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ORIGINAL ARTICLE

Correlation of the external occipital protuberance with venous sinuses: a magnetic resonance imaging study

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Abstract

Purpose To date, no study has explored the external occipital protuberance (EOP) using neuroimaging modalities.This study aims to characterize them using magnetic resonance imaging (MRI).

Methods A total of 96 patients underwent thin-sliced, post-contrast MRI. The sagittal images were analyzed.

Results In 97%, the EOPs were delineated as a focal external protrusion of the midline region of the occiput with varying morphologies. In 89% of 93 patients with identifiable EOPs, parts of the intracranial dural sinuses were found to lie just below the inion, the most prominent point of the EOP. The most frequently targeted dural sinus was the confluence of sinuses that was found in 57%, followed by the superior sagittal sinus. In 16%, a bony foramen and transmitting vessel were detected in the EOP, connecting between the diploic channels and the subcutaneous veins. Furthermore, in 33%, bony foramina and transmitting venous structures were identified in the region just below the EOPs, connecting between the diploic channels and the subcutaneous veins.

Conclusions The intracranial dural venous sinus is located just below the EOP with a high probability. Most bony foramina in the EOP and midline suboccipital region may transmit veinous structures connecting to the diploic channel.

Keywords Bony foramina · Diploic channel · External occipital protuberance

Introduction

The human occipital bone has been frequently investigated in paleoanthropological studies because it has several features that help to differentiate various fossil hominin species. Among these is the separation between the inion and the endinion, or between the most prominent point of the external occipital protuberance (EOP) and its counterpart in the inner skull [1, 21]. The EOP is commonly identified as an inconsistent bony ridge with varying morphologies at the level of the superior nuchal line, a horizontal bony ridge. In a previous study, spine-type was the most common in women, while flat-type was the most common in men [7]. The median nuchal line is a longitudinal bony ridge, which courses in the midline below the EOP to near the posterior margin of the foramen magnum (Fig. 1). The trapezius and semispinalis capitis muscles attach to the superior nuchal line. The superior oblique, rectus capitis posterior major, and rectus capitis posterior minor muscles attach to the inferior nuchal line, a horizontal bony ridge found at the mid-level of the median nuchal line. The nuchal ligament attaches to the inferior nuchal line [16]. The EOP has been explored as a craniometric point of the occipital bone, an indicator of gender discrimination, and a site of occipitocervical fixation and its relationship with dural venous sinuses lying below [2–4, 6, 8, 10, 13, 14, 20]. In clinical settings, unusually enlarged EOPs and painful exostosis of the EOP have received attention [9, 11, 12, 15, 17, 18].

Studies using dry skulls and cadaver heads have documented that the emissary foramina were found in 2.6–9.5% of the occipital bones, mainly in the lateral suboccipital region and around the foramen magnum [5, 11, 19]. However, to the best of our knowledge, no study has yet explored the EOP using neuroimaging modalities. Therefore, this study aimed to characterize them using magnetic resonance imaging (MRI).

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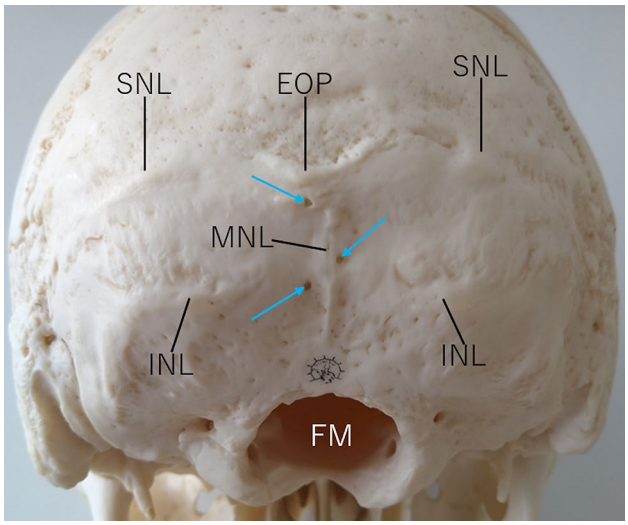

Fig. 1 The inferoposterior view of a human skull showing the external occipital protuberance (EOP) and relevant structures. On this skull, three well-developed bony foramina are identified in the midline suboccipital region, beside the median nuchal line (*arrows*). *FM,* foramen magnus; *INL,* inferior nuchal line; *MNL,* median nuchal line; *SNL,* superior nuchal line

