Clinical analysis of thoracic ossified ligamentum flavum without ventral compressive lesion

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Abstract The aim of this study was to analyze the clinical characteristics of thoracic ossified ligamentum flavum (OLF) and to elucidate prognostic factors as well as effective surgical treatment modality. The authors analyzed 106 thoracic OLF cases retrospectively from January 1999 to December 2008. The operative ($n = 40$) and the non-operative group ($n = 66$) were diagnosed by magnetic resonance imaging (MRI) and/or computed tomography

(CT) imaging. We excluded cases exhibiting ventral compressive lesions causing subarachnoid space effacement in thoracic vertebrae as well as those with a coexisting cervical compressive myelopathy. Those in the operative group were treated with decompressive laminectomy as well as resection of OLF. The preoperative neurologic status and postoperative outcomes of patients, as indicated by their modified Japanese Orthopedic Association (mJOA) scores and recovery rate (RR), Modic changes, the axial (fused or non-fused) and sagittal (omega or beak) configurations of OLF, and the ratios of the cross-sectional area (CSA) and anteroposterior diameter (APD) of the most compressed level were studied. The most commonly affected segment was the T10–11 vertebral body level ($n = 49$, 27.1%) and the least affected segment was the T7–8 level ($n = 1$, 0.6%). The ratios of the CSA in non-fused and fused types were 77.3 and 59.3% ($p < 0.001$). When Modic changes were present with OLF, initial mJOA score was found to be significantly lower than those without Modic change (7.62 vs. 9.09, $p = 0.033$). Neurological status improved after decompressive laminectomy without fusion (preoperative vs. last mJOA; 7.1 ± 2.01 vs. 8.57 ± 1.91 , $p < 0.001$). However, one patient exhibited transient deterioration of her neurological status after surgery. In the axial configuration, fused-type OLF revealed a significant risk for a decreased postoperative mJOA score (0–7, severe and moderate) (Odds ratio: 5.54, $\chi^2 = 4.41$, $p = 0.036$, 95% CI: 1.014–30.256). The results indicated that the new categorization of axial-type of OLF is a helpful predictor of postoperative patient outcome and fused type was related with poor prognosis. In OLF cases free from ventral lesions compressing the spinal cord, decompressive laminectomy is enough for successful surgical outcome. Therefore, early surgical treatment will be considered in cases with fused-type OLF compressing

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spinal cord even though they do not have myelopathic symptoms.

Keywords Thoracic · Ossified ligamentum flavum · Compressive myelopathy · Axial type · Laminectomy

Introduction

Since its first description by Polgär [1], ossified ligamentum flavum (OLF) has often been reported in the literature, as a cause of an insidious and long-lasting myeloradiculopathy of the thoracic spinal cord [2–4]. Although the number of reported cases of OLF has increased and much of its pathophysiology determined, the pathogenetic mechanism and natural history still remain poorly understood because almost all the literature have been based on surgical series. Moreover, whole spine magnetic resonance imaging (MRI) or computed tomography (CT) often reveals incidental lesions of OLF or tandem ossified lesions in association with OLF [5, 6]. It is also known that thoracic OLFs were accompanied with degenerative changes frequently [7]. However, the impact of these lesions on pathophysiology of the thoracic OLF remains unclear. In the present study, the authors analyzed 106 cases of thoracic OLF including operative and non-operative cases in an effort to evaluate the clinical characteristics, prognostic factor, and effective surgical management of OLF.

Materials and methods

From January 1999 to December 2008, 106 patients having thoracic OLF at two institutes (Seoul National University Hospital and Seoul National University Bundang Hospital) were included. A retrospective review of consecutive series was conducted following approval from the IRB. Radiologic data were reviewed by three musculoskeletal radiologists with more than 10 years of experience. The patients were divided into the operative group ($n = 40$) and the non-operative group ($n = 66$), all of whom had been diagnosed as thoracic OLF by MRI and/or CT imaging. We excluded those cases of thoracic OLF occurring with concurrent ventral compressive lesion, such as the ossification of posterior longitudinal ligament (OPLL) at the same level or cervical compressive myelopathy such as OPLL or cervical spondylosis with the intention of evaluating the effect of the thoracic OLF purely.

