



Interdural high signal on CISS sequence: an alternative CSF pathway?

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Abstract

Purpose The falx cerebri, falx cerebelli, and tentorial notch exhibit a peculiar morphology with a two-layered, dural leaf that protrudes into the cranial cavity with a free edge. However, there are few studies exploring this morphology using neuroimaging techniques. The present study aimed to explore these dural structures using magnetic resonance imaging.

Methods A total of 65 outpatients were included in this study. Following initial examinations with conventional sequences, the constructive interference in steady-state (CISS) sequences were performed in thin-sliced, coronal sections.

Results In 78% of the subjects, the interdural spaces presenting with high signal were identified in the falx cerebri. These spaces were located adjacent to the uppermost part of the falx, formed by two dural leaves and the superior sagittal sinus, and tapered downward where the leaves united to form the falx cerebri. At the tentorial notch, these spaces were found in 52% of the 65, most predominantly in the medial edge followed by the tentorium cerebelli-tentorial notch junctional region. Forty-one percent of patients had a dural opening into the cerebral cistern. The interdural spaces with high signal were not identified in the tentorium cerebelli in any of the subjects.

Conclusions The falx cerebri and tentorial notch form the interdural spaces that may provide alternative cerebrospinal fluid pathways. The coronal CISS sequence is suitable for delineating such interdural spaces.

Keywords Interdural spaces · Falx cerebri · Tentorium cerebelli · CSF pathway · CISS sequence

Introduction

Despite extensive investigation, the production and absorption of cerebrospinal fluid (CSF) are still not well understood [12, 13]. Recent experimental studies have suggested that the dural lymphatic network may function as CSF drainage pathways to the deep cervical, nasal, and orbital lymphatics [1, 2, 6–11]. Furthermore, a previous study with postmortem human specimens showed that the parasagittal dura mater has an extensive network of intradural channels. These were found to connect to the superior sagittal sinus and assumed to function as CSF pathways [4]. The falx cerebri, falx cerebelli, and tentorial notch exhibit a peculiar morphology represented by a two-layered dural leaf that protrudes into the cranial cavity with a

free edge. Furthermore, with these anatomical characteristics, they are broadly adjacent to the CSF on both surfaces. However, there have been few studies exploring them using neuroimaging techniques [14].

The constructive interference in steady-state (CISS) sequence is a gradient-echo magnetic resonance imaging (MRI) sequence that has been used to delineate a wide range of normal structures and pathologies. It can be useful when routine MRI sequences do not provide optimal anatomical information [3, 5, 15].

The present study aimed to explore these peculiar dural structures using the CISS sequence.

Materials and methods

This retrospective study included a total of 65 outpatients. They presented to our hospital between September 2010 and April 2011 due to headache, dizziness, vertigo, tinnitus, hemisensory disturbance, scintillating scotoma, and focal seizures. The patient population comprised 36 men and 29 women with an age range of 9 to 77 years (mean 48 years). None of the 65 patients

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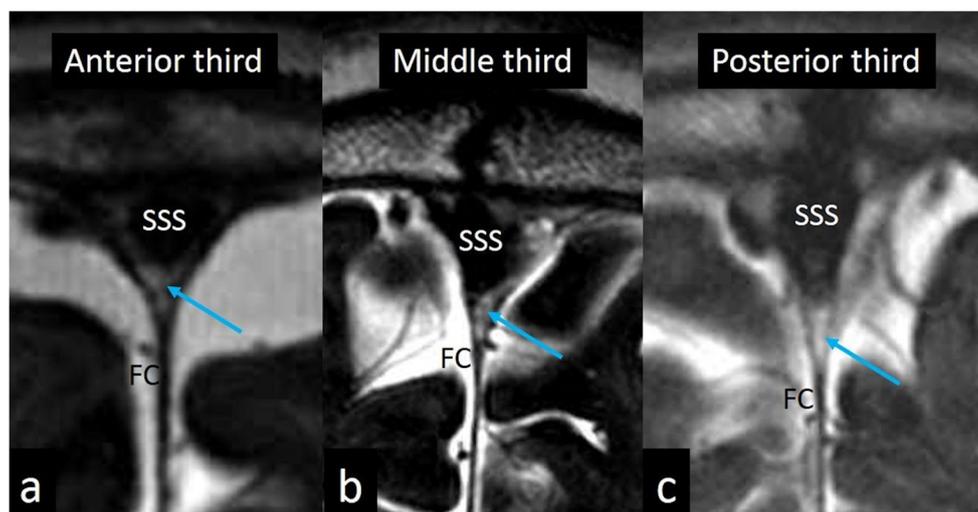


