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Effect of Asymptomatic Postoperative Epidural Hematoma on Recovery Rate After Surgery for Myelopathy Caused by Thoracic Ossified Ligamentum Flavum

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ABSTRACT

AIM: To analyze the clinical characteristics of thoracic ossified ligamentum flavum (OLF) and clarify prognostic factors.

MATERIAL and METHODS: We retrospectively collected clinical data from the medical records of 29 patients who underwent decompressive surgery for myelopathy caused by thoracic OLF from 2011 to 2019. Associations between various clinical and radiological factors and surgical outcomes were analyzed.

RESULTS: The mean preoperative and final follow-up modified Japanese Orthopaedic Association scores were 6.7 and 7.9 points, respectively (mean follow-up period, 22.4 months; $p<0.0001$). Univariate analysis revealed that preoperative symptom duration and postoperative epidural hematoma on magnetic resonance imaging (MRI) were significant surgical outcome predictors. The recovery rate was higher in patients without postoperative epidural hematoma (n=16) than in those with postoperative epidural hematoma (n=13; 38.7% ± 28.1% vs. 12.9% ± 24.4% mm; $p=0.01$). Multiple regression analysis showed that postoperative epidural hematoma on MRI was a significant surgical outcome predictor ($p<0.05$).

CONCLUSION: Posterior decompressive laminectomy and resection of OLF can be considered effective. Postoperative epidural hematoma on MRI may be an important surgical outcome predictor.

KEYWORDS: JOA score, Postoperative epidural hematoma, Recovery rate, Thoracic ossified ligamentum flavum

ABBREVIATIONS: CT: Computed tomography, **mJOA:** Modified Japanese Orthopaedic Association, **MRI:** Magnetic resonance images, **OLF:** Ossified ligamentum flavum, **OPLL:** Ossification of the posterior longitudinal ligament

INTRODUCTION

Thoracic myelopathy caused by thoracic ossified ligamentum flavum (OLF) is relatively rare. OLF has increasingly been recognized as a major cause of acquired thoracic spinal canal stenosis. Thoracic OLF has been reported more frequently in East Asian countries, with a prevalence of 3.8% in southern China and a prevalence of 6.2% for men and 4.8% for women in Japan (1,8). OLF is typically diagnosed at its late stages because of its unnoticeable onset and extremely slow progression (19). Surgical treatment is required when symptoms appear because conservative treatment is typically ineffective, although thoracic OLF progression is slow (19).

Spinal cord decompression is the goal of surgical treatment. Posterior decompressive laminectomy is the most common procedure advocated. However, complications occur frequently, and surgical outcomes may be unsatisfactory (15,21,22,24,27). Prolonged presurgical symptoms have been associated with poor prognosis (19). Accordingly, early decompression in the course of OLF-induced thoracic myelopathy is recommended, suggesting the need for relevant prognostic

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factors. The present retrospective study aimed to analyze clinical outcomes following surgery for myelopathy caused by thoracic OLF and to determine relevant prognostic factors.

MATERIAL and METHODS

This retrospective study reviewed the records of consecutive patients who underwent surgical decompression for myelopathy caused by thoracic OLF at Kameda Medical Center, Kamogawa, Chiba, Japan, between April 2011 and June 2019. The diagnosis of myelopathy was based on clinical symptoms and signs. OLF was diagnosed based on preoperative imaging studies, including plain radiography, computed tomography (CT), and magnetic resonance imaging (MRI) (Figure 1A-G). Of the patients, 52 were eligible for inclusion. We excluded patients who underwent another spine operation (e.g., cervical or lumbar surgery) after surgery for thoracic OLF and those later diagnosed with a neurological disorder other than thoracic myelopathy (e.g., amyotrophic lateral sclerosis). Moreover, patients with incomplete medical records and those lost to follow-up were excluded. Finally, 29 patients were included for analysis. Approval was obtained from the institutional review board of Kameda Medical Center (No. 20-048).

