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ORIGINAL ARTICLE

Radiographic and clinical features of thoracic disk disease associated with myelopathy: a retrospective analysis of 257 cases

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Abstract

Purpose To analyze the clinical and radiographic characteristics of thoracic disk disease associated with myelopathy (TDM).

Methods This is a retrospective clinical review of prospectively collected imaging data based at a single institute. Based on preoperative CT and MRI, we classified TDM as thoracic disk herniation (TDH), THD with ossification (THDO), TDH with posterior bony avulsions of the vertebrae (TDH with PBA), TDH with posterior vertebral osteophytes (TDH with PVO), giant thoracic osteophyte and calcific discitis with herniation (CDH). Patient characteristics and radiographic data were compared between different types of TDM.

Results Among the 257 patients included, 12.06% of patients presented with symptoms after traumatic events. The most frequent complaint at onset and preoperative was back pain (29.2%) and subjective lower limb weakness (75.5%), respectively. All TDH with PBA is distributed at the lower thoracic segments, while CDH predominantly in the middle and lower thoracic segments. TDH with PBA was more frequent in men than TDH and CDH. Compared with TDH, TDHO, and TDH with PVO, TDH with PBA was younger in surgery age, and TDH and CDH had lower preoperative JOA scores than TDH with PBA. CDH had a larger ventral occupying ratio than TDH, TDHO, and TDH with PBA.

Conclusions The onset of TDM was generally insidious but may be triggered acutely by apparently trivial events. With a low prevalence, TDM varied clinical symptoms. Different types of TDM had various clinical features, which might indicate different pathological mechanisms.

Keywords Thoracic disk diseases · Clinical features · Radiographic characteristics · Thoracic disk herniation · THD with ossification

Introduction

Thoracic disk diseases (TDD) are a relatively rare occurrence compared to disk herniations in the cervical or lumbar spine. The incidence of symptomatic TDD is estimated to be 1 in 1000 to 1 in 1,000,000 in the general population, and thoracic discectomy procedures make up only 0.15–4% of all spinal disk surgical procedures [1, 2]. The presentation is a combination of pain, ataxia, the motor deficit in lower limbs, paresthesia, and bowel and bladder dysfunction. The variety of clinical manifestations makes diagnosis difficult since it can mimic several medical conditions and is often misdiagnosed as a cardiac, gastrointestinal, neoplastic, demyelinating disease, and cervical or lumbar disorders [3, 4]. Thus, accurate diagnosis and treatment of TDD still is a challenge in clinical practice because of its rarity and various presentation. Misdiagnosis can lead to prolonged

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preoperative disease duration, which can lead to irreversible nerve damage and even unnecessary surgery in the wrong region of the spine, which seriously affects the quality of life of patients [5].

The anatomical pathology of thoracic disk disease with myelopathy (TDM) is diverse, and previous studies have a confusing classification of TDM with different names [6–8]. Only a few studies use the term "thoracic disk disease" [9–13]. Some researchers classified TDD into "soft disk herniation" and "hard/sclerosing thoracic disk herniation" according to whether the disk herniation has calcification or partial ossification [14–16]. For TDH with calcification, other studies also called it "calcified thoracic disk herniation" [17–21], "thoracic intervertebral disk calcification and herniation" [22] or "calcific discitis with thoracic disk herniation" [23]. Then, a close relationship is shown between thoracolumbar disk herniation and typical or atypical Scheuermann's disease [24], and it has been reported that up to 85.7% of patients with TLDH had posterior bony avulsions of the vertebrae (PBA) [25]. TDH with osteophytes formation at the posterior edge of the vertebral body is also one of the causes of thoracic myelopathy [26–28]. Moreover, "giant thoracic osteophyte" is defined by Coumans et al. [29], which refers to isolated, more extensive than typical degenerative osteophytes. Although various diagnostic names are used, the terms mentioned above are related to thoracic disk disease.

Due to the low incidence, relatively few previous reports, and the lack of bulk case data, unfortunately, much is unknown about the pathogenesis of TDM and no systematic consensus on the disease at present. Although previous studies have reported the effectiveness of different surgical procedures for TDM, clinical and radiographic features of different TDM have not been reported. We speculate that different types of TDM may indicate different natural history, pathogenesis, and clinical features. Thus, we conducted this study to test this hypothesis.

Patients and methods

Study design and subjects

This was a retrospective study of 276 patients who underwent surgery after a diagnosis of TDM (T1/2–T12/L1) at our department between June 2006 and June 2019. The exclusion criteria were diffuse idiopathic skeletal hyperostosis, spinal infections, spinal compression fractures, malignant tumors of the spine, thoracic kyphosis, and scoliosis rotational deformity. Finally, nineteen patients who had incomplete radiographic materials were excluded. Ultimately, 257 patients were enrolled. All patients had neurologic symptoms caused by TDM that warranted surgery. Information on the demographic characteristics, the initial and preoperative complaints, predisposing factors, causes of aggravation, compressed segments, and preoperative disease duration were assessed. In addition, we evaluated the clinical examination findings, including deep tendon reflexes (DTRs), Babinski sign, and the JOA score (full score, 11 points) [30]. This study was approved by the Ethical Committee of our hospital and was conducted according to the principles of the Declaration of Helsinki. The informed consent was waived because this was a retrospective study.

