Epidemiological survey of ossification of the ligamentum flavum in thoracic spine: CT imaging observation of 993 cases

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Abstract

Objective To investigate the characteristics of epidemiological distribution of the ossification of the ligamentum flavum (OLF) in the thoracic spine including the incidence, segmental distribution, and shape.

Methods Chest spiral computed tomography scans of 993 cases (male 506, female 487, mean age 60 years, range 5–102 years) who presented due to chest symptoms were analyzed with axial slices combined with sagittal slices. The conditions of OLF in the thoracic spine, including segments, thickness, location, and dural sac compression, were recorded. Prevalence was standardized according to the “Age Structure of Population in Beijing 2008”.

Results Among the population investigated, the standardized prevalence rate was 63.9 %. The standardized prevalence rate for males (68.5 %) was higher than that for females (59.0 %). The highest prevalence rate of OLF was in the 50–59 years age group (79.2 %); however, high density originated it can be found in individuals aged 10–19 years. The comparison of different thoracic segments showed that T10–11 (44.0 %) and T11–12 (41.6 %) had the highest prevalence rates.

Conclusion The prevalence of ossification of the ligamentum flavum was highest in the 50–59 years group, but also occurred in early years. OLF occurs more frequently in the lower than in the upper and middle thoracic regions and its prevalence increases with aging.

Keywords Ossification · Ligamentum flavum · Thoracic · Epidemiology

Introduction

Ossification of the ligamentum flavum (OLF) was first reported by Polgar in 1920 [1]. OLF occurs mainly in the Asian population [2–8] and there are only a few reports in the Caucasian, African, and Arabic racial groups [9–14]. OLF is one of the commonest causes of thoracic spinal stenosis and spinal cord compression, which can cause serious neurological symptoms or even paraplegia. Currently, the etiology and epidemiological characteristics of OLF are unknown and epidemiological investigations using diagnostic imaging methods have rarely been performed [3, 15]. Diagnostic methods were lateral radiographs [15] or MRI scans [3], but there are many factors that can contribute to local spinal bone overlaps in the lateral chest radiograph, which is not sensitive enough to identify the tiny areas of OLF. MRI is less sensitive for the observation of ossification, which can be found only when the regions of ossification are round, triangular, or bulky, with low signal intensity and protruding into the vertebral canal, thus compressing the dural sac [6, 16]. Both the ligamentum flavum with small strip ossifications and no obvious change in thickness and the normal ligamentum flavum show low signals on MRI, and therefore cannot be distinguished. Therefore, both imaging methods have a low

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sensitivity for OLF, which may underestimate its prevalence. Multi-detector computed tomography (MDCT) scanning eliminates overlapping factors and, with a high-resolution on density, it has a high sensitivity for ossification [3, 6]. Some studies that used chest CT as a diagnostic method have been published, but their sample sizes were small [17], which means that it is difficult to observe the epidemiological characteristics of OLF completely and comprehensively.

The large sample size population selected for this study comprised 993 patients who presented with chest symptoms and underwent chest MDCT from the PACS system of our hospital in a single month. A systemic analysis was performed on the prevalence rate of thoracic OLF, and features of distribution and morphology, to reflect the prevalence rate of the general population more accurately.

Materials and methods

Population selection

A total of 1,063 patients who presented to our hospital with chest symptoms and underwent a chest spiral CT scan in February 2010 were selected. Three patients were excluded as they had undergone previous thoracic surgery, and 36 others were excluded as their scans did not include the vertebral body of T12. If two or more chest CTs were performed within 1 month, the last examination in that month was selected as the research object, which removed a further 31 scans. After patients were confirmed to have a posterior protrusion angle of the thoracic spine of $<25^\circ$, a total of 993 patients were enrolled, including 506 men and 487 women, aged from 5 to 102 years with a mean age of 60 years.

CT scanning methods and diagnostic criteria

Preoperative CT scanning was performed with a 64-row MDCT scanner (LightSpeed VCT; GE Medical System, Chalfont St. Giles, UK) or a 16-MDCT scanner (Sensation; Siemens, Erlangen, Germany). The scanning parameters were 0.625 or 0.75 mm of collimation, respectively, and images were reconstructed with a 5-mm section thickness and at 5-mm intervals. Axial and sagittal slices were used for observations. The radiographic characteristics of MDCT were high-density spots, strips, and irregularly shaped areas on the level of facet joints, inside the vertebral plate and outside the dural sac. When combined with the sagittal scan, the volume effects caused by the hyperosteo-geny of the upper and lower vertebral plate or the facet joints were excluded (Fig. 1). Measurement of the vertical distance between the thickest point of ossified ligament and