Preoperative comorbidities (e.g., diabetes mellitus and hypertension) and MRI and CT findings were recorded. The presence or absence of intramedullary high-signal intensity on T2-weighted MRI, as well as the presence or absence of ventral compressive lesions and vacuum phenomenon on CT, were particularly observed (Figures 1A-G; 2A-D).

All patients underwent posterior decompressive laminectomy. Decompressive laminectomy consisted of removal of the laminae and OLF. Facet joints were preserved as much as possible to prevent the worsening of instability. A floating fragment of the adherent ligament was left behind to avoid unintentional dural tear and cerebrospinal fluid leakage in cases with OLF adhesion to the dura mater. An epidural drainage tube was placed to prevent epidural hematoma and removed after 2 days in cases without cerebrospinal fluid leakage by dural tear. Only posterior decompression was performed and not discectomy in cases with accompanied disc herniation. Spinal fusion with internal instrumentation in patients with focal kyphosis due to vertebral compression fracture or those with ossification of the posterior longitudinal ligament (OPLL) was considered to prevent neurologic deterioration caused by kyphosis progression. Two patients underwent posterior segmental instrumented fusion in addition to decompressive laminectomy. Of these, one patient had a history of a vertebral compression fracture at T12 and OLF at T11–12. The other patient had a thoracic OPLL at the OLF level (T9–10). Furthermore, one patient with combined symptomatic lesions simultaneously underwent lumbar laminectomy for lumbar canal stenosis.

Patients routinely underwent MRI of the thoracic spine on postoperative day 7. Particular attention was focused on the presence of postoperative epidural hematoma, defined as an abnormal epidural signal change causing obliteration of the epidural space with spinal cord compression.

Surgical outcomes were assessed using a modified Japanese Orthopaedic Association (mJOA) scoring system and the