Radiographic measurements

The compressed segments were defined as the segments that required operation, confirmed with T2-weighted MRI and CT. According to the preoperative CT and MRI, TDM was divided into:

(1) Thoracic disk herniation (TDH): MR and CT showed degenerative changes in thoracic intervertebral disks with partial or total rupture of the annulus fibrosus, protrusion (or prolapse) of the nucleus pulposus tissue from the rupture site to the posterior (lateral) side or spinal canal, and thus compression of adjacent tissues, such as spinal nerve root and spinal cord, without ossification of the annulus fibrosus and posterior longitudinal ligament, and no calcification of the nucleus pulposus (Fig.1a, b).
(2) Thoracic disk herniation with ossification (THDO): TDH with ossification of the posterior structure of the nucleus pulposus (posterior longitudinal ligament or annulus fibrosus) (Fig. 2a, b).
(3) TDH with posterior bony avulsions of the vertebrae (TDH with PBA): TDH was confirmed by MRI, and CT showed an irregular bony defect in the posterior margin of the cranial or (and) caudal vertebral body with an avulsed bony edge that can be partially continuous with the vertebral body or separated. MR reveals that the defect in the vertebral body is filled with disc material (Fig. 3a, b) [31].
(4) TDH with posterior vertebral osteophytes (TDH with PVO): MRI and CT showed intervertebral disc herniation combined with osteophytes formation at the posterior edge of adjacent upper and lower vertebral bodies, presenting labial-like or broad basal-tip spine-like protuberances (bone spurs hyperplasia). Intervertebral disc material filling between the upper and lower osteophytes, and spinal cord or nerve root was compressed (Fig. 4) [32].
(5) Giant thoracic osteophyte (GTO): (1) isolated, (2) occurs in the absence of other structural abnormalities such as ventral osteophytes or instability, (3) penetrates

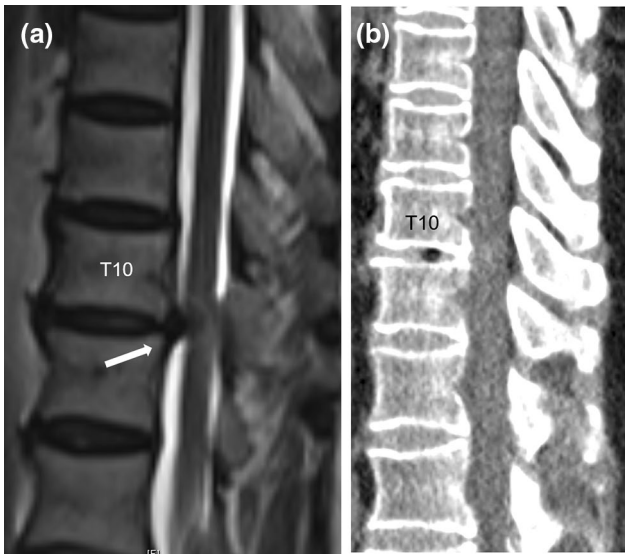

Fig. 1 Sagittal magnetic resonance imaging (MRI) scans and computed tomography (CT) of the thoracic spine demonstrating TDM caused by TDH. 1(**a**) A typical T2W MRI image of a patient with TDH spinal compression and T2-hyperintensity at the T10-11 disk level. The white arrow indicates the herniated disk. 1(**b**) CT showed vacuum phenomena involving the T10-11 intervertebral disks, without ossification of the annulus fibrosus or posterior longitudinal ligament, and no calcification of the nucleus pulposus

the dura, and (4) is larger than typical osteophytes (Fig. 5) [29].

(6) Calcific discitis with herniation (CDH): CT demonstrated calcification of the nucleus pulposus in the intervertebral space along with calcification of the intervertebral disk protruding into the vertebral canal, and the spinal cord was compressed (Figs.6) [23]. Intraoperative findings were like semisolid toothpaste or lime sludge.

When comparing clinical features of different types of TDM divided above, we only analyzed the 201 patients with a single segment involved to exclude the influence of multiple compression segments. The spinal cord ventral occupying ratio was measured according to the method described by Hott et al. [33], which defines the ventral occupying more than 40% of the spinal canal as a unique condition called giant occupying. All CT and MRI scans were evaluated by two independent observers who were blinded to the patient group and patient medical records. The radiographs were numbered randomly, and each observer was provided a data collection sheet to record the measurements. To improve the measurement precision, all 257 cases were measured twice by each observer, and the mean of the two measurements was considered.

