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ORTHOPAEDIC SURGERY

Neurological manifestations of thoracic myelopathy

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Abstract
Introduction Investigation of preoperative manifestations of thoracic myelopathy in a large population has not been reported. The aim of this study was to identify symptoms specific to anatomical pathology or compressed segments in thoracic myelopathy through investigation of preoperative manifestations.
Materials and methods Subjects were 205 patients [143 men, 62 women; mean age, 62.2 (range 21–87 years)] with thoracic myelopathy who underwent surgery at our affiliate institutions from 2000 to 2011. The disease distribution included ossification of the ligamentum flavum (OLF) in 106 patients, ossification of the posterior longitudinal ligament (OPLL) in 17, OLF with OPLL in 17, intervertebral disc herniation (IDH) in 23, OLF with IDH in 3, and spondylosis in 39. We assessed (1) initial and preoperative complaints, (2) neurological findings, (3) Japanese Orthopaedic Association scores (JOA, full score, 11 points), (4) the compressed segments, and (5) preoperative duration. Multivariate analyses were performed to examine potential relationships between preoperative manifestations and anatomical pathology or compressed segments.
Results The multivariate analyses revealed relationships between lower limb muscle weakness and T10/11 anterior compression; lower limb pain and T11/12 anterior compression; low back pain and T11/12 compression; and hyporeflexia in the patellar tendon reflex/foot drop and T12/L1 anterior compression.
Conclusion This study elucidated symptoms specific to anatomical pathology or compressed segments in thoracic myelopathy. These relationships can be helpful in the initial investigation of thoracic diseases, although additional measures such as MRI or CT are necessary for definitive diagnosis.

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Table 1 Patient demographics

	OLF	OPLL	IDH	SPD	OLF + OPLL	OLF + IDH	Four-group comparison *p*-value	Two-group comparison *p*-value
No. of patients	106 (52 %)	17 (8 %)	23 (11 %)	39 (19 %)	17 (8 %)	3 (1 %)		
Male:female	80:26	5:12	18:5	30:9	8:9	2:1	0.002*	OPLL-OLF: <0.001* OPLL-IDH: 0.003* OPLL-SPD: 0.002*
Age at surgery, years (mean ± SD, range)	62.1 ± 12.0 22–87	58.1 ± 11.8 37–76	60.8 ± 16.0 21–86	67.3 ± 11.3 37–87	57.7 ± 8.6 44–71	59.3 ± 4.7 54–63	0.032*	
Preoperative disease duration, days (mean ± SD, range)	636 ± 932 20–5,933	390 ± 285 49–1,112	252 ± 423 6–2,030	512 ± 893 16–3,891	1,250 ± 1,887 55–6,448	282 ± 66 207–331	0.005*	IDH-OLF:0.006* IDH-OPLL:0.002*
Preoperative JOA score (mean ± SD, range)	5.8 ± 2.0 0–10	4.1 ± 1.9 0–8	6.0 ± 2.4 0.5–10	5.0 ± 1.8 2–10.5	4.2 ± 1.7 1.5–9	4.7 ± 1.6 3.5–6.5	0.001*	OPLL-OLF:0.002* OPLL-IDH:0.008*

OLF + OPLL and OLF + IDH are excluded in the four-group and two-group comparisons

OLF ossification of the ligamentum flavum, *OPLL* ossification of the posterior longitudinal ligament, *IDH* intervertebral disc herniation, *SPD* spondylosis

* Statistically significant

Keywords Thoracic myelopathy · Ossification of the ligamentum flavum · Ossification of the posterior longitudinal ligament · Intervertebral disc herniation · Epiconus · Conus medullaris

Introduction

Diagnosis of thoracic myelopathy tends to be delayed because of its rarity [1, 2] and its diverse neurological manifestations. These diverse manifestations result from the anatomical uniqueness of the thoracic spine. The neurological symptoms resulting from thoracic disorders are sometimes misdiagnosed as cervical or lumbar disorders [3]. Misdiagnosis can lead to a prolonged preoperative disease duration, which can cause irreversible neurological damage and even unnecessary surgical procedures performed on the wrong spinal region [4]. Although previous studies report the clinical outcomes of different surgical procedures or the radiographic risk factors for poor clinical outcomes [5–9], possible correlations between preoperative manifestations and anatomical pathology [i.e., ossification of the posterior longitudinal ligament (OPLL), ossification of the ligamentum flavum (OLF), intervertebral disc herniation (IDH), and spondylosis (SPD)] or compressed segments (most severely involved anatomical segments) have not been discussed. In the present study, we retrospectively examined 205 patients with thoracic myelopathy to identify symptoms that were specific for anatomical pathology or compressed segments.

Materials and methods

The patient data were collected through retrospective review of charts and radiographic images at eight affiliate institutes of Osaka University. We identified a total of 205 patients who underwent surgery for degenerative thoracic myelopathy from 2000 to 2011. The disease distribution included OLF in 106 patients, OPLL in 17, OLF with OPLL in 17, IDH in 23, OLF with IDH in 3, and SPD in 39 (Table 1). There were 143 men and 62 women, and their mean age was 62.2 years (range 21–87 years). The mean preoperative disease duration was 595 days (range 6–6,448 days). The initial complaints, preoperative complaints, compressed segments, and preoperative disease duration were assessed. In addition, we assessed the clinical examination findings, including deep tendon reflexes (DTRs), ankle clonus, Babinski sign, lower limb muscle strength, and the JOA score (full score, 11 points) [10]. In the present manuscript, the initial complaints are indicated by "complaints (onset)" and preoperative complaints are indicated by "complaints (pre-op)." Comorbidities that can affect neurological evaluation included diabetes, which was present in 42 patients (20 %).