Fig. 1 a–c Coronal images of the constructive interference in steady-state sequence of different patients at the level of the anterior (a), middle (b), and posterior third (c) of the superior sagittal sinus showing the interdural spaces with high T2 signal adjacent to the uppermost part of the falx

cerebri. The spaces, formed by two dural leaves and the superior sagittal sinus, taper downwards where the dural leaves unite to form the falx cerebri. The spaces show variable shapes and sizes (a–c, arrow). FC: falx cerebri; SSS: superior sagittal sinus

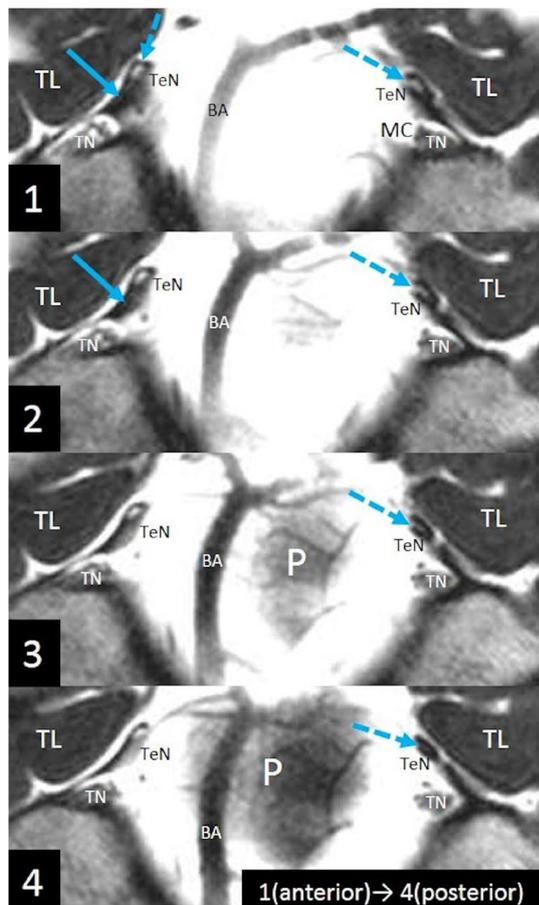


Fig. 2 Serial coronal images of the constructive interference in steady-state sequence showing the interdural spaces lying in the tentorial notch (1–2, solid arrows), forming a small cavity with an opening into the prepontine cistern at the medial edge (1–4, dotted arrow). BA: basilar artery; MC: Meckel's cave; P: pons; TL: temporal lobe; TN: trigeminal nerve; TeN: tentorial notch