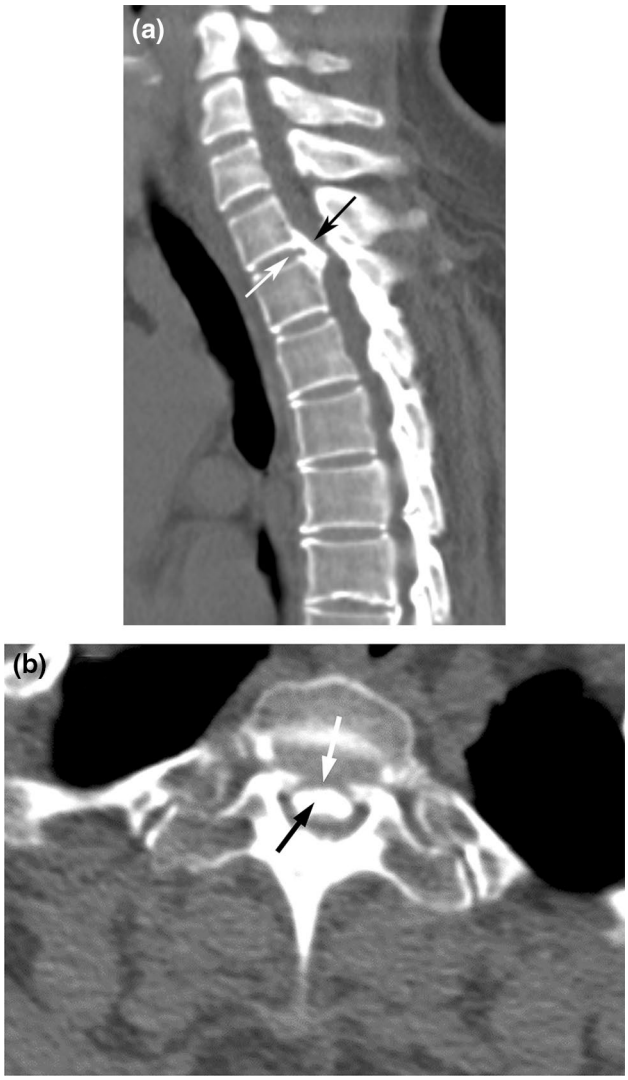

Fig. 2 CT scan of thoracic disk herniation with posterior longitudinal ligament ossification (THDO). 2(**a**) Sagittal CT and 2(**b**) axial CT, the white arrow indicates the herniated disk, and the black arrow indicates the ossified posterior longitudinal ligament

Statistical analysis

SPSS software (version 22.0; IBM) was used for statistical analysis. The proportion, segmental distribution, and clinical features of different TDM in all 257 patients were summarized. Comparisons among TDH, TDHO, TDH with PBA, TDH with PVO, and CDH were performed with the Mann–Whitney U test after the Kruskal–Wallis test; a corrected $p < 0.01$ (corrected by the Bonferroni method) was used to indicate significance. Intra-observer reproducibility and inter-observer reliability were calculated using the intraclass correlation coefficient (ICC) for occupying ratio and classification. ICC values were interpreted as follows: 0.00 to 0.20 indicated slight agreement; 0.21 to 0.40 indicated fair

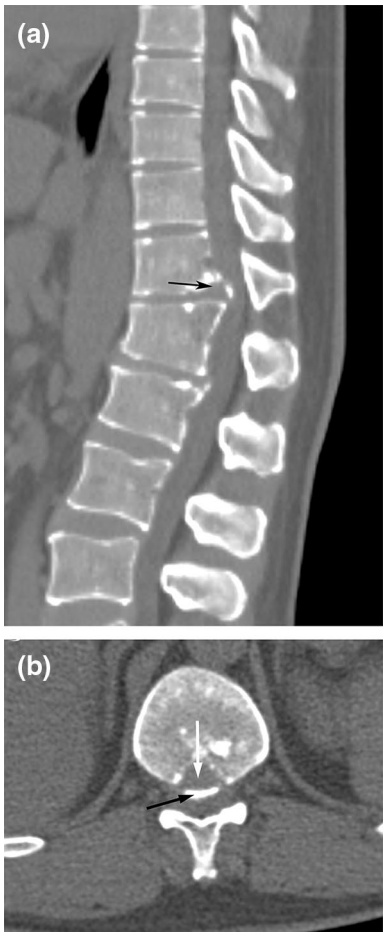

Fig. 3 CT of the thoracic spine demonstrating TDM caused by TDH + PBA. 3(**a**) Sagittal CT shows a defect at the posterior–inferior edge of the T11 vertebra, and the defect is filled with disk material. 3(**b**) Axial CT at the same level demonstrates the irregular defect (white arrow) and the avulsed bony mass (black arrow)

agreement; 0.41 to 0.60 indicated moderate agreement; 0.61 to 0.80 indicated substantial agreement; and 0.81 to 1.00 indicated almost perfect agreement was used for statistical analysis [34].

Results

Patient characteristics

From March 2006 to March 2019, 59,286 patients underwent spinal surgery, including 3354 patients who underwent thoracic surgery. During the same period, 276 patients with TDM were treated, which accounted for 0.47% and 8.23% in spinal surgery and thoracic surgery. After excluding 19 patients who had incomplete radiographic materials, 257 (93.12%) patients (194 males, 63 females; mean age 48.13 ± 14.15 years; range, 19 to 84 years) were included (3,084 disk levels). Twenty-nine (11.3%) patients belonged to the age group of younger than 30 years, 51 (19.8%) patients to 30–39 years, 44 (17.1%) patients to 40–49 years, 71 (27.6%) patients to 50–59 years, 48 (18.7%) patients to 60-69 years, 12 (4.7%) patients to 70–79 and 2 (0.8%) patients were aged 80 years or over. The first three occupations of the patients were farmers (24.5%), company employees (12.5%), and workers (10.5%).