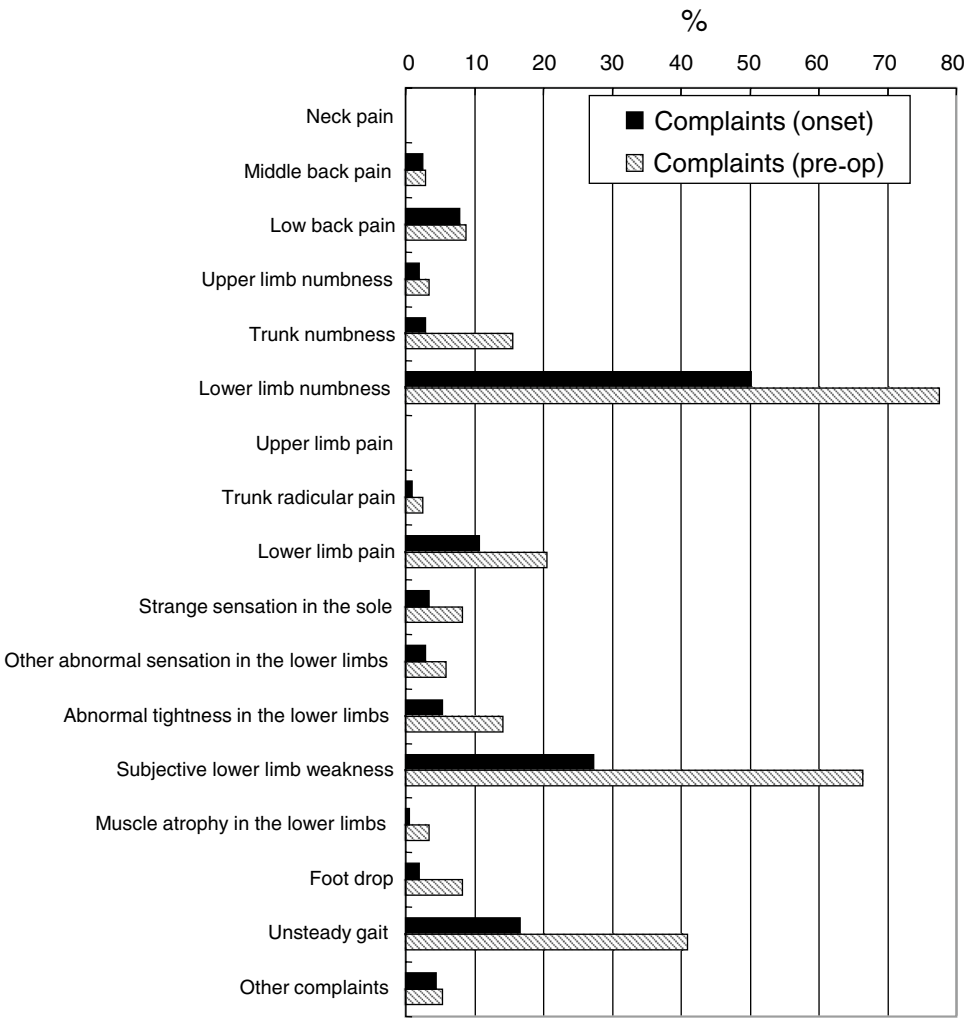

Fig. 1 Frequency of complaints (onset, pre-op). The most frequent complaint was lower limb numbness (onset 50 %, pre-op 78 %), followed by subjective lower limb weakness (onset 28 %, pre-op 67 %) and unsteady gait (onset 17 %, pre-op 41 %). Low back pain indicated lumbar back pain, middle back pain indicated thoracic back pain, and trunk radicular pain indicated radicular pain in the trunk after excluding lumbar and thoracic back pain

The complaints (onset) and complaints (pre-op) were further classified into 17 categories, which are listed in Fig. 1. For example, low back pain at onset was labeled low back pain (onset), and low back pain occurring immediately before surgery was labeled low back pain (pre-op). Complaints presented without "(onset)" or "(pre-op)" were used to describe all complaints, regardless of their timing.

The DTRs evaluated for the upper limbs included Hoffmann's sign, Wartenberg's sign, and those for the biceps, brachioradialis, and triceps tendons. The lower limb DTRs evaluated included the patellar tendon reflex (PTR) and Achilles tendon reflex (ATR). Pathological reflexes, such as ankle clonus and the Babinski sign, also were examined.

Deep tendon reflexes were classified into three categories: hyperreflexia, normoreflexia, and hyporeflexia. Hyperreflexia was defined as having an exaggerated DTR in either or both limbs. Ankle clonus and the Babinski sign also were categorized as positive or negative. Preoperative lower limb muscle strength included assessment of the iliopsoas (IP), quadriceps femoris (QF), tibialis anterior (TA), and gastrocnemius (GS) using manual muscle testing (MMT 0–5 grades). Manual muscle testing grades <4 were defined as clinically weak.

