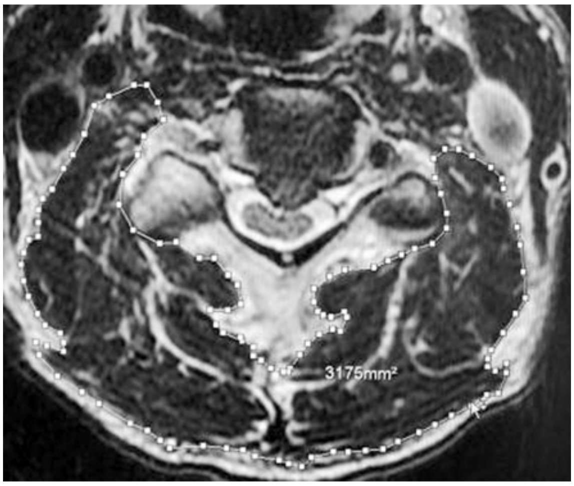

Figure 2. Measurements of the cross-sectional areas of the cervical posterior muscles on axial T2-weighted magnetic resonance images at the level of C4/C5.

Statistical analysis

Fisher's exact test and the Mann-Whitney *U* test were applied to compare the perioperative factors and the recovery rate of the JOA score between the Mild and the Severe groups and the radiological parameters after LP between the two subgroups. Fisher's exact test was applied to examine the distribution of EH or scar formation. Wilcoxon's signed-rank test was applied to examine the surgery-specific improvements in NDI in the two groups at 1 year after surgery and the changes in the radiological parameters over time after LP. Differences with a *P* value less than 0.05 were considered statistically significant.

Results

Perioperative-related factors

The relationships between the two groups and the perioperative-related factors are shown in Table 2. There was no significant difference in any pre- and intraoperative-related factors between the Mild and Severe groups by grading at 24 hours after surgery. Of the postoperative factors, the extent of the posterior shift of the cervical spinal cord at C4 and C6 in the Severe group (2.2 and 2.2 mm, respectively) was significantly smaller than that in the Mild group (3.4 and 4.2 mm, respectively).

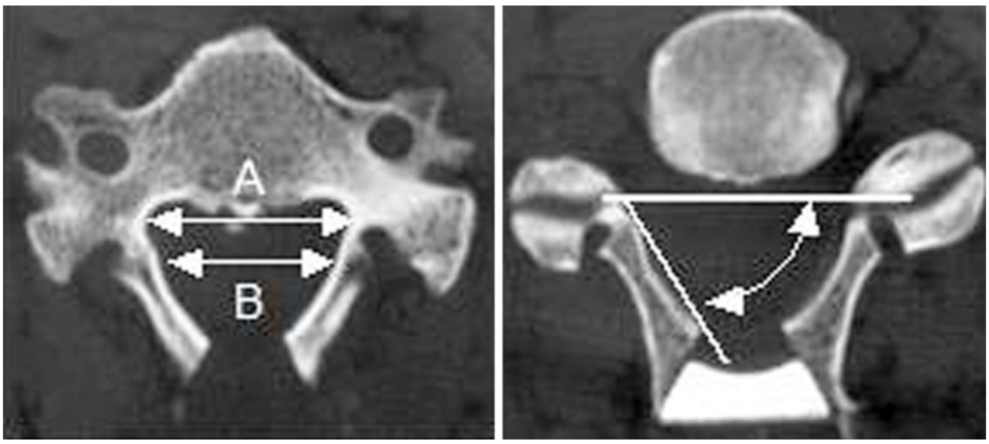

Figure 3. Widths between the bilateral gutters (left) and the inclination angles of the lamina (right) measured on axial computed tomography images. (A) Transverse diameter of the spinal canal; (B) distance (inside) between bilateral gutters.