Of the total 106, there were 51 men and 55 women, ranging in age from 35 to 87 years (mean age, 61.2 years). The duration of symptoms was varying from 1 week to 10 years (mean 10.5 months) prior to visiting the hospital. In every case, neurological assessment was conducted

using a modified Japanese Orthopedic Association (mJOA) scoring system (Table 1). The severity of mJOA scores was ranked as mild (8–11), moderate (4–7), and severe (0–3). In the non-operative group, neurological status was determined in outpatient clinic setting. In the operative group, it was determined before and after surgery, as well as at the final visit. Postoperative neurological recovery was estimated on the basis of the recovery rate (RR) = (postoperative – preoperative mJOA score)/(11–preoperative mJOA score) $\times$ 100%. A score of 75–100% was designated as excellent, 50–74% good, 25–49% fair, and 0–24% poor [5]. The demographic data of the patients are listed in Table 2.

We measured the location, number of affected segments, configurations of OLF in axial (fused vs. non-fused) and sagittal (beak or omega) plain, the existence of Modic change [6], and disc degeneration (i.e., signal loss in corresponding intervertebral disc without ventral subarachnoid space effacement in sagittal T2 weighted images) in the area of maximal compression.

A cross-sectional area (CSA) of the spinal canal measured by Prasad's method [7] (Fig. 1). The APD (anteroposterior diameter) and CSA were measured at the most compressed level and one level above and below it. The authors chose representative affected level at the most compressed level. The ratio of APD was calculated using the following ratio of APD = APD of affected segment/

Table 1 A modified Japanese Orthopedic Association (mJOA) scoring system for the assessment of thoracic myelopathy

Neurological status	Score
Lower-limb motor dysfunction	
Unable to walk	0
Able to walk on flat floor w/walking aid	1
Able to walk up/downstairs w/handrail	2
Lack of stability and smooth reciprocation of gait	3
No dysfunction	4
Lower-limb sensory deficit	
Severe sensory loss or pain	0
Mild sensory deficit	1
No deficit	2
Trunk sensory deficit	
Severe sensory loss or pain	0
Mild sensory deficit	1
No deficit	2
Sphincter dysfunction	
Unable to void	0
Marked difficulty in micturition	1
Minor difficulty in micturition	2
No dysfunction	3
Total	11

Table 2 Demographic data of 106 patients with ossified ligamentum flavum (OLF)

Variables	Mean $\pm$ SD (range)		<i>p</i> value
	Operative group	Non-operative group	
Age	57.08 (37–75)	63.73 (35–87)	0.002
Sex			0.009
Male	26	25	
Female	14	41	
Preop mJOA	7.1 $\pm$ 2.01	10 $\pm$ 1.79	<0.001
Final mJOA	8.58 $\pm$ 1.91	NA	
Symptom duration (month)	28.76 (1 week–10 years)	NA	
Follow up duration (month)	17.3 (1–69)	NA	
Cord signal change on T2WI			<0.001
No	15	64	
Yes	25	2	
Myelopathy			<0.001
No	2	65	
Yes	38	1	
Configuration			
Sagittal			0.01
Beak	27	27	
Omega	13	39	
Axial			0.003
Fused	18	11	
Non-fused	22	55	
Coexistence			
DDD			0.524
No	26	46	
Yes	14	20	
Modic change			0.072
No	32	61	
Yes	8	5	
Outcome (by RR)			
Poor	10	(0 $\leq$ RR < 25%)	NA
Fair	10	(25 $\leq$ RR < 50%)	NA
Good	12	(50 $\leq$ RR < 75%)	NA
Excellent	8	(75 $\leq$ RR $\leq$ 100%)	NA

DDD Degenerative disc disease,
mJOA modified Japanese
Orthopedic Association, RR
Recovery rate, NA Not available

average of APD just above and below affected segment $\times$ 100%. The ratio of CSA was calculated in the same way (Fig. 1). In those with multiple segmental involvement, the maximal compressed level served as a representative segment for the radiological measurements. The configuration of OLF was classified into omega and beak type in the sagittal plane as mentioned previously [8]; and we added a new categorization of fused and non-fused types in the axial plane according to the presence or absence of bridging bone between both sides of OLF (Fig. 2).

