Magnetic resonance imaging findings in ossification of the posterior longitudinal ligament of the cervical spine

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Object. Because of the lack of magnetic resonance (MR) signal from cortical bones, MR imaging is inadequate for diagnosing ossified lesions in the spinal canal. However, MR imaging provides important information on spinal cord morphology and associated soft-tissue abnormality. The purpose of this study is to determine the role of MR imaging in the diagnosis and treatment of patients with ossification of the posterior longitudinal ligament (OPLL) of the cervical spine.

Methods. The authors reviewed MR imaging findings in 42 patients with cervical OPLL who were examined with a superconducting MR imaging system. The types of OPLL reviewed included eight cases of continuous, 21 cases of segmental, and 13 cases of the mixed type. All patients were treated surgically either by anterior (26 cases) or posterior decompression (16 cases).

Conclusions. The T₁-weighted images clearly demonstrated the spinal cord deformity caused by OPLL. Associated disc protrusion was found to be present at the maximum compression level in 60% of the patients in this series. The highest incidence of disc protrusion (81%) was found in patients with segmental OPLL. Intramedullary hyperintensity on T₂*-weighted imaging was noted in 18 patients (43%). The neurological deficits observed in these 18 patients were significantly more severe than those observed in the other 24 patients. Postoperative MR imaging revealed improvement in the spinal cord deformity, although the intramedullary hyperintensity was still observed in most cases. The present study demonstrates the importance of associated disc protrusion in the development of myelopathy in patients with cervical OPLL. Magnetic resonance imaging findings may be used to help determine the actual levels of spinal cord compression and to suggest the method of surgical treatment.

KEY WORDS • ossification of the posterior longitudinal ligament • disc protrusion • magnetic resonance imaging • spinal cord compression • surgical approach

OSSIFICATION of the posterior longitudinal ligament (OPLL) is a well-known spinal disorder in Japan, although the literature indicates that this disease also affects a significant number of non-Japanese Asians and Caucasians. The cervical spine is the most common site of OPLL. Narrowing of the spinal canal caused by the ossified ligament has been attributed to development of cervical myelopathy. However, as noted by Nakanishi, et al., the occurrence of myelopathy might depend not only on the relative width of the cervical spinal canal and the bulk of the cord, but also on pathological changes that are not revealed by roentgenography alone. As illustrated by the presence of asymptomatic patients with prominent cervical OPLL and symptomatic patients with relatively small OPLL, this is important to use state-of-the-art neuroradiological diagnostic modalities in the evaluation of patients with cervical OPLL.

Ossification of the posterior longitudinal ligament is clearly demonstrated by conventional tomography. Distribution of OPLL in the spinal canal is accurately visualized on bone window computerized tomography (CT) scanning. Because there is a lack of magnetic resonance (MR) signal from cortical bones, MR imaging is inadequate for diagnosing small ossified lesions in the spinal canal. Magnetic resonance imaging does, however, provide important information on deformity of the spinal cord and intramedullary changes. An associated soft-tissue abnormality such as disc protrusion can also be visualized by means of MR imaging. In this study, we retrospectively analyzed MR imaging findings and the neurological states of patients with cervical OPLL who were examined with a superconducting MR imaging system and underwent surgical treatment in our institution. The purpose of this study was to determine the role of MR imaging in diagnosis and treatment of cervical OPLL.

Clinical Material and Methods

Patient Population

Between 1988 and 1995, 42 patients with cervical OPLL (31 men and 11 women), ranging in age from 32 to 71 years (mean 55.4 years) were treated surgically in our institution. All patients were examined preoperatively...
with a superconductive 1.5-tesla MR imaging system (Signa; General Electric Medical Systems, Milwaukee, WI; or Magnetom; Siemens, Erlangen, Germany). On admission to our institution, the patients exhibited neurological deficits in varying degrees from mild weakness in the upper extremities to severe tetraparesis. The neurological state of the patient was evaluated according to the Neurosurgical Cervical Spine Scale (NCSS), a method of scoring motor function of the upper and lower extremities and sensory deficits. Using this scale (Table 1), the maximum score is 14 (patient is free of neurological deficits) and the minimum score is 3 (patient is severely disabled with motor and sensory deficits).

