Advances in Medical Sciences 59 (2014) 196–199

Contents lists available at ScienceDirect

Advances in Medical Sciences

journal homepage: www.elsevier.com/locate/advms

Original Research Article

# Spinal cerebrospinal fluid leaks detected by radionuclide cisternography and magnetic resonance imaging in patients suspected of intracranial hypotension

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ARTICLE INFO

*Article history:*
Received 21 February 2013
Accepted 19 December 2013
Available online 9 June 2014

*Keywords:*
Intracranial hypotension
Magnetic resonance imaging
Cerebrospinal fluid
Radionuclide imaging
Headache

ABSTRACT

*Purpose:* Although many studies have described various features of neuroimaging tests associated with intracranial hypotension, few have examined their validity and reliability. We evaluated the association between CSF leaks detected by radionuclide cisternography and abnormal MRI findings in the accurate diagnosis of intracranial hypotension.

*Patients/methods:* We retrospectively assessed 250 patients who were suspected of intracranial hypotension and underwent subsequent radionuclide cisternography. We obtained 159 sagittal and 153 coronal T2-weighted MRI images and 101 gadolinium-enhanced T1-weighted MRI images. We assessed the CSF leaks in relation to a sagging brain, the maximum subdural space in sagittal and coronal images, and dural enhancement.

*Results:* Overall, 186 (74%) patients showed CSF leaks on radionuclide cisternography. A sagging brain was observed in 21 (13%) of the 159 patients with sagittal MRIs. A sagging brain was not associated with CSF leaks (14% vs. 10%; $p = 0.49$). Compared to patients without CSF leaks, those with CSF leaks tended to have a larger maximum subdural space in both the sagittal (3.7 vs. 4.1 mm) and coronal (2.5 vs. 2.8 mm) images; however, the differences were not significant ($p = 0.18$ and $p = 0.53$, respectively). Dural enhancement was observed only in one patient, who presented with CSF leaks on radionuclide cisternography.

*Conclusions:* Our study, which included a relatively large population, did not find any association between the findings of radionuclide cisternography and MRI. Future research should focus on identifying more valid neuroimaging findings to diagnose intracranial hypotension accurately.



## 1. Introduction

Once considered an exceedingly rare disorder, intracranial hypotension has recently been identified as an important cause of persistent headaches. It is characterized by orthostatic headache and low cerebrospinal fluid (CSF) pressure. However, the nature of intracranial hypotension remains largely unknown. Spinal CSF leakages have been theorized to be associated with the development of intracranial hypotension. The most common treatment is the injection of autologous blood into the epidural space, or epidural blood patch.

Neither a gold standard nor diagnostic criteria have been established to define intracranial hypotension [1]. Although many studies have described various features of neuroimaging tests that have been observed in patients with intracranial hypotension [2–11], few have examined their validity and reliability. Since spinal CSF leaks are thought to cause intracranial hypotension, detecting CSF leaks should be useful in making an accurate diagnosis. Radionuclide cisternography is particularly useful for identifying CSF leaks and studying the CSF circulation. In fact, cisternography often reveals the approximate site of the leak by demonstrating radioactivity across the dural sac [2,3,5,6,8,12–15].

Magnetic resonance imaging (MRI) has also been reported to be of great help in the diagnosis of intracranial hypotension. Typical

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http://dx.doi.org/10.1016/j.advms.2013.12.007
1896-1126/

MRI findings, such as subdural fluid accumulation, pachymeningeal enhancement, venous engorgement, pituitary hyperemia, and a sagging brain, have been reported in intracranial hypotension [1,4–7,9,10,16]. However, such diagnostic abnormalities are not always detected [17,18] and relatively high proportion (20%) of the cases shows no abnormalities [1]. Since those studies were based on relatively small patient series or single cases, the sensitivity of MRI remains to be confirmed. It is essential to investigate the spectrum of abnormalities on MRI that correspond to intracranial hypotension. In addition, the associations between MRI findings and CSF leaks detected by radionuclide cisternography should be evaluated.

Therefore, this study investigated the incidence of CSF leaks by radionuclide cisternography and abnormal MRI findings that are commonly reported in intracranial hypotension. In addition, we evaluated the association between these two techniques in the accurate diagnosis of intracranial hypotension.

## 2. Patients and methods

The study protocol was approved by the internal review board of Teikyo University School of Medicine. We retrospectively assessed 250 patients who presented with suspected intracranial hypotension and underwent subsequent radionuclide cisternography between January 2003 and August 2006. Intracranial hypotension was suspected when a patient complained of typical orthostatic headaches or had a history of minor trauma and complained about persistent headaches, cranial nerve dysfunction, autonomic dysfunction, or higher brain dysfunction. The patient group consisted of 110 males (44%) and 140 females with an age range of 9–76 (mean 39 $\pm$ 12) years. Of these, 200 patients had a history of minor trauma: head injury in 43 patients (17%), whiplash injury in 142 (57%), and other injuries in 15 (6%).

Radionuclide cisternography was performed following a lumbar injection of $^{111}$In-diethylenetriamine penta-acetic acid. Images were obtained shortly after injection and 2, 4, and 6 h later. Direct signs of tracer leakage into the spinal epidural space are typically observed with the early accumulation of the tracer in the urinary bladder. Therefore, CSF leakage has been defined as direct signs of tracer in the spinal epidural space or early accumulation of the tracer in the urinary bladder, without direct signs of leakage (2 h after injection) [2,3,5,6,8,12–14]. One of the authors (T.N.) reviewed all of the images. All of the patients' medical records and imaging studies were reviewed.

