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Sagittal Progression of Ossification After Posterior Cervical Surgery for Ossification of the Posterior Longitudinal Ligament

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ABSTRACT

Background: Several risk factors have been associated with sagittal progression of ossification of the posterior longitudinal ligament (OPLL), yet there remains no consensus regarding its postoperative behavior. This study investigated the longitudinal changes in OPLL following posterior cervical surgery and aimed to identify factors related to postoperative sagittal progression.

Methods: Twenty-six patients (23 men and 3 women; mean age 62.0 ± 13.1 years) who underwent posterior cervical spine surgery for OPLL and at least 1 year of computed tomography follow-up were retrospectively reviewed. Changes in the ossification index (OP-index), defined as the sum of ossified vertebral and intervertebral levels, were evaluated using serial computed tomography scans. Postoperative sagittal OPLL progression was defined as an OP-index increase ≥1 point over the preoperative OP-index score. Univariate and multivariate logistic regression analyses were conducted to identify associated factors.

Results: Postoperative sagittal OPLL progression was observed in 13 of 26 patients (50%). Progression tended to be more frequent in fusion cases than in nonfusion cases (58.8% vs 33.3%, $P = 0.41$). Multivariate analysis revealed segmental-type OPLL as an independent risk factor for postoperative sagittal progression (OR 17.6, 95% CI 1.14–272). Mean follow-up duration was 35.3 ± 24.8 months. Among the patients who showed postoperative sagittal OPLL progression, the mean time to progression was 26.0 ± 19.0 months. No significant associations were found between OPLL advancement and age, sex, body mass index, nutritional status, number of fused levels, or duration of follow-up. Sagittal OPLL progressed inside the fused segment in 90% of fusion cases.

Conclusion: Postoperative sagittal OPLL progression can occur regardless of fusion surgery, with a potentially higher risk in patients with the segmental type. Long-term postoperative studies are needed to clarify ossification dynamics in OPLL patients.

Clinical Relevance: Postoperative sagittal progression of cervical OPLL may occur regardless of posterior fusion surgery, particularly in patients with segmental-type OPLL.

Level of Evidence: 4.

Cervical Spine

Keywords: ossification of posterior longitudinal ligament, ossification progression, posterior surgery, fusion surgery

INTRODUCTION

Ossification of the posterior longitudinal ligament (OPLL) is a spinal disorder characterized by heterotopic bone formation within the posterior longitudinal ligament, most commonly in the cervical spine. This condition can lead to compression of the spinal cord, resulting in progressive myelopathy. OPLL is particularly prevalent in East Asian populations,[1] and its management remains a significant clinical challenge. Surgical treatment is often required for patients with symptomatic cervical myelopathy due to OPLL. With or without fusion, posterior decompression is widely performed to relieve spinal cord compression. However, postoperative radiological OPLL progression is often observed, which has raised concerns about long-term outcomes.[2] Understanding the behavior of OPLL after surgery is therefore essential for planning appropriate follow-up strategies and reducing the risk of reoperation. Although several studies have proposed risk factors for OPLL progression, including age, the extent of ossification, and morphological subtype, there is currently no consensus. Moreover, the influence of surgical fusion on ossification dynamics after surgery remains controversial, with the clinical implications

of different OPLL subtypes not well established. We hypothesized that posterior fixation did not necessarily suppress postoperative OPLL progression and that the morphological subtype of OPLL might affect postoperative ossification behavior.

The present study examined the radiological sagittal progression of OPLL following posterior cervical spine surgery to search for patient and surgical factors associated with postoperative ossification advancement.

METHODS

Patients who underwent posterior cervical surgery for symptomatic OPLL with postoperative computed tomography (CT) follow-up of at least 12 months were included. Patients with previous cervical surgery, trauma, infection, tumor, or insufficient imaging data were excluded. Ultimately, 26 patients (23 men and 3 women, mean age 62.0 ± 13.1 years) were analyzed. Each surgical procedure was selected by the surgeon. The nonfusion group consisted of patients who underwent laminoplasty without posterior instrumentation. The presence or absence of posterior ligament ossification was evaluated by cervical CT preoperatively and at 6 months, 1 year, 2 years, and at the most recent follow-up for calculations of ossification index (OP-index). In this study, OPLL progression was defined as sagittal (craniocaudal) extension reflected by an increase in OP-index, rather than thickness or volumetric enlargement. The OP-index was defined as the total number of vertebral bodies and intervertebral levels affected by ossification, with intervertebral levels counted only when continuous ossification was present.[3] The interrater reliability of OPLL evaluation by CT was 0.86. We investigated the relationships of pre- and postoperative changes in the OP-index with patient and surgical factors.