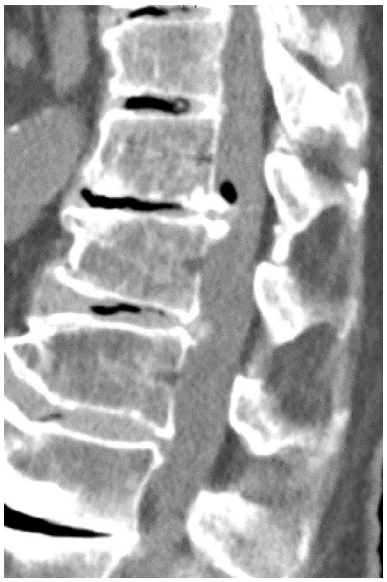

Fig. 4 Sagittal CT demonstrating TDM caused by TDH with PVO. Bone spurs hyperplasia at the posterior edge of T12 and L1

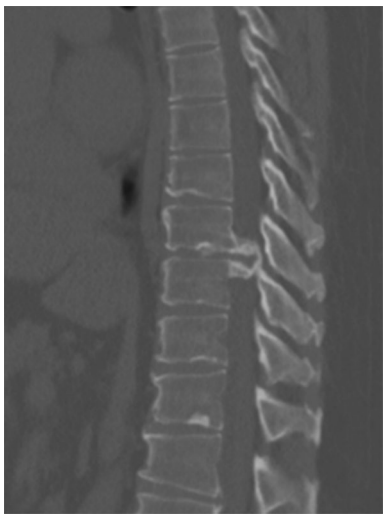

Fig. 5 Sagittal CT demonstrating TDM caused by giant thoracic osteophyte: isolated, occurs in the absence of other structural abnormalities such as ventral osteophytes or instability, penetrates the dura, and is larger than typical osteophytes

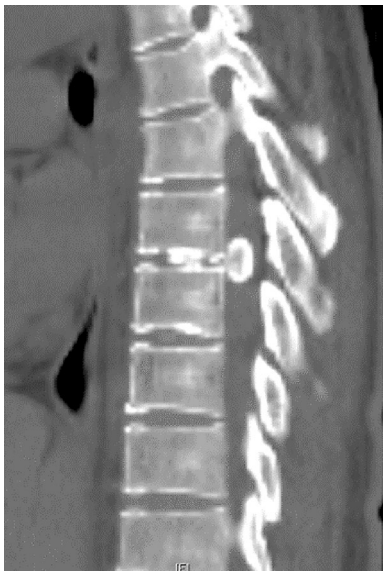

Fig. 6 Sagittal CT demonstrating TDM caused by calcific discitis with herniation (CDH): CT demonstrated calcification of the nucleus pulposus in the intervertebral space along with calcification of the intervertebral disk protruding into the thoracic canal

Clinical features of TDM

The median preoperative disease duration was 24 months (range0.01–360.00 months). Thirty-one (12.06%) patients presented with symptoms had clear predisposing factors before the development of initial symptoms [lifting heavy objects (13), Car accident (2), back sprain (1), jumping on flat ground (1), fall damage (10), swimming (1), dancing (1), strike (2)]. The complaints at onset and preoperative are summarized in Table 1. The most frequent complaint at onset was low back pain (29.2%), followed by lower limb numbness (28.4%). Symptoms of 127 (49.4%) patients worsen significantly at a median of 22 months after onset. Only seven patients have specific triggers [knocked down by a car (1), fatigue (1), fall damage (4), trauma (1)]. The most frequent complaint at preoperative was subjective lower limb weakness (75.5%), followed by low limb numbness (74.3%). The frequency of all complaints increased from onset to surgery. The preoperative Frankel grade was D in 156 patients, C in 15 patients, B in 83 patients, and A in three patients. Scheuermann's disease was coexisting in 137 patients (typical 31, atypical 106).

Classification and segmental distribution of TDM

There were 331 levels of the 257 patients with TDM, and 201 (78.20%) patients had single-level involvements. Forty-six patients had two-level TDM, six had three-level TDM, and the other four had more three-level TDM. The most commonly affected levels were T11/12 (36.3%), T12/L1 (29.3%), and T10/11 (17.2%). The lower thoracic segments between T9 and L1 were the major locations for TDM, accounting for 87.3%, whereas upper thoracic 3.3% and middle thoracic 9.4%.

