Floating Dural Sac Sign is a Sensitive Magnetic Resonance Imaging Finding of Spinal Cerebrospinal Fluid Leakage

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Abstract

We would like to propose floating dural sac sign, which is observed as a hyperintense band or rim around the spinal dural sac on axial T2-weighted images, as a sensitive sign to identify cerebrospinal fluid (CSF) leakage. One hundred patients with orthostatic headache were prospectively registered in 11 hospitals. These patients were examined by brain magnetic resonance (MR) imaging (n = 89), radioisotope cisternography (n = 89), MR myelography (n = 86), axial T2-weighted imaging of the spine (n = 70), and computed tomography myelography (n = 2). In this study, we separately evaluated the imaging findings of intracranial hypotension and spinal CSF leakage. Among 100 patients, 16 patients were diagnosed as having spinal CSF leaks. Of 70 patients examined with axial T2-weighted imaging, 14 patients were diagnosed with spinal CSF leaks, and floating dural sac sign was observed in 17 patients, 13 patients with spinal CSF leaks and 4 without CSF leaks (sensitivity 92.9%, specificity 92.9%). Of 86 patients examined by MR myelography, extradural fluid was observed in only 3 patients (sensitivity 21.4%, specificity 100%). The floating dural sac sign was a sensitive sign that can be used to identify CSF leakage. Spinal axial T2-weighted imaging might be a good screening method for spinal CSF leakage that can help to avoid the need for lumbar puncture.

Key words: cerebrospinal fluid leakage, spontaneous intracranial hypotension, spinal magnetic resonance imaging, T2-weighted magnetic resonance imaging, lumbar puncture

Introduction

Spontaneous intracranial hypotension is an established entity of clinical disorders that are characterized by orthostatic headache and diffuse pachymeningeal gadolinium enhancement on magnetic resonance (MR) imaging with or without various characteristic MR imaging findings.5,7–10,13 The concept of this disorder has been changing and expanding since the term spinal cerebrospinal fluid (CSF) hypovolemia was proposed instead of intracranial hypotension.6 Both these disorders are thought to be caused by spontaneous CSF leakage,16 so the presence of a CSF leak is important to prove if a treatment with an epidural blood patch is planned.5,14 Radioisotope (RI) cisternography,5,17 MR myelography,19,21,23 spinal MR imaging,4,11,22 computed tomography (CT) myelography,14,15 and intrathecal gadolinium-enhanced MR myelography have been reported to show spinal CSF leaks.1,20 This study proposes the occurrence of floating dural sac sign, which is observed as a hyperintense band or rim around the spinal dural sac on axial T2-weighted images (Fig. 1), as a sensitive sign to screen for CSF leakage. We named this finding floating dural sac sign because it is similar to floating aorta sign, which indicates the marked paraaortic lymph node swelling observed on abdominal CT in patients with malignant lymphomas.

Materials and Methods

This research was planned as a prospective observational study. A total of 100 patients with orthostatic headache were registered between May 2008 and March 2011 in 11 hospitals under the Cerebrospinal...
Fig. 1  Sagittal fat-saturated T2-weighted (A), axial fat-saturated T2-weighted at the T1 level (B), and axial fat-saturated T1-weighted with contrast medium at the T1 level (C) magnetic resonance images illustrating floating dural sac sign. The dural sac is floating in the fluid of the spinal column (B; arrows), although epidural fluid cannot be distinguished from subarachnoid cerebrospinal fluid on the sagittal image (A). Part of the extradural fluid, which is not enhanced (C; arrowheads) could show cerebrospinal fluid leaks. The enhanced part of the extradural fluid is considered to be a dilated vein.

Table 1  Imaging criteria for spinal cerebrospinal fluid (CSF) leaks

<table>
<thead>
<tr>
<th>A) Spinal MR images/MR myelograms</th>
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<tbody>
<tr>
<td>Probable: extradural fluid continuing subarachnoid space</td>
</tr>
<tr>
<td>Strongly suspected: extradural fluid continuing subarachnoid space or extradural fluid without a gadolinium enhancement</td>
</tr>
<tr>
<td>Suspected: extradural fluid</td>
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<table>
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<tr>
<th>B) RI cisternography</th>
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<tbody>
<tr>
<td>Strongly suspected: localized abnormal RI accumulation</td>
</tr>
<tr>
<td>Suspected: asymmetric abnormal RI accumulation in any region or symmetric abnormal RI accumulation of cervical and/or thoracic regions</td>
</tr>
<tr>
<td>* When accompanied a circulation insufficiency, decision should be upgrade, i.e. strongly suspected to probable, suspected to strongly suspected.</td>
</tr>
<tr>
<td>* Circulation insufficiency is decided when RI accumulation of the vertex is poorer than that of basal cistern in a RI cisternogram obtained 24 hours after injection.</td>
</tr>
<tr>
<td>* A Christmas tree sign (symmetric abnormal RI accumulation of lumbar region) is omitted in this study because it is possible caused by technical failures (half-in half-out) or postpuncture CSF leaks.</td>
</tr>
<tr>
<td>* The indirect finding of early visualization of the bladder is also omitted.</td>
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<th>C) CT myelography</th>
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<tbody>
<tr>
<td>Definite: extradural contrast media continuing subarachnoid space</td>
</tr>
<tr>
<td>Probable: extradural contrast media without continuing postpuncture CSF leaks</td>
</tr>
</tbody>
</table>