Materials and methods

This retrospective study included 96 outpatients who underwent MRI examinations at the Medical Satellite Yaesu Clinic between August 2009 and April 2016. These patients presented with headaches, dizziness, tinnitus, hearing loss, and focal seizures. The study population consisted of 46 men and 50 women aged 51.2 ± 16.5 years (mean ± standard deviation; range, 8–78 years). Initial examinations using axial T1- and T2-weighted, T2 gradient echo, fluid-attenuated inversion recovery, and diffusion-weighted imaging and magnetic resonance angiography confirmed that none of the patients had signs of pathological conditions in the cerebrum, cerebellum, brainstem, skull, cranial dura maters, and scalp of the occipitocervical region. Patients presenting with occipital headaches were excluded. Subsequently, the patients underwent a volumetric imaging examination after intravenous gadolinium infusion (0.1 mmol/kg) in the axial, coronal, and sagittal planes, involving the entire cranial vault. The following parameters were adopted: repetition time, 4.1 ms; echo time, 1.92 ms; slice thickness, 1 mm; interslice gap, 0 mm; matrix, 320 × 320; field of view, 250 mm; flip angle, 13°; and scan duration, 7 min 25 s. All imaging sequences were performed using a 3.0-T MRI scanner (Achieva R2.6; Philips Medical Systems, Best, The Netherlands). Imaging data were transferred to a workstation (Virtual Place Lexus 64, 64th edition; AZE, Tokyo, Japan) and independently analyzed by two of the authors (S.T. and H.I.). Patients with stenosis or obstruction in the intracranial dural venous sinuses were excluded from this study. A low detection performance of the EOP-associated fine venous structures was found during the preliminary examinations with the axial and coronal imaging. Therefore, only the sagittal images were analyzed.

This study was conducted in accordance with the guidelines of our institution and those of the Medical Satellite Yaesu Clinic regarding human research. Written informed consent was obtained from all patients prior to participation in the study.

Results

In 93 of 96 patients (97%), the EOPs were identified as a focal, external bony rise in the midline region of the occiput with varying morphologies. In addition, the distal ends of the trapezius and semispinalis capitis muscles are attached to it. The thickness and length of the occipital bone caudal to the EOPs were also variable in the cross-sections without any specific trends in association with age or sex (Fig. 2). In 3 (3%), the EOP or its most prominent point, inion, was indistinct and not discernable (Fig. 3). Therefore, the EOP and midline suboccipital regions were explored in 93 patients with identifiable EOPs. In 89% of the 93, parts of the intracranial dural sinuses were located just below the inion, the most prominent point of the EOP (Fig. 4). The most frequently targeted dural sinus was the confluence of sinuses (57%), followed by the superior sagittal sinus (26%). In 3%, the sagittal and occipital sinuses were located below the inion. In 11%, there was no dural venous sinus lying below the inion (Table 1).

In 16% (15/93), a bony foramen and transmitting vessel were identified to course in the EOP (Table 2). Among them, 14 were venous channels connecting between the diploic channel and subcutaneous veins (Fig. 5). The remaining one was an emissary vein connecting the confluence of the sinuses and the subcutaneous vein (Fig. 6). Furthermore, in 33%, bony foramina and transmitting vessels were identified at varying heights of the midline suboccipital region below the EOPs. All of these vessels were emissary veins connecting between the diploic channel and the subcutaneous veins (Fig. 7). To facilitate the analysis, the region below the EOP was arbitrarily divided into three segments: the upper (UT), middle (MT), and lower third (LT) levels (Fig. 8). The venous channel was most frequently located in the MT and was found in 16%, followed by LT (12%) and UT (5%). Five percent of the channels comprised multiple pathways (Table 2).