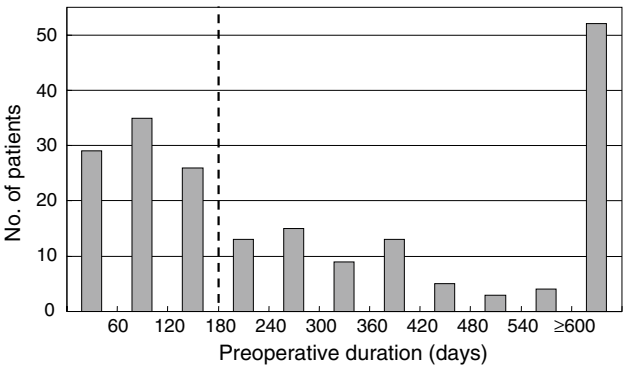

Fig. 2 Distribution of preoperative duration. The histogram shows the distribution of preoperative disease duration. A bimodal distribution was evident after excluding patients with preoperative disease duration longer than 600 days

Table 2 Distribution of PTR, ATR, ankle clonus, and Babinski sign

	Hyperreflexia	Normoreflexia	Hyporeflexia
PTR	88 (68 %)	12 (9 %)	29 (22 %)
ATR	73 (57 %)	24 (19 %)	32 (25 %)
	Present	Absent	Not recorded
Ankle clonus	55 (43 %)	68 (53 %)	6 (5 %)
Babinski sign	51 (40 %)	50 (39 %)	28 (22 %)

PTR patellar tendon reflex, *ATR* Achilles tendon reflex

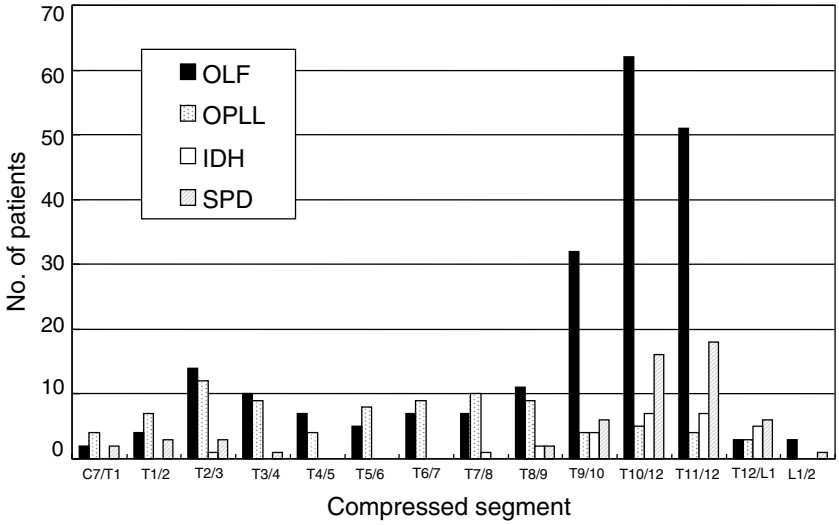

Fig. 3 Distribution of compressed segments based on anatomical pathology

Bladder dysfunction was evaluated based on the JOA bladder subscore (0–3) [10]. A grade of zero or one was considered severe dysfunction.

The compressed segments were defined as the segments that required operation, which were confirmed with T2-weighted magnetic resonance imaging (MRI) in 202 patients or computed tomography after myelography (CTM) in 3. Cervical and lumbar MRI or CTM were performed simultaneously with thoracic imaging to exclude coexistence of cervical or lumbar diseases. We determined the level at which the conus medullaris (TLCM) terminated in 115 (80 %) of the 144 patients who had compression from T10/11 to L1/2. The termination level was defined with reference to the vertebra or intervertebral disc (upper, middle, lower vertebra level, or intervertebral disc level).

Because the distributions of preoperative disease duration was bimodal (except for those with duration >600 days) the patients were assigned to either a short-duration group (<180 days; 91 patients) or a long-duration group (≥180 days and <600 days; 62 patients; Fig. 2).

PASW Statistics software version 18 (SPSS Inc., Chicago, IL) was used for statistical analysis. Comparisons between two groups were performed with the Mann–Whitney *U* test and Fisher's exact test. In these comparisons, p values <0.05 were considered significant. Multivariate logistic regression analyses with forward stepwise selection were performed to assess predictors of preoperative manifestations. Before performing the multivariate logistic regression analyses, we confirmed that correlation coefficients between any two independent variables were below 0.7. Comparisons among four groups were performed with the Mann–Whitney *U* test after the Kruskal–Wallis test; a corrected $p < 0.0083$ (corrected by the Bonferroni method) was used to indicate significance.