CT: computed tomography, MR: magnetic resonance, RI: radioisotope.

Table 2  Diagnostic criteria for spinal cerebrospinal fluid (CSF) leakage

<table>
<thead>
<tr>
<th>Definite CSF leakage</th>
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<tr>
<td>If present a definite finding on CT cisternograms.</td>
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<table>
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<tr>
<th>Probable CSF leakage</th>
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</thead>
<tbody>
<tr>
<td>If present a probable finding on any examinations.</td>
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<tr>
<td>If present strongly suspected findings at the same level on both spinal MR images/MR myelograms and RI cisternograms.</td>
</tr>
<tr>
<td>If present a strongly suspected finding and a suspected finding at the same level on spinal MR images/MR myelograms and RI cisternograms.</td>
</tr>
<tr>
<td>Possible CSF leakage</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>If present suspected findings at the same level on both spinal MR images/MR myelograms and RI cisternograms.</td>
</tr>
<tr>
<td>If present a strongly suspected finding or a suspected finding on spinal MR images/MR myelograms or RI cisternograms.</td>
</tr>
</tbody>
</table>

CT: computed tomography, MR: magnetic resonance, RI: radioisotope.

the diagnosis of intracranial hypotension. For this purpose, only the dural thickness was evaluated with contrast enhancement. The diagnosis of intracranial hypotension was made if a patient with an orthostatic headache had diffuse meningeal enhan-
sensitive MR Imaging Finding of Spinal CSF Leakage

Sensitivity, specificity, and accuracy were calculated after the evaluation of the imaging findings for the axial T2-weighted images of the spine, MR myelograms, and brain MR images that were performed before lumbar puncture.

The present study protocol was approved by the Local Research Ethics Committees of all participating institutions in this research group.

Results

Among the 100 patients with orthostatic headache, 16 were diagnosed with probable spinal CSF leakage according to the diagnostic criteria (Table 2), although there was no definite spinal CSF leakage. We finally decided that CSF leaks were present in these 16 patients with probable spinal CSF leakage.

Of the 70 patients examined with axial T2-weighted imaging, 14 were diagnosed with spinal CSF leaks and 56 were not. The floating dural sac sign was observed in 17 patients (Figs. 2 and 3), 13 patients with spinal CSF leaks and 4 without CSF leaks (sensitivity 92.9%, specificity 92.9%, accuracy 92.9%). Seven of the 17 patients who exhibited the floating dural sac sign underwent MR imaging with contrast medium, and epidural fluid collection was confirmed in 4 patients in the entire epidural space (n = 1) or focally (n = 3). In 2 of these 17 patients, adipose tissue occupied the entire epidural space of the spinal column.

Of the 86 patients examined with MR myelography, 14 were diagnosed with spinal CSF leaks and 72 were not. Paraspinal extradural fluid was observed in 3 patients with spinal CSF leaks (sensitivity 21.4%, specificity 100%, accuracy 87.2%).

Of the 89 patients examined with brain MR imaging, pachymeningeal enhancement was observed in 20 patients, who were diagnosed with intracranial hypotension. Of these 20 patients, 13 patients had spinal CSF leaks and 7 did not. Of the remaining 69 patients without pachymeningeal enhancement, only 2 patients had spinal CSF leaks. Assuming that the finding of pachymeningeal enhancement indicated CSF leakage, the sensitivity was 86.7%, the specificity was 90.5%, and the accuracy was 89.9%.

CT myelography was performed in only 2 patients in this study. A CSF leak was confirmed at the cervical portion of the spine in one patient, and leaks were also observed at the puncture site in both patients.