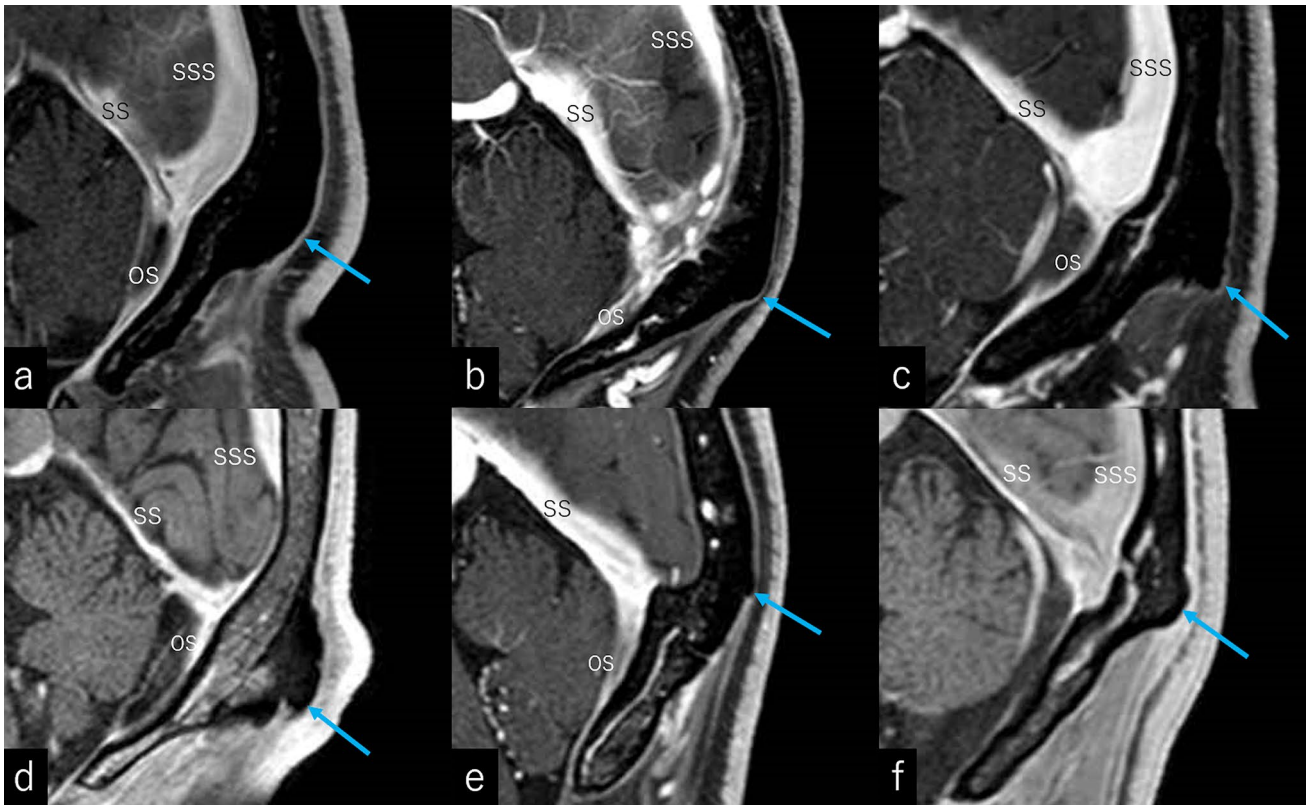

Fig. 2 Post-contrast sagittal magnetic resonance images of different patients at the level of the inion, the most prominent point of the external occipital protuberance, showing variable morphologies of the external occipital protuberance (**a**–**f** arrow) with diverse thicknesses and lengths in the cross-section of the caudal occipital bone. *OS,* occipital sinus; *SS,* straight sinus; *SSS,* superior sagittal sinus