From the 250 patients who underwent radionuclide cisternography, 159 sagittal and 153 coronal images of T2-weighted images (both $n = 152$) and 101 gadolinium-enhanced T1-weighted images were obtained in our facility. Sagging of the brain was defined as when the tip of the cerebellar tonsil was positioned at or below the level of the foramen magnum line (a line drawn from the inferior tip of the clivus to the osseous base of the posterior lip of the foramen magnum) in a sagittal T2-weighted image. The maximum subdural space in the frontal area in sagittal and coronal T2-weighted images was also measured.

The data were anonymized by numerical coding and recorded in a database. In addition to sex and age, history of trauma was recorded, including head, whiplash, or other injuries.

We assessed CSF leaks in relation to demographic factors, sagging of the brain, the maximum subdural space present in sagittal and coronal images, and dural enhancement. The differences between patients with and without CSF leaks were examined with the chi-square test for categorical variables and with the $t$-test or Wilcoxon rank sum test for continuous variables. All analyses were performed using the SAS statistical package (SAS Institute Inc., Cary, NC, USA). The criterion for significance was set at $p < 0.05$.

## 3. Results

Overall, 186 (74%) patients showed CSF leaks, including direct signs of tracer leakage into the spinal epidural space in 154 patients (62%) and early accumulation of the tracer in the urinary bladder (without direct signs of leak) in 32 patients (13%).

Among the 159 patients for whom sagittal images were obtained, sagging of the brain (Fig. 1a) was observed in 21

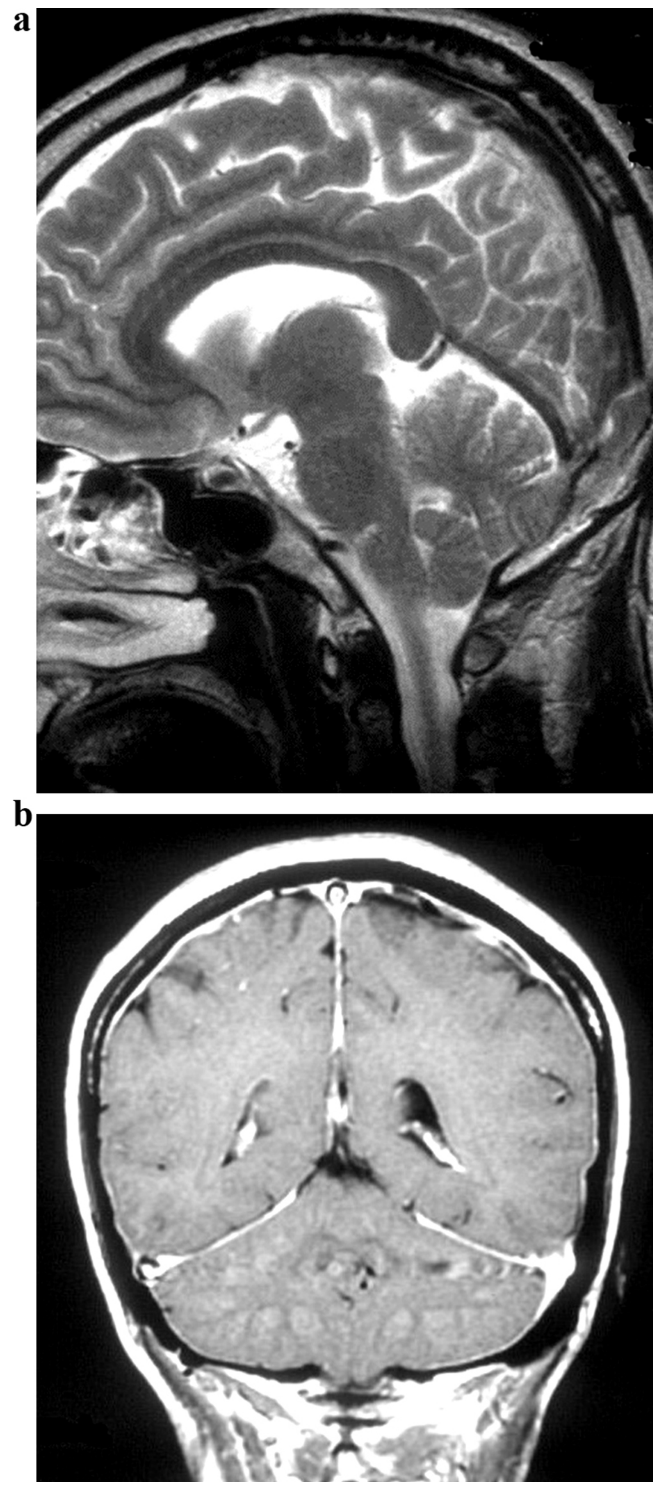

**Fig. 1.** T2-weighted magnetic resonance image in the sagittal view shows brain sagging, or downward tonsillar displacement (a) and T1-weighted image in the coronal view with contrast medium shows diffuse pachymeningeal enhancement (b).