The classification of TDM showed excellent intra-observer and inter-observer reliability (ICC = 0.98 and 0.96, respectively), indicating that the classification was reliable. There were 85 (25.7%) TDH, 32 (9.7%) TDHO, 147 (44.4%) TDH with PBA, 37 (11.2%) TDH with PVO, 6 (1.8%) GTO, and 24 (7.3%) CDH. The distribution of a different TDM identified by CT and MRI is shown in detail in Table 2 and Fig. 7. The distribution of different types of TDM shows a significant difference ($X^2 = 82.56$, $p < 0.001$). CDH mainly distributed in the middle and lower thoracic spine, while TDH with PBA is only distributed in the lower thoracic spine and GTO distributed in the upper and the lower thoracic spine (Table 3).

Clinical features of different types of TDM

The clinical features of five different types of TDM are shown in Table 4. In this part, we only analyzed the 201 patients with a single segment involved to exclude the influence of multiple compression segments, and GTO was also not analyzed because of only six cases. The age of patients with TDH with PBA was 40.55 ± 12.18 years at surgery, which was significantly younger than patients with TDH, TDHO, and TDH with PVO ($p < 0.001$). 90.5% TDH with PBA patients were male, which significantly higher than the proportion of male patients with TDH ($p < 0.001$) and CDH ($p = 0.006$). 71.4% of patients with TDHO showed at some point in time when symptoms significantly worsen before the surgery, which was significantly higher than the proportion of TDH with PBA patients ($p = 0.003$). The duration between the time symptoms significantly worsen from the onset of TDH with PVO patients and TDHO patients was significantly longer than that of patients with TDH and CDH. Those with TDH with PBA had higher preoperative mJOA scores than those with TDH ($p = 0.001$) and CDH ($p < 0.001$). Compared to TDH with PBA, TDH with PVO, and CDH, TDH had a lower ventral occupying rate, and CDH had a higher ventral occupying rate than TDHO and TDH with PBA and CDH, and TDH with PBA had a higher proportion of giant occupying than TDH and TDHO. For the ventral occupying ratio, the ICC across the 201 cases for intra-observer was 0.964 (95% confidence interval [CI], 0.955 to 0.971) and for inter-observer was 0.945 (95% confidence interval [CI], 0.932 to 0.956), which showed almost perfect agreement. The incidences of typical or atypical

Table 1 Clinical features of patients with TDM

Variable	
Age, years	48.13 ± 14.15(19 ~ 84)
Gender (male:female)	194 (75.5%):63 (24.5%)
Preoperative duration	24 (6–48)
No. of patients with symptoms worsen, n(%)	127 (49.4%)
Duration from onset to exacerbation, months	22 (6–60)
Preoperative symptoms and signs	
Middle back pain	64 (24.9%)
Low back pain	122 (47.5%)
Low back discomfort	12 (4.7%)
Trunk numbness	60 (23.3%)
Lower limb numbness	191 (74.3%)
Lower limb pain	93 (36.2%)
Abnormal tightness in the lower limbs	4 (1.6%)
Subjective lower limb weakness	194 (75.5%)
Subjective lower limb weakness	13 (5.1%)
Unsteady gait	126 (49.0%)
Foot drop	29 (11.3%)
Zonesthesia	32 (12.5%)
Sphincter dysfunction	93 (36.2%)
Intermittent claudication	65 (25.3%)
Spasticity	76 (29.6%)
PTR (hyperreflexia:normal reflexia:hyporeflexia)	139 (54.1%):49 (19.1%):69 (26.8%)
ATR (hyperreflexia:normal reflexia:hyporeflexia)	88 (34.2%):77 (30.0%):92 (35.8%)
Babinski sign positive	118 (45.9%)
Preoperative mJOA score	5.92 ± 2.05
Typical Scheuermann's disease	31 (12.1%)
Atypical Scheuermann's disease	106 (41.2%)

Values are presented as number of cases (%), mean ± SD, or median (Q1–Q3)

mJOA, Modified Japanese Orthopedic Association (JOA); PTR, patellar tendon reflex; ATR Achilles tendon reflex

Scheuermann's disease were all significantly higher in the TDH with the PBA group than in other groups.

Discussion

This study retrospectively reviewed a total of 331 thoracic intervertebral disk levels in 257 patients undergoing surgery with TDM and analyzed the epidemiology, clinical manifestations, and radiographic and clinical features of different types of TDM. Our study results showed that the incidence of TDM was low, and the ratio of male to female was about 3:1, and the surgical ages of patients were mainly between 30 and 70 years old. The lower thoracic segments were the primary locations for TDM. The onset of TDM was generally insidious, but some of the patients had apparent predisposing factors before the development of initial symptoms, and the symptoms of nearly half of patients worsen significantly after onset. TDM mainly affected the lower limbs. There were significant differences in radiographic and clinical features among patients with different types of TDM (Table 4).

Symptomatic TDH is a rare condition, and a history of trauma has been found in 3 to 37% of TDH cases [35], and Scheuermann's disease patients are more susceptible to develop TDH [24, 25]. Our study found that patients with TDM accounted for 0.47% of spinal surgery and 8.23% of thoracic surgery in the same period, and 12.06% of patients had a clear history of trauma before onset, which was similar to previous reports.