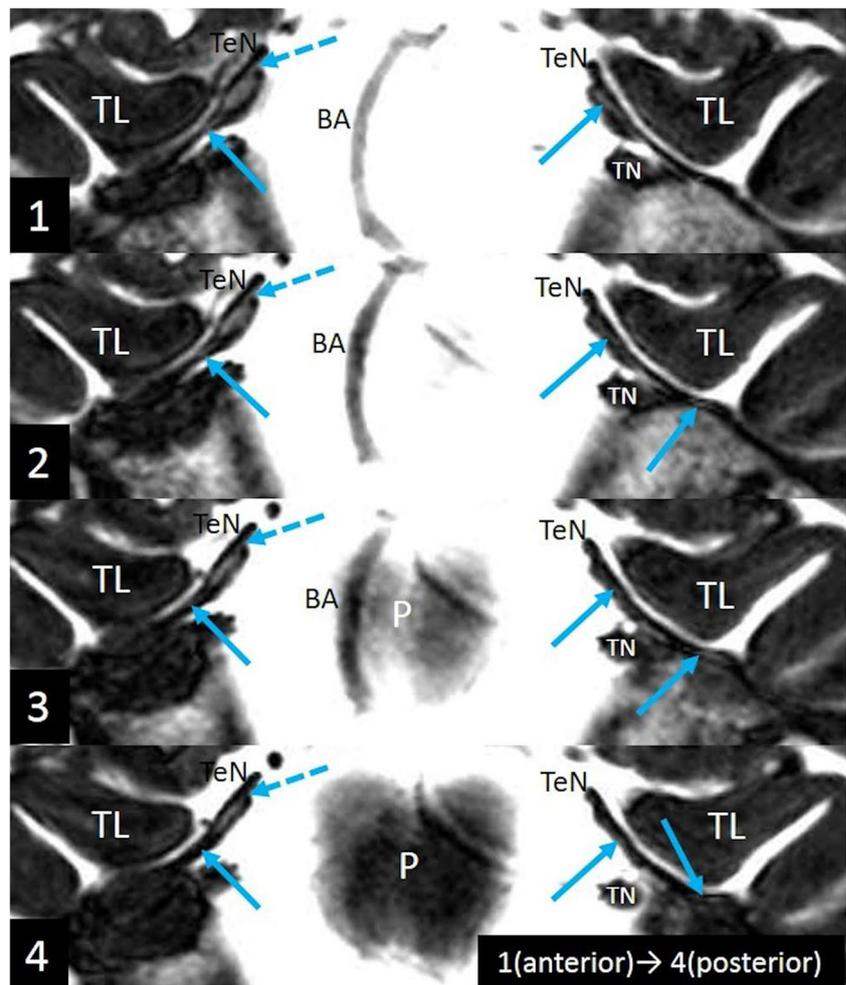
had any previous history of aneurysmal subarachnoid hemorrhage, meningitis, encephalitis, traumatic brain injury accompanying skull fractures or cerebrospinal fluid leakage, primary brain tumor complicated by leptomeningeal seeding, or meningeal metastasis from cancer. These pathologies were excluded following initial MRI examinations using axial T1-weighted, T2-weighted, T2-gradient echo, fluid-attenuated inversion recovery, and diffusion-weighted sequences. Thereafter, the patients underwent thin-sliced, CISS sequence imaging in the coronal plane covering the whole cranial vault between the anterior limit of the optic nerve and the posterior limit of the cerebellar hemispheres. The following MRI parameters were used: TR 2000 ms; TE 311 ms; slice thickness 2.00 mm; interslice gap 0 mm; matrix 320×274 ; FOV 160 mm \times 160 mm; FA 90° ; and scan duration 5 min 30 s. All the examinations were performed using a 3.0-T MRI scanner (Achieva R2.6; Philips Medical Systems, Best, The Netherlands). Coronal CISS sequence imaging data were transferred to a workstation (Virtual Place Lexus64, 64 edition; AZE, Tokyo, Japan) and analyzed independently by two of the authors (S.T. and H.I.).

The present study was performed in accordance with our institution's guidelines for human research. Written informed consent for this study was obtained from all the participants.

Results

In 78% of the 65 subjects, the interdural spaces presenting with high signal were identified in the falx cerebri.

Fig. 3 Serial coronal images of the constructive interference in steady-state sequence showing the interdural spaces lying in the tentorial notch (1–4, solid arrows), forming a large cavity with an opening into the prepontine cistern at the medial edge (1–4, dotted arrows)



All of these spaces were located adjacent to the uppermost part of the falx, formed by two dural leaves laterally and the lower surface of the superior sagittal sinus superiorly, and tapered downward where the dural leaves united to form the falx cerebri (Fig. 1). In all of these subjects, the spaces were identified to communicate with the subarachnoid spaces of the cerebral convexity through dural defects. The interdural spaces with high signal were highly variable in shape and size. Even in the same subject, the morphology of these spaces showed considerable variability depending on the location in the cranial cavity. Ninety-two percent of the spaces were identified in the posterior third of the falx cerebri, followed by 82% in the middle third, and 25% in the anterior third. Furthermore, the serial CISS images allowed the delineation of the course and morphology of the interdural spaces in the tentorial notch in 52% (34/65). Twenty percent (13/65) of these spaces were found on the right side, 14% (9/65) on the left, and 18% (12/65) bilaterally. These spaces were most predominant in the medial edge, comprising 74% (25/34) of all,

followed by the tentorium cerebelli-tentorial notch junctional region comprising 24% (8/34), and the upper part of the tentorial notch found in 3% (1/34). The dura mater of the junctional region where the interdural spaces with high signal were found was locally thickened. Forty-eight percent (12/25) of the interdural spaces that were identified in the medial edge of the tentorial notch formed a cavity of varying size and communicated with the prepontine cistern through a dural opening at the medial edge (Figs. 2 and 3). Furthermore, in four subjects, fine arachnoid granulations were found in the tentorial notch lying near the medial edge (Fig. 4). In addition, 25% (2/8) of the interdural spaces that were identified in the tentorium cerebelli-tentorial notch junctional region exhibited a dural opening into the supracerebellar cistern (Fig. 5). In one patient, the interdural spaces were identified in the upper part of the tentorial notch, lacking a dural opening into the cerebral cistern (Fig. 6). The interdural spaces were not delineated in the tentorium cerebelli in any of the 65 subjects. These outcomes are summarized in Table 1.