Surgical indications were progressive thoracic myelopathy and dorsal pain. We performed total laminectomy and resection of the OLF. The dura beneath the OLF was also

removed and duroplasty was mandated, when it was adhered to OLF. But the lateral fusion or decompressive laminoplasty was not performed.

Statistical analysis

Continuous variables were described as means and standard deviations or ranges, and categorical variables were expressed as percentages. The χ^2 test (or Fisher's exact test if an expected value was less than 5) was used to compare the categorical variables between the groups. A Student's *t* test and one-way ANOVA were used to compare continuous variables. A multinomial logistic regression analysis was performed, using SPSS 12.0 (Apache software

Fig. 1 Diagram of the measurement of the cross-sectional area of segment affected by OLF (a). Demonstration of the calculation of the ratio of the anteroposterior diameter (APD) on the T2-weighted sagittal magnetic resonance image of the thoracic spine (b). Ratio of APD = $C/[A + B]/2 \times 100\%$

foundation, Chicago, IL), to identify parameters that could be used to predict clinical outcomes.

Results

Clinical characteristics

The most common symptom leading to perform MRI was leg pain ($n = 33$, 31.1%) followed by lower extremity weakness ($n = 17$, 16%), axial pain ($n = 15$, 14.2%) and gait disturbance ($n = 15$, 14.2%). The symptoms related to compressive myelopathy were presented in 39 patients (36.8%). Only 41 patients had symptoms attributable by the OLF lesion and 65 cases were regarded as incidental lesions.

The mean initial mJOA score of all patients was 8.91 ± 2.34 (Table 2). In the group of patients with myelopathy, the mJOA scores and ratios of CSA and APD were significantly lower ($p < 0.001$) than those without it. Also, when the intramedullary hyperintense lesion was presented on T2-weighted image (T2WI), this group showed a lower mJOA score and ratios of CSA and APD significantly than that without signal changes on T2WI ($p < 0.001$).

A multinomial logistic regression analysis revealed that the ratio of CSA was the only significant factor influencing a patient's initial status ($p = 0.014$, CI: 0.902–0.989).

Configuration of OLF

There were 67 patients with single level involvement and 39 with multisegmental diseases (2–6 levels). A total of 181 segments were affected with OLF in the 106 cases studied. Of that, 110 (60.8%) were located in the lower thoracic spine (T9–12), 46 (25.6%) in the upper thoracic spine (T1–4), and 17 (9.4%) in the mid-thoracic spine

Fig. 2 New categorization of the axial configuration of OLF by non-fused type (a, b) and fused type (c, d) and the categorization originally appeared in Kuh et al. [8] of the sagittal configuration of OLF by beak type (e) and omega type (f) are shown

(T5–8). The most commonly affected segment was the T10–11 vertebral body level, as demonstrated in 49 cases. The least affected segment was the T7–8 level, with only a single case (Fig. 3).

Among the affected segments, we focused on the most compressive OLF segment. The mean APD of a normal thoracic canal was 14.2 mm (10.7–19.2), and the mean CSA of a normal thoracic canal was 173 mm² (117–287). Alternatively, the mean APD of the most compressive segment was 10.3 mm (2.8–16.4), and the mean CSA of the most compressive segment was 104 mm² (28–212). For the most compressive one, the mean ratio of APD and CSA were 72.38 and 60.07%, respectively.

In the axial configuration, there were 77 non-fused types and 29 fused types. In the sagittal configuration, there were

Fig. 3 Distribution of OLF in the thoracic spines of 106 patients (a) and the multiplicity of OLF involvement in every case (b)

54 beak types and 52 omega types. The average ratio of the CSA of the non-fused and fused types were 77.3 and 59.3% ($p < 0.001$). The average ratio of the CSA of beak- and omega-types were 55.9 and 64.4% ($p = 0.011$).

A Modic change was presented in 13 cases. In addition, disc degeneration without the effacement of the ventral CSF space in the sagittal plane was found at the affected segment in 35 cases. In cases where Modic changes coexisted with OLF, their initial mJOA scores were significantly lower than in those free from Modic change (7.62 vs. 9.09, $p = 0.033$).