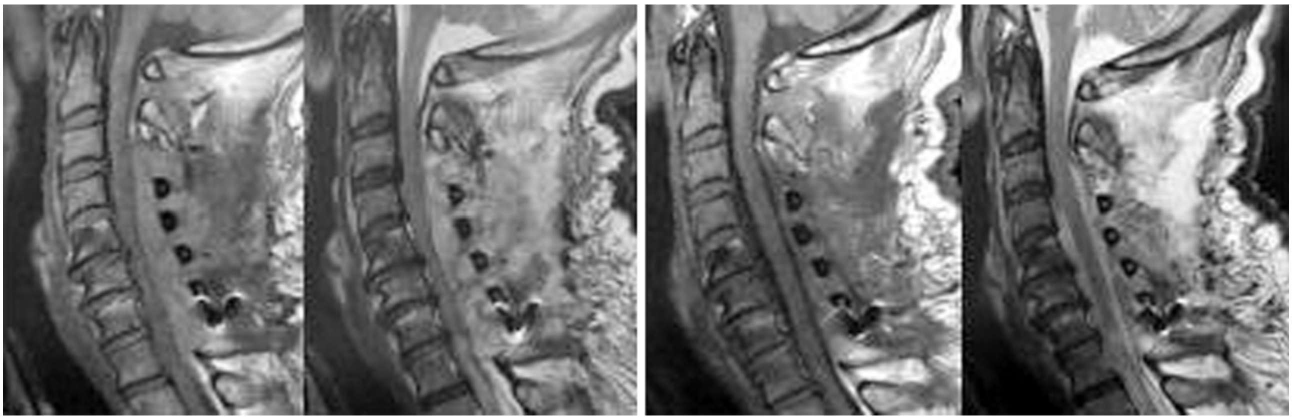

Figure 4. A male patient with Grade 5 (left) epidural hematoma after posterior decompression and fusion. The patient reported severe neck pain and paresis of the extremities. The epidural hematoma improved to a Grade 3 (right) after surgical removal of the hematoma.

Table 3. Distribution of Grade of Postoperative Mass Posterior to the Dural Sac after LP.

Postoperative	LP (*n*=69)	*P* value
24 hours	Mild: 57 (G1: 21, G2: 22, G3: 14), Severe: 12 (G4: 8, G5: 4)	
	↓	0.0563
2 weeks	Mild: 41 (G1: 5, G2: 12, G3: 24), Severe: 28 (G4: 21, G5: 7)	
	↓	0.1063
6 months	Mild: 58 (G1: 7, G2: 39, G3: 12), Severe: 11 (G4: 11, G5: 0)	
	↓	0.0007
1 year	Mild: 62 (G1: 13, G2: 41, G3: 8), Severe: 7 (G4: 7, G5: 0)	

n: number of patients; LP: laminoplasty; Mild: Mild group; Severe: Severe group; G: Grade

Table 4. Distribution of Grade of Postoperative Mass Posterior to the Dural Sac after PDF.

Postoperative	PDF (*n*=33)	*P* value
24 hours	Mild: 32 (G1: 2, G2: 17, G3: 13), Severe: 1 (G4: 1, G5: 0)	
	↓	>0.9999
2 weeks	Mild: 28 (G1: 2, G2: 11, G3: 15), Severe: 5 (G4: 5, G5: 0)	
	↓	>0.9999
6 months	Mild: 32 (G1: 15, G2: 15, G3: 2), Severe: 1 (G4: 1, G5: 0)	
	↓	0.0303
1 year	Mild: 32 (G1: 19, G2: 12, G3: 1), Severe: 1 (G4: 1, G5: 0)	

n: number of patients; PDF: posterior decompression and fusion; Mild: Mild group; Severe: Severe group; G: Grade

Table 5. Comparison of Radiological Parameters in the Mild and Severe Groups at All Evaluation Times up to 1 Year after Surgery.

	Mild group	Severe group	*P* value
Postoperative C2-C7 lordotic angle			
6 months (degrees)	21.9±12.5	15.2±13.0	0.1073
1 year (degrees)	21.3±12.0	22.4±10.2	0.6462
Postoperative range of motion at C2-C7			
6 months (degrees)	27.4±10.7	25.8±6.7	0.7817
1 year (degrees)	27.4±10.4	28.8±9.5	0.7131

Distribution of the grading of epidural hematoma or scar formation, and postoperative radiological parameters

One male patient (0.9%) with Grade 5 EH and CSM with malalignment and a large longitudinal distance index (5.31) demonstrated severe neck pain and paresis of the extremities, and underwent hematoma removal surgery one day after the first PDF. His Grade 5 EH improved to a Grade 3 EH after surgery (Fig. 4). The surgery-specific distributions of grading at 24 hours, 2 weeks, 6 months, and 1 year after surgery for all patients are shown in Table 3, 4. Significant *P* values by Fisher's exact test in the tables indicate similar distributions between the two periods.