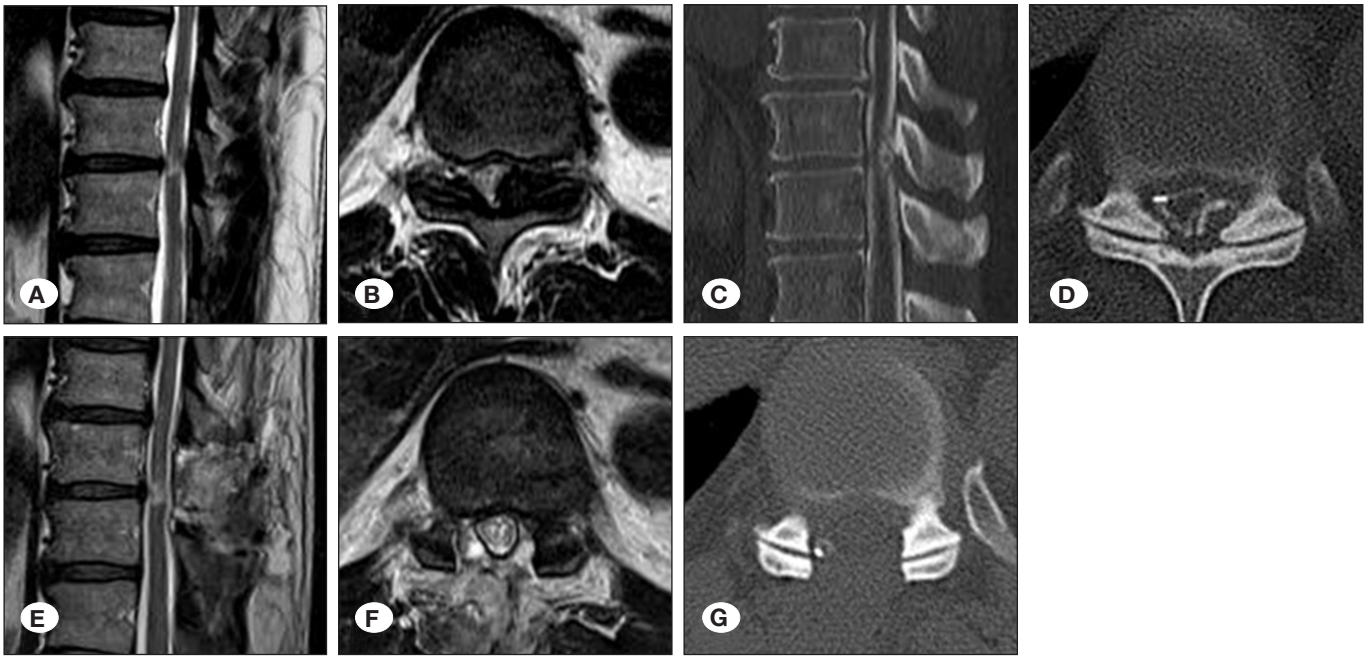

Figure 1: Representative radiographic findings. Preoperative T2-weighted magnetic resonance imaging (MRI) shows spinal cord compression and intramedullary signal change (**A and B**). Preoperative computed tomography (CT) myelography shows ossified ligamentum flavum (**C and D**). Postoperative MRI shows the decompression and absence of epidural hematoma (**E and F**). Postoperative CT shows the resection of the ossified lesion and limited destruction of the facet (**G**).

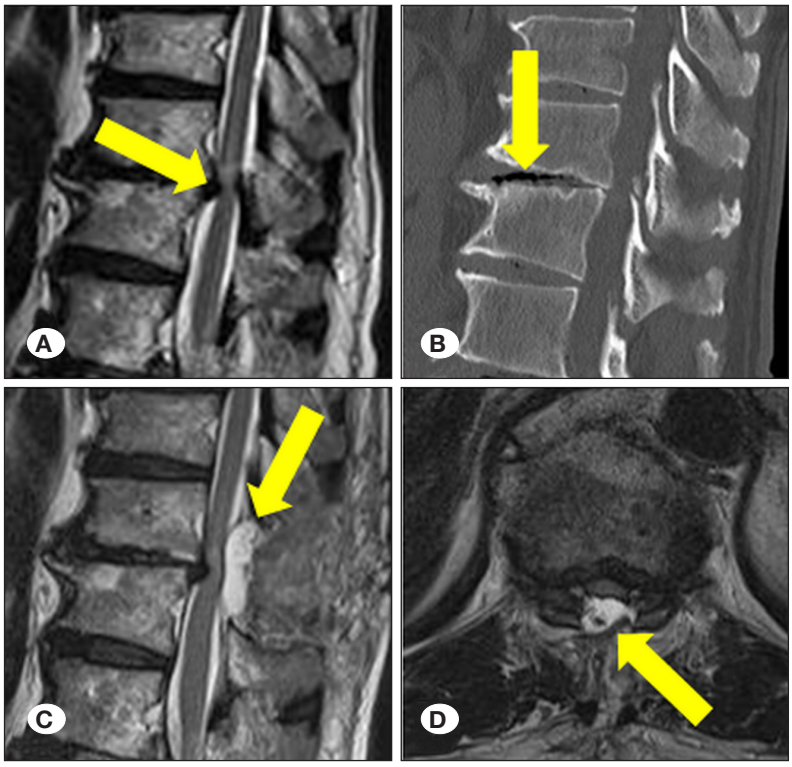

Figure 2: Radiographic findings of the ventral compressive lesion, vacuum phenomenon and postoperative epidural mass. Preoperative T2-weighted magnetic resonance imaging (MRI) shows ventral compressive lesion (yellow arrow) **(A)**. Preoperative computed tomography (CT) shows the vacuum phenomenon (yellow arrow) **(B)**. MRI shows a postoperative epidural mass (yellow arrow) that is an abnormal epidural signal change causing obliteration of the epidural space with spinal cord compression **(C and D)**.

Hirabayashi recovery rate (9,14). Table I shows the mJOA scale. The Hirabayashi recovery rate (in percentage) was calculated as follows: (final follow-up mJOA score – preoperative mJOA score)/(11 – preoperative mJOA score) × 100.

