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ORIGINAL ARTICLE

Questionable Adequacy of Magnetic Resonance for the Detection of Ossification of the Posterior Longitudinal Ligament of the Cervical Spine

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ABSTRACT

Objective: *To investigate the sensitivity of magnetic resonance for detecting cervical ossification of the posterior longitudinal ligament.*

Methods: *A retrospective review of 427 patients in whom cervical ossification of the posterior longitudinal ligament was reported on either magnetic resonance or computed tomography at a regional hospital between 2004 and 2010. Computed tomography was the gold standard for confirming the presence of such ossification. Those patients in whom computed tomography was performed before magnetic resonance were excluded to eliminate bias. Thickness, length, and type of ossification of the posterior longitudinal ligament were investigated to evaluate their influence on sensitivity.*

Results: *In all, 45 eligible patients were identified, of which 20 were correctly identified by magnetic resonance and 21 were incorrectly identified, yielding a sensitivity of 49%. In four patients, the ossification was incorrectly identified as positive (positive predictive value, 83%). The mean (± standard deviation) maximum ossification thickness in patients correctly identified was thicker than in those whose ossification was not noted (4.5 ± 2.1 mm vs. 3.2 ± 1.2 mm, $p = 0.0189$). On average more vertebrae were affected by ossification in those that were correctly identified compared to those that were not (3.0 ± 1.4 vs. 2.4 ± 1.0 vertebrae), but the difference was not statistically significant.*

Conclusion: *In our series, the sensitivity of magnetic resonance in detecting ossification of the posterior longitudinal ligament was only moderate; ossification cannot be excluded by such imaging. In our study, magnetic resonance yielded a sensitivity of 49%, which compared unfavourably with the two largest Japanese studies, but differences in disease morphology and frequency could account for such diversity. Although magnetic resonance is not the first-choice imaging modality to study ossification of the posterior longitudinal ligament, familiarisation with its subtle suggestive features is recommended, as it is increasingly used as the initial imaging modality to investigate myelopathy. In the event of unexplained spinal canal narrowing, a search for ossification of the posterior longitudinal ligament should be made first by plain X-ray, and then by computed tomography.*

Key Words: *Magnetic resonance Imaging; Ossification of posterior longitudinal ligament; Spine*

中文摘要

磁共振造影作為評估頸椎後縱韌帶骨化的影像學工具是否適當？

王啓佳、梁安祥、袁銘強

目的：探討使用磁共振造影評估頸椎後縱韌帶骨化的敏感度。

方法：回顧2004年至2010年間於一所分區醫院內，曾接受磁共振或電腦斷層造影（CT）發現頸椎後

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縱韌帶骨化的427名患者。CT是確診此症的黃金標準。為避免影響結果，本研究並不包括在磁共振造影之先已接受CT的患者。我們亦探討了頸椎後縱韌帶骨化的厚度、長度及種類會否影響磁共振造影的敏感度。

結果：共45位患者被納入研究範圍，其中20人的磁共振正確診斷頸椎後縱韌帶骨化的情況，另21人的磁共振未能診斷骨化的情況，得出的敏感度為49%。其餘4人被誤診為頸椎後縱韌帶骨化（陽性預測值為83%）。被正確診斷病情的患者中，骨化的最大平均（±標準差）厚度比那些未被診斷者大（4.5 ± 2.1毫米比3.2 ± 1.2毫米，p = 0.0189），另外，他們受影響的椎骨數目亦相對較多（3.0 ± 1.4比2.4 ± 1.0），但未達統計顯著性。

結論：本研究結果顯示磁共振造影對於評估頸椎後縱韌帶骨化的敏感度只有49%，屬中等，顯示此技術未必可以排除病人骨化的可能性。本研究結果與另外兩個日本大型研究的結果不相乎，可能是因為各研究對於頸椎後縱韌帶骨化的嚴重程度及種類，以至發病率並不相同。雖然磁共振並不是診斷頸椎後縱韌帶骨化的第一線篩檢工具，醫生應熟習這症在磁共振影像上的細微表現，因為這技術漸漸被廣泛應用在脊髓病的影像學上。如果遇上不能解釋的椎管狹窄病例，應先利用X射線檢查是否有頸椎後縱韌帶骨化，繼而使用CT為病人確診。

INTRODUCTION

Ossification of the posterior longitudinal ligament (OPLL) is commonly thought to be the most prevalent in ethnically Japanese men aged more than 40 years, with a frequency as high as 4.3%.[1] However as fellow “Orientals”, the Chinese are also at increased risk of OPLL compared to Caucasians; in the Chinese the frequency may be as high as 3%.[2] Moreover, since OPLL is a known cause of cervical myelopathy, its presence significantly influences the spinal surgeon’s approach.