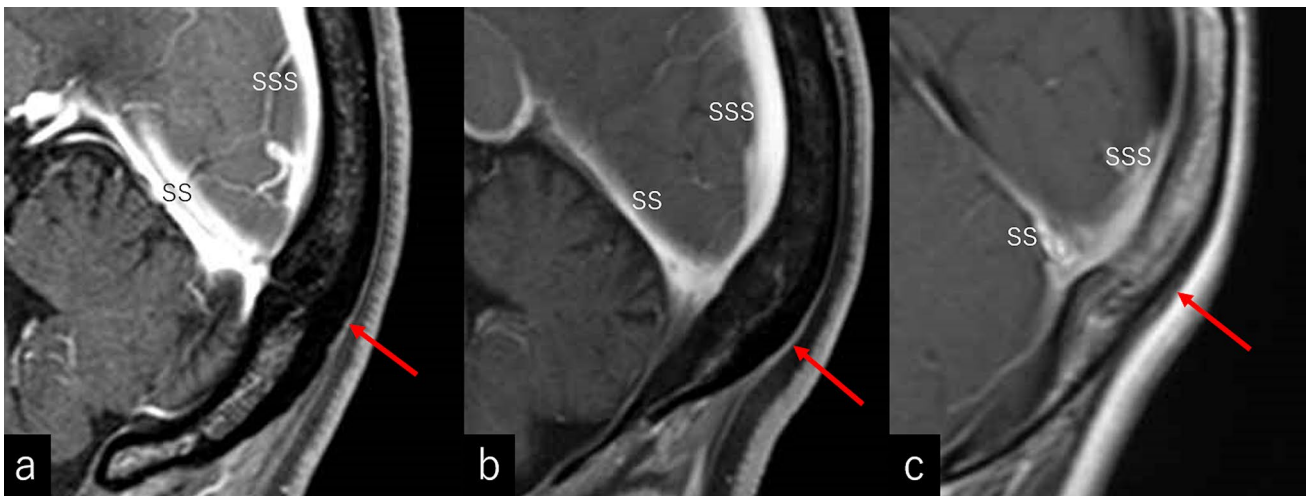

Fig. 3 Post-contrast midsagittal magnetic resonance images of different patients showing indistinct external occipital protuberances on its most prominent point, inion (***a-c*** arrow). *SS,* straight sinus; *SSS,* superior sagittal sinus

