

Recovery of Lower Limb Motor Function After Surgery for Thoracic Ossification of the Ligamentum Flavum in Non-Ambulatory Patients

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Abstract

Background

To characterize postoperative ambulatory recovery in non-ambulatory patients with thoracic ossification of the ligamentum flavum (TOLF) and identify factors associated with poor recovery.

Methods

We retrospectively reviewed 71 consecutive patients with TOLF who were unable to walk preoperatively and underwent posterior decompression and instrumented fusion between January 2012 and December 2023. Postoperative ambulatory recovery was assessed using the lower-extremity motor component of the modified Japanese Orthopaedic Association (mJOA) score. Patients with a postoperative motor score ≥ 3 were classified as having good recovery and those with a score ≤ 2 as having poor recovery. Clinical and radiographic variables were compared between groups, followed by univariable and multivariable logistic regression analyses.

Results

Sixty-one patients (85.9%) achieved some degree of ambulatory recovery, including 32 (45.1%) with good recovery. Compared with the good-recovery group, patients with poor recovery were older (59.9 ± 10.8 vs 52.3 ± 10.4 years, $P = .005$), had a longer duration of preoperative inability to walk (median, 3 vs 2 months, $P = .005$), more frequent thoracolumbar involvement (82.1% vs 37.5%, $P < .001$), and more frequent previous lumbar surgery (25.6% vs 6.2%, $P = .030$). Multivariable analysis identified thoracolumbar involvement (OR, 6.015; 95% CI, 1.791–21.044; $P = .005$) and previous lumbar surgery (OR, 6.442; 95% CI, 1.013–40.952; $P = .048$) as factors associated with poor recovery.

Conclusion

Thoracolumbar involvement and previous lumbar surgery were associated with poorer recovery, although the imprecision of these estimates warrants cautious interpretation and external validation.

Introduction

Thoracic ossification of the ligamentum flavum (TOLF) is a progressive degenerative spinal disorder characterized by ectopic ossification of the ligamentum flavum, leading to thoracic spinal canal stenosis and compressive myelopathy[1, 2]. As the disease progresses, chronic compression of the thoracic spinal cord may result in severe neurological deficits, including gait disturbance, lower-extremity weakness, sensory dysfunction, and bladder impairment[3, 4]. Among these, gait impairment is the most common symptom, and in severe cases, patients may become non-ambulatory [5]. And, surgical

decompression remains the primary treatment for symptomatic TOLF, as conservative management is generally ineffective.

In clinical practice, the potential to regain good independent ambulation after surgery is a major concern for patients with TOLF who present with severe lower-limb motor dysfunction. The thoracic modified Japanese Orthopaedic Association (mJOA) score is often used to evaluate the neurological function status score of TOLF patients, with the lower extremity motor function score accounting for the largest proportion[6]. Previous studies have primarily focused on overall neurological outcomes in TOLF, with limited attention to patients presenting with inability to walk. In particular, the clinical characteristics and prognostic factors associated with recovery of ambulation in this subgroup remain poorly defined. And in clinical practice, TOLF patients with inability to walk usually concerned whether they could walk again.

The present study aimed to characterize non-ambulatory TOLF patients and to identify factors associated with postoperative recovery of walking ability.

Methods

Patient Recruitment

This retrospective cohort study included consecutive patients with thoracic ossification of the ligamentum flavum (TOLF) who underwent surgical decompression at a single center between January 2012 and December 2023.

Patients were eligible if they met the following criteria: (1) radiological confirmation of TOLF at the T1–T12 level; (2) severe preoperative neurological impairment with inability to walk; and (3) a minimum postoperative follow-up of 24 months. Exclusion criteria included: (1) other thoracic spinal pathologies (e.g., ossification of the posterior longitudinal ligament, disc herniation, spinal deformity, vertebral fracture, infection, tumor, or ankylosing spondylitis); and (2) comorbid conditions affecting neurological assessment, such as sequelae of cerebral infarction, peripheral neuropathy, lower limb arterial disease, or significant urinary tract disorders.

All patients underwent posterior decompression with en bloc laminectomy and instrumented fusion performed by a specialized spine surgery team (Fig. 1).

Male, 60-years-old, had T10-11 OLF (A CT, B T2-MRI) and received T10-11 en block laminectomy and instrumented fusion (C and D X-ray one week after operation).

Data Collection

Clinical data include age, gender, body mass index (BMI), duration of the medical history, number of compression segments, blood loss and duration time of operation, history of previous spine surgery and postoperative complications. Imaging data include distribution level of OLF and high-intensity area (HIA)

on T2-weighted magnetic resonance imaging (MRI). Thoracolumbar segment was defined as T10-L1 level (10th thoracic vertebra – 1th lumbar vertebra level).