Among the patients treated with LP, the percentage in the

Table 6. Comparison of Radiological Parameters after LP between the S-M and S-S Subgroup.

	S-M subgroup (*n*=21)	S-S subgroup (*n*=7)	*P* value
Postoperative C2-C7 lordotic angle			
6 months (degrees)	23.2±12.7	14.8±12.4	0.1056
1 year (degrees)	21.2±11.7	18.5±16.9	0.9366
Postoperative range of motion at C2-C7			
6 months (degrees)	27.1±5.9	26.5±7.4	0.8113
1 year (degrees)	30.5±7.9	21.9±8.0	**0.0385**

Bold indicates a significant *P* value

S-M: Severe-Mild; S-S: Severe-Severe; LP: laminoplasty

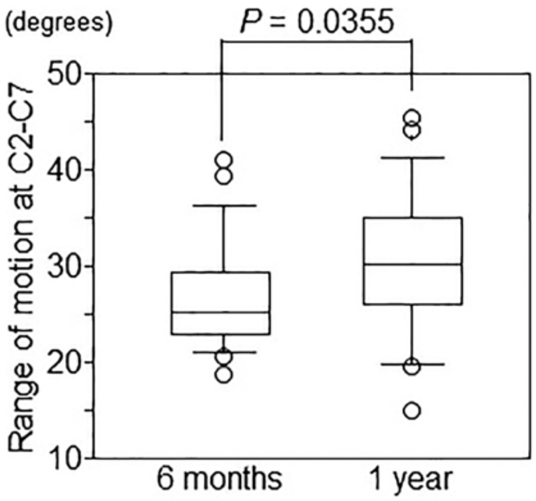

Figure 5. Change in the range of motion (ROM) at C2-C7 from 6 months and 1 year in the S-M subgroup. The C2-C7 ROM at 6 months (27.1°) significantly increased to 30.5° at 1 year (*P*=0.0355).

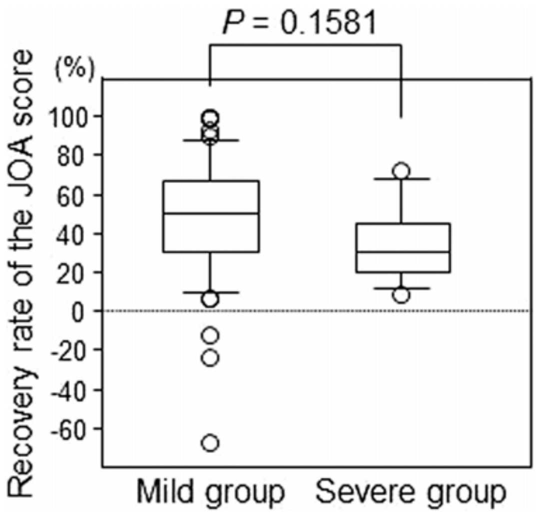

Figure 6. Recovery rate of the Japanese Orthopedic Association (JOA) score at 1 year postoperatively. The JOA score recovery rate for patients in the Mild group (48%) was higher than that in the Severe group (35%) after cervical laminoplasty.

Severe group at 24 hours after surgery (17%) increased to 41% at 2 weeks, and subsequently decreased to 16% at 6 months after surgery. Only seven (10%) patients remained in the Severe group at 1 year after LP.

For patients treated with PDF, the percentage in the Severe group at 24 hours after surgery (3%) increased to 15% at 2 weeks, subsequently decreasing to 3% at 6 months postoperatively. Only one (3%) patient remained in the Severe group at 1 year after PDF.

The relationships between the two groups with regard to radiological parameters after LP are shown in Table 5. C2-C7 lordotic angle and C2-C7 ROM up to 1 year after surgery did not differ between the two groups at all evaluation times. Results of the comparison of the radiological parameters between the S-M and S-S subgroups are shown in Table 6. At 1 year after LP, C2-C7 ROM in the S-S subgroup (21.9°) was significantly smaller (P = 0.0358) than that in the S-M subgroup (30.5°). The changes in radiological parameters from 6 months to 1 year postoperatively were also investigated in each subgroup after LP. In the S-M subgroup, although C2-C7 lordotic angle at 6 months (23.2°) was similar to that at 1year (21.2°), C2-C7 ROM at 6 months (27.1°) significantly increased to 30.5° at 1year (P = 0.0355) as shown in Fig. 5. In the S-S subgroup, the C2-C7 lordotic angle and C2-C7 ROM at 6 months (14.8° and 26.5°, respectively) were similar to those at 1 year (18.5° and 21.9°, respectively).