Fig. 1 **a** MDCT axial slices show strip high density in the facet joint capsules in the facet joint level and median lamina, but the thickness of the ligamentum flavum did not change significantly; **b** sagittal reconstruction shows that the strip high density originated from the lamina (arrow)

the lamina was defined as the thickness of the ossified ligamentum flavum. The location of the ossified ligamentum flavum was analyzed as being around the joint capsules of the facet joints and/or the median lamina, and it was noted whether the ossified ligamentum flavum caused deformation of the dural sac due to compression. Two or more consecutive segments of OLF were classified as continuous ossification, and the others were classified as non-continuous ossification. Six radiologists with over 5 years of experience in the diagnosis of spinal degeneration were trained uniformly. With two in a team, they measured all data from the enrolled cases, and each team analyzed data from 331 patients. Disagreements were resolved by discussion.

Statistic analysis

SPSS version 15.0 was used for the statistical analysis. χ^2 test was performed for the ordinal variable. Spearman correlation analysis was performed for age and prevalence. If $P < 0.01$, the difference was statistically significant.

Results

A total of 993 subjects were enrolled in this study, including 506 men and 487 women, with an average age of 60 years (5–102 years). A total of 713 subjects had OLF, with a prevalence rate of 71.8 %. According to standardization of the population using the “Age Structure of Population in Beijing 2008” in the Beijing Statistical Yearbook 2009, the standardized prevalence rate was 63.9 %. The standardized prevalence rate for males (68.5 %) was higher than women (59.0 %; Table 1). The comparison of different age groups showed that no OLF occurred in the 0–9 years age group; the prevalence in the 10–19 years age group increased significantly to 50 %, and in the 20–89 years age group the prevalence rate ranged from

60.0 to 70.0 %. The distribution tendency was platform-like, in which the 50–59 years age group had the highest prevalence rate at 79.2 %. A Spearman correlation analysis on the age and prevalence rates showed a positive correlation between the two (correlation coefficient 0.794, $P = 0.006$, Table 2; Fig. 2).

The distribution of different thoracic segments and sex groups of OLF is shown in Table 3 and Fig. 3. The highest prevalence rates were at T10–11 (44.0 %) and T11–12 (41.6 %). With the exception of T2–3, T10–11, and T11–12, the differences in the prevalence of each segment between men and women were statistically significant ($P < 0.005$). A total of 3,898 ligamentum flava were

ossified, with the average thickness of 3.03 ± 0.76 mm (range 1.4–7.1 mm). Among them, 2,617 (67.1 %) dural sacs were deformed due to compression.

Of all cases of OLF, 947 (24.3 %) were located in the medial lamina, 1,181 (30.3 %) near the facet joint capsules, and 1,770 (45.4 %) occurred in both the facet joint capsules and the medial lamina. In the 713 patients with OLF, 209 (29.3 %) were with single-segment disease and 504 (70.7 %) were multi-segmented. Among the patients with multi-segment disease, 434 (86.1 %) had continuous ossification, and 70 (13.9 %) were non-continuous. Among the continuous ossifications, OLF in two continuous segments predominated. The ossification span range in patients with continuous ossification is shown in Fig. 4.

Table 1 Characteristics of sex distribution of patients with OLF in the thoracic spine

	Total	Number with OLF	Prevalence rate (%)	Standardized prevalence rate (%)
Male	506	387	76.5	68.5
Female	487	326	66.9	59.0

The overall prevalence rate for men and women, $*P = 0.001$

Table 2 Age distribution of patients with thoracic OLF

Age (years)	Total number	Number with OLF	Morbidity rate (%)
0–9	2	0	0.0
10–19	16	8	50.0
20–29	63	42	66.7
30–39	64	40	62.5
40–49	102	77	75.5
50–59	183	145	79.2
60–69	205	138	67.3
70–79	268	199	74.3
80–89	86	60	69.8
>90	4	4	100.0

Fig. 2 The age distribution of thoracic OLF

Discussion

Imaging methods

The etiology of OLF is unknown. Currently, there is no comprehensive data on the epidemiological distribution of OLF, which produces some difficulties in the etiological studies of OLF. Kudo et al. [15] observed 1,744 people using lateral chest X-rays, with a prevalence rate for OLF in males of 6.2, and 4.8 % in females. Guo et al. [3] studied 1,768 volunteers using MRI and found a prevalence rate of 3.8 %. There are many factors that can contribute to local spinal bone overlaps in the lateral chest radiograph, which is not sensitive enough to identify the tiny areas of OLF. MRI is also less sensitive for the observation of ossification, which can be found only when the regions of ossification are round, triangular, or bulky with low signal intensity and protruding into the vertebral canal, thus compressing the dural sac [6, 16]. Therefore, lateral chest radiographs and MRI are likely to underestimate the prevalence of OLF. CT has a high-density resolution and no overlapping factors. It has a high sensitivity to ossification and can find the early formation of OLF when there is no obvious change in the thickness [7, 8]. Therefore, MDCT was used in this study to identify the prevalence of OLF in a large study population, with greater sensitivity compared to previous studies.