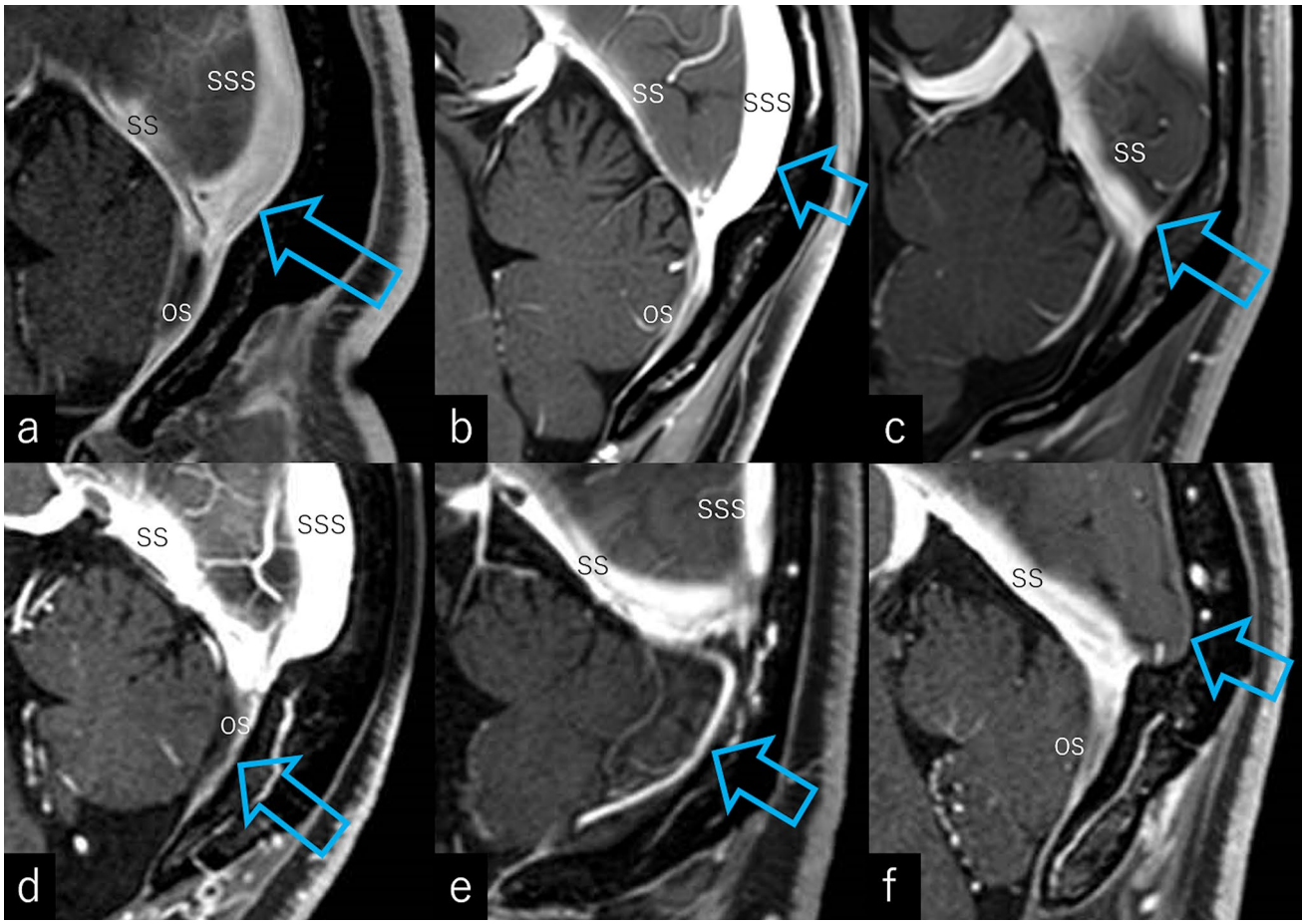

Fig. 4 Post-contrast sagittal magnetic resonance images of different patients at the level of the inion showing relationships between the inion and the dural sinuses lying just below (**a**–**f** thick arrow): the confluence of sinuses (**a**); the superior sagittal sinus (**b**); the straight sinus (**c**); the occipital sinus (**d**); and no sinus lying below (**e**, **f**). *OS,* occipital sinus; *SS,* straight sinus; *SSS,* superior sagittal sinus

Table 1 Frequencies of the dural venous sinuses located just below the inion

Dural sinus just below the inion	Frequency
Conf	57% (53/93)
SSS	26% (24/93)
SS	3% (3/93)
OS	3% (3/93)
NS	11% (10/93)

Conf, confluence of sinuses; *NS,* no dural venous sinus located just below; *OS,* occipital sinus; *SS,* straight sinus; *SSS,* superior sagittal sinus

Table 2 Summary of identified bony foramina and their frequencies

	Frequency
BF of EOP	16% (15/93)
Suboccipital BF	
UT	5% (5/93)
MT	16% (15/93)
LT	12% (11/93)
Multiple suboccipital BFs	5% (5/93)

BF, bony foramen; *EOP,* external occipital protuberance; *LT,* lower third; MT, middle third; *UT,* upper third

Discussion

In this study, approximately 90% of the EOPs were located just above the intracranial dural venous sinuses, with the confluence of sinuses most frequently targeted. These findings agree with a previous report that recommended avoiding the EOP for the site of occipitocervical fusion because of the risk of intraoperative sinus injury [14]. This also means that when using the EOP for the site of fixation, the topographical relationship between the EOP and underlying dural venous sinuses needs to be carefully evaluated to determine a safe site on the EOP

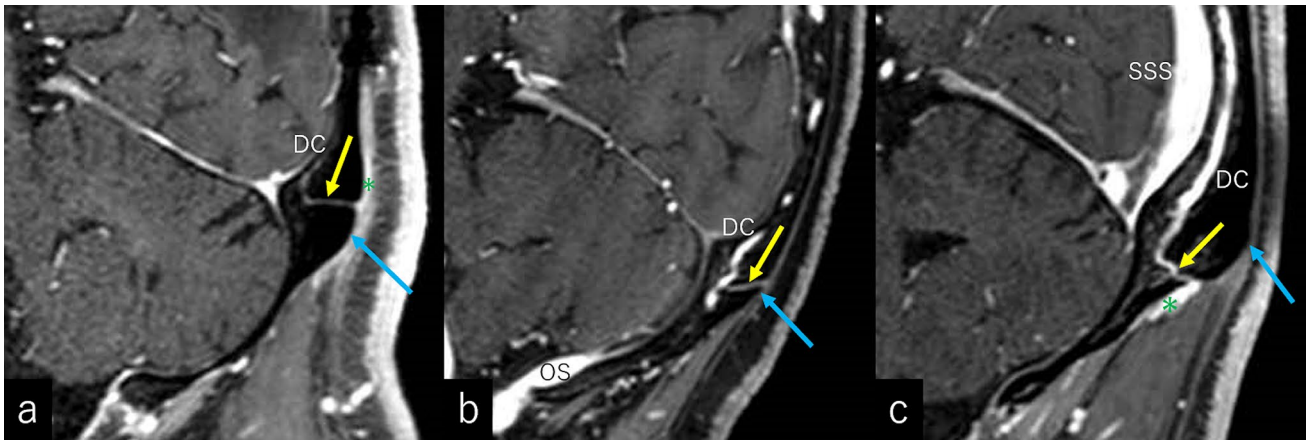

Fig. 5 Post-contrast parasagittal magnetic resonance images of different patients showing bony foramen and transmitting vessel of the external occipital protuberance (**a**–*c* yellow arrow) that connects the diploic channel and the subcutaneous veins (**a**, **c**, asterisk). *DC,* diploic channel; *OS,* occipital sinus; *SSS,* superior sagittal sinus; *Blue arrow:* external occipital protuberance