The etiology of different types of TDM is different. Herniation of the nucleus pulposus must be caused by a combination of high pressure within the nucleus and weakness of the annulus fibrosus. Aging is associated with increased deposition of insoluble collagen in the disk matrix, which reduces the gelatinous nature of the nucleus pulposus as well as the elasticity of the annulus fibrosus. When the annulus becomes less elastic, the probability of tearing increases in

Table 2 Distribution of compressed segments of 331 disks in 257 patients based on anatomical pathology of different TDM

Segment	TDH n (%)	TDHO n (%)	TDH with PBA n (%)	TDH with PVO n (%)	GTO n (%)	CDH n (%)	Total
T1-2	0 (0%)	1 (33.3%)	0 (0%)	1 (33.3%)	1 (33.3%)	0 (0%)	3(0.9%)
T2-3	1 (50.0%)	0 (0%)	0 (0%)	0 (0%)	1 (50.0%)	0 (0%)	2(0.6%)
T3-4	2 (50.0%)	0 (0%)	0 (0%)	1 (25.0%)	0 (0%)	1 (25.0%)	4(1.2%)
T4-5	1 (50.0%)	0 (0%)	0 (0%)	1 (50.0%)	0 (0%)	0 (0%)	2(0.6%)
T5-6	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (100%)	1(0.3%)
T6-7	1 (20.0%)	0 (0%)	0 (0%)	2 (40.0%)	0 (0%)	2 (40.0%)	5(1.5%)
T7-8	2 (20.0%)	1 (10.0%)	0 (0%)	2 (20.0%)	0 (0%)	5 (50.0%)	10(3.0%)
T8-9	3 (25.0%)	3 (25.0%)	0 (0%)	3 (25.0%)	0 (0%)	3 (25.0%)	12(3.6%)
T9-10	3 (16.7%)	2 (11.1%)	1 (5.6%)	5 (27.8%)	1 (5.6%)	5 (27.8%)	18(5.4%)
T10-11	29 (50.9%)	5 (8.8%)	14 (24.6%)	3 (5.3%)	1 (1.8%)	5 (8.8%)	57 (17.2%)
T11-12	31 (29.2%)	11 (9.2%)	65 (54.2%)	11(9.2%)	0 (0%)	2 (1.7%)	120(36.3%)
T12-L1	12 (12.4%)	9 (9.3%)	67 (69.1%)	8 (8.2%)	1 (1.0%)	0 (0%)	97 (29.3%)
Total	85(25.7%)	32(9.7%)	147(44.4%)	37(11.2%)	6(1.8%)	24(7.3%)	331(100%)

The evaluation and ratio calculations were based on the total number of 331 disk lesions in those 257 patients

Values are presented as number of cases (%)

TDH, thoracic disk herniation; THDO, THD with annulus fibrosus or posterior longitudinal ligament ossification; TDH with PBA, TDH with posterior bony avulsions of the vertebrae; TDH with PVO, TDH with posterior vertebral osteophytes; *GTO*, giant thoracic osteophyte; *CDH*, calcific discitis with herniation

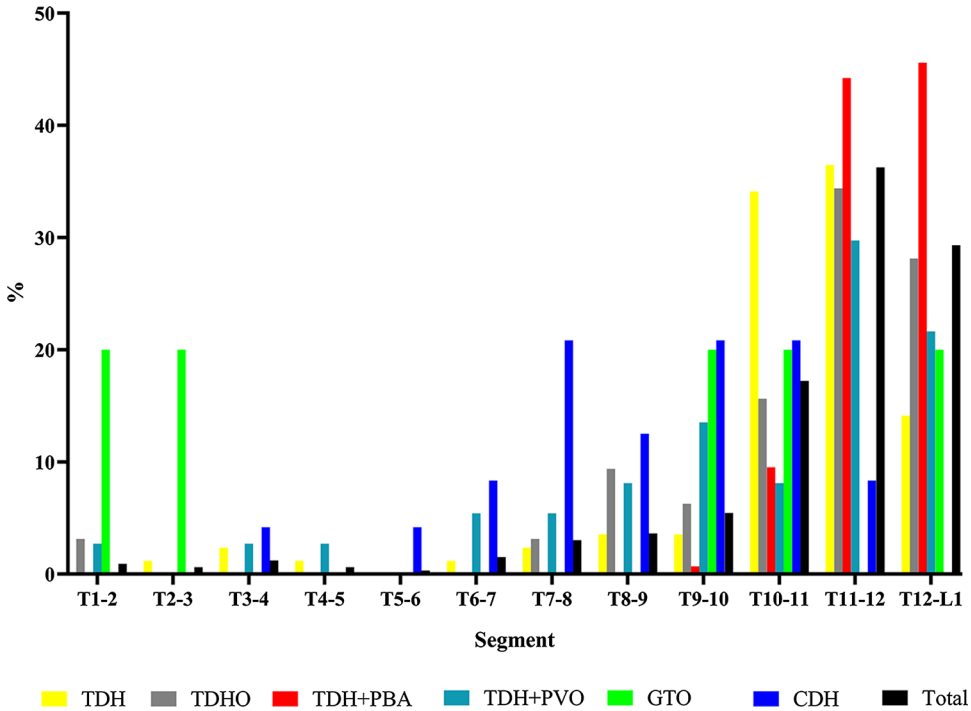

Fig. 7 Distribution of compressed segments based on anatomical pathology. The histogram demonstrates the segmental distribution of TDM patients. Most TDM is lower thoracic segments between T9 and L1 (87.3%). The most common levels of involvement are T11-12 (36.3%), (36.3%), T12/L1 (29.3%), and T10/11 (17.2%). CDH mainly distributed in the mid-lower thoracic spine, while TDH with PBA only distributed in the lower thoracic spine and GTO distributed in the upper and the lower thoracic spine

