Significance of the double-layer and single-layer signs in the ossification of the posterior longitudinal ligament of the cervical spine

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Object. The purpose of this study was to elucidate the significance of the signs of dural penetration, which were previously described by Hida et al. This goal was accomplished by an analysis of preoperative computed tomography scans and a review of the medical records of patients who underwent removal of the ossification of the posterior longitudinal ligament (OPLL) via the anterior approach.

Methods. Outcomes in 197 patients with cervical OPLL who underwent anterior decompression and fusion were studied retrospectively. The types of OPLL, single- and double-layer signs of dural penetration, diameter of the central hypodense mass of the double-layer sign, and the presence of actual dural penetration were evaluated.

Signs of dural penetration were found in 30.5% of patients. These signs were much more prevalent in patients with nonsegmental OPLL. Dural defects were present in 20 (52.6%) of 38 patients with double-layer signs and in three (13.6%) of 22 patients with single-layer signs. Among patients in the double-layer sign group, the mean diameter of the central hypodense masses was thicker in the group with an actual dural defect. Although not to the degree reported by Hida et al., the double-layer sign had a significant association with dural defects. In particular, the thicker the central hypodense mass of the double-layer sign, the greater the possibility of a dural defect. However, a single-layer sign had less significance than a double-layer one.

Conclusions. Surgeons should be alert to the increased possibility of a dural defect when there is a double-layer sign with a thick central hypodense mass in nonsegmental OPLL.

Key Words • dural penetration • double-layer sign • single-layer sign • ossification • posterior longitudinal ligament

Surgical removal of the OPLL mass via the anterior approach may cause unexpected complications, a primary one being leakage of CSF through a dural defect.6,8–11 The increased opportunity for spinal cord or nerve root damage may cause disastrous neurological deterioration in patients with this condition.6 In addition, CSF fistulas can occur during multilevel anterior cervical corpectomy and fusion performed for OPLL.6,8,11

If surgeons had the capability to detect whether the OPLL mass had penetrated the dura mater prior to the anterior approach, this would facilitate operative planning and avoid unnecessary complications.1–5 Hida et al.8 described CT findings associated with dural penetration and replacement by OPLL. Both single- and double-layer signs were among those findings.

The purpose of this study was to elucidate the significance of the signs of dural penetration by an analysis of preoperative CT scans and a review of medical records in patients who underwent removal of OPLL via the anterior approach.

Clinical Material and Methods

One hundred ninety-seven patients with cervical OPLL (138 men and 59 women; mean age 57 years [mean ± SD 56.8 ± 9.5 years], range 38–81 years) who underwent anterior decompressions and fusions were included in this study. Surgical options were one- to five-level anterior procedures. Preoperative imaging examinations (especially CT scans) and medical records (including operative records) were retrospectively reviewed in these patients, and the two signs of dural penetration, type of OPLL, and the presence of actual dural penetration and CSF leakage were evaluated.

The signs of dural penetration were divided into two
types based on the shape in relation to the OPLL. Hida et al. defined two CT findings that were indicative of dural penetration. The first, the single-layer sign, was defined as a large focal mass of uniformly hyperdense OPLL. The second, the double-layer sign, was characterized by anterior and posterior rims of hyperdense ossification separated by a central hypodense mass (the hypertrophied but nonossified PLL). Figure 1 presents schematic drawings of the single- and double-layer signs. We evaluated these signs in the bone window levels of the axial and sagittal reformations of the preoperative CT scans obtained in these patients. We also measured the thickest AP diameters of the central hypodense masses of the double-layer signs in the bone window levels of the axial CT scans. The purpose of the measurements was to find differences between the groups of patients with double-layer signs in whom actual dural defects were or were not found. Figure 2 presents examples of the single- and double-layer signs and the method of measurement of the central hypodense masses. We thoroughly evaluated the medical records, including the operative records, to determine whether there was actual dural penetration by OPLL and accompanying CSF leakage.

All of the statistical analyses of the data were processed on a personal computer by using commercially available software (SPSS, Inc.). A probability value of 0.05 or less was considered to indicate statistical significance. The means are stated as ± SDs.