**Diagnostic Imaging**

Cervical OPLL was diagnosed by using roentgenography, conventional tomography, and plain CT scanning of the cervical spine. The types of cervical OPLL in the 42 patients were determined using conventional tomograms according to the classification of Hirabayashi, et al. There were eight cases (19%) of continuous OPLL, 21 cases (50%) of segmental OPLL, and 13 cases (31%) of the mixed type in this series. Magnetic resonance imaging studies included T₁-weighted images (spin-echo; TR 500–600 msec, TE 15–20 msec) and T₂*-weighted images (gradient-echo; TR 200–230 msec, TE 15–20 msec; flip angle 10–12°) of the cervical spine obtained in the sagittal and axial planes. In the present study, analysis of the MR imaging findings especially focused on the deformity of the spinal cord observed at the maximum compression level on T₁-weighted images, intramedullary signal changes on T₂*-weighted images, and associated disc lesions. Disc protrusion was diagnosed when the T₁- and T₂*-weighted images showed a soft-tissue mass protruding posteriorly from the intervertebral disc space beyond the posterior aspects of adjacent vertebral bodies and ossified ligaments. Conventional tomograms and CT scans of the cervical spine were used to confirm that these protruding lesions were not covered by OPLL. Deformity of the spinal cord at the maximum compression level was expressed by the ratio of the sagittal diameter divided by the

![Fig. 1. Case 1. a: Conventional sagittal tomogram of the cervical spine demonstrating continuous OPLL from C-3 to C-4. b: Sagittal T₁-weighted MR image revealing deformity of the spinal cord due to compression by OPLL at C3–4. c: Postoperative sagittal T₁-weighted MR image. The patient underwent corpectomy at C3–4 and anterior fusion from C-2 to C-5 using an iliac bone graft. Good decompression of the spinal cord is visualized.](image-url)

**TABLE 1**

<table>
<thead>
<tr>
<th>Score</th>
<th>Status</th>
</tr>
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<tbody>
<tr>
<td><strong>lower-extremity motor function</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>total disability: chair bound or bedridden</td>
</tr>
<tr>
<td>2</td>
<td>severe disability: needs support in walking on flat surface &amp; unable to ascend or descend stairways</td>
</tr>
<tr>
<td>3</td>
<td>moderate disability: difficulty in walking on flat surface &amp; needs support in ascending or descending stairways</td>
</tr>
<tr>
<td>4</td>
<td>mild disability: no difficulty in walking on flat surface, but mild difficulty in ascending or descending stairways</td>
</tr>
<tr>
<td>5</td>
<td>normal: normal walking w/ or w/o abnormal reflexes</td>
</tr>
<tr>
<td><strong>upper-extremity motor function</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>total disability: totally unable to perform daily activities w/ motor weakness</td>
</tr>
<tr>
<td>2</td>
<td>severe disability: severe difficulty in performing daily activities w/ hand &amp;/or finger clumsiness</td>
</tr>
<tr>
<td>3</td>
<td>moderate disability: moderate difficulty in performing daily activities w/ hand &amp;/or finger clumsiness</td>
</tr>
<tr>
<td>4</td>
<td>mild disability: no difficulty in performing daily activities, but mild hand &amp;/or finger clumsiness</td>
</tr>
<tr>
<td>5</td>
<td>normal: normal performance of daily activities, w/ or w/o abnormal reflexes</td>
</tr>
<tr>
<td><strong>sensory function &amp;/or pain</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>severe disturbance: severe difficulty in performing daily activities w/ incapacitating sensory disturbance &amp;/or pain</td>
</tr>
<tr>
<td>2</td>
<td>moderate disturbance: moderate difficulty in performing daily activities w/ sensory disturbance &amp;/or pain</td>
</tr>
<tr>
<td>3</td>
<td>mild disturbance: normal performance of daily activities, but mild sensory disturbance &amp;/or pain</td>
</tr>
<tr>
<td>4</td>
<td>normal: no sensory disturbance or pain</td>
</tr>
</tbody>
</table>