Results

The most frequent complaint was lower limb numbness (onset 50 %, pre-op 78 %), followed by subjective lower limb weakness (onset 28 %, pre-op 67 %), and unsteady gait (onset 17 %, pre-op 41 %; Fig. 1). The frequency of all complaints increased from onset to surgery. Lower limb muscle weakness was observed in 67 (33 %), 35 (17 %), 60 (29 %), and 39 (19 %) patients for the IP, QF, TA, and GS, respectively. The distribution of the preoperative urinary function scores were grades 0 (12, 6 %), 1 (40, 20 %), 2 (74, 36 %), and 3 (79, 39 %). The average preoperative JOA score was 5.4 (range 0–10.5). After excluding 76 patients with upper limb hyperreflexia or diabetes mellitus, we examined the PTR, ATR, ankle clonus and the Babinski sign in 129 patients (Table 2).

Table 3 Multivariate logistic regression analysis including anatomical pathology

Dependent variable	Significant independent variable	*p* value	Odds ratio (95 % CI)
Complaints			
Lower back pain	IDH	0.001	6.76 (2.28–20.1)
	T11/12 Comp	0.002	5.38 (1.88–15.4)
Trunk numbness	T11/12 Comp	0.003	0.19 (0.06–0.56)
Lower limb pain	C7/T1-T9/10 Comp	0.001	0.25 (0.11–0.55)
	T10/11 Comp	0.031	0.44 (0.21–0.93)
Subjective lower limb weakness	OLF	0.018	0.46 (0.25–0.88)
Foot drop	IDH	0.007	4.58 (1.53–13.7)
Unsteady gait	T12/L1 Comp	0.019	0.17 (0.04–0.74)
Reflexes			
Hyporeflexia in the PTR	IDH	0.002	4.59 (1.76–12.0)
	Age: 10 year	0.005	1.64 (1.16–2.32)
	T11/12 Comp	0.024	2.47 (1.13–5.41)
	Upper limb hyperreflexia	0.035	0.20 (0.04–0.89)
Hyporeflexia in the ATR	Age: 10 year	0.002	1.64 (1.20–2.24)
	Diabetic mellitus	0.032	2.29 (1.08–4.86)
	Upper limb hyperreflexia	0.016	0.29 (0.10–0.79)
Positive ankle clonus	Upper limb hyperreflexia	0.001	3.43 (1.63–7.24)
	Age : 10 year	0.005	0.70 (0.55–0.90)
Babinski sign	T12/L1 Comp	0.046	0.25 (0.07–0.98)
Lower limb muscle strength			
Weak IP	IDH	0.048	2.31 (1.01–5.32)
Weak QF	IDH	0.004	4.07 (1.56–10.6)
Weak TA	IDH	0.005	3.37 (1.46–7.82)
Weak GS	IDH	0.002	3.95 (1.65–9.50)
Severe urinary dysfunction (JOA subscore 0 or 1)	OPLL	0.015	2.67 (1.21–5.88)

Only significant independent variables are listed

Comp compression, *OLF* ossification of the ligamentum flavum, *OPLL* ossification of the posterior longitudinal ligament, *IDH* intervertebral disc herniation, *SPD* spondylosis, *IP* iliopsoas, *QF* quadriceps femoris, *TA* tibialis anterior, *GS* gastrocnemius, *CI* confidence interval

Disease distribution in compressed segments and comparison of patient demographics according to anatomical pathology

Among the patients with OLF, the distribution was predominantly at the T9/10, T10/11, and T11/12 segments in 70 % of all compressed segments. Among those patients with OPLL, the distribution was mainly in the upper or middle thoracic segments. Intervertebral disc herniation and SPD were seen at the lower thoracic segments (Fig. 3).

Patients who had a combination of two diseases were excluded in the comparison of diseases. Compared to OLF, IDH, and SPD, OPLL was more frequent in women than men. Intervertebral disc herniation had shorter preoperative disease duration than OLF an OPLL, and those with OPLL had lower preoperative JOA scores than those with OLF and IDH (Table 1).

Predictors for preoperative manifestations

To assess the predictors for each preoperative manifestation, multivariate logistic regression analyses with forward stepwise selection were applied to the potential independent variables, including anatomical pathology, compressed segments, age, sex, diabetes mellitus, and upper limb hyperreflexia (Table 3). All four anatomical pathology variables showed an uneven spatial distribution of compressed segments in terms of the rostral–caudal and anterior–posterior directions. To account for the possibility that anatomical pathology and compressed segments were confounding variables, we performed the analyses in two steps. In the first step, anatomical pathology and compressed segments were included as predictors without distinction between anterior and posterior directions. In the second step, after excluding anatomical pathology, compressed segments were subdivided based on anterior or posterior compression. If compressed segments were significant predictors at the second step, then compressed segments should be significant rather than anatomical pathology. On the other hand, if the second step analysis showed no significant compressed segments despite the identification of significant anatomical pathology in the first step, then anatomical pathology was considered a significant predictor. The compressed segments were divided into four categories that included C7/T1-T9/10, T10/11, T11/12, and T12/L1. On multivariate analysis, six preoperative manifestations were significant predictors

Table 4 Multivariate analyses by anterior–posterior compression excluding anatomical pathology