The associated skeletal abnormalities were diffuse idiopathic skeletal hyperostosis (DISH) in six patients and block vertebrae on the next level of the OLFs in 3.

Surgical outcome

Forty patients underwent decompressive laminectomy. With respect to the operative and non-operative groups, there were significant differences in age (57.08 vs. 63.73, $p = 0.001$), preoperative mJOA scores (7.1 vs. 10.0, $p < 0.001$), ratios of CSA (47.02 vs. 67.98%, $p < 0.001$), and APD ratios (62.74 vs. 78.22%, $p < 0.001$).

In general, patient neurological status had improved at final follow-up from a pre-operative mean mJOA score of 7.1 ± 2.01 to 8.57 ± 1.91 points ($p < 0.001$); however, one patient exhibited transient deterioration of her neurological status after surgery.

The RR of neurological function ranged from 0 to 100% (mean $\pm$ SD; $47.5 \pm 31.5\%$). Further, surgical outcomes

were excellent in 8 (20%) patients, good in 12 (30%), fair in 10 (25%), and poor in 10 (25%). It was found that as the ratio of CSA increased, the postoperative mJOA scores also increased. Following from this, there was no significant difference in the ratio of CSA among excellent, good, fair, and poor group (one-way ANOVA, $F = 1.058$, $p = 0.379$).

Dural tearing was noticed in six patients from the operative group, all of which were repaired. However, other complications were not observed. An additional operation was performed in two cases because the tandem thoracic asymptomatic OLF had progressed and become symptomatic.

The multinomial logistic regression analysis revealed that a worsening in a patient's outcome (0–7, severe and moderate), represented by postoperative mJOA scores, was significantly correlated only with the axial configuration of OLF ($p = 0.027$, CI: 0.000–0.555) (Table 3). In the axial configuration, the fused-type OLF revealed a significant risk of achieving a worse outcome (Odds ratio: 5.54, $\chi^2 = 4.41$, $p = 0.036$, 95% CI: 1.014–30.256).

Discussion

OLF of the spine progresses insidiously over a long period of time and can eventually cause myeloradiculopathy and pain [2–4, 9]. More than 30 reports have been described for a minimum of 10 OLF cases. Because of its rarity, unknown pathogenesis and insufficient epidemiological

Table 3 Factors associated with postoperative mJOA scores in patients by means of multinominal logistic regression analysis

Risk factors	Relative risk (Worse outcome: postoperative mJOA < 8)	<i>p</i> value	95% CI
Longer duration of symptom	1.028	0.241	0.982–1.077
Increased ratio of CSA	0.891	0.065	0.788–1.007
Increased ratio of APD	0.965	0.471	0.875–1.064
Presenting myelopathy	13.699	0.088	0.676–250
Presenting cord signal change on T2WI	5.762	0.307	0.2–165.621
Presenting Modic change	9.615	0.164	0.398–250
Presenting Fused type	166.667	0.027	1.802–1000000

CSA Cross sectional area,
APD Anteroposterior diameter,
significant *p* value <0.05

data [10, 11], most reports focus on surgical treatment and its symptomatic characteristics. The current study is the largest scale report regarding thoracic OLF without ventral compressive lesions [12, 13]. As the number of asymptomatic cases recognized by MRI and/or CT increases, we would be able to focus on the natural history and characteristics of OLF including non-operative cases.

Within the vertebral column, OLF was found frequently in thoracic vertebra. In the literature, the lower thoracic spine is the most frequently affected segment while the mid-thoracic vertebrae (T5–8) are rarely affected within the thoracic spine [3, 14–17]. This propensity was also seen in the non-operative OLF cases. It has been reported that the location of OLF is less vulnerable in mobile segments such as the cervical and lumbar vertebra than in the thoracic vertebrae [3, 14–18]. This phenomenon gives us insight about pathogenetic mechanism of OLF. As the range of motion is more restricted in thoracic spine than cervical or lumbar one, the length of elastic fibers in ligamentum flavum is kept in a narrow range during dynamic motion and calcification may occur more frequently in this stable environment. The second consideration is spinal curvature. The kyphosis in thoracic spine in contrary to lordosis in cervical or lumbar ones may be thought to be another contributing factor. However, this concept cannot explain relatively less prevalence of mid-thoracic spine which has maximal kyphotic angle. In fact, OLF occurs more frequently in upper or lower thoracic spine as shown in our series. As these regions are transitional areas in spinal curvature (i.e., kyphosis to lordosis), the elastic fibers in ligamentum flavum may be relaxed and thickened relatively. In addition to the anatomical difference relating to mechanical stress involving constraints on the articular processes during segmental motion, this difference may also be attributed to increased instability in lower thoracic spine [18–21]. Lower thoracic vertebrae seem to be particularly easy to make degenerative processes due to the high tensile force present on the posterior column [12, 18]. Maigne et al. [18] reported that OLF occurred most frequently at the lower thoracic spine especially thoracolumbar junction and its appearance correlated with a