The localization of OPLL before and after cervical spine surgery was investigated as well. Patients were grouped based on the presence or absence of sagittal OPLL progression and compared using Fisher's exact test or Welch's *t* test. The primary outcome was postoperative radiological sagittal OPLL progression, defined as an increase in OP-index ≥1 point over the preoperative score. The selection of factors included in the multivariate analysis was performed by stepwise model testing based on Akaike's information criteria. Kaplan–Meier or Cox proportional hazards analyses were not performed due to the small sample size and limited number of progression events. All statistical analyses were conducted using EZR software (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (The Foundation for Statistical Computing, Vienna, Austria). EZR is a modified version of R commander designed to add statistical functions frequently used in biostatistics. The level of significance was set at $P < 0.05$.

This study was approved by the institutional review board of our institution (No. 6696).

RESULTS

Postoperative sagittal OPLL progression occurred in 13 of 26 cases (50%; Table 1; Figure). The average time to ossification extension in patients who experienced ossification extension was 26.0 ± 19.0 months. Among progression patients, preoperative OPLL thickness at the affected level was 4.9 ± 1.5 mm in the fusion group

Table 1. Characteristics and operative and postoperative details of included patients.

Characteristic	Progression Group (*N* = 13)	Nonprogression Group (*N* = 13)	*P*
Gender, men:women	12:1	11:2	>0.99
Age, y	59.8 ± 13.6	64.2 ± 12.7	0.40
BMI	28.3 ± 4.3	27.1 ± 6.4	0.59
GNRI	115.4 ± 11.2	114.9 ± 17.0	0.93
Preoperative OP-index	5.4 ± 3.5	6.1 ± 3.2	0.60
Segmental type	5 (38.4%)	2 (15.3%)	0.37
K-line (−)	5 (38.5%)	5 (38.5%)	>0.99
Comorbidity			
HT	2 (15.3%)	6 (46.1%)	0.20
DM	3 (23.0%)	4 (30.7%)	>0.99
Fusion	10 (76.9%)	7 (53.8%)	0.41
Number of fusion levels (vertebrae)	4.3 ± 2.8	2.8 ± 2.9	0.18
Follow-up period, mo	41.6 ± 28.2	29.0 ± 19.3	0.19
Preoperative JOA score	10.5 ± 2.9	10.9 ± 2.4	0.77
2 y postoperative JOA score	13.5 ± 2.9	15.8 ± 0.75	0.046
JOA score recovery rate (%)	51.3 ± 29.3	76.0 ± 14.4	0.047

Abbreviations: BMI, body mass index; DM, diabetes mellitus; GNRI, geriatric nutritional risk index; HT, hypertension; JOA, Japanese Orthopedic Association; OP-index, ossification index.
Note: Values represent the mean ± SD.