Dependent variable	Significant independent variable	*p* value	Odds ratio (95 % CI)
Complaints			
Low back pain	T11/12 Ant Comp	0.037	3.35 (1.08–10.4)
	T11/12 Post Comp	0.038	2.75 (1.15–8.84)
	T10/11 Post Comp	0.043	0.27 (0.07–0.96)
Trunk numbness	T11/12 Post Comp	0.009	0.23 (0.08–0.69)
Lower limb pain	C7/T1-T9/10 Post Comp	0.010	0.29 (0.12–0.75)
	T11/12 Ant Comp	0.045	2.72 (1.02–7.21)
Subjective lower limb weakness	T11/12 Post Comp	0.026	0.50 (0.27–0.92)
Foot drop	T12/L1 Ant Comp	0.002	9.33 (2.34–37.3)
Reflexes			
Hyporeflexia in the PTR	T12/L1 Ant Comp	0.004	7.58 (1.89–30.4)
	Age : 10 year	0.006	1.63 (1.15–2.31)
	Upper limb hyperreflexia	0.032	0.20 (0.04–0.87)
Hyporeflexia in the ATR	Age: 10 year	0.002	1.64 (1.20–2.24)
	Diabetic mellitus	0.032	2.29 (1.08–4.86)
	Upper limb hyperreflexia	0.016	0.29 (0.10–0.79)
Positive ankle clonus	Upper limb hyperreflexia	0.003	3.14 (1.48–6.64)
	Age : 10 year	0.005	0.70 (0.54–0.89)
Lower limb muscle strength			
Weak IP	T10/11 Ant Comp	0.015	3.13 (1.25–7.85)
Weak QF	T10/11 Ant Comp	0.010	3.58 (1.36–9.45)
Weak TA	T10/11 Ant Comp	0.006	3.89 (1.47–10.3)
	T10/11 Post Comp	0.003	0.34 (0.17–0.70)

Only significant independent variables are listed

Comp compression, *Ant* anterior, *Post* posterior, *IP* iliopsoas, *QF* quadriceps femoris, *TA* tibialis anterior, *GS* gastrocnemius, *CI* confidence interval

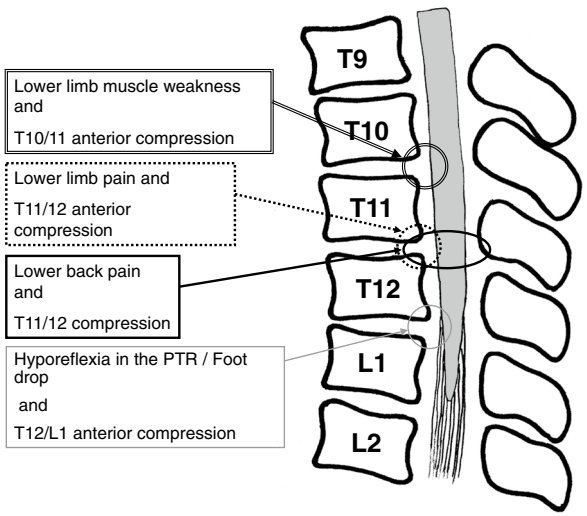

Fig. 4 Schematic showing significant correlations between compressed segments and the manifestations

with odds ratios greater than three and a $p < 0.05$, except for diabetes mellitus and upper limb hyperreflexia. Strong positive correlations were found among the following factors: (1) low back pain and IDH or T11/12 compression; (2) foot drop and IDH; (3) hyporeflexia in the PTR and IDH; and (4) weak QF, TA or GS and IDH.

In addition, strong negative correlations (odds ratio <0.33 and $p < 0.05$) were found between: (1) trunk numbness and T11/12 compression; (2) lower limb pain and C7/T1-T9/10 compression; (3) unsteady gait/Babinski sign and T12/L1 compression. Age was a significant positive predictor for hyporeflexia in the PTR and ATR, and a significant negative predictor for ankle clonus.

Differences based on anterior–posterior compression

As the next step, compressed segments were subdivided based on anterior or posterior compression, independent of the anatomical pathology to avoid confounds between these two variables. The independent variables were compressed segments (divided between anterior and posterior at C7/T1-T9/10, T10/11, T11/12, and T12/L1), age, sex, diabetes mellitus, and upper limb hyperreflexia (Table 4; Fig. 4). Other than diabetes mellitus and upper limb hyperreflexia, there were strong positive correlations (odds ratio >3 and $p < 0.05$) between: (1) low back pain and T11/12 anterior compression; (2) foot drop/hyporeflexia in the PTR and T12/L1 anterior compression; and (3) weak QF, TA, or GS and T10/11 anterior compression. Strong negative correlations (odds ratio <0.33 and $p < 0.05$) were found between: (1) lower back pain and posterior T10/11 compression; (2) trunk numbness and posterior T11/12 compression; and (3) lower limb pain and posterior C7/T1-T9/10 compression.