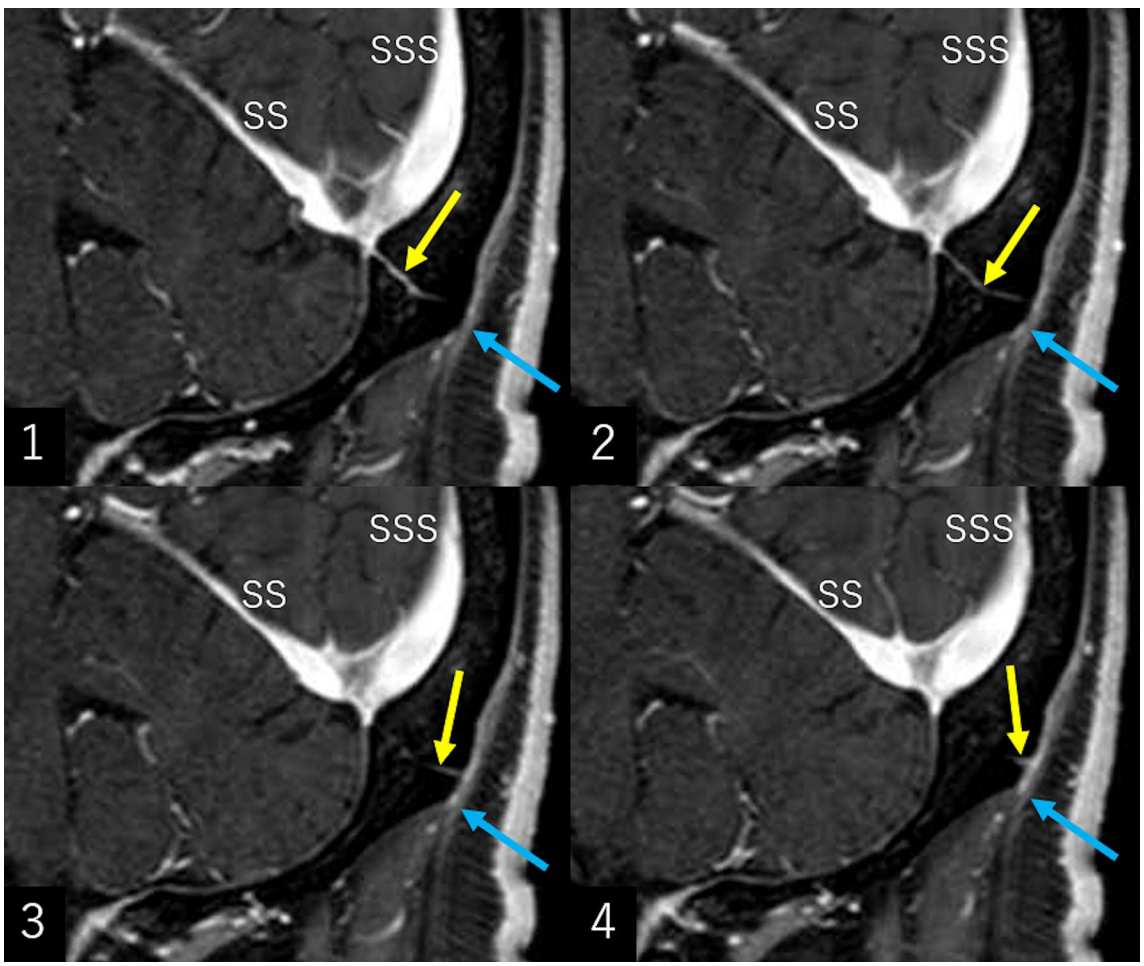

Fig. 6 Serial images of post-contrast sagittal magnetic resonance imaging of a patient showing an emissary vein (*yellow arrow*) coursing in the external occipital protuberance, connecting the confluence of sinuses and the subcutaneous vein (*blue arrow*). *SS,* straight sinus; *SSS,* superior sagittal sinus