The neurological function is evaluated by the modified Japanese Orthopaedic Association Score (mJOA) (Table 1). The calculation of recovery rate (RR): $[(\text{postoperative mJOA score} - \text{preoperative mJOA score}) / (11 - \text{preoperative mJOA score})] \times 100\%$. Patients with postoperative mJOA score-lower limb motor function ≥ 3 is defined as good recovery and were divided into group 0. Patients with postoperative mJOA score-lower limb motor function ≤ 2 is defined as poor recovery and were divided into group 1.

Table 1
Thoracic Modified Japanese Orthopaedic Association (mJOA) Score

Category	Description of Dysfunction	Score
Motor Function of Lower Extremities	Unable to walk	0
	Needs cane or brace for walking on flat surface	1
	Needs assistance only when walking upstairs or downstairs	2
	Can walk without assistance, but walk unstably	3
	Normal	4
Sensory Function of Lower Extremities	Significant sensory loss	0
	Mild sensory loss	1
	Normal	2
Sensory Function of Trunk	Significant sensory loss	0
	Mild sensory loss	1
	Normal	2
Bladder Function	Urinary retention or incontinence	0
	Severe dysuria (feeling of residual urine, dribbling)	1
	Mild dysuria (urinary frequency, hesitancy)	2
	Normal	3

Statistical Analysis

Quantitative variables with normal distribution were presented as mean $\pm$ standard deviation and were analyzed using independent-sample t tests, while skewed variables were presented as median

(interquartile range, IQR) and were analyzed using the Wilcoxon rank-sum test. Categorical variables were analyzed using the chi-square test. Logistic regression analysis was used to identify independent risk factors and variables with P value < 0.1 in univariate logistical regression were included in the multivariate logistical regression analysis. Statistical analyses were performed using SPSS version 25.0, with P < 0.05 considered statistically significant.

Results

Patient Characteristics

Table 2 showed a total of 71 patients were included in the final analysis, with a slight female predominance (55%). The mean age was 57.9 ± 10.1 years. Most patients underwent multilevel decompression, with a median of 3 segments involved. The lower thoracic spine was the most commonly affected region, although multilevel and cross-regional involvement were frequent (Fig. 2). Most patients (61/71, 85.9%) got different degrees of recovery of walk ability, and about 45.1% (32/71) patients could get good recovery.

Table 2
Demographic characteristics and baseline clinical data of patients in the
thoracolumbar ossification of ligamentum flavum group

Item	Data	
Age	57.9 ± 10.1	
Gender	Male	32
	Female	39
Duration of the medical history (months)	7 (22)	
Duration of unable to walk (months)	3 (4)	
BMI (kg/m ²)	28.1 (6.5)	
Number of surgical segments	3 (3)	
HIA on MRI	Yes	54
	No	17
Duration time of operation (min)	126.7 ± 51.6	
Blood loss of operation (ml)	200 (100)	
Cerebrospinal fluid leakage	Yes	21
	No	50
Surgical site infection	Yes	2
	No	69
Postoperative mJOA score-lower limb motor function	0	10
	1	28
	2	1
	3	10
	4	22
Preoperative mJOA score	3 (2)	
Recovery rate	57.7%±24.5%	

The most common region involved by ossification of ligament flavum was lower thoracic spine.

U means upper thoracic spine. M means middle thoracic spine. L means lower thoracic spine

HIA on MRI were observed in 54 patients (76.1%). Postoperative complications included cerebrospinal fluid leakage in 21 patients (29.6%) and surgical site infection in 2 patients (2.8%). The mean operative

time was 126.7 ± 51.6 minutes, and median intraoperative blood loss was 200 mL (IQR, 100 mL). The mean recovery rate of neurological function was $57.7\% \pm 24.5\%$.

Comparison Between Good and Poor Recovery Groups

Based on postoperative lower extremity motor function, 32 patients were classified as having good recovery and 39 as poor recovery (Table 3). Patients in the poor recovery group were significantly older than those in the good recovery group (59.9 ± 10.8 vs 52.3 ± 10.4 , $P = 0.005$). The duration of inability to walk prior to surgery was also longer in the poor recovery group (median 3 vs 2 months, $P = 0.005$). Thoracolumbar involvement was markedly more frequent in patients with poor recovery (82.1% vs 37.5%, $P < 0.001$). In addition, a history of lumbar spine surgery was more common in the poor recovery group (25.6% vs 6.2%, $P = 0.030$). No significant differences were observed between groups in terms of diabetes mellitus, preoperative mJOA score, BMI, number of surgical segments, MRI signal changes, operative time, blood loss, or postoperative complications (all $P > 0.05$).