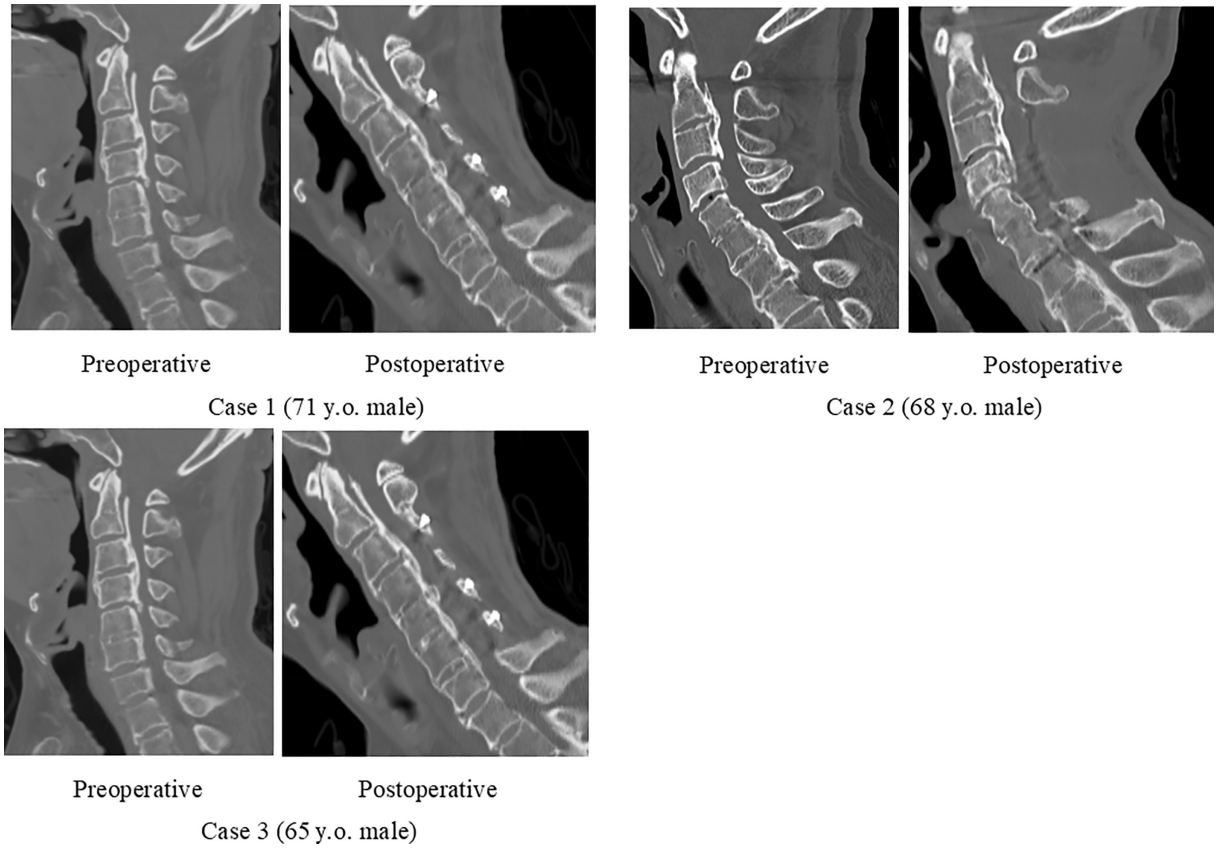

Figure. Representative cases of postoperative ossification of the posterior longitudinal ligament progression after posterior cervical decompression and fusion surgery. y.o., year old.

and 3.7 ± 1.1 mm in the nonfusion group (P = 0.21). The postoperative increase in thickness was 0.37 ± 0.94 mm and 0.033 ± 0.65 mm, respectively (P = 0.51). Sagittal OPLL advancement was recorded in 10 fusion cases (58.8%) and 3 nonfusion cases (33.3%) in the nonfixation group, which was statistically comparable (P = 0.41). Among the 10 cases of fusion, sagittal ossification progressed in 9 cases (90%) inside the fixation range and 5 cases (50%) outside the fixation range. We observed no significant difference in preoperative Japanese Orthopedic Association score between the groups (P = 0.77). However, postoperative Japanese Orthopedic Association score at 2 years was significantly lower in the progression group (P = 0.046), in addition to the recovery rate (P = 0.047; Table 1). No patient required reoperation due to sagittal ossification advancement. No significant differences were observed between the progression and nonprogression groups in terms of gender, age, body mass index, nutritional status expressed as the geriatric nutritional risk index,[4] preoperative OP-index, medical history, presence or absence of K-line (−), presence or absence of fusion, number of fused vertebrae, or follow-up period. Although not statistically significant, there was a tendency for the progression group to have a younger age, more fixed vertebrae, and a longer follow-up period.

Multivariate analysis revealed the segmental type as a significant independent factor associated with postoperative sagittal OPLL progression, with an OR of 17.6 (Table 2). A subgroup analysis of the 17 patients who underwent fixation surgery revealed postoperative sagittal ossification progression in all 3 cases (100%) of the segmental type and in 7 cases (50%) of the continuous/mixed type (P = 0.228). Ossification outside the fixation range progressed in 1 case (33.3%) of the segmental type, vs 8 cases (57.1%) of the continuous/mixed type (P = 0.57). Ossification progression inside the fixation range was observed in all 3 segmental-type cases.

DISCUSSION

A recent systematic review of reoperation following OPLL surgery revealed that postoperative ossification progression was the most common cause of reoperation.[1] Younger age, thick ossification, ossification involving ≥3 vertebral levels, and continuous/mixed types were associated with a high risk of ossification advancement after surgery as well.[5] Moreover, extensive

Table 2. Impact of patient-related factors on sagittal OPLL progression.