Statistical analysis was performed using R statistical software. Results were reported as means ± standard deviation. The student's t-test evaluated differences between preoperative and final follow-up mJOA scores. The Mann–Whitney U test or Fisher's exact test was used, as appropriate, to evaluate differences in various factors between patients grouped according to the presence of a postoperative epidural hematoma. A p value of <0.05 was considered significant.

RESULTS

Table II presents the clinical data, including the follow-up period, preoperative and final follow-up mJOA scores, recovery rate, and complications. The study group comprised 19 men and 10 women with a mean age of 70.0 (range, 54–86) years. T10–11 was the most commonly affected level, with involvement observed in 17 (58.6%) patients (Figure 3). The mean final follow-up mJOA score was significantly higher than the preoperative score (7.9 ± 1.5 vs. 6.7 ± 1.7 points; p=0.007). The mean recovery rate was 27.2% (range, –28.6%–100%). No patient developed a wound infection that required surgical debridement. No patient required reoperation, including evacuation surgery due to postoperative neurologic deterioration. The recovery rate at discharge (mean number of days, 17.4) of all patients was 22.1% ± 18.1% (range, 0%–66.7%). Although the rate improved in both patients at

Table I: Japanese Orthopaedic Association Score Modified to Exclude the Sections Regaring Upper Extremity Function

Neurological status	Score (points)
Motor dysfunction of lower limbs	
Unabel to walk	0
Able to walk on flat foor with walking aid	1
Able to walk up and down stairs with handrail	2
Lack of stability and smooth reciprocation of gait	3
Normal	4
Sensory deficit in lower limbs	
Severe sensory loss or pain	0
Mild sensory loss	1
Normal	2
Sensory deficit in trunk	
Severe sensory loss or pain	0
Mild sensory loss	1
Normal	2
Sphincter dysfunction	
Unable to void	0
Marked difficulty in micturition	1
Mild difficulty in micturition	2
Normal	3

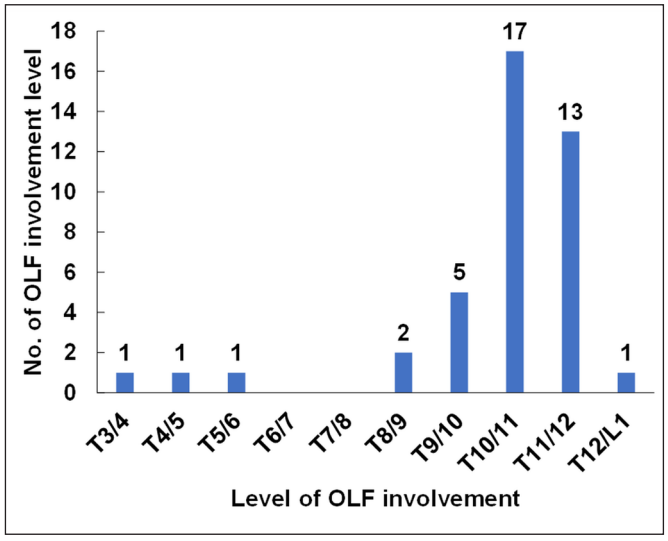

Figure 3: Distribution of involved levels in thoracic ossified ligamentum flavum.

Table II: Summary of Demographic Data and Perioperative Parameters

Variable	Value
Age, years, mean ± s.d. (range)	70.0 ± 8.9 (54–86)
Sex (men/women)	19/10
Symptom duration, months, mean ± s.d. (range)	22.2 ± 30.3 (1–120)
Hospitalization, days, mean±s.d. (range)	17.3 ± 9.6 (8–50)
Follow-up period, months, mean ± s.d. (range)	22.4 ± 18.1 (6–60)
Single level invovement, number (%)	21 (72.4)
Fixation, number (%)	2 (6.9)
Preoperative intramedullary high singal intensity, number (%)	19 (65.5)
Preoperative mJOA	6.7 ± 1.7 (2.5–10)
Final follow-up mJOA	7.9 ± 1.5 (4–11)
JOA recovery rate (%)	27.2 ± 29.1 (-28.6–100)
Dural tear, number (%)	2 (6.9)
Operation time, min	121.3 ± 64.4 (60–406)
Blood loss during operation, mL	46.0 ± 59.3 (10–320)
Postoperative hematoma on MRI, number (%)	13 (44.8)

discharge, the recovery rate at the final follow-up worsened in two patients. The reason for neurological worsening was unclear. No patient developed thoracic kyphosis or slip or experienced failure of internal fixation throughout the follow-up period.