Results

Surgical levels varied based on the symptoms and signs. There were 60 cases of anterior cervical discectomy and fusion (one-level, 25; two-level, 24; three-level, 10; and five-level, one); 136 cases of anterior cervical corpectomy and fusion (one-level, 50; two-level, 63; three-level, 22; and four-level, one); and one case of a combined form of anterior cervical discectomy and fusion with anterior cervical corpectomy and fusion. Mesh cages or strut bone grafts and plates with screw systems were used in all cases.

The double-layer sign of dural penetration was found in 38 patients, and the single-layer sign was found in 22. A total of 60 patients (30.5%) had signs of dural penetration. There were statistically significant differences between groups with and without dural penetration signs as far as the proportion of patients with the nonsegmental type of OPLL and the frequency of dural penetration (p < 0.05). The proportion of patients with the nonsegmental type of OPLL was higher in the group with the dural penetration sign. The frequency of dural penetration was higher in the group with the double-layer sign than in the other groups. Analysis of other variables, such as the mean age and sex ratio, yielded no statistically significant differences among groups. Table 1 presents a summary of the data.

Type of OPLL and Frequency of Signs of Dural Penetration

The types of OPLL were segmental, continuous, mixed, and other. The “other” type refers to a circumscribed, ossified lesion confined to the intervertebral disc space. In relation to the type of OPLL, there were 12 cases (11.8%) of a dural penetration sign among the 102 patients with segmental OPLL and 48 cases (50.5%) of this sign among the 95 patients with nonsegmental OPLL. There was a significant difference between the segmental and nonsegmental types of OPLL with respect to the frequency of signs of dural penetration (p < 0.05).

Type of Dural Penetration Signs and Actual Dural Penetration

On review of the medical records, we found that dural penetration at the site of the sign was present in 20 (52.6%) of 38 patients with a double-layer sign, and in only three (13.6%) of 22 patients with a single-layer sign. In contrast to these findings, a dural defect was found in only two (1.5%) of 137 patients who had no sign of dural penetration. There was a significant difference between the double-layer sign group and the “no-sign” group with respect to the frequency of dural penetration and CSF leakage (p < 0.05). However, there was no statistically significant difference between the single-layer sign group and the no-sign group with respect to these same factors (p > 0.05).

Double-Layer Signs With or Without Actual Dural Penetration

Thirty-eight patients had a double-layer sign. Among those, in 20 (52.6%) actual dural penetration occurred at the

FIG. 1. Schematic drawings showing the signs of dural penetration. Upper: Double-layer sign, consisting of anterior and posterior ossified rims separated by a centrally hypertrophied PLL. Lower: Single-layer sign, consisting of a single homogeneous ossified PLL mass.
Double-layer and single-layer signs in cervical OPLL

site of the sign, and they had a CSF fistula postoperatively. The mean AP diameter of the thickest hypodense mass of the double-layer sign in the bone window level of the axial CT scans was $3.73 \pm 1.54$ mm. In the double-layer sign group, with or without actual dural penetration, these AP diameters were $4.26 \pm 1.34$ mm and $3.14 \pm 1.56$ mm, respectively. There was a significant difference between the two groups with respect to this measurement ($p < 0.05$).

**Discussion**

One of the most important functions of the dura mater is to protect nervous tissues from external harm. Nevertheless, once the dura mater is ossified due to a disease such as OPLL, surgical manipulation may cause serious injury to the nervous tissues as well as to the dura mater itself if the surgeon lacks knowledge of the relationships among the aforementioned structures.\(^7\)\(^8\)\(^9\) Thus, in planning anterior procedures to treat this condition, anticipation of dural ossification and dural penetration by the OPLL mass is important to avoid CSF leakage and accidental damage to the spinal cord or nerve roots.\(^5\)\(^8\)\(^9\)

Hida et al.\(^8\) initially described two CT findings that appeared to signal dural penetration. The first, the single-layer sign, consisting of a single homogeneous OPLL mass, appeared to be somewhat less specific for focal dural penetration.\(^4\) In their study only one of nine patients with a single-layer sign had a dural defect, and in our study only three (13.6%) of 22 patients with a single-layer sign had this defect. Furthermore, there was no statistically significant difference between the single-layer sign group and the no-sign group with respect to the frequency of dural penetration and CSF leakage. Thus, the significance of the single-layer sign is less important than that of the double-layer sign.