Discussion

The present study showed that the floating dural sac sign was a sensitive finding of spinal CSF leakage. This finding has been previously described as fluid outside the theca, collapsed dural sac with a...
festooned appearance,\textsuperscript{3} shrunken dural sacs,\textsuperscript{3} and collapsed dural sac with a hexagonal contour.\textsuperscript{22} However, the importance to screen for CSF leakage might not be recognized. On the other hand, extradural fluid on MR myelography was observed in only 3 patients, even though MR myelography has been used widely as a screening method.\textsuperscript{10,21,22} In an in vivo study, the connective tissue of the epidural space of the spinal column was loose in contrast to that of the skull. It is easy to hypothesize that CSF flowing out from the subarachnoid space through a dural tear would tend to collect around the dura mater in the spinal column. In such conditions, MR myelography or RI cisternography might not be able to demonstrate extradural fluid because these methods cannot distinguish epidural fluid in the spinal column from the subarachnoid CSF. Both methods should be able to delineate extradural fluid if CSF flows into the paraspinal space through the extradural space around some nerve sleeves.

The floating dural sac sign can be observed in a patient with a distended spinal epidural vein, enlarged epidural adipose tissue, or an epidural hematoma, in addition to patients with epidural fluid in the spinal column. The finding of a distended spinal epidural vein is frequently observed in spontaneous intracranial hypotension.\textsuperscript{3,4,11,22} MR imaging with contrast medium is needed to distinguish CSF leak from distended vein, but we performed this examination in only 7 patients and confirmed epidural fluid in 4 of these 7 patients. Spinal epidural lipomatosis is a different disorder that is characterized by overgrowth of fat in the extradural space, and is associated with administration of exogenous steroids or elevation of endogenous steroids.\textsuperscript{41} However, enlarged epidural adipose tissue is also seen in patients with intracranial hypotension and this may be one of the causes of enlarged epidural adipose tissue. Epidural hematoma occurring in the spinal column is a serious condition that is easily distinguished from other conditions by clinical and radiological features.

Postpuncture CSF leakage that causes intracranial hypotension has been well recognized.\textsuperscript{10,17} MR imaging and MR myelography before and after RI cisternography on 10 patients with orthostatic headache found that 5 had lumbosacral CSF leaks after the lumbar puncture, whereas none showed CSF leaks before the puncture.\textsuperscript{12} In 4 of the 5 patients with CSF leaks, RI cisternography showed lumbosacral CSF leaks. Therefore, postpuncture CSF leakage may occur with a high incidence, so screening methods for CSF leakage should avoid lumbar punctures. Thus, spinal axial T\textsubscript{2}-weighted imaging might be a good screening method for spinal CSF leakage.

Sagittal T\textsubscript{2}-weighted images may detect epidural fluid in the spinal column. However, displacement of the dural sac is often hard to recognize, possibly because a linear shadow is also caused by truncation artifact, flow void, or the cauda equina. In addition, the linear shadow of the dura itself may be hard to recognize due to poor spatial resolution with a wide field of view. Three-dimensional imaging can be considered an option for obtaining both sagittal and axial T\textsubscript{2}-weighted images.\textsuperscript{18}

Pachymeningeal enhancement on brain MR images was observed in 20 of our patients. Thirteen of these 20 patients had spinal CSF leaks. Pachymeningeal enhancement, which was not included in the present diagnostic criteria for spinal CSF leakage, is related to CSF leaks. Most spontaneous intracranial hypotension is thought to be caused by spinal CSF leaks.\textsuperscript{1,5,8,10,14–16,23} Thus, pachymeningeal enhancement with a high sensitivity rate of 86.7% can be an independent and sensitive sign of CSF leakage.

In this study, 16 of 100 patients with orthostatic headache were diagnosed with spinal CSF leaks. Some patients with CSF leaks might not be diagnosed correctly because our diagnostic criteria for CSF leaks did not include findings on brain MR imaging or clinical features, and because not all patients received adequate investigations. In addition, patients showing the Christmas tree sign at the lumbosacral region on RI cisternography were diagnosed with CSF leakage only if definite or probable findings were observed on MR imaging/MR myelography (or CT myelography). To establish the correct diagnosis of CSF leakage, CT myelography or MR myelography with intrathecal gadolinium administration has been recommended.\textsuperscript{1,15,20} We agree that definite proof of a CSF leak should be obtained by either CT myelography or MR myelography with intrathecal gadolinium administration. However, CT myelography was performed in only 2 patients in this study, and intrathecal injection of gadolinium is not allowed in Japan. We plan to perform a study of CSF leakage with a study protocol that includes spinal axial T\textsubscript{2}-weighted imaging and CT myelography in the near future.

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Conflicts of Interest Disclosure

We declare that we have no conflict of interest. All authors who are members of The Japan Neurosurgical Society (JNS) have registered online Self-reporting COI Disclosure Statement Forms through the website for JNS members.

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