Table 3

Comparative analysis of clinical factors between patients with discrepant recovery of postoperative lower motor function

Item		Group0 (n = 32)	Group1 (n = 39)	P
Age		52.3 ± 10.4	59.9 ± 10.8	0.005
Gender	Male	13	19	0.495
	Female	19	20	
Diabetes mellitus	Yes	2	6	0.404
	No	30	33	
Preoperative mJOA score		3.1 ± 1.6	3.4 ± 1.4	0.409
Duration of the medical history (months)		8 (10)	7 (12)	0.354
Duration of unable to walk (months)		2 (2)	3 (2)	0.005
BMI (kg/m ²)		28.4 (6.6)	27.7 (6.8)	0.795
Number of surgical segments		3 (2)	3 (3)	0.567
Pathogenic segment involving thoracolumbar level	Yes	12	32	<0.001
	No	20	7	
History of lumbar spine surgery	Yes	2	10	0.030
	No	30	29	
History of cervical spine surgery	Yes	9	11	0.094
	No	23	28	
HIA on MRI	Yes	6	11	0.353
	No	26	28	
Duration time of operation (min)		137.5 ± 63.1	120.0 ± 43.0	0.335
Blood loss of operation (ml)		200 (100)	225 (175)	0.720
Cerebrospinal fluid leakage	Yes	8	13	0.269
	No	24	26	
Surgical site infection	Yes	1	1	0.087
	No	31	38	

Risk Factor Analysis

In univariate logistic regression analysis, age (OR = 1.070, P = 0.006), duration of inability to walk (OR = 1.198, P = 0.069), and thoracolumbar involvement (OR = 7.619, P < 0.001) were associated with poor postoperative recovery of walking ability (Table 4). Multivariate logistic regression analysis identified thoracolumbar involvement (OR = 6.015, 95% CI: 1.791–21.044, P = 0.005) and history of lumbar spine surgery (OR = 6.442, 95% CI: 1.013–40.952, P = 0.048) as the independent predictors of poor recovery in this cohort of patients (Table 4).

Table 4
Univariate and multivariate logistic regression analyses of postoperative ability of walk

	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P	OR (95% CI)	P
Age	1.070 (1.019–1.123)	0.006	1.059 (0.991–1.131)	0.089
Gender	0.720 (0.280–1.852)	0.496		
Diabetes mellitus	2.727 (0.511–14.559)	0.240		
Preoperative mJOA score	1.146 (0.831–1.581)	0.450		
Duration of the medical history (months)	1.008 (0.994–1.022)	0.272		
Duration of unable to walk (months)	1.198 (0.986–1.455)	0.069	1.048 (0.913–1.203)	0.505
BMI (kg/m ²)	1.006 (0.942–1.076)	0.849		
Number of surgical segments	0.992 (0.800–1.229)	0.940		
Pathogenic segment involving thoracolumbar level	7.619 (2.570–22.588)	<0.001	6.015 (1.791–21.044)	0.005
History of lumbar spine surgery	5.172 (1.043–25.662)	0.068	6.442 (1.013–40.952)	0.048
History of cervical spine surgery	1.004 (0.355–2.839)	0.994		
HIA on MRI	0.587	0.356		

Notes: 1. In logistic regression analyses 0 means good recovery of postoperative lower limb motor function and 1 means poor recovery of postoperative lower limb motor function. 2. Male-0, Female-1.

	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P	OR (95% CI)	P
	(0.190–1.816)			
Duration time of operation (min)	0.993 (0.980–1.006)	0.278		
Blood loss of operation (ml)	0.999 (0.998–1.001)	0.422		
Cerebrospinal fluid leakage	1.011 (0.991–1.031)	0.453		
Surgical site infection	0.816(0.049– 13.579)	0.887		
Notes: 1. In logistic regression analyses 0 means good recovery of postoperative lower limb motor function and 1 means poor recovery of postoperative lower limb motor function. 2. Male-0, Female-1.				