We confirmed the diagnosis of ligamentum flavum ossification and excluded partial spatial phenomenon of hyperostosis using consecutive slices for observation and cross-reference axial and sagittal images.

Sample selection

Subjects of previous OLF studies were normal populations [15], volunteers [3], or clinical patients presenting with other symptoms [17]. The sample size of studies in normal population (1,744 persons) and volunteers (1,768) was

Table 3 Segments and sex distribution of thoracic OLF

Segment	Patient number			Prevalence rate			
	Male	Female	Total	Male (%)	Female (%)	Total (%)	<i>P</i> value*
T1–2	32	17	49	6.30	3.50	4.90	0.039
T2–3	35	24	59	6.90	4.90	5.90	0.185
T3–4	67	36	103	13.20	7.40	10.40	0.003
T4–5	85	46	131	16.80	9.40	13.20	0.001
T5–6	109	52	161	21.50	10.70	16.20	0.000
T6–7	126	75	201	24.90	15.40	20.20	0.000
T7–8	121	64	185	23.90	13.10	18.60	0.000
T8–9	122	59	181	24.10	12.10	18.20	0.000
T9–10	175	105	280	34.60	21.60	28.20	0.000
T10–11	251	186	437	49.60	38.20	44.00	0.279
T11–12	220	193	413	43.50	39.60	41.60	0.214

* Statistical analysis was conducted on the difference in the prevalence rates between men and women, and $P < 0.05$ indicated significant difference

Fig. 3 The segment and sex distribution of thoracic OLF **Fig. 4** Distribution of the ossification span range in patients with continuous ossification

large, but the methods used were lateral chest X-ray and MRI, with a poor sensitivity. CT examination in normal population and volunteers for the purpose of epidemiological investigation cannot be achieved due to the impact of radiation doses. Moreover, the sample population of currently available studies in volunteers is affected by the

willingness of volunteers, which may have a certain bias, and the average age is young (38 years), which would not completely reflect the epidemiological distribution of OLF across the population. To date, the only OLF study with the use of CT was that by Williams et al., which observed thoracolumbar OLF with chest and abdominal CT. Their sample size was 100, the sample population was solely white Caucasians, and the prevalence rate was 26 % [17]. Therefore, due to the limitation of sample size and sample population, currently all the studies are unable to reflect the prevalence rate of thoracic OLF accurately.

The advantage of the sampling method used in our study was that it avoided bias caused by using volunteers as a sample, and there is no evidence to suggest that there is correlation between lung disease and OLF. Therefore, the epidemiological distribution of OLF in this population could be assessed objectively. However, this selection method has some limitations. However, the age structure of the population under investigation was not exactly the same as the general population. To solve this problem, we standardized the population using the “Age Structure of Population in Beijing 2008” in the Beijing Statistical Yearbook 2009. Another disadvantage was that certain patients with serious OLF may not visit hospitals due to lung disease, because severe spinal stenosis restricts ambulation, resulting in a slightly lower prevalence rate of OLF.

Population distribution

The prevalence rate of OLF in the population investigated in this series was significantly higher than the results of other studies, with a prevalence rate of 63.9 % in the standardized population. The study by Guo et al. found the population prevalence rate of OLF to be 3.8 %, and Kudo

et al. found it to be approximately 5 %, which may be caused by the low sensitivity of the imaging methods. The study by Williams et al. on OLF with the use of CT showed a prevalence rate of 26 %. The reason was considered to be due to the thicker section thickness and lower resolution of CT at the time of this study and a different sample population which included only white Caucasians. In this study, the most surprising finding was that OLF even occurred in the 10- to 19-year-old population. The results suggest that OLF can occur in younger ages than was previously thought. For the 20- to 89-year-old age group, the prevalence rates ranged from 60.0 to 70.0 %, with the platform-like distribution tendency, and the age group with the highest prevalence rate was 50–59 years (79.2 %), which suggested that the development of OLF may be associated with degeneration. However, in the older patients, the OLF may be thicker and compress the dural sac more severely. It should be stated that this study only observed whether or not the OLF compressed the dural sac, but did not grade the degree of compression, so this conclusion requires further research. We also found that the prevalence of OLF in men was higher than in women at most segments (8/11, 72.7 %), which was in line with most of the literature. This finding may be due to heavier physical activity in men, which causes heavier stress on the ligamentum flavum [4, 5, 7, 20]. However, in some studies, the prevalence rates were reported to be higher in women than in men [3, 13].