The second (double-layer) sign, which is characterized by anterior and posterior ossified rims separated by a centrally hypertrophied PLL, was more pathognomonic for a diffusely absent dura mater.\(^4\) In the study by Hida et al., 10 of 12 patients with this sign had no separate dural plane at the time of surgery. In our study, actual dural defects were present in 20 (52.6%) of 38 patients with a double-layer sign. This was a statistically higher percentage than that in patients with no sign of dural penetration. Nevertheless, it was not as high as that in the study by Hida et al., which included only 21 patients.

Considering our results and the larger sample size, the significance of the double-layer sign should be adjusted to a lower value than that suggested by Hida et al.’s results. However, we can state that the association of a double-layer sign with a dural defect is marked enough to alert surgeons. Furthermore, as in our study, the diameter of the central hypodense mass was larger in the actual dural penetration group than in the nonpenetration group with a double-layer sign. Thus, when the central hypodense mass of the double-layer sign is thicker, the possibility of a dural defect is higher. Hida et al. stated that the more pronounced stenosis of the spinal canal caused by the OPLL was also associated with a dural defect in two of the dural penetration signs. The meaning of a thicker central hypodense mass may be explained as in their finding. That is, because

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**TABLE 1**

Summary of the data for 197 patients with OPLL with and without signs of dural penetration*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Double-Layer Sign (38 patients)</th>
<th>Single-Layer Sign (22 patients)</th>
<th>No Sign (137 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sex ratio (M/F)</td>
<td>26:12</td>
<td>13:9</td>
<td>99:38</td>
</tr>
<tr>
<td>mean age in yrs ± SD</td>
<td>57.3 ± 8.4</td>
<td>59.0 ± 11.2</td>
<td>56.4 ± 9.6</td>
</tr>
<tr>
<td>type of OPLL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>continuous</td>
<td>28</td>
<td>14</td>
<td>33</td>
</tr>
<tr>
<td>segmental</td>
<td>7</td>
<td>5</td>
<td>90</td>
</tr>
<tr>
<td>mixed</td>
<td>3</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>other</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>proportion of NS (%)†</td>
<td>81.6</td>
<td>77.3</td>
<td>34.3</td>
</tr>
<tr>
<td>rate of DP (%)‡</td>
<td>52.6</td>
<td>13.6</td>
<td>1.5</td>
</tr>
</tbody>
</table>

* DP = dural penetration; NS = nonsegmental type of OPLL.
† Statistically significant difference between the dural penetration sign group and the no-sign group ($p < 0.05$).
‡ Statistically significant difference between the double-layer sign group and the other groups ($p < 0.05$); no statistically significant difference between the single-layer sign group and the no-sign group ($p > 0.05$).

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*Fig. 2. Axial and sagittal CT scans demonstrating the signs of dural penetration. A: The double-layer sign, consisting of anterior and posterior ossified rims separated by a centrally hypertrophied PLL. In the axial view, the double arrow shows the method of measurement of the central hypodense mass, and in the sagittal view the arrow points to the level being demonstrated in the axial view. B: The single-layer sign, consisting of a single homogeneous ossified PLL mass. In the sagittal view, the arrow points to the level being demonstrated in the axial view.*
the central hypodense mass is thicker, encroachment on the spinal canal may be greater, although not all the time.
The incidence of a sign of dural penetration was 30.5% in our study, which is comparable to the results of Epstein’s study. The dural penetration sign was much more frequent in the patients with nonsegmental than in those with segmental OPLL. Mizuno et al. also reported similar results to those in our study.

Conclusions
Although not to the degree reported by Hida et al., the double-layer sign had a significant association with dural defects in our study. In particular, the thicker the central hypodense mass of the double-layer sign, the greater the possibility of a dural defect. A single-layer sign, however, had less significance than a double-layer one in predicting a dural defect. Surgeons should be alert to the increased possibility of a dural defect when they encounter a double-layer sign with a thick central hypodense mass in nonsegmental OPLL.

References

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