Univariate analysis showed that age, sex, diabetes mellitus, OLF levels, ventral compressive lesion at the OLF level, preoperative intravertebral vacuum phenomenon at the OLF level, preoperative mJOA score, operation time, blood loss during surgery, and preoperative intramedullary high-signal intensity on MRI were not significantly associated with the surgical outcome (Table III). The recovery rate at final follow-up was significantly associated with preoperative symptom duration and postoperative epidural hematoma on MRI ($p<0.05$). Multiple regression analysis showed that postoperative epidural hematoma on MRI significantly predicted the surgical outcome ($p<0.05$; Table IV). Furthermore, the patients were divided into two groups according to the presence of hematoma (Table V). Age, sex, hypertension, diabetes mellitus, alcohol consumption, smoking, anticoagulant and/or antiplatelet medication use, operation time, blood loss during surgery, and OLF levels did not differ significantly between the groups.

DISCUSSION

Thoracic OLF is rare and usually asymptomatic. The disease insidiously progresses over a long period and can eventually cause myelopathy. The OLF prevalence was higher in men than in women, consistent with previous studies (15,20). This may be attributable to heavier physical activity in men, which causes greater stress on the ligamentum flavum. The lower thoracic levels (T10–12) are the most frequently affected segments according to the previous reports, whereas the middle thoracic levels (T5–8) are rarely affected (3,12). The current study found similar results.

Surgery is the sole treatment that can adequately address the compression of neurologic structures caused by OLF (21). The most commonly used therapeutic approach involves posterior laminectomy and OLF removal. The lamina fenestration technique that creates a keyhole in the lamina and preserves the lower lamina, facet joint, and ligamentum flavum, has been reported as an alternative minimally invasive surgical option for treating thoracic OLF (7). All patients in the current study underwent posterior decompressive laminectomy. The use of spinal fusion in patients with myelopathic thoracic OLF remains controversial. Kyphotic spinal deformity following thoracic laminectomy may cause neurologic deterioration (15). Spinal fusion with internal instrumentation was performed in two (6.9%) patients with OLF at the thoracolumbar junction in the current study to minimize the risk of kyphotic deformity. Fusion surgery with instrumentation may be appropriate for patients with severe OLF and preoperative myelopathy (4). The need for spinal fusion should be evaluated in further comparative studies.

Several studies have reported numerous factors that may affect the surgical outcome, including preoperative neurologic status, age, preoperative symptom duration, dura mater

Table III: Univariate Analysis of Mean Postoperative Recovery Rate Stratified According to Various Factors

Factors	Classification	No.	Mean±s.d.	t	p
Age, years, mean (range)	<70	14	30.9 ± 33.7	0.67	0.51
	>=70	15	23.6 ± 34.8		
Sex	Men	19	21.2 ± 27.1	-0.79	0.44
	Women	10	30.3 ± 30.4		
Diabetes mellitus	Yes	7	16.2 ± 28.1	-1.15	0.26
	No	22	30.6 ± 29.2		
Preoperative duration of symptoms, months	<7	13	40.2 ± 29.2	2.34	0.03
	>=7	16	16.5 ± 25.2		
Number of OLF levels	1	21	28.7 ± 32.3	0.47	0.64
	>=2	8	23.0 ± 19.5		
Ventral compressive lesion	Yes	18	24.7 ± 28.3	-0.58	0.57
	No	11	31.2 ± 31.4		
Preoperative intravertebral vacuum phenomenan	Yes	15	25.0 ± 28.8	0.41	0.69
	No	14	29.5 ± 30.4		
Preoperative intramedullary high signal intensity	Yes	19	32.5 ± 32.6	1.39	0.18
	No	10	16.9 ± 18.4		
Preoperative mJOA score	<=6	12	29.5 ± 23.8	0.35	0.73
	>6	17	25.5 ± 33.0		
Operation time	<120	17	23.6 ± 29.1	-0.77	0.45
	>=120	12	32.1 ± 29.8		
Blood loss during operatioin	<50	19	26.3 ± 27.9	-0.22	0.83
	>=50	10	28.8 ± 32.9		
Postoperative hematoma on MRI	Yes	13	12.9 ± 24.4	2.61	0.01
	No	16	38.7 ± 28.1		