* Based on Kadoya, 11
Magnetic resonance imaging of cervical OPLL transverse diameter of the spinal cord observed on T2-weighted axial images (cord deformity ratio = sagittal diameter/transverse diameter).

Surgical Technique

All patients underwent surgical treatment for myelopathy caused by cervical OPLL. Anterior cervical corpectomy and interbody fusion using autogenous iliac bone grafts were performed in 26 patients (62%). Posterior decompression by means of either laminectomy (six cases) or laminoplasty (10 cases) was performed in 16 patients (38%). The choice of surgical treatment basically depended on the extent of spinal cord compression caused by the OPLL. Anterior decompression is the primary choice of surgical treatment for the patient with cervical OPLL, if the spinal cord compression does not exceed four intervertebral disc levels or three vertebral bodies. If the patient shows greater extension of spinal cord compression, posterior decompression is performed.

Statistical Analysis

The mean values of the spinal cord deformity ratio and NCSS scores were expressed as means ± standard deviations. For comparison of mean values, the Student’s t-test was used. Probability values less than 0.05 were considered significant in this study.

Illustrative Cases

Case 1

This 45-year-old man presented with a 1-year history of mild motor weakness and decreased superficial sensation in the bilateral upper extremities.

Examination. Conventional tomography of the cervical spine showed continuous OPLL at the C3–4 levels (Fig. 1a). Magnetic resonance imaging revealed compression of the spinal cord caused by the ossified ligament (Fig. 1b). There was no abnormal signal intensity on the T2*-weighted images of the spinal cord. The total preoperative NCSS score was 12/14 (5/5 in lower-extremity and 4/5 in upper-extremity motor function, and 3/4 in sensory function).

Operation and Postoperative Course. We performed a corpectomy at the C3–4 levels and anterior fusion from C2 to C-5 by using an iliac bone graft. The preoperative symptoms of the upper limbs completely disappeared after surgery. Postoperative MR imaging demonstrated decompression and recovery of the anteroposterior diameter of the spinal cord at C3–4 (Fig. 1c).

Case 2

This 56-year-old man presented with a 4-year history of progressive motor weakness in his upper and lower extremities, gait disturbance, and neck pain.

Examination. On admission to our institution, the patient showed moderate tetraparesis with atrophic interosseous muscles in both hands. The patient’s total NCSS score was 7/14 (3/5 in lower-extremity and 2/5 in upper-extremity motor function and 2/4 in sensory function). Conventional tomography showed continuous OPLL at C3–4 and below C-5 (Fig. 2a). Magnetic resonance imaging revealed deformity of the spinal cord caused by compression by the ossified ligament from the C-4 to C-5 levels (Fig. 2b). Intramedullary hyperintensity was demonstrated on T2*-weighted images (Fig. 2c and d).

Operation and Postoperative Course. Although the OPLL extended more longitudinally in the spinal canal, anterior decompression and fusion were performed from C3–4 to C5–6 with corpectomy of C-4 and C-5 (Fig. 2e) according to the MR imaging findings. Postoperatively, the patient displayed a mild improvement in his tetraparesis. The patient’s postoperative NCSS score was 6/14 (2/5 in lower-extremity and 2/5 in upper-extremity motor function, and 2/4 in sensory function).

Case 3

This 75-year-old man presented with a 9-year history of tetraparesis with progressive gait disturbance.