	Univariate		Multivariate	
Factor	**OR (95% CI)**	***P***	**OR (95% CI)**	***P***
Age (+10 y)	0.76 (0.41–1.42)	0.39		
Women	2.18 (0.17–27.6)	0.54		
BMI (+1)	1.04 (0.89–1.21)	0.58		
GNRI (+10)	1.02 (0.58–1.78)	0.93		
Preoperative OP-index	0.93 (0.73–1.19)	0.59		
OP-index > 5	0.72 (0.15–3.47)	0.69		
Segmental type	3.44 (0.52–22.4)	0.19	17.6 (1.14–272)	0.040
K-line (−)	1.00 (0.20–4.86)	>0.99		
Hypertension	0.21 (0.033–1.36)	0.10		
Diabetes mellitus	0.67 (0.11–3.87)	0.65		
Fusion	2.86 (0.52–15.5)	0.22		
Number of fusion levels (+1 vertebra)	1.21 (0.91–1.61)	0.18	1.48 (0.97–2.25)	0.063
Follow-up period (+1 y)	1.34 (0.85–2.09)	0.20	1.62 (0.89–2.94)	0.11

Abbreviations: BMI, body mass index; GNRI, geriatric nutritional risk index; OP-index, ossification index; OPLL, ossification of posterior longitudinal ligament.

preoperative ossification was a high-risk factor for postsurgical ossification progression following laminoplasty.[2] In the present study, the segmental type displayed a significant association with postoperative sagittal OPLL progression, and ossification advancement within the fixation range was observed in all cases undergoing fusion. Neither age nor the extent of preoperative ossification showed significant associations in our cohort.

Mechanical stress plays an important role in OPLL progression by inducing osteogenic differentiation of spinal ligament cells and promoting the secretion of bone morphogenetic proteins.[6] While some reports have shown that fixation reduces the risk of ossification progression in OPLL,[7–9] other studies maintain that fixation does not reduce the risk of ossification advancement.[10–12] Katsumi et al found that the annual increase in OPLL volume was significantly lower in a posterior decompression and fusion group than in a laminoplasty group, with the progression rate further decreasing over time in fusion patients.[9] On the other hand, Kang et al reported that the progression rate of cervical OPLL was significantly higher in a posterior fixation group vs a laminoplasty group and identified posterior fixation as an independent risk factor for accelerated progression.[12] In our study, fixation surgery was not significantly associated with postoperative sagittal bone progression. Moreover, no suppressive effects from fixation were evident. We observed a tendency for the progression group to exhibit a higher number of fixed vertebrae. Although the number of cases was small and no significant difference was observed, this potential correlation warrants further investigation. Last, since each procedure was decided by the surgeon, we could not rule out that patients prone to bone progression were concentrated in the fixation group due to selection bias.

This study had several limitations, including a small number of cases, a short follow-up period, and a lack of consideration of thickness and overall ossification size. Although OPLL is known to be more prevalent in men, the marked male predominance in our cohort further limits the generalizability of the findings. As surgical procedures were selected at the discretion of the operating surgeon, selection bias could not be excluded. In addition, formal reader blinding and sample-size calculation were not performed due to the retrospective design. Despite the segmental type being significantly associated with sagittal OPLL progression in the multivariate analysis, the results differed from those in the univariate analysis. This discrepancy likely reflects model instability, collinearity among covariates, and the limited sample size rather than a robust independent association. Therefore, our findings should be interpreted as exploratory and hypothesis generating. The above limitations require addressing in future research.

Although the predominance of sagittal ossification progression within the fixation range is reported descriptively and does not imply a causal relationship, segmental OPLL may extend the OPLL range and require stabilization of the intervertebral space through spinal fusion. Despite the observed sagittal extension, thickness progression was minimal and did not differ between the fusion and nonfusion groups. This distinction between longitudinal extension and thickness progression may partially explain incongruities with previous studies, which have primarily evaluated volumetric or thickness changes. Postoperative sagittal ossification progression was identified during routine radiological follow-up, and most patients remained asymptomatic throughout the observation period. However, patients with radiological sagittal OPLL progression demonstrated significantly worse neurological

recovery, suggesting that postoperative ossification behavior might have clinical relevance. The clinical value of these findings lies in forming long-term surveillance strategies rather than predicting the immediate need for revision surgery; postoperative sagittal OPLL progression may occur regardless of posterior fixation, particularly in segmental-type OPLL, highlighting the need for long-term radiological follow-up. Given the small sample size and potential for selection bias, our findings should be cautiously interpreted as hypothesis generating rather than definitive.

CONCLUSION

This study revealed no inhibitory effect of fixation on postoperative sagittal ossification progression in OPLL surgery. Segmental OPLL may progress to subsequent and continuous ossification. As ossification advancement may occur after OPLL surgery regardless of fixation, additional long-term follow-up is recommended.

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