Statistical significant difference between the 2 groups by Student's t-test.

Table IV: Multiple Regression Analysis of Significant Univariate Variables

Risk factors	Parameter estimate	Standard error	t	p
Symptom duration, months	-0.238	0.16	-1.47	0.15
Postoperative hematoma on MRI	-26.6	9.71	-2.74	**0.0**1

Statistical significant difference between the 2 groups by multiple linear regression (n=29).

ossification, presence of ossified anterior longitudinal ligament, OLF level and type, number of affected levels, impaired joint position sense in the great toe, intramedullary signal change on T2-weighted MRI, and Modic changes (10,11,15,25,26). The current study confirmed that preoperative symptom duration was a significant mJOA score recovery rate predictor based on univariate analysis findings. Similarly, some previous studies have reported that preoperative symptom duration significantly correlates with the surgical outcome (3,26). Therefore, chronic spinal cord compression may lead to irreversible damage due to demyelination and gray matter necrosis (26). Surgical intervention should be performed at the earliest to achieve the best results.

Table V: Patient Factors Stratified according to Presence of Postoperative Hematoma on MRI

Factors	Hematoma (+)	Hematoma (-)	p
Number of patients	13	16	
Age (year)	69.3 ± 9.2	70.6 ± 8.8	0.63
Sex (men/woman)	9/4	10/6	1.000
Hypertension	6 (46.2)	9 (56.3)	0.72
Diabetes mellitus	3 (23.1)	4 (25.0)	1.000
Alcohol	3 (23.1)	4 (25.0)	1.000
Smoking	5 (38.5)	4 (25.0)	0.69
Anti-coagulant and/or anti-platelet medications	3 (23.1)	4 (25.0)	1.000
Operation time	133.8 ± 92.6	111.3 ± 25.3	0.840
Blood loss during surgery	59.6 ± 84.0	35 ± 25.1	0.69
Number of OLF levels, 1 level	10 (76.9)	11 (68.8)	0.70

Statistical significant difference between the 2 groups by Mann–Whitney U-test or Fisher's exact test.