Segmental distribution

The ligamentum flavum in the thoracic spine has the role of maintaining spinal stability and preventing excessive ante-flexion. OLF was most likely to occur in the lower thoracic spine (T10–12), which is consistent with the report by Guo et al. Some studies considered that this location is in the transitional area between the thoracic and lumbar vertebrae, and the protection of bony thorax is weak. The posterior vertebral columns in the lower thoracic segments have higher tension and are more likely to degenerate, resulting in the proliferation and hypertrophy of collagen, as well as deposition of calcium pyrophosphate dehydrate and calcium hydroxyapatite in the ligament, leading to OLF [18]. Some scholars believe that when local stress is abnormally increased, the elastic fibers in the ligamentum flavum will rupture and degenerate, causing microdamage. Repeated injuries and repair processes will inevitably cause hypertrophy and fibrosis of the ligamentum flavum, ultimately leading to calcification of the ligamentum flavum [19].

Morphological characteristics

In this study, of the 21,846 ligamenta flava studied in 993 people, 3,898 developed OLF, in which 2,617 caused

deformation of the dural sac due to compression (67.1 % of all the OLFs, 11.8 % of all the ligamenta flava). The average thickness of the OLF was 3.03 ± 0.76 mm (range 1.4–7.1), whereas the thickness of normal ligamentum flavum in the Chinese population is 2.0 mm; therefore, the majority of OLFs found in this series were less severe. Among all the patients with multi-segment disease, the majority (86.1 %) had continuous ossification, and a small number (13.9 %) had non-continuous ossification, which was consistent with previous reports [3]. Further long-term follow-up studies are required as to whether or not those ligamenta flava with thin ossifications that do not cause compression of the dural sac will develop into OLF in the future.

We analyzed the location of OLF in detail. Among all the OLFs, 947 (24.3 %) were located in the medial lamina, 1,181 (30.3 %) near the facet joint capsule, and 1,770 (45.4 %) were located both near the facet joint capsule and the medial lamina. The proportions of OLF that occurred in the medial lamina and near the facet joint capsule were comparable.

Ossification or calcification of the ligamentum flavum

The density of the ligamentum flavum on MDCT alone cannot tell apart ossification and calcification. Calcification of the ligamentum flavum is one of the CPPD (calcium pyrophosphate dihydrate) deposition diseases, which is very uncommon in the spine. It affects mostly the cervical vertebrae, and lumbar spine comes next. So far, only about ten cases of ligamentum flavum calcification of the thoracic spine have been reported [21]. Therefore, calcification of the ligamentum flavum in the thoracic vertebrae is very rare. Furthermore, from considerations of morphology, ossification affects the vertebral lamina but calcification does not. In our study, we used cross-reference sagittal images to make certain relationship between hyperintensity of the ligament and vertebral lamina. All evidence stated above proved what we observed was not calcification, but ossification.

Clinical significance

In this study, we found that the ossification of the ligamentum flavum in the thoracic spine was relatively common in the normal population, with a prevalence rate of 63.9 %. As many previous studies showed lower prevalence of the fact stated above, however our study improved understanding(s) of this phenomenon. We believe that it is not necessary to do this examination as a conventional method with respect to the radiation dosage. However, for patients with spondylotic myelopathy caused by ligamentum flavum ossification, the examination needs to be performed.

Conclusion

This study is the first large-scale epidemiological study on OLF in patients who presented with chest symptoms and underwent MDCT examination in a northern city of China. The study found that the prevalence rate of OLF was much higher, at 63.9 %, than in previous reports. The process of OLF occurred earlier than was previously thought and was even found in 10- to 19-year-old individuals. The prevalence peaked in the 50–59 years age group, and tended increase with increasing age. The prevalence was higher in men than in women. The lower thoracic segments of T10–12 had the highest prevalence, which suggests that the development of OLF is associated with stress. This indicates that, in the population currently investigated, the incidence of thoracic OLF was associated with degeneration of the thoracic vertebrae.

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Conflict of interest None.

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