Discussion

Complaint about dysfunction of walk is the most common symptom of TOLF patients. We conducted this research to explore the clinical characteristics and prognosis of TOLF patients with inability to walk. We founded that most patients (61/71, 85.9%) could get different degrees of recovery of walk ability and patients with poor recovery of ability of walk had advanced age (59.9 ± 10.8 vs 52.3 ± 10.4 , $P = 0.005$), longer duration of unable to walk (3(2) vs 2(2), $P = 0.005$), larger proportion of segment involving thoracolumbar level (82.1% vs 37.5%, $P < 0.001$) and larger proportion of history of lumbar spine surgery (25.6% vs 6.2%, $P = 0.030$). And thoracolumbar involvement (OR = 6.015, 95% CI: 1.791–21.044, $P = 0.005$) and history of lumbar spine surgery (OR = 6.442, 95% CI: 1.013–40.952, $P = 0.048$) could predict the postoperative recovery of lower limb motor function.

Age

Advanced age was associated with poorer recovery (OR = 1.070, $P = 0.006$) in univariate analysis, although this effect did not remain significant in multivariate analysis (OR = 1.059, $P = 0.089$). In research of Yamada T et al, age was an important factor to influence the recovery of patients with thoracic OLF[7]. They found that elderly patients might had greater chance of lumbar spondylosis surgery due to degeneration of aging, so elderly TOLF patients had poorer recovery of surgical outcome. Tayal A also mentioned that the poor prognosis of elderly patients with thoracic OLF was related to high incidence of postoperative complications[8]. We agreed with their points. What's more, aging is associated with fragility of physical functions, decline of resistance to external strike and internal imbalance, and degeneration of nervous system and the motor system[9, 10]. Therefore, chronic spinal cord

compression in older patients may result in more irreversible neural damage, limiting postoperative functional improvement. Although age was not identified as an independent predictor in our multivariate model, the observed trend suggests that advanced age remains an important consideration in perioperative risk assessment.

Duration of inability to walk

Patients with poor postoperative recovery of walk had longer duration of unable to walk (3(2) vs 2(2), $P = 0.005$), although there is no statistical difference in univariate and multivariate logistic regression analyses ($OR = 1.198$, $P = 0.069$; $OR = 1.048$, $P = 0.505$). The duration of preoperative symptoms is an important factor affecting the recovery of neurological function in TOLF patients[8, 11–13]. Inability to walk usually followed other initial symptoms, which might indicate that the degree of spinal cord damage was increasing. Prolonged neurological impairment likely reflected more severe and chronic spinal cord compression, which might lead to irreversible damage. Although this factor did not remain independently significant in logistic regression analysis, the finding is clinically meaningful. These findings underscore the importance of early diagnosis and timely decompression before irreversible spinal cord damage occurs.

Lesion involving thoracolumbar spine and lumbar spine

We founded that thoracolumbar involvement ($OR = 6.015$, 95% CI: 1.791–21.044, $P = 0.005$) and history of lumbar spine surgery ($OR = 6.442$, 95% CI: 1.013–40.952, $P = 0.048$) were identified as the independent predictors in multivariate analysis. Firstly, this might be explained by the unique biomechanical and neuroanatomical characteristics of the thoracolumbar junction. Compared with the relatively stable mid-thoracic spine, the thoracolumbar region is subjected to greater mechanical stress and mobility, which may exacerbate spinal cord compression and postoperative instability[8]. Secondly, the thoracolumbar region contains anatomically critical neural structures, including the conus medullaris and lumbosacral enlargement, which are closely associated with lower-extremity motor control and bladder function[14, 15]. Compression at this level may therefore result in disproportionately severe neurological impairment compared with lesions located in the mid-thoracic spine.

Interestingly, a history of lumbar spine surgery was associated with poor postoperative recovery in univariate analysis, although it did not remain independently significant after multivariate adjustment. However, history of cervical surgery was not founded relation to recovery of walk. The research conducted by Nemeth C mentioned that despite the interruption of the supraspinal pathways that occurred in spinal cord injury, the neuromuscular junctions innervated by motor neurons below the injury level remained intact[16]. Consequently, we speculated that compared with cervical spine surgery, lesions involving the thoracolumbar spine and lumbar spine are more likely to cause severe damage to the neural pathways controlling lower limb motor function, leading to poorer recovery.

These findings highlight the importance of early surgical intervention in patients with TOLF, particularly before the onset or progression of severe walking impairment. Recognition of thoracolumbar involvement as a strong prognostic factor may aid in risk stratification and patient counseling. Surgeons

should be aware that patients with lesions at the thoracolumbar junction may have a higher risk of limited postoperative recovery and may require closer follow-up and rehabilitation planning.

Importantly, the wide confidence intervals around the odds ratios for both thoracolumbar involvement and previous lumbar surgery indicate that the precision of these estimates is limited. Accordingly, larger prospective multicenter studies are needed to determine whether these factors consistently predict failure to regain ambulatory function and to obtain more precise estimates of their independent effects.