Postoperative clinical outcomes

Among the patients treated with LP, although the difference between the recovery rates of the JOA score was not statistically significant (P = 0.1581), there was a statistical trend for higher rates in the Mild group (47.5%) as compared with the Severe group (34.7%) at 1 year after surgery (Fig. 6). For those treated with PDF, we could not compare the recovery rates of the JOA scores because there was only one patient in the Severe group at 1 year after surgery. The mean recovery rates of the JOA score among all patients after PDF was 40.9% 1 year after surgery.

For patients treated with LP, preoperative NDI (15.6 points) was significantly improved (P = 0.0011) at 1 year postoperatively (12.1 points) in the Mild group (Fig. 7). Meanwhile, NDI was similar at preoperative and postoperative points (18.6 vs. 17.3 points) in the Severe group at 1 year postoperatively (Fig. 6). For patients treated with PDF,

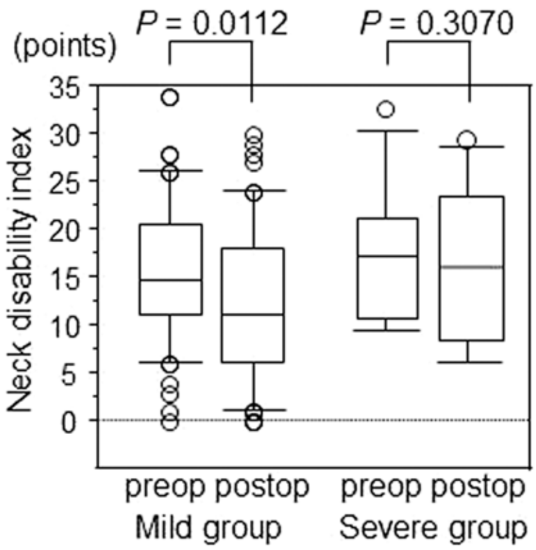

Figure 7. Postoperative improvements in neck disability index (NDI) after cervical laminoplasty at 1 year after surgery. NDI significantly improved postoperatively in the Mild group, but was unchanged in the Severe group.

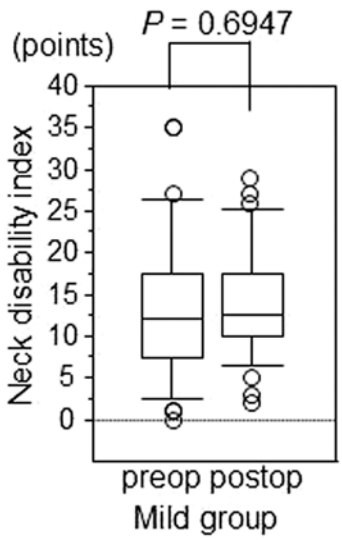

Figure 8. Postoperative improvements in neck disability index (NDI) after cervical laminoplasty at 1 year after posterior decompression and fusion (PDF). NDI in the Mild group did not improve at 1 year after PDF.

preoperative NDI (13.6 points) was similar 1 year postoperatively (14.2 points) in the Mild group (Fig. 8), and we could not compare preoperative and postoperative NDI in the Severe group (n = 1).

Discussion

Several reports have described symptomatic postoperative EH after posterior cervical spine surgery[2-6]. Recently, Schroeder et al. investigated retrospectively a total of 16,582 cervical spine surgeries (8,887 anterior procedures and 7,695 posterior procedures) across multiple centers, and reported fewer EHs in anterior procedures (5.63 per 10,000 anterior cases) than in posterior procedures (13.00 per 10,000 posterior cases)[20]. Most hematomas often result in a sudden inability to move the extremities just after surgeries[2,6]. Yet, a case report presenting three patients with severe neck pain on physical examination showed a slow-growing postoperative EH despite normal motor function[4]. In any case, serious complications require the urgent surgical removal of EHs. In the current study, one male (0.9%) with CSM, malalignment, and a large longitudinal distance index (5.31) after PDF underwent urgent surgery to remove a grade 5 EH the day after primary surgery (Fig. 4). The patient's symptoms were partial paralysis of the upper and lower limbs and severe neck pain (visual analog scale, 74/100 mm), even after sustained morphine intravenous injections. Although we examined the perioperative-related factors associated with the postoperative EH, no significant pre- and intraoperative risk factors could be identified. Of the postoperative factors, the extent of the posterior shift of the cervical spinal cord at C4 and C6 in the Severe group was significantly smaller than that in the Mild group. A large postoperative EH might reduce the postoperative posterior shift of the spinal cord.