OPLL is more common in the cervical spine (70%) than either the thoracic (15%) or lumbar (15%) spine. In the cervical spine, the middle and upper cervical vertebrae are commonly involved. Morphologically, four forms have been described. The continuous and segmental forms account for up to 95% of all cases. The former extends over several contiguous vertebral bodies while the latter is fragmented behind each vertebra. The mixed form includes the combination of continuous and segmental form. The fourth or retrodiscal form is situated exclusively behind the intervertebral disc and may be radiologically indistinguishable from a posterior osteophyte or calcified disc.[3]

Because of the lack of magnetic resonance (MR) signal from cortical bone, computed tomography (CT) is the imaging modality of choice and MR’s principal use is the assessment of associated cord compression and intramedullary cord lesions, such as myelomalacia and oedema. However, MR can be used to make this critical diagnosis and features of OPLL on T1 and T2 are well-established, albeit subtle. The sensitivity of MR for identifying OPLL has only been studied twice, both more than 15 years ago in Japan; sensitivity being reported as up to 91% and proportional to the lesion thickness. We hypothesised that in Hong Kong, where the prevalence is lower than that in Japan,[2] the sensitivity of MR used for this purpose might also be lower. This study therefore aimed to investigate the sensitivity of MR in identifying OPLL and evaluate the impact on such imaging due to OPLL thickness, category and number of vertebrae affected.

METHODS

A keyword search of CT reports endorsed between 2004 and 2010 at Tuen Mun Hospital retrospectively identified 427 patients with the presence of confirmed cervical OPLL. Among these, 77 had also been examined by MR of the cervical spine but in order to eliminate bias, patients in whom OPLL had been previously diagnosed by CT were excluded, which left 41 eligible patients. A similar keyword search was performed for MR imaging reports over the same time period at the same location, in order to identify patients in whom cervical OPLL was mentioned on the MR report only. Follow-up CTs were then assessed to confirm the presence or absence of disease. An additional four patients were identified using this method, all having had OPLL falsely diagnosed. A total of 45 patients were therefore included in the analysis.

CT was performed using a 16-slice helical multidetector Phillips scanner. OPLL was detected on cervical spine examinations (using 1 mm axial thickness slices with 0.6 mm increments) or as an incidental finding on other CT studies covering the cervical spine (using 1-3 mm axial slice thickness with 0.6-3.0 mm increments). One non-blinded radiologist with three years' experience using both axial and sagittal reconstructions for measuring the maximum thickness of the ossified segment and the number of vertebrae affected retrospectively reviewed the CT images of all 45 patients on computer monitors. Classification of the morphological distribution (continuous, segmental, or mixed) was also recorded. OPLL was defined as an ossified mass in the posterior margin of the vertebral bodies in a vertical axis (to differentiate it from posterior osteophytes). Unpaired *T*-tests were used to calculate statistical significance of the thickness and number of affected vertebrae. Data were collected on patient age, gender, date of first diagnostic CT, maximum OPLL thickness on CT, the cervical vertebrae involved, the CT classification (continuous, segmental, mixed, discal), and the date of the first MR.

MR was performed on a GE or Phillips 1.5T unit with a spine coil. Acquired sequences included spin echo T1-weighted, T2-weighted sequences in the axial plane and T1-weighted, T2-weighted spin echo and proton density turbo spin echo sequences in the sagittal plane.

Table 1. Imaging parameters.

	TR (ms)	TE (ms)
Sagittal		
T1-weighted	600	Min
T2-weighted	3500	120
Proton density	2000	15
Axial		
T1-weighted	600	Min
T2-weighted	3500	120

Table 2. Summary of results.

	True positives	False negatives	False positives
No. of patients	20	21	4
Mean OPLL thickness (mm)	4.5 ± 2.1	3.2 ± 1.2*	-
Mean no. of vertebrae affected	3.0 ± 1.4	2.4 ± 1.0†	-
Most affected vertebrae	C4, C5, C6	C4, C5	-
No. of segmental OPLL	14 (70%)	16 (76%)	-

Abbreviation: OPLL = ossification of the posterior longitudinal ligament.
* p = 0.0189.
† p = 0.1210.

A section thickness / gap of 3 mm / 0.5 mm was used in the sagittal plane and 4 mm / 1 mm in the axial plane. Imaging parameters are shown in Table 1. Images were not available for some of the older studies, therefore only reports were assessed.