Table 5 Comparison between short-duration and long-duration groups

	Short-duration group (<180 days)	Long-duration group (≥180 and <600 days)	*p* value
No. of patients	91	62	
Male:female	61:30	42:20	0.927
Age at surgery, years (mean ± SD, range)	62.7 ± 13.7 21–87	60.7 ± 11.5 30–83	0.246
Preoperative duration, days (mean ± SD, range)	89.7 ± 46.7 6–176	338 ± 109 180–587	<0.001*
Preoperative JOA score (mean ± SD, range)	4.8 ± 1.9 0–10.0	5.6 ± 2.3 0–10.5	0.035*
Complaints (onset)			
Subjective weakness in the lower limbs	32 (35.2 %)	12 (19.4 %)	0.035*
Abnormal tightness in the lower limbs	0 (0.0 %)	7 (11.3 %)	0.001*
Lower limb muscle strength			
Weak IP	41 (45.1 %)	13 (21.0 %)	0.002*
Weak QF	26 (28.6 %)	4 (6.5 %)	0.001*
Weak GS	25 (27.2 %)	7 (11.3 %)	0.016*

Only preoperative manifestations with significant differences are listed. Patients with disease duration >600 days were excluded

IP iliopsoas, *QF* quadriceps femoris, *GS* gastrocnemius, *CI* confidence interval

* Statistically significant

Table 6 Frequency distribution of the conus medullaris termination level

Termination level of the conus medullaris	Overall	T11/12 compression without low back pain	T11/12 compression with low back pain
T12 lower 1/3	1 (0.9 %)		
T12/L1	3 (2.6 %)	3	
L1 upper 1/3	10 (8.7 %)	5	
L1 middle 1/3	19 (16.5 %)	8	1
L1 lower 1/3	22 (19.1 %)	11	
L1/L2	34 (30.0 %)	7	8
L2 upper 1/3	12 (10.4 %)	4	4
L2 middle 1/3	9 (7.8 %)	6	
L2 lower 1/3	4 (3.5 %)	2	
L2/L3	1 (0.9 %)	1	
Total	115 (100 %)	47	13
Unknown	29	17	2
		$^{\dagger}p = 0.006$*	

* Statistically significant

† Fisher's exact test

Comparisons between short- and long-duration groups

The preoperative JOA score was significantly lower in the short-duration group than in the long-duration group. The most frequent initial complaint by patients in the short-duration group was subjective lower limb weakness, which was less frequent in the long-duration group. "Abnormal tightness in the lower limbs" (onset) was seen only in the long-duration group. The incidence of weak IP, QF, and GS muscles was higher in the short-duration group than in the long-duration group (Table 5).

Of the 113 patients who had compression at a single segment, patients with T11/12 compression ($n = 43$) had a significantly longer preoperative disease duration [1,063 days (range 16–5,933 days); $p = 0.004$] than the other patients [$n = 70$, 341 days (range 6–2,128 days)].

Termination level of the conus medullaris

The TLCM was from the middle-third of the L1 vertebra to the L1/2 intervertebral disc in 65 % of patients. There was no significant difference for sex. Correlations between the TLCM and the aforementioned level-dependent manifestations, including lower limb muscle weakness (T10/11 anterior compression), lower limb pain (T11/12 anterior compression), low back pain (T11/12 compression), and hyporeflexia in the PTR/foot drop (T12/L1 anterior compression) were investigated. Only low back pain had a significant relationship with TLCM (Fisher's exact test, Table 6). In the majority of patients with low back pain concomitant with T11/12 compression, TLCM was at the L1/2 intervertebral disc level and the upper-third of the L2 vertebra.

Discussion

Neurological manifestations caused by lower thoracic and thoracolumbar lesions are often classified as the epiconus syndrome, conus medullaris syndrome, or cauda equina syndrome [11]. However, the clinical manifestations of these lesions are diverse and complicated to diagnose because of the anatomical complexity of thoracic region [3, 4, 12–14]. The present study showed that some neurological manifestations of lower thoracic or thoracolumbar lesions had strong correlations with the specific anatomical pathology and compressed segments.

Relationships between the manifestations and anatomical pathology

Among the anatomical pathologies, IDH more frequently showed correlations with the manifestations. Intervertebral disc herniation was a significant predictor for low back pain, foot drop, PTR hyporeflexia, and lower limb weakness. On the other hand, OPLL emerged as a significant positive predictor for severe urinary dysfunction because no significant compressed segments were identified for severe urinary dysfunction in the second step of the multivariate analysis.

Relationships between manifestations and compressed segments by anterior and posterior compression

Patients with low back pain were predominantly compressed at T11/12, regardless of anterior or posterior compression. One explanation for this relationship is the involvement of upper lumbar nerve roots including the L2 nerve root. Although there are individual differences in the TLCM [15] (TLCM in patients who showed low back pain and T11/12 compression were largely localized at the L1/2 intervertebral disc level and the upper-third of the L2 vertebra), the T12 to L3 nerve roots flank the spinal cord at the T11/12 level (Fig. 5) [16]. Involvement of the L2 nerve root, whose infiltration is proposed to be an effective treatment for low back pain [17, 18] may explain why patients with T11/12 compression showed a high prevalence of low back pain. Patients with T11/12 anterior compression showed a higher rate of lower limb pain, and there was a significant correlation between T12/L1 anterior compression and foot drop. These correlations also may be explained by the involvement of lumbar nerve roots [16]. T12/L1 anterior compression was implicated as preoperative predictors for hyporeflexia in the PTR, which can be related to lumbar nerve root involvement (Fig. 5). Patients who had T10/11 anterior compression were more likely to have lower limb muscle weakness. Given the fact that only T11 and T12 nerve roots exist at this level (Fig. 5) [16], this muscle weakness is explained by long tract involvement or the involvement of spinal cord segments L2 to L5 if they were located more rostally than previously thought [11].