proportion to age [13]. We found that the average age of patients with THD was the oldest, which may be related to the degeneration of the intervertebral disk. Calcification or ossification of thoracic disks are common, which were described in some previous studies using the term "hard thoracic herniated thoracic," and this referred that CT scans and MRI showed an ossified or calcified herniation or both [14]. Gille et al. [15] reported 18 cases of hard thoracic herniated disks, and pathological examination showed ossification in ten cases and calcification in eight cases. The histopathological examination of herniated ossified disk reveals bony lamella organized in trabecula containing fatty marrow, while calcified disk showed calcium deposits and crystals. Calcium deposits often accumulate in the nucleus pulposus

Table 3 The distribution of 331 disks in different-type thoracic disk diseases

TDM	Thoracic vertebrae		
	Upper (T1-5)	Middle (T5-9)	Lower (T9-L1)
Total	11 (3.3%)	31 (9.4%)	289 (87.3%)
TDH	4 (4.7%)	6 (7.1%)	75 (88.2%)
TDHO	1 (3.1%)	4 (12.5%)	27 (84.4%)
TDH with PBA	0 (0.0%)	0 (0.0%)	147(100.0%)
TDH with PVO	3 (8.1%)	10 (27.0%)	24 (64.9%)
GTO	2 (33.3%)	0 (0%)	4 (66.7%)
CDH	1 (4.2%)	11 (45.8%)	12 (50.0%)

The evaluation and ratio calculations were based on the total number of 331 disk lesions in those 257 patients

Values are presented as number of cases (%)

TDH, thoracic disk herniation; *THDO*, *THD* with annulus fibrosus or posterior longitudinal ligament ossification; *TDH* with *PBA*, *TDH* with posterior bony avulsions of the vertebrae; *TDH* with *PVO*, *TDH* with posterior vertebral osteophytes; *GTO*, giant thoracic osteophyte; *CDH*, calcific discitis with herniation

and/or the annulus fibrosis resulting from degeneration or various underlying diseases such as Scheuermann's disease, metabolic syndromes, or previous trauma. The difference is that ossified components in herniated disk material usually originate from the adjacent posterior longitudinal ligament, with areas of adhesions [36]. However, it is difficult to distinguish the origination of ossification from the annulus fibrosus and the posterior longitudinal ligament ossification on the imaging.

The calcification mechanism remains unknown, and previous reports have been published that a calcified HTD may sometimes regress spontaneously [23]. Causes of intervertebral disk calcification include alkaptonuria, hemochromatosis, amyloidosis, hyperparathyroidism, and in the vast majority of cases, degenerative changes [23]. Calcific discitis is a self-limiting disorder that is generally considered only in children and most commonly presents as axial pain. However, only five patients (21.7%) present pain in our CDH group, and all patients had clear surgical indications with neurological deficits and severe preoperative symptoms refractory to conservative

Table 4 Clinical features of different types of TDM in 201 single-level involved patients