Examination. On admission, the patient showed motor weakness and decreased sensation in the upper and lower extremities, atrophy of the forearm and hand muscles, and a markedly spastic gait. The patient’s total NCSS score was 6/14 (2/5 in lower-extremity and 2/5 in upper-extremity motor function, and 2/4 in sensory function). Conventional tomography demonstrated segmental OPLL at the C-6 and C-7 levels (Fig. 3a). Magnetic resonance imaging revealed spinal cord compression from C3–4 to C-7 (Fig. 3b). Marked deformity of the spinal cord was recognized from C-5 to C-7. Spinal cord compression at C5–6 was found to be produced by associated disc protrusion (Fig. 3b and c). Intramedullary hyperintensity was demonstrated from C-3 to C-7 on T2*-weighted images (Fig. 3c).

Operation and Postoperative Course. Because of the longitudinal extension of the spinal cord compression (four vertebral body levels), posterior decompression by an expansive laminoplasty from C-3 to C-7 was performed. Postoperatively, the patient showed improvement in the gait disturbance and sensory deficits. The patient’s postoperative NCSS score was 8/14 (3/5 in lower-extremity and 2/5 in upper-extremity motor function, and 3/4 in sensory function).

Results

Ossification of the Posterior Longitudinal Ligament and Associated Disc Protrusion

Preoperative MR imaging of the cervical spine clearly demonstrated deformity of the spinal cord caused by compression by the OPLL or an associated disc protrusion. Ossified ligament was demonstrated as a hypointense area adjacent to the posterior surface of the vertebral bodies on T1- and T2*-weighted images. An area of hyperintensity in the ossified ligament, which indicated fatty bone marrow tissue, was also occasionally observed. Disc protrusion was recognized in two (25%) of eight cases of continuous OPLL, 19 (90%) of 21 cases of segmental OPLL, and seven (54%) of 13 cases of the mixed type of OPLL. Maximum cord compression was usually recognized at the intervertebral levels. Ossified ligament was responsible for the maximum cord compression in the majority of patients with continuous and mixed-type OPLL, whereas
protruded discs produced maximum cord deformity in most of the patients with segmental OPLL. Disc protrusion produced maximum cord compression in two cases (25%) of continuous OPLL, 17 cases (81%) of segmental OPLL, and six cases (46%) of the mixed type. Thus, the associated disc protrusion was responsible for neurological deficits in 25 (60%) of 42 cases of OPLL in our series.

Neurological State and Spinal Cord Deformity

The preoperative NCSS scores of 42 patients ranged from 5 to 13 (median 10). The cord deformity ratios in these 42 patients were distributed between 0.12 and 0.48 (mean 0.28 ± 0.08; Fig. 4). Patients with approximately the same value of cord deformity ratio often showed different neurological deficits (Fig. 4); however, when the patients were divided into two groups according to the severity of their neurological deficits (18 patients in the low-score group [NCSS score of 5–9]; 24 patients in the high-score group [NCSS score of 10–13]), the mean cord deformity ratio of the low-score group (0.25 ± 0.07) was significantly lower (p = 0.04) than that of the high-score group (0.30 ± 0.09).

Intramedullary Signal Changes

The T$_2$*-weighted images displayed intramedullary hyperintensity in 18 patients (43%; five patients with continuous OPLL, nine with segmental OPLL, and four with the mixed type of OPLL). The hyperintense areas were present at or around maximum compression levels. Longitudinally, areas of hyperintensity were confined to the intervertebral disc level in six cases, approximately one to two vertebral levels in six cases, and three to five vertebral levels in six cases. Images obtained in six patients showed a characteristic “fried egg–like” or “snake-eye” hyperintensity that was coincidental with the gray matter of the spinal cord in the axial T$_2$*-weighted images. Neurological deficits in the 18 patients in whom intramedullary hyperintensity was demonstrated on MR imaging were more severe (NCSS scores of 5–11, mean 8.1 ± 1.9) than those in the other 24 patients (NCSS scores of 7–13, mean 10.4 ± 1.4). Also, the mean cord deformity ratio of the 18 patients in whom intramedullary hyperintensity was demonstrated (0.24 ± 0.06) was significantly lower than that of the other 24 cases (0.31 ± 0.08; p = 0.005).
Follow-Up Results