Limitation

Several limitations should be acknowledged. First, the retrospective single-center design introduces potential selection and information bias and limits the generalizability of the findings. Second, the relatively small sample size and limited number of poor-recovery events may have reduced statistical power and resulted in instability of the multivariable logistic regression estimates, particularly for variables with low prevalence. Thirdly, due to most of these patients had multiple involving segments, the effect of classification of TOLF morphology on recovery could not be discussed sufficiently. Therefore, prospective multicenter studies are needed to elucidate the predictors of neurological recovery in non-ambulatory TLOLF patients.

Conclusion

Non-ambulatory patients with thoracic ossification of the ligamentum flavum may still achieve meaningful recovery of ambulatory function after surgical decompression. In this cohort, thoracolumbar involvement and a history of lumbar spine surgery were independently associated with poorer postoperative ambulatory recovery, whereas older age and a longer duration of preoperative inability to walk were associated with poorer outcomes in univariable analyses but did not remain independently significant after adjustment. Given the limited sample size and the imprecision of the estimated effects, these findings should be interpreted cautiously and regarded as potential prognostic indicators rather than definitive predictors. Further prospective, multicenter studies with larger cohorts and validated measures of ambulatory function are warranted to confirm these associations and improve individualized prognostic counseling.

Abbreviations

TOLF

thoracic ossification of the ligamentum flavum

mJOA

modified Japanese Orthopaedic Association

BMI

body mass index

HIA

high-intensity area

MRI
magnetic resonance imaging
RR
recovery rate
IQR
interquartile range
OR
odds ratio
CI
confidence interval

Declarations

Ethics approval:

The Ethical Committee of Peking University Third Hospital approved this research (IRB00006761). Written informed consent and consent for participation were obtained.

Consent for publication:

Not applicable

Competing interests:

The authors have no financial or proprietary interests in any material discussed in this article.

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Author Contribution

ZX and GC contributed equally to this study. ZX wrote this article; YH, LY and GC collected the data. GC and SJ analysed the data. XG and WZ provided guidance on statistics. WL designed the study. FZ and CS guide the entire research.

Data Availability

All data will be retained in Peking University Third Hospital and the research group. The datasets generated during the current study are not publicly available but are available from the corresponding author on reasonable request.

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Figures



Figure 1

One case in this cohort of patients

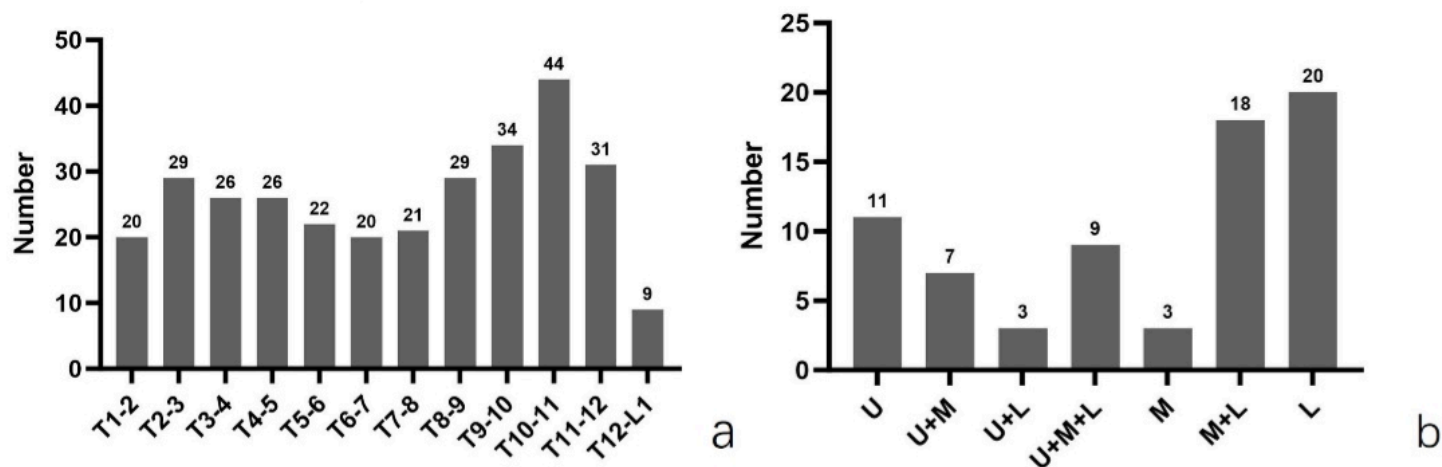


Figure 2

Distribution of segments received decompression in this cohort of patients.