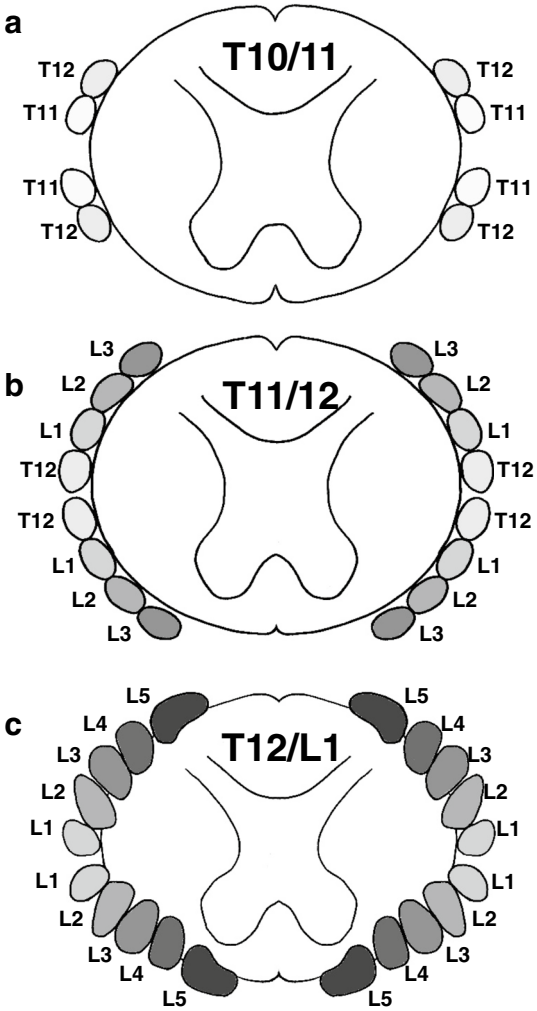

Fig. 5 Schematic showing significant correlations between compressed segments and the manifestations. **a** T10/11. The T11 and T12 on the top are dorsal sensory roots and the T11 and T12 on the bottom are ventral motor roots. **b** T11/12. The roots on the top are sensory and the roots on the bottom are motor. **c** T12/L1. The upper neural elements are sensory and the lower elements are motor

Common non-specific manifestations

Among the frequent complaints of patients with thoracic myelopathy, compressed segments and anatomical pathology were not identified as positive predictors for lower limb numbness or unsteady gait. However, only T11/T12 compression was negatively associated with subjective lower limb weakness, meaning it had a low probability if patients showed subjective weakness. As a previous report indicated [19], gait disturbance is one characteristic symptom of myelopathy. The analysis of gait may clarify the

characteristics of thoracic myelopathy, and may be valuable in the level diagnosis. Unfortunately, that analysis was not included in the present study, but further work including information related to gait disturbance is planned.

Factors associated with longer preoperative duration

Previous reports indicated that a longer preoperative duration is a significant predictor for poor results after surgery for thoracic myelopathy [6, 20–22]. The present study showed that elusive complaints such as "abnormal tightness in the lower limbs" are related to a longer preoperative duration. In contrast, serious manifestations that impair activities of daily living, such as subjective lower limb weakness and objective lower limb muscle weakness, can significantly shorten the preoperative duration. These manifestations can lead doctors to examine the thoracic region. T11/12 compression, which correlates with low back pain, also correlates with long preoperative duration. Such patients may be treated for lumbar disease because T11/12 is not often included in lumbar MRI.

This study has several limitations. We cannot conclude that non-specific symptoms such as lower limb numbness and unsteady gait were caused by thoracic myelopathy because we did not collect postoperative data on the corresponding symptoms. Furthermore, it is difficult to show direct correlations between manifestations and nervous system anatomy, such as nerve root locations and spinal cord segments. However, our study can add new information to the anatomical distribution of nerve roots and spinal cord segments in lower thoracic lesions.

Conclusion

This multicenter study clarified statistical correlations between compressed segments and the complex clinical manifestations caused by thoracic myelopathy. These correlations will help to better direct our attention to thoracic diseases and may facilitate early diagnosis though additional imaging investigations such as MRI or CTM, which are necessary for definitive diagnosis.