RESULTS

In the 41 patients with OPLL, ages ranged from 32 to 86 (mean, 61) years; 13 were women. The mean ± standard deviation (SD) of OPLL thickness was 3.8 ± 1.8 mm. Regarding the 45 patients in this analysis, 20 cases had been correctly identified as having OPLL by MR prior to CT (true positive) and 21 cases had not been detected (false negative), giving a sensitivity of 49%. In four patients, OPLL was incorrectly positively identified (false positive), yielding a positive predictive value of 83%.

The mean ± SD OPLL thickness in the group correctly identified by MR was 4.5 ± 2.1 mm while it was 3.2 ± 1.2 mm for cases not detected by MR (p = 0.0189). The mean ± SD number of affected vertebrae in those correctly detected by MR was 3.0 ± 1.4 compared to 2.4 ± 1.0 in those in whom it was missed (p = 0.1210).

Vertebrae C4, C5 and C6 were equally affected (13 patients with each) in those in whom OPLL was correctly identified. There were 14 patients with C4 affected and 15 with C5 affected among those in whom OPLL was missed. The segmental type of OPLL was most common in both groups; 70% (n=14) and 76% (n=16), respectively. Table 2 shows the tabulated results.

DISCUSSION

The posterior longitudinal ligament runs from the second cervical vertebra to sacrum along the posterior surface of vertebrae and discs. It is closely adherent to and blends with the annulus fibrosus of the discs and adjacent margins of the vertebral bodies. This accounts for the difficulty in differentiating retrodiscal OPLL from posterior osteophytes or calcified discs. Fortunately, purely retrodiscal OPLL is the least common form, comprising 7% of cases.[4,5]

At mid-vertebral levels, however, the ligament is separated from vertebral margins by a 1-2 mm gap that is filled with connective tissue and a venous plexus. This explains the typical radiographic and CT appearance of a sharp and thin radiolucent line separating the OPLL from the posterior vertebral margin (Figure 1).[6,7] OPLL can also extend away from the midline following the anatomy of the posterior longitudinal ligament, which is relatively narrow over the vertebral bodies and wide over the discs. The superficial layer of the posterior longitudinal ligament extends laterally to cover the intervertebral discs, whilst other fibres merge into the dura mater.[8]

CT is the method of choice for detecting the presence and extent of ossified lesions while MR is typically used to reveal the nature of cord compression such as myelomalacia, oedema, demyelination, or cyst formation and root sleeve involvement. The extent of myelomalacia and oedema of the cervical cord is best seen in sagittal and axial T2-weighted sequences.

OPLL is considered difficult to detect on MR because of the lack of signal from an ossified ligament in both T1- and T2-weighted images. The low signal is further masked on T1 against the low-signal cerebrospinal fluid (CSF) and on T2 with adjacent low-signal cervical vertebrae.[9] Iso-intensity on T1 has been reported and regarded as representing proliferation of small vessels in the hyperplastic ligament.[10] Fatty bone marrow formation has also been histopathologically identified within these lesions, and increased T1 signal intensity representing this tissue has been reported (Figure 2).[4,11-13] Despite this, the two largest MR imaging studies of cervical OPLL in a Japanese population showed that as few as 33 to 44% of ossified lesions could be identified using sagittal T1-weighted imaging, and