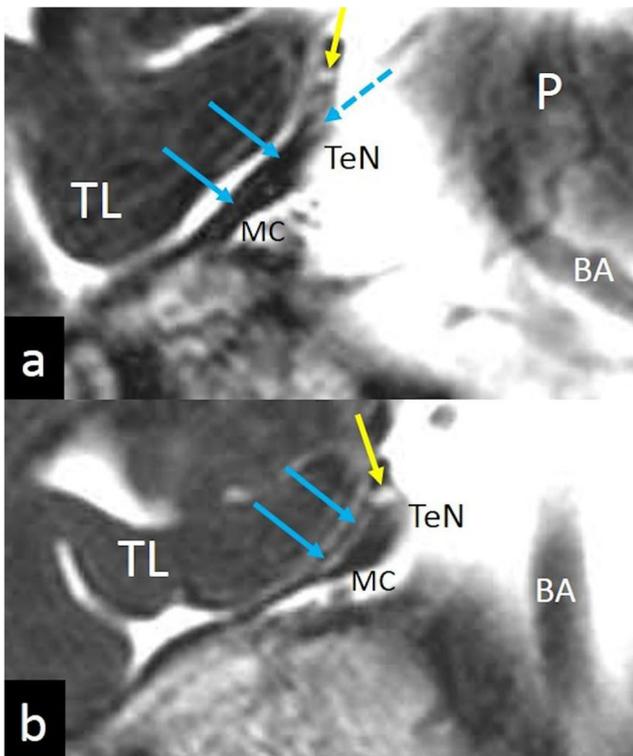


Fig. 4 a, b Coronal images of the constructive interference in steady-state sequence of different patients, right halves, showing fine arachnoid granulations lying near the medial edge of the tentorial notch (a, b, yellow arrow). Solid blue arrow: interstitial spaces in the tentorial notch. Dotted blue arrow: opening of the interstitial space

Discussion

In the present study using the coronal CISS sequence, the interstitial spaces presenting with high signal were identified in the uppermost part of the falx cerebri and in the tentorial notch, in 78% and 52% of presenting outpatients, respectively. Moreover, 41% of the latter population had a dural opening into the prepontine and supracerebellar cisterns. These findings suggest that some of the intracranial CSF may use these interstitially formed spaces as draining pathways. Furthermore, these interstitial spaces connecting with the CSF by way of dural defects could be a pathway through which the CSF reach the intradural lymphatic channels that connect to the extracranial lymphatic systems [1, 10]. Two-layered dural leaves with a free edge that are amenable for broad contact with the CSF may be advantageous when functioning as a CSF pathway. These speculations should be verified in future investigations with more sophisticated techniques and manners. In that case, MRI sequences more sensitive for delineating the fine interstitial spaces would be ideal.

There were limitations in the present study. Our study was performed in a retrospective manner with the participants not randomly assigned. The group of subjects had an inhomogeneous age and sex composition. Furthermore, the fine interstitial spaces were assessed only on coronal CISS images.