Postoperative follow-up periods in this series ranged from 3 to 67 months (mean 17 months). All but three cases showed neurological improvement after surgery, although the 18 patients in whom intramedullary hyperintensity was demonstrated on T$_2$*-weighted images had lower NCSS scores pre- and postoperatively (mean preoperative NCSS score 8.1 ± 1.9; mean postoperative NCSS score 10.4 ± 2.2) than the other 24 patients (mean preoperative NCSS score 10.4 ± 1.4; mean postoperative NCSS score 12.9 ± 1.2).

Magnetic resonance imaging studies were repeated in 24 patients 1 to 67 months after surgery. The postoperative MR images demonstrated that the spinal cord deformity was significantly improved after decompressive surgery (mean preoperative cord deformity ratio 0.28 ± 0.07, mean postoperative cord deformity ratio 0.44 ± 0.07; p < 0.01). Intramedullary hyperintensity on preoperative T$_2$*-weighted images was demonstrated in 12 of the 24 patients. The intramedullary hyperintensity was still observed on postoperative T$_2$*-weighted images in 11 of these 12 patients, although all of these patients showed neurological improvement after surgery.

Discussion

Ossification of Posterior Longitudinal Ligament and Disc Protrusion

Magnetic resonance imaging findings of cervical OPLL have been reported by several authors. Magnetic resonance T$_1$- and T$_2$*-weighted images have demonstrated ossified ligaments with hypointensity adjacent to the posterior aspect of the vertebral bodies. The appearance of increased signal intensity in the OPLL on T$_1$*-weighted images, which indicates presence of fatty bone marrow, has also been reported. The radiological findings of OPLL in the present series were consistent with these reported features. The present study also demonstrated the importance of associated disc protrusion in the development of myelopathy in patients with OPLL. In our series, protruded discs were present at the level of maximum spinal cord compression in 60% of the patients. The type of OPLL greatly influenced the incidence of the associat-
ed disc protrusion. Patients with segmental OPLL had the highest incidence (81%) of disc protrusion, which was responsible for their myelopathy. This result was consistent with the results reported by Hanakita, et al. In their study, 79% of patients with segmental OPLL had coexisting disc protrusion, whereas the incidence of disc protrusion in patients with continuous and mixed-type OPLL was 17% and 38%, respectively. Pathological studies reported by other authors also described disc protrusions in patients with cervical OPLL.

The rate of occurrence of disc protrusion in patients with cervical OPLL is unknown. An epidemiological survey revealed that OPLL of the cervical spine was present in approximately 3.2% of the Japanese population older than 50 years of age. It is also known that spinal cord symptoms are not present in all individuals with radiographically demonstrated OPLL in the cervical spine. It should be noted that the incidence of disc protrusion in our series was derived from symptomatic OPLL cases. This fact suggests that disc protrusion plays a major role in the development of myelopathy in some cervical OPLL patients. If the patient has a marked spinal cord compression caused by disc protrusion with relatively thin OPLL at the vertebral body levels, a simple discectomy and interbody fusion can be one option for surgical treatment.