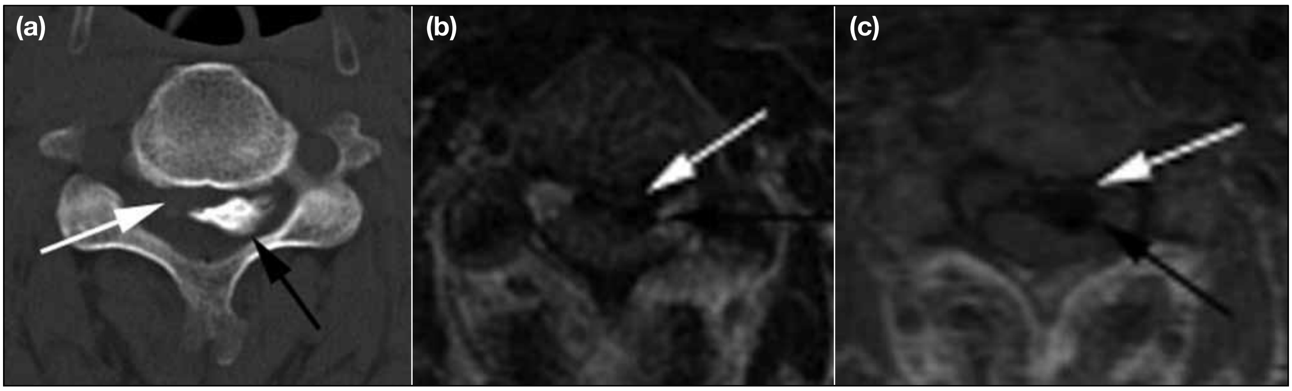

Figure 1. A 57-year-old male positively identified on initial magnetic resonance with confirmatory computed tomography (CT). (a) Axial CT, (b) T2-weighted and (c) T1-weighted axial images at the same level shows thickened and continuous ossification of the posterior longitudinal ligament (black arrows) with characteristic sharp and thin radiolucent line or intermediate signal separating the ossified posterior longitudinal ligament from the posterior vertebral margin (white arrows).

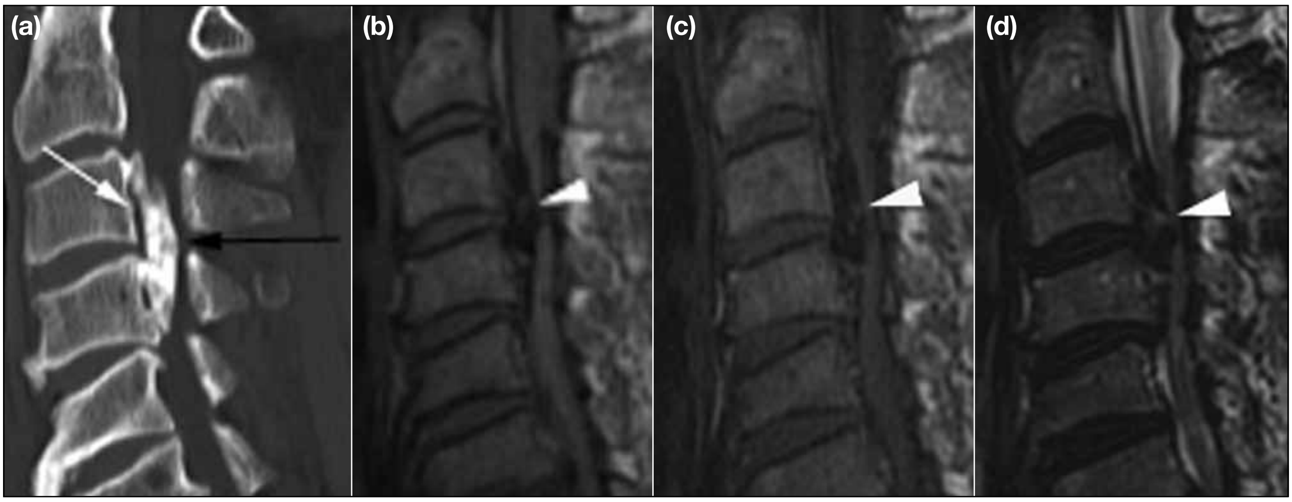

Figure 2. The same 57-year-old male positively identified on initial magnetic resonance (MR) with confirmatory computed tomography (CT). (a) Sagittally reconstructed CT shows thickened and continuous ossification of the posterior longitudinal ligament (OPLL; black arrow) with characteristic sharp and thin radiolucent line separating the ossified posterior longitudinal ligament from the posterior vertebral margin (white arrow). (b) Proton density, (c) T1-weighted and (d) T2-weighted sagittal images of the same patient. Note the small focus of high signal within the OPLL at the level of C3/4 which could represent fatty marrow signal (white arrowheads).

44 to 57% with sagittal T2-weighted imaging. Axial sequences were more sensitive (up to 91%).[9,13] It has been suggested that axial proton density produces the best contrast between the ossified lesions, vertebral bodies, and the CSF. Differentiation of calcified discs and large posterior osteophytes provide the most challenging diagnostic dilemmas that commonly mask OPLL.

In contrast to these two large Japanese studies, our series evaluated the sensitivity of MR as a whole, rather than as individual sequences, which involved an ethnically Chinese population. Moreover, our sample of 41 patients yielded an overall MR sensitivity of 49%. We propose three possible explanations for this disparity.