unique orientation of the facet joints that generated increased rotatory instability and micromotion [18]. In this study, there were three cases of OLF at adjacent levels of segmentation failure. Therefore, we can postulate biomechanical factors related with pathogenesis of OLF are (1) limited range of motion, (2) transitional area of spinal curvature, and (3) mechanical stress of the facet joint and ligamentum flavum.

The CSA ratios of affected segments are strongly correlated with preoperative patient status as indicated by the mJOA scores, myelopathy, and high signal change in T2WI of the spinal cord; however, this ratio did not demonstrate any significant correlation with postoperative outcomes. Some reports have shown correlations between preoperative mJOA scores or the duration of a preoperative symptom with postoperative outcomes [10]. In many studies, the classification for configuration of OLF failed to show any significance as a prognostic factor [8, 10, 14, 15, 22, 23]. In our series, the classification of axial configuration into fused or non-fused types demonstrated a significant correlation to patient outcome. According to this new classification which make it possible to anticipate a patient's postoperative outcome, we recommend that surgical treatment should be considered in patients with fused type OLF compressing the spinal cord even if they do not have a definite symptom of myelopathy because poor outcome would be expected in delayed surgery when an overt symptom of myelopathy has occurred.

As in other series, the operative group indicated significant improvement and non-operative treatment for symptomatic patients is not effective [15, 16, 24]. Surgery is the sole treatment that can adequately address the compression of neurologic structures caused by OLF [15, 24, 25].

Cases of OLF coexisting with Modic changes achieved a significantly lesser clinical improvement as compared with those free from Modic changes. Thus, concomitant intervertebral disc degeneration may have negative impact on clinical improvement.

The OLF lesion is far from the anterior gray horn. Moreover, the thoracic spinal cord which is always

subjected to some longitudinal tensile stress is more susceptible to mechanical and neurological damage from anterior impingement than the posterior compression of OLF [9, 26]. Some reports have mentioned that surgical results were not always satisfactory after laminectomy and most authors agree that thoracic OLF should not be approached posteriorly if it exists with tandem ossification or degenerative lesions at the same or adjacent levels [22, 27]. Both OLF and OPLL need to be removed simultaneously in such instances because there have been several reported cases in which paraplegia developed acutely after thoracic laminectomy [10, 28]. Meanwhile, some authors have recommended laminoplasty [16, 27, 29] or laminectomy with lateral fusion [14, 29] in the treatment of OLF because of their increased instability and late-onset thoracic kyphotic deformity which is one of the factors that leads to poor prognosis. However, we performed decompression and resection of the OLF only by decompressive laminectomy, and did not perform posterolateral fusion or laminoplasty. Though transient neurological deterioration was observed in one case, she had recovered eventually and postoperative late neurological deterioration was not found. Based on this, it is possible for surgeons to expect that OLF cases without ventral compressive lesions will achieve good clinical improvement after decompressive laminectomy without fusion.

Conclusion

The OLF is rare but treatable cause of thoracic myelodysplasia by decompressive surgery. We suggest biomechanical factors related with development of OLFs are limited range of motion, transitional area of spinal curvature, and mechanical stress of facet joint and ligamentum flavum including micro-motion based on their predilection in lower thoracic spine. The new classification of axial configuration is a helpful predictor of postoperative outcome and we recommend decompressive laminectomy in patients with fused type OLF compressing the spinal cord even if they do not have a definite symptom of myelopathy, which is a safe and satisfactory treatment of choice for OLF cases without ventral compressive lesions.

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