The mechanisms of disc protrusion in cervical OPLL have not been clarified. Our current results and those of the previous report seem to indicate a significant contribution of dynamic factors of the cervical spine, because a protruded disc is most frequently observed in patients with segmental OPLL, in whom intervertebral motion of the cervical spine is preserved. Hanakita, et al. proposed that the fragility of the posterior longitudinal ligament and the annulus fibrosus would cause disc protrusion, because pathological changes in the posterior longitudinal ligament, such as hypertrophy and laceration, have been known to occur in the pathological processes of OPLL. Kubo, et al. reported that the deep layer of the posterior longitudinal ligament was intimately related to the annulus fibrosus. It is speculated that the posterior longitudinal ligament becomes hypertrophic and then the ligament at the vertebral body levels becomes ossified in cases of segmental OPLL. The posterior longitudinal ligament at the vertebral body levels will lose elasticity and cause abnormal mechanical stress to the hypertrophic posterior longitudinal ligament at the intervertebral disc levels with neck motion. Such mechanical stress will be responsible for degenerative changes in the posterior longitudinal ligament and the annulus fibrosus, which are eventually followed by disc protrusion.

Intramedullary Hyperintensity

The clinical significance and origin of intramedullary hyperintensity observed on T1- or T2*-weighted images in OPLL patients are not fully clarified. Such an abnormal signal change in the spinal cord has also been reported in patients with cervical spondylosis. The abnormal hyperintensity may reflect myelomalacia due to spinal cord compression. Several authors have tried to analyze the clinical significance of intramedullary hyperintensity on images of patients with cervical spondylosis or OPLL. Unfortunately these studies have failed to show a significant relationship between intramedullary hyperintensity and clinical symptoms. In the present study, the mean (NCSS) score of neurological deficits in patients exhibiting intramedullary hyperintensity on MR imaging was found to be significantly lower than that in patients who did not exhibit intramedullary abnormality in our series, although this finding did not indicate poor functional prognosis. Also in the present study, six of the 18 patients with intramedullary hyperintensity presented "fried egg-like" or "snake-eye" hyperintensity in the spinal cord on T1- or T2*-weighted axial images. This characteristic pattern of intramedullary abnormality is known to represent cystic changes in the gray matter.
Magnetic resonance imaging of cervical OPLL

It is likely that intramedullary hyperintensity represents histopathological changes in the spinal cord; however, some of these changes may not result in clinical symptoms. For example, the spinal cord that is mildly affected by cervical OPLL can show cystic changes in gray matter while the surrounding white matter is preserved. Such a patient will show only mild neurological deficits with intramedullary hyperintensity on T₁-weighted MR imaging. The spinal cord that is severely affected by OPLL or cervical spondylosis has been reported to show degenerative changes in the white matter, with ascending and descending degeneration of white matter tracts. It is likely that these white matter changes, including walerian degeneration, are also responsible for the intramedullary hyperintensity, especially in patients with severe neurological deficits. The other possible origin of the intramedullary hyperintensity will be congestive or edematous changes in the spinal cord caused by disturbed venous drainage due to spinal cord compression. However, this possibility is unlikely in the present series, because the pre- and postoperative MR imaging studies revealed that intramedullary hyperintensity was still observed after satisfactory decompressive surgery in most patients.

Role of MR Imaging in Surgical Treatment

It is true that the presence of cervical OPLL does not always indicate the presence of spinal cord compression at corresponding levels. In our series, OPLL frequently extended longitudinally in the spinal canal, yet spinal cord compression was localized to relatively short segments, as shown in Case 2. Also, OPLL extended up to the C-2 level in 12 of our 42 patients. Six of these patients underwent posterior decompression from the C-1 or C-2 levels, whereas six other patients were treated anteriorly. The latter six patients underwent corpectomy of the vertebral bodies between C-3 and C-6 (C3–4: two cases; C3–5: one case; C4–5: two cases; and C5–6: one case); however, corpectomy of the C-2 vertebral body was not performed because MR imaging had shown little spinal cord compression at this level. Thus, our results indicate that in the evaluation of patients with cervical OPLL, MR imaging is useful in determining the actual compression level. Because selection of the surgical treatment of cervical OPLL primarily depends on the length of spinal cord compression, findings on MR imaging will help determine whether to use the anterior or posterior approach. We believe that MR imaging has an important role in establishing the diagnosis of spinal cord compression and in making the decision as to which surgical treatment is appropriate for patients with cervical OPLL.

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