In the current multiple linear regression analyses, a postoperative epidural hematoma on MRI, defined as abnormal epidural signal change causing epidural space obliteration with spinal cord compression, was the most important recovery rate predictor. No patients required evacuation surgery for postoperative neurologic deterioration (e.g., new-onset paresis, intractable pain, or urinary dysfunction). The recovery rate at discharge (mean number of days, 17.4) for patients with and without epidural hematoma was 13.7% ± 14.0% (range, 0%–45.5%) and 28.8% ± 18.7% (range, 0%–66.7%), respectively ($P < 0.02$). Postoperative epidural hematoma is a complication that can cause symptomatic spinal cord compression and requires evacuation surgery. To our knowledge, this is the first study to demonstrate postoperative epidural hematoma on MRI as a significant surgical outcome predictor of myelopathy caused by thoracic OLF. Previous studies have typically focused on symptomatic postoperative hematoma requiring reoperation (24), which is relatively rare and has a reported overall incidence of approximately 0.4% (5,6,24). Some reports have mentioned that symptomatic postoperative hematoma was more frequent following thoracic spine surgery than following cervical or lumbar surgery, possibly because of the associated spinal kyphotic alignment and spinal blood flow (5,17,18). Anno et al. reported that the space between the paravertebral muscles and the spinal cord in the thoracic spine is narrower than that in the cervical and lumbar spine, exhibiting lordotic alignment (5). Paravertebral muscle edema following surgery may further narrow this space and lead to the easily compressible spinal cord and hematoma formation in the thoracic spine. Moreover, the thoracic spinal cord reportedly has less blood flow than that in the cervical and lumbosacral levels (17). Hematoma in the thoracic spine has a higher likelihood of a neurologic deficit, because of this ischemic environment. A postoperative epidural hematoma on MRI did not require evacuation for postoperative neurologic deterioration (e.g., new-onset paresis, intractable pain, or urinary dysfunction). However, it was the most important recovery rate predictor. The findings of the current study suggest that postoperative epidural hematoma on MRI cause inadequate decompression, exhibiting similar results in patients with prolonged symptoms and inhibiting neurologic recovery despite the absence of apparent neurologic deterioration. This finding highlighted that further careful hemostasis during surgery is recommended. The question was whether evacuation of postoperative epidural hematoma on MRI would hasten patient improvement. In the current study, the rate of postoperative epidural hematoma on MRI was high (44.8%; Table II). Therefore, performing evacuation on all those patients was not feasible. However, several sensory changes in those patients can be present, which may be observed in the more accustomed dorsal epidural area. In some cases, evacuation can be considered after careful confirmation of the neurologic findings of patients.

The factors for bleeding were examined to categorize the patients into two groups according to the presence of hematoma (Table V). However, there were no significant differences between the groups with respect to age, sex, hypertension, diabetes mellitus, alcohol consumption, smoking, anticoagulant and/or antiplatelet medication use, operation time, blood loss during surgery, and OLF levels.

In the presence of ventral compressive lesions and preoperative intravertebral vacuum phenomenon at OLF level, laminectomy alone may worsen the neurologic function after surgery because of the worsening ventral compression of the spinal cord caused by spinal instability (2,13). Some authors have recommended laminectomy with fusion in OLF treatment to prevent further instability and late-onset thoracic kyphotic deformity (3,15). In the current study, preoperative ventral compressive lesions and intravertebral vacuum phenomenon were not significantly associated with the surgical outcome. The lack of worsened outcomes following ventral compressive lesions and preoperative intravertebral vacuum phenomenon on CT may be attributed to the absence of patients who

developed thoracic kyphosis throughout the follow-up period. Adequate spinal cord decompression, careful resection of the ossified lesion and limited destruction of the facet joints can preserve segmental stability and prevent late-onset neurologic deterioration (16, 23). The follow-up period may have been insufficient. Moreover, the small number of patients included in this study possibly preserved the identification of significant results.

Furthermore, the current study observed that age, sex, diabetes mellitus, levels involved, preoperative mJOA score, and preoperative intramedullary high-signal intensity on T2-weighted MRI were not significantly associated with surgical outcome. Whether these factors predict a surgical outcome is uncertain, considering that the current findings are inconsistent with previous studies. It remains to be elucidated whether these factors are truly unrelated to surgical outcomes. Statistical significance was possibly not reached in the current study because of the small number of patients.

The current study was limited by its retrospective single-center design and small sample size. In addition, only 29 of the 52 eligible patients were included in the analysis. Moreover, the current findings require validation via future large-scale investigations.

CONCLUSION

Surgical treatment for thoracic myelopathy caused by thoracic OLF is effective. A postoperative epidural hematoma on MRI may be an important surgical outcome predictor. It may inhibit neurological recovery, although it does not induce symptom aggravation.

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DATA STATEMENT

The data in this paper is available to access.

AUTHORSHIP CONTRIBUTION

Study conception and design: IM, MK, MY

Data collection: IM

Analysis and interpretation of results: IM

Draft manuscript preparation: IM

Critical revision of the article: MK, TK, MY

Other (study supervision, fundings, materials, etc...): MK, TK, MY

All authors (IM, MK, TK, MY) reviewed the results and approved the final version of the manuscript.

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