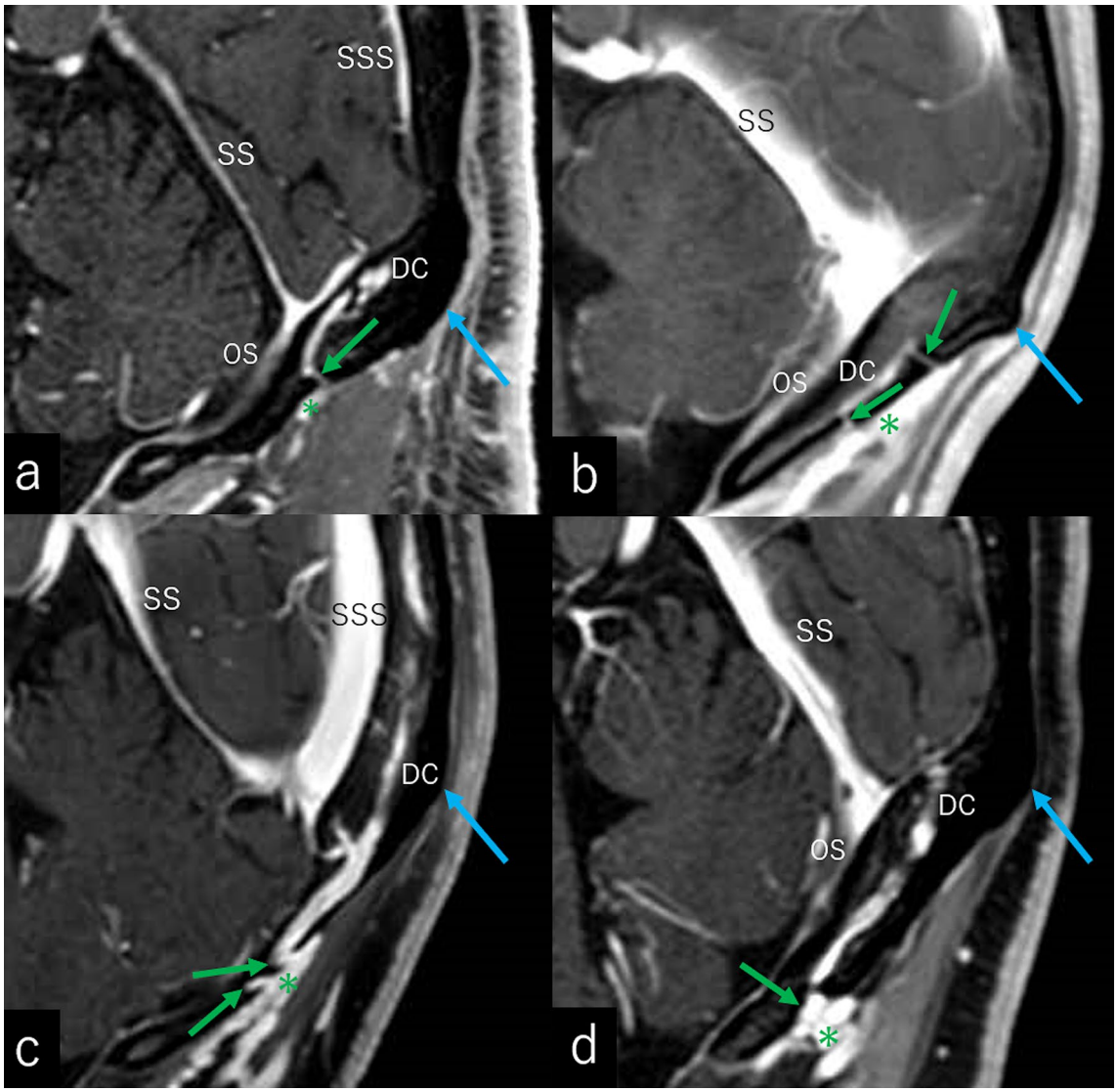

Fig. 7 Post-contrast parasagittal magnetic resonance images of different patients showing bony foramina and transmitting vessels at variable heights of the midline suboccipital region, below the external occipital protuberance (**a**–**d**, blue arrow). These vessels are connecting the diploic channel (*DC*) and the subcutaneous veins (**a**–**d**, asterisk). *OS,* occipital sinus; *SS,* straight sinus; *SSS,* superior sagittal sinus