The changes in patterns of distribution of postoperative EH or scar formation were similar between the two surgical methods. Specifically, the number of patients in the Severe group increased from 24 hours to 2 weeks postoperatively, decreased from 2 weeks to 6 months postoperatively, and did not change from 6 months to 1 year postoperatively. An increase in the number of patients in the Severe group from 24 hours to 2 weeks postoperatively might have occurred after removal of the suction drainage tubes at 2 or 3 days after surgery. At 1 year after LP, C2-C7 ROM in the S-S subgroup was significantly smaller than that in the S-M subgroup. Furthermore, although C2-C7 ROM at 6 months had significantly increased by 1year after LP in the S-M subgroup, C2-C7 ROM at 6 months was similar to that at 1 year. Therefore, decreasing scar formation from 2 weeks to 6 months after LP led to larger postoperative C2-C7 ROM after LP. In other words, postoperative scar formation in the Severe group at 6 months after LP led to poorer postoperative C2-C7 ROM. After LP, seven (10%) patients remained in the Severe group at the end of follow-up. On the other hand, after PDF, only one (3%) patient remained in the Severe group at 1 year. Kim et al. examined the postoperative outcomes of 50 patients after LP and fusion, reporting no postoperative restenosis or epidural fibrosis[12]. When treating with PDF, the continuous pulsation of the dural sac from the cervical spinal fusion might be an influencing factor for small postoperative epidural scar formation.

Regarding postoperative clinical outcomes among those treated with LP, although the difference between the recovery rates of the JOA score was not statistically significant, there was a trend toward higher rates in the Mild group (48%) than in the Severe group (35%). After a power analysis, we presume that too few patients in the Severe group (seven patients) was a main factor affecting the significance (data not shown), and that significance may be reached in a larger study. Furthermore, preoperative NDI was significantly improved postoperatively in the Mild group but not in the Severe group. Kitahara et al. reported that a 73-year-old male developed recurrent cervical myelopathy 6 months after C4-C6 laminectomy due to dynamic spinal cord compression by postlaminectomy membrane, as identified on CT myelography[7]. In the present study, therefore, postoperative epidural scar formation might compress the spinal cord in response to movement after LP[21], and this might affect the improvement in the JOA score and the NDI. For patients treated with PDF, on the other hand, we could not compare the recovery rate of JOA score and the NDI between the two groups because most patients were classified as Mild at the final follow-up.

The severity of postoperative EH or scar formation after LP is related to surgical outcomes, including JOA score, NDI, and C2-C7 ROM. Therefore, severe scar formation should be prevented after LP. Although the addition of posterior fusion to LP offers a potential solution, postoperative C2-C7 ROM is lost completely. Moreover, although postoperative immobilization with a collar over the long term is another possibility, it leads to reduction of neck movement and may cause extensive atrophy of the cervical muscles despite LP preserving the cervical posterior muscles. At present, unfortunately, given the current clinical evidence, we are unable to recommend a specific method for the prevention of severe scar formation after LP.

The new grading system of the mass posterior to the dural sac after posterior spine surgery has the following advantages: 1) it is relatively easy to implement and 2) MRI is less invasive. Because this grading system uses the dorsal dural sac space, grading is not affected by signal changes from the hematoma on MRI by hemosiderosis over time. Furthermore, MRI can be urgently undertaken after surgery if the patient presents with symptomatology. However, the biggest limitation of our study was the small number of cases; a larger study is necessary in the future to ascertain the significance and relevance of our findings.

Conclusion

The changes in the distribution pattern of postoperative EH or scar formation were similar between the two surgical methods. When treated with LP, the severity of postoperative scar formation related to surgical outcomes, including the recovery rate of the JOA score, NDI improvements, and postoperative C2-C7 ROM; in contrast, most patients treated with PDF showed mild scar formation at the final follow-up.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Author Contributions: Kazunari Takeuchi wrote and prepared the manuscript, and all of the authors participated in the study design. All authors have read, reviewed, and approved the article.

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