First, the severities of disease in the two samples were quite different. Our patients had a mean OPLL thickness of 3.8 ± 1.8 mm, while Otake et al[9] used a population with a mean OPLL thickness of 7.7 mm. Yamashita et al[13] found a mean ± SD thickness of correctly detected OPLL by MR to be 5.4 ± 1.8 mm, compared to 4.5 ± 2.1 mm in our cases. Second, the frequency of segmental OPLL (Figure 3) in our sample (up to 78%) was higher than that in the two Japanese studies (40-50%).[9,13] This could reduce the detection rate. Thus, the two Japanese studies[9,13] reported that this form of OPLL (as opposed to the continuous type) was more difficult to be visualised by MR, possibly related to differences in OPLL thickness between the various types. However, Otake et al[9] only used plain radiography of the cervical spine to select their patients, while Yamashita et al[13] utilised plain radiography, tomography, and CT. The use of inherently less sensitive imaging modalities biases these studies to exclude less severe cases, i.e. patients with thinner OPLL and segmental types. Third, the lower frequency of OPLL in ethnic Chinese could have contributed to the reduced awareness of the subtle MR imaging features by the relevant radiologists.

Limitations

In a few of our cases, considerable time elapsed between the date of the initial MR and the subsequent confirmatory CT (up to 9 years), which introduces the possibility of disease progression in the interim and reduces the accuracy of our results. However, this was of little concern, as OPLL has been shown to be a slowly progressing process; one study on 112 patients showed maximum growth in thickness of 3.4 mm after 10 years.[14] Selection bias was inevitably introduced due to the requirement that CT must also have been performed to confirm the diagnosis. Also many cases may have been missed by MR in which CT was not performed and therefore the patient was excluded from this study.

This study only used the written reports of the MR studies to calculate the sensitivity and correlated with features detected on CT. In the future, MR images could be analysed to study the frequency of the aforementioned detectable MR features. Unfortunately, this was not possible in this study as many of the MR images were not digitally archived and so could not be retrieved. A larger population sample could improve the statistical power of our results and help determine an accurate minimum MR-detectable OPLL thickness.

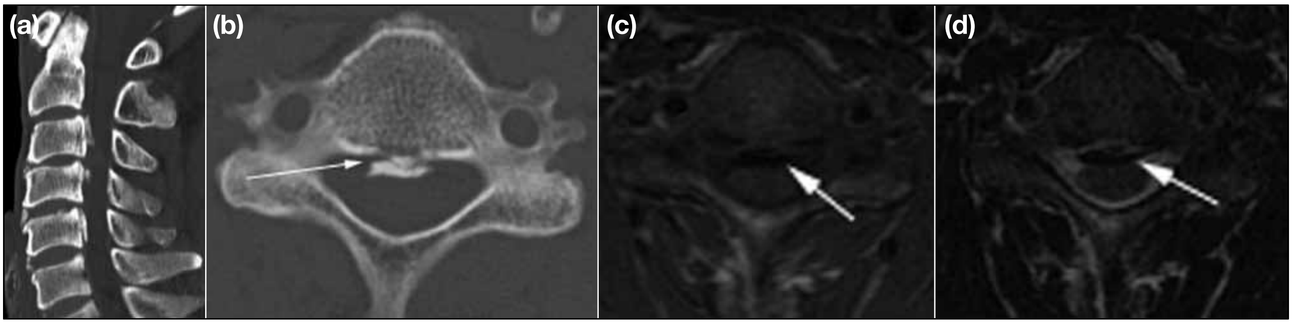

Figure 3. A 65-year-old male with thin ossification of the posterior longitudinal ligament (OPLL) that was missed by initial magnetic resonance. (a) Sagittally reconstructed computed tomography (CT) shows the segmental morphology of the OPLL. (b) Axial CT demonstrates the characteristic thin radiolucent line separating the ossified posterior longitudinal ligament from the posterior vertebral margin (white arrow). (c) T1-weighted axial and (d) T2-weighted axial sequences show the thin linear signal void that, in retrospect, represented the OPLL (white arrows). No abnormality was seen on the sagittal sequences (not shown).

CONCLUSION

In a local regional hospital, our study showed MR to have 49% sensitivity and a positive predictive value of 83% for the detection OPLL. Thickness was shown to be a statistically significant variable contributing to MR detection. The number of vertebrae covered by OPLL was larger for cases identified as positive by MR, but this difference was not statistically significant. Our detection rates compare unfavourably with the two largest Japanese studies, but population disease morphology and frequency could explain these differences. Although MR is not the first-choice imaging modality for OPLL, familiarisation with subtle MR findings suggestive of OPLL could be helpful, as MR use to assess cervical myelopathy is widespread and frequently the initial imaging modality performed to search for a diagnosis. In the event of unexplained narrowing of the spinal canal, a search for OPLL should begin with a plain X-ray, and then a CT.

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