References

1. Yonenobu K, Ebara S, Fujiwara K, Yamashita K, Ono K, Yamamoto T, Harada N, Ogino H, Ojima S (1987) Thoracic myelopathy secondary to ossification of the spinal ligament. J Neurosurg 66(4):511–518
2. Ohtsuka K, Terayama K, Yanagihara M, Wada K, Kasuga K, Machida T, Matsushima S (1987) A radiological population study on the ossification of the posterior longitudinal ligament in the spine. Arch Orthop Trauma Surg 106(2):89–93
3. Toribatake Y, Baba H, Kawahara N, Mizuno K, Tomita K (1997) The epiconus syndrome presenting with radicular-type neurological features. Spinal Cord 35(3):163–170
4. Miyauchi A, Iwasaki M, Okuda S, Morita M, Kita K (2004) Symptoms for the patients with ossification of the ligamentum flavum. Bessatsu Seikeigeka 45:94–101
5. Yoon SH, Kim WH, Chung SB, Jin YJ, Park KW, Lee JW, Chung SK, Kim KJ, Yeom JS, Jahng TA, Chung CK, Kang HS, Kim HJ (2011) Clinical analysis of thoracic ossified ligamentum flavum without ventral compressive lesion. Eur Spine J 20(2):216–223
6. Aizawa T, Sato T, Sasaki H, Matsumoto F, Morozumi N, Kusakabe T, Itoi E, Kokubun S (2007) Results of surgical treatment for thoracic myelopathy: minimum 2-year follow-up study in 132 patients. J Neurosurg Spine 7(1):13–20
7. Matsumoto M, Toyama Y, Chikuda H, Takeshita K, Kato T, Shindo S, Abumi K, Takahata M, Nohara Y, Taneichi H, Tomita K, Kawahara N, Imagama S, Matsuyama Y, Yamazaki M, Okawa A (2011) Outcomes of fusion surgery for ossification of the posterior longitudinal ligament of the thoracic spine: a multicenter retrospective survey: clinical article. J Neurosurg Spine 15(4):380–385
8. Matsumoto M, Chiba K, Toyama Y, Takeshita K, Seichi A, Nakamura K, Arimizu J, Fujibayashi S, Hirabayashi S, Hirano T, Iwasaki M, Kaneoka K, Kawaguchi Y, Ijiri K, Maeda T, Matsuyama Y, Mikami Y, Murakami H, Nagashima H, Nagata K, Nakahara S, Nohara Y, Oka S, Sakamoto K, Saruhashi Y, Sasao Y, Shimizu K, Taguchi T, Takahashi M, Tanaka Y, Tani T, Tokuhashi Y, Uchida K, Yamamoto K, Yamazaki M, Yokoyama T, Yoshida M, Nishiwaki Y (2008) Surgical results and related factors for ossification of posterior longitudinal ligament of the thoracic spine: a multiinstitutional retrospective study. Spine 33(9):1034–1041
9. Ando K, Imagama S, Wakao N, Hirano K, Tauchi R, Muramoto A, Kato F, Yukawa Y, Kawakami N, Sato K, Matsubara Y, Kanemura T, Matsuyama Y, Ishiguro N (2012) Examination of the influence of ossification of the anterior longitudinal ligament on symptom progression and surgical outcome of ossification of the thoracic ligamentum flavum: a multicenter study. J Neurosurg Spine 16(2):147–153
10. Anonymous (1994) Japanese orthopaedic association: scoring system for cervical myelopathy. Jpn J Orthop Assoc 68:490–503
11. Ando T (2002) Anatomy and symptomatology of the lower end of the spinal cord. Spine Spinal Cord 15(4):266–271
12. Otani K, Yoshida M, Fujii E, Nakai S, Shibasaki K (1988) Thoracic disc herniation: surgical treatment in 23 patients. Spine 13(11):1262–1267
13. Tokuhashi Y, Matsuzaki H, Uematsu Y, Oda H (2001) Symptoms of thoracolumbar junction disc herniation. Spine 26(22):E512–E518
14. Matsumoto M, Chiba K, Toyama Y (2002) Disc herniation at the thoracolumbar junction. Spine Spinal Cord 15(4):293–297
15. Soleiman J, Demaerel P, Rocher S, Maes F, Marchal G (2005) Magnetic resonance imaging study of the level of termination of the conus medullaris and the thecal sac: influence of age and gender. Spine 30(16):1875–1880
16. Wall EJ, Cohen MS, Abitbol JJ, Garfin SR (1990) Organization of intrathecal nerve roots at the level of the conus medullaris. J Bone Jt Surg Am 72(10):1495–1499
17. Murata Y, Kato Y, Miyamoto K, Takahashi K (2009) Clinical study of low back pain and radicular pain pathways by using l2 spinal nerve root infiltration: a randomized, controlled, clinical trial. Spine 34(19):2008–2013
18. Ohtori S, Nakamura S, Koshi T, Yamashita M, Yamauchi K, Inoue G, Orita S, Eguchi Y, Suzuki M, Ochiai N, Kishida S, Takaso M, Aoki Y, Kuniyoshi K, Nakamura J, Ishikawa T, Arai G, Miyagi M, Kamoda H, Suzuki M, Takahashi Y, Toyone T, Yamagata M, Takahashi K (2010) Effectiveness of L2 spinal nerve infiltration

for selective discogenic low back pain patients. J Orthop Sci 15(6):731–736
19. Singh A, Crockard HA (1999) Quantitative assessment of cervical spondylotic myelopathy by a simple walking test. Lancet 354(9176):370–373
20. Miyakoshi N, Shimada Y, Suzuki T, Hongo M, Kasukawa Y, Okada K, Itoi E (2003) Factors related to long-term outcome after decompressive surgery for ossification of the ligamentum flavum of the thoracic spine. J Neurosurg 99(3 Suppl):251–256
21. Shiokawa K, Hanakita J, Suwa H, Saiki M, Oda M, Kajiwara M (2001) Clinical analysis and prognostic study of ossified ligamentum flavum of the thoracic spine. J Neurosurg 94(2 Suppl):221–226
22. Takei Y (1996) Posterior decompression surgery of thoracic myelopathy due to ossification of intraspinal canal ligaments. J Tokyo Med Coll 54:253–263