and appropriate trajectory for fixation before surgery. Most venous vessels passing through the bony foramina of the EOPs were observed to connect the diploic channel and the extracranial and subcutaneous veins. Furthermore, all of the identified vessels located below the EOPs of the midline suboccipital region were connected to the diploic and subcutaneous veins. Therefore, most veins transmitting the bony foramina at and below the EOP were thought to be the draining pathways of the diploic channels that eventually pour into the extracranial venous system. These were not the emissary veins directly connecting the intracranial and extracranial sides. In addition, more than 80% of the identified bony foramina were located in the middle and lower thirds. The characteristic topographical predisposition may reflect a peculiar function of the diploic channels distributed in the region. In the present investigation, bony foramina and transmitting veins were identified in 33% of the EOPs of the midline suboccipital region, while there was no emissary vein observed in the region. In contrast, previous studies using dry skulls and cadaver heads documented that the emissary foramina and transmitting veins were identified in 2.6–9.5% of cases in the occipital bone [5, 11, 19]. These discrepancies may be mainly derived from the differences in the adopted methodology. High-resolution, contrast-enhanced MRI may be advantageous in detecting

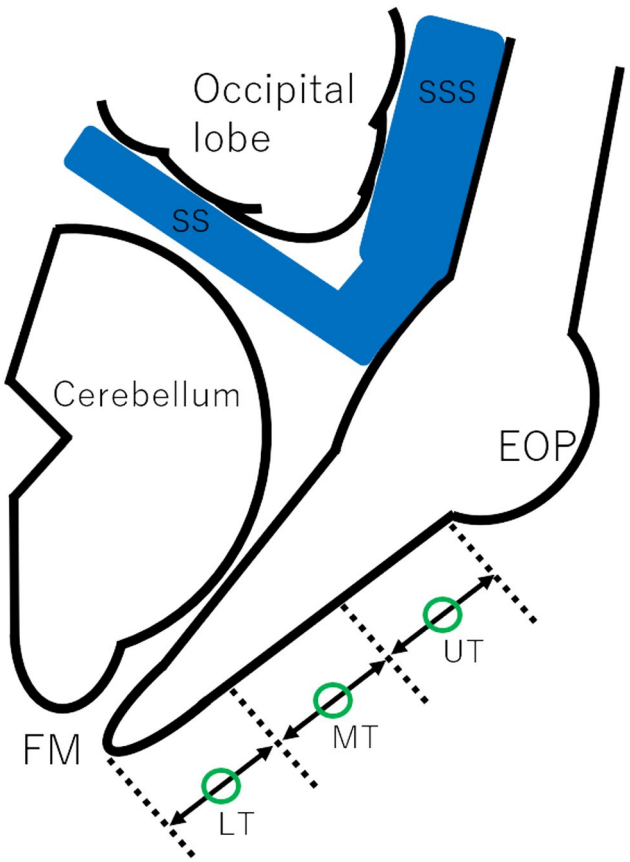

Fig. 8 Schematic illustration of the sagittal section at the most prominent level of the external occipital protuberance (EOP). The part of the occipital bone below the *EOP* is divided into three segments: the upper, middle, and lower thirds. *FM,* foramen magnum; *LT,* lower third; *MT,* middle third; *SS,* straight sinus; *SSS,* superior sagittal sinus; *UT,* upper third

intraosseously coursing venous structures in vivo, while these veins are difficult to explore on dry skulls and cadaver specimens.

This study has limitations and weaknesses. The study population consisted of patients with inhomogeneous age distribution and uneven sex ratio. Patients were retrospectively evaluated and not randomly assigned. Furthermore, the EOPs and transmitting fine venous structures were assessed only on the observations of the sagittal MRI images. Therefore, a well-controlled, prospective study is necessary in a large population to validate the outcomes of our study. Unproven etiology of unusually enlarged EOPs that have been documented to be prevalent in young adult populations is also a subject to be resolved [9, 17]. Despite these limitations, we believe that the results of this study can be a help for better understanding of the EOP, in addition to safe surgical maneuvers around it.

Conclusions

The intracranial dural venous sinus is located just below the EOP with a high probability. Most bony foramina in the EOP and midline suboccipital region may transmit veinous structures connecting to the diploic channel.

Author contributions ST conceived the study. HO collected the imaging data. ST and HI analyzed the imaging data. ST wrote the manuscript.

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Declarations

Conflict of interest The authors have no conflicts of interest to declare regarding the materials or methods used in this study or the findings presented in this paper.

Ethical approval All procedures performed in the study were in accordance with the ethical standards of the institutional and/or national research committee and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all participants included in the study.

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