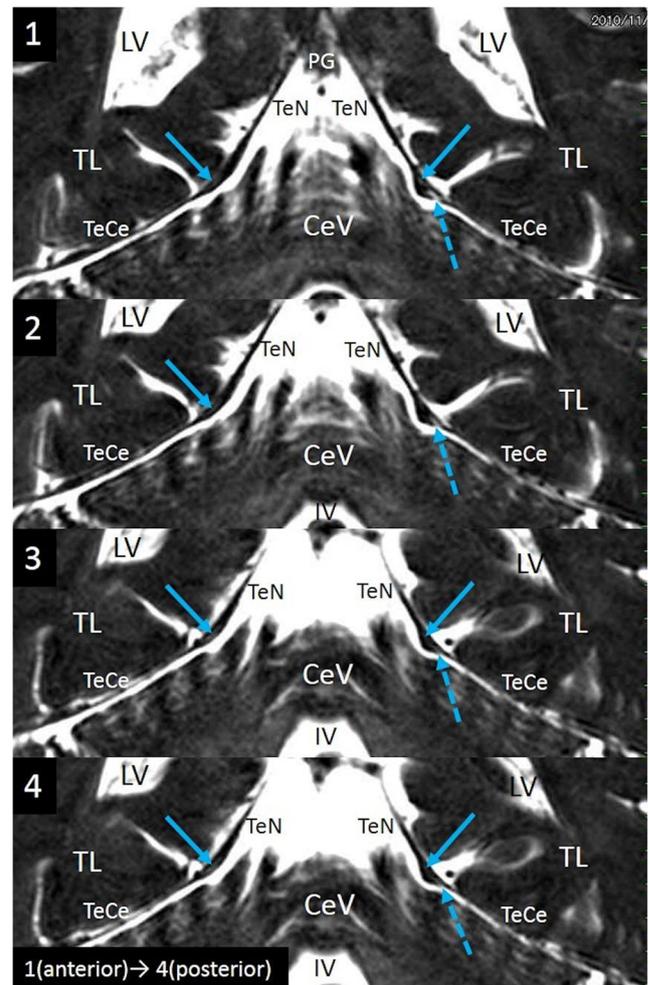


Fig. 5 Serial coronal images of the constructive interference in steady-state sequence showing the interstitial spaces lying in the tentorium cerebelli-tentorial notch junctional region (1–4, solid arrow), with an opening into the supracerebellar cistern (1–4, dotted arrow). CeV: cerebellar vermis; LV: trigone of the lateral ventricle; PG: pineal gland; TeCe: tentorium cerebelli; IV: fourth ventricle

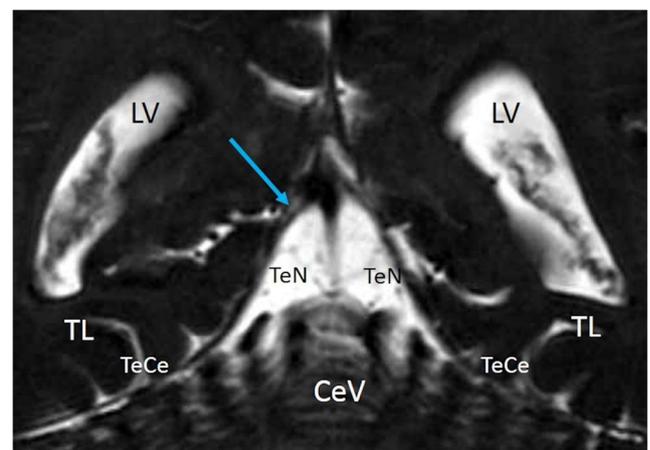


Fig. 6 Coronal image of the constructive interference in steady-state sequence showing the interstitial space lying in the upper part of the tentorial notch (arrow)

Table 1 Summary of identified interdural spaces. *CISS* constructive interference in steady-state sequence, *FC* falx cerebri, *TeCe* tentorium cerebelli, *TeN* tentorial notch

Uppermost part of FC	78% (51/65)
Anterior third	24% (12/51)
Middle third	82% (42/51)
Posterior third	92% (47/51)
Tent	52% (34/65)
Right	20% (13/65)
Left	14% (9/65)
Bilateral	18% (12/65)
Location	
Medial TeN	74% (25/34)
Opening into the cistern	48% (12/25)
TeCe-TeN junction	24% (8/34)
Opening into the cistern	25% (2/8)
Upper TeN	3% (1/34)
Opening into the cistern	0% (0/1)

Despite these limitations, we believe that the findings provided by our methodology suggest an alternative CSF pathway through the cranial interdural spaces.

Conclusions

The falx cerebri and tentorial notch form the interdural spaces that may provide alternative CSF pathways. The coronal CISS sequence is suitable for delineating such interdural spaces.

Authors' contribution to the manuscript Satoshi Tsutsumi and Hideo Ono developed the study project.

Yukimasa Yasumoto was involved in data collection and management. Satoshi Tsutsumi and Hisato Ishii analyzed the data. Satoshi Tsutsumi wrote the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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