	TDH	TDHO	TDH + PBA	TDH + PVO	CDH	Five-group comparison *p* value
No. of patients	53(26.4%)	21(10.4%)	84(41.8%)	20(10.0%)	23 (11.4%)	
Age	57.25 ± 14.60	54.52 ± 9.84	40.55 ± 12.18	54.35 ± 11.34	48.74 ± 8.82	< 0.001*
Two-group comparison *p* value: TDH + PBA vs TDH, $p < 0.001$; TDH + PBA vs TDHO, $p < 0.001$; TDH + PBA versus TDH + PVO, $p < 0.001$						
Gender (male)	34(64.2%)	14(66.7%)	76 (90.5%)	15 (75.0%)	15 (65.2%)	0.001*
Two-group comparison p value: TDH + PBA vs TDH, $p < 0.001$; TDH + PBA versus CDH, $p = 0.006$						
No. of patients with symptoms worsen	28(52.8%)	15(71.4%)	30(35.7%)	9(45.0%)	11(47.8%)	0.039*
Two-group comparison *p* value: TDHO versus TDH + PBA, $p = 0.003$						
[a]Duration from onset to exacerbation, months	13.5(2.7–33.5)	36(23.5–68)	23(12–70)	36(12–88)	11(6.5–17)	0.004*
Two-group comparison *p* value: TDHO versus TDH, $p = 0.005$; TDHO versus CDH, $p = 0.003$; TDH + PVO versus TDH, $p = 0.008$; TDH + PVO versus CDH, $p = 0.007$						
mJOA	5.53 ± 2.06	5.69 ± 2.32	6.74 ± 1.73	5.63 ± 2.63	4.76 ± 2.14	< 0.001*
Two-group comparison *p* value: TDH + PBA vs TDH, $p = 0.001$; TDH + PBA versus CDH, $p < 0.001$						
Ventral occupying rate	52.76 ± 28.71	53.24 ± 13.50	57.64 ± 10.32	63.04 ± 13.63	74.87 ± 11.79	< 0.001*
Two-group comparison p value: TDH vs TDH + PBA, $p = 0.001$; TDH versus TDH + PVO, $p < 0.001$; TDH versus CDH, $p < 0.001$; TDHO versus CDH, $p < 0.001$; TDH + PBA versus CDH, $p < 0.001$						
No. of patients with giant occupying	38 (71.7%)	16 (76.2%)	83 (98.8%)	19(95.0%)	23(100%)	< 0.001*
Two-group comparison p value: TDH versus TDH + PBA, $p < 0.001$; TDH versus CDH, $p = 0.004$;TDHO versus TDH + PBA, $p = 0.001$; TDHO versus CDH, $p < 0.001$						
Scheuermann`s disease	21(39.6%)	8(38.1%)	70(83.3%)	3(15.0%)	0(0%)	< 0.001*
Two-group comparison *p* value: TDH + PBA versus TDH, $p < 0.001$; TDH + PBA versus CDH, $p < 0.001$; TDH + PBA versus TDHO, $p < 0.001$; TDH + PBA versus TDH + PVO, $p < 0.001$; CDH versus TDH, $p < 0.001$; CDH versus TDHO, $p < 0.001$;						

Values are presented as number of cases (%), mean ± SD, or median (Q1–Q3)

TDH, thoracic disk herniation; *THDO, THD* with annulus fibrosus or posterior longitudinal ligament ossification; *TDH* with *PBA*, *TDH* with posterior bony avulsions of the vertebrae; *TDH* with *PVO*, *TDH* with posterior vertebral osteophytes; *CDH*, calcific discitis with herniation; *SD* Scheuermann`s disease

[a]Data are not normally distributed; median (Q1–Q3) and the rank-sum tests were used here

*Statistically significant

therapy. No metabolic disorders mentioned above were diagnosed in all CDH patients. Besides, we observed that the free nucleus pulposus tissue during surgery was like a semisolid toothpaste with a smooth, lentiform, and round shape, which could be removed entirely after flushing with wash water. We speculated that calcification occurred after long-term stable calcium deposition in the thoracic intervertebral disk. At this stage, no clinical symptoms can be observed. Subsequently, a series of spontaneous liquefaction and inflammatory reactions damaged the annulus fibrosus and eventually leading to thoracic disk herniation and severe neurological symptoms. The pathogenesis and treatment of calcific discitis with herniation still need to be further explored.

The pathogenesis of osteophytes is also related to the degeneration of nucleus pulposus. With age, the nucleus pulposus loses water content and turgor, leading to a decrease in disk height and a decrease in resiliency to load-bearing weight. Concomitantly, the annulus fibrosus also begins to lose its elasticity. To maintain maximal load-bearing potential, the margins of the zygapophyseal joint form bony projections increase the surface area for weight distribution. This adaptation does not adequately relieve joint pressure, resulting in an increased bony protrusion from the vertebral body [37].

The epiphyseal ring ossifies at 4 to 6 years of age and fully fused to maturity before the age of 18 to 25 years. It is firmly attached to the annulus fibrosus by Sharpey's fibers, but the apophyseal ring is weakly joined to the vertebral body. There are several hypotheses about the occurrence of posterior bony avulsions of the vertebrae, including sports injuries and injuries, repetitive extension, and degeneration of the disk and cartilage [31]. Previous studies have found that TDH with PBA is associated with typical and atypical Scheuermann's disease [25]. Compared with other types of TDM, the age of TDH with PBA is younger, and preoperative symptoms are mild. That may be associated with microtrauma and disk degeneration.

This study is a large sample single-center retrospective study, and we review 257 cases with TDM proposing a classification of TDM and describe the epidemiology and clinical characteristics. Furthermore, we compare the clinical features of different types of TDM. According to our present knowledge, no literature has reported the above. However, this study also has some limitations. This study is a single-center retrospective study, and the low incidence of TDM may have a specific impact on the results. Secondly, in this study, there was no histopathological verification of TDM types based on imaging classification, which requires further research.

Conclusion

The onset of TDM was generally insidious and progressive but may be triggered acutely by apparently trivial events. The results of this study indicate that the prevalence of TDM was low while with varied clinical symptoms. TDM mainly affected the sensory and motor functions of lower limbs and often needed surgical treatment. Different types of TDM had various clinical features, which might indicate different pathological mechanisms.

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Compliance with ethical standards

Conflict of interest None of the authors has any potential conflict of interest.

Ethical approval This study was performed in compliance with the approval of our institution's investigational review board (IRB00006761-M2020047) and registering in the Chinese Clinical Trial Registry (registration ID: ChiCTR2000030948. http://www.chictr.org.cn/index.aspx).

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