



Original Article

Does diploic venous flow drain extracranially in the pterional area? A magnetic resonance imaging study

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ABSTRACT

Background: To the best of our knowledge, no study using neuroimaging modalities has documented calvarial diploic veins (DVs) connected to the extracranial sites. This study aimed to characterize them using magnetic resonance imaging (MRI).

Methods: A total of 88 patients underwent thin-sliced contrast MRI. In addition, the DVs coursing through the pterional area were observed on three injected cadaver heads.

Results: On postcontrast MRI, the DVs of the pterional area directly drained into the temporalis muscle or supplied branches coursing into the muscle in 43% on the right side and 40% on the left. The DVs and their branches were highly variable in diameter and number. In 9% of cases, the DV of the pterional area was found to drain into an extracranial site and connected to large venous channels distributed in the temporalis muscle. Furthermore, in 17% of cases, the DVs drained into the extracranial sites in the frontal skull region, followed by 9% in the parietal, 2% in the occipital, and 1% in the temporal regions. The DVs coursed superficially in the pterional area on both sides of all three cadaver heads. On one side, the DV in the area was open to an extracranial site.

Conclusion: Part of the diploic venous flow drains extracranially in the pterional area. This area may provide an important interface between the calvarial DVs and the extracranial venous system.

Keywords: Diploic vein, Extracranial bypass, Magnetic resonance imaging, Pterion

INTRODUCTION

Diploic veins (DVs) are distinct venous channels formed in the calvarial diploe and are thought to show ontogenetic changes.^[10] Despite investigations so far, the anatomofunctional implications of the DVs are still not well understood.^[1,6,11-13] The pterion is a well-known landmark on the skull in both adults and children, and its precise localization is important, especially when performing a frontotemporal craniotomy.^[3,14] The pterion is commonly formed by confluence of the coronal, squamosal, sphenofrontal, and sphenosquamosal sutures [Figure 1]. However, the location, morphology, and morphometry of it are highly variable.^[9] The temporalis muscle plays a pivotal role in mastication, spanning the lateral surfaces of the mandible and skull, involving the pterional area. The muscle is thought to possess at least five functional compartments supplied by the anterior and posterior deep temporal and middle temporal arteries. Furthermore, the muscle commonly shows a pairing pattern including double veins and an artery.^[4,5] A previous study with

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cadaver dissection documented that the DV in the anterior temporal region was observed to drain extracranially in the pterional area but did not mention its extracranial pathway.^[6]

To the best of our knowledge, no study has yet used neuroimaging modalities for exploring calvarial DVs with extracranial courses. Therefore, this study aimed to characterize these veins using contrast-enhanced magnetic resonance imaging (MRI).

MATERIALS AND METHODS

This retrospective study included 88 outpatients who underwent MRI at the Medical Satellite Yaesu Clinic between April 2010 and October 2015. These patients presented with headache, dizziness, tinnitus, hearing loss, sensory disturbances, and focal seizures. Patients with the previous traumatic brain injury or skull fractures were excluded from the study. The study population consisted of 44 men and 44 women aged 50.4 ± 16.4 years (mean \pm standard deviation; range, 13–78 years). Initial examinations using axial T1- and T2-weighted, T2 gradient echo, fluid-attenuated inversion recovery, and diffusion-weighted imaging confirmed that none of the patients had signs of pathological conditions in the scalp, skull, or intracranial dural sinuses. Subsequently, the patients underwent volumetric imaging examination with 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 authors (S.T. and H.I.). The DVs connected to the extracranial sites were assessed in the pterional and supratentorial calvarial convexity areas involving the frontal, parietal, occipital, and temporal skull regions. Due to the low detection performance of the DVs that were confirmed during the preliminary observations, postcontrast axial images were not used for analysis.

Furthermore, the DVs coursing in the pterional area were assessed on six sides of three cadaver heads. Before dissection, the internal jugular veins were injected bilaterally with blue silicone. Then, a scalp incision was made conforming with a conventional frontotemporal craniotomy. The scalp flap and temporalis muscle were reflected *en bloc* to observe the DVs in blue through the outer table. Dissections were performed by one of the authors (S.T.) at the Department of Neurological Surgery, University of Florida, Gainesville, FL, USA.

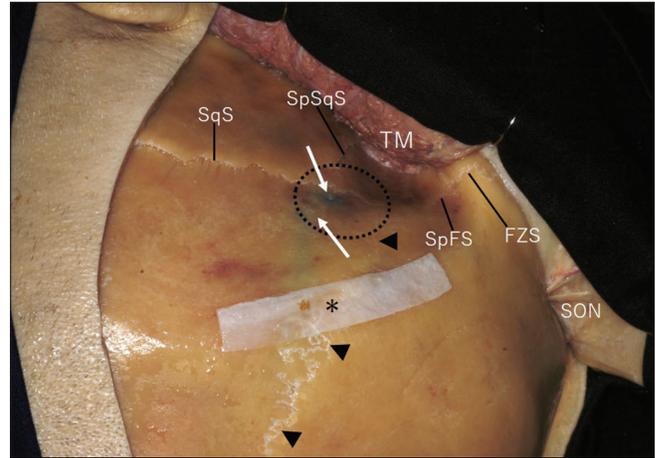


Figure 1: A cadaver head, left side, showing reflection of the scalp flap and temporalis muscle for performing a frontotemporal craniotomy. The pterional area (within dashed circle) is formed by confluence of the coronal (arrowheads), squamosal (SqS), sphenofrontal (SpFS), and sphenosquamosal (SpSqs) sutures. FZS: Frontozygomatic suture; SON: Supraorbital nerve; TM: Temporalis muscle; Arrows: Diploic veins; Asterisk: Part of the fascia of temporalis muscle attached to the linea temporalis.

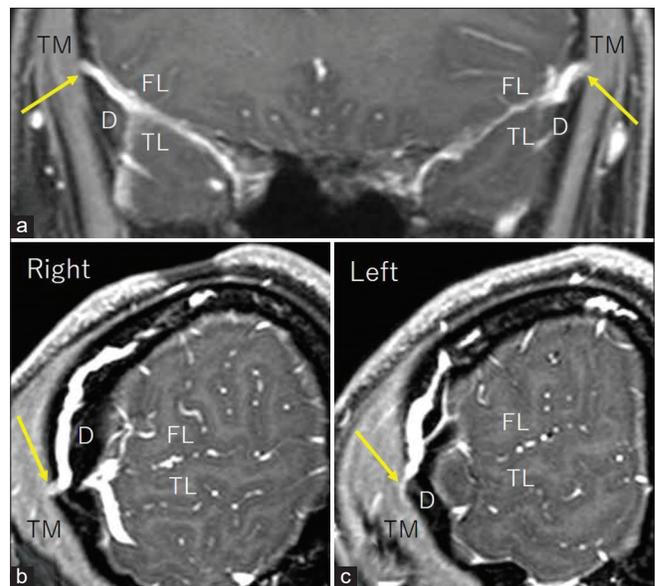


Figure 2: Postcontrast coronal (a) and sagittal (b and c) T1-weighted magnetic resonance images at the corresponding levels showing diploic veins of the pterional area directly draining into the temporalis muscle (a and b, arrow) or supplying a branch coursing into the muscle (a and c, arrow). D: Diploic; FL: Frontal lobe; TL: Temporal lobe; TM: Temporalis muscle.

The study was conducted in accordance with the guidelines for human research of our institution and those of the Medical Satellite Yaesu Clinic. The written informed consent was obtained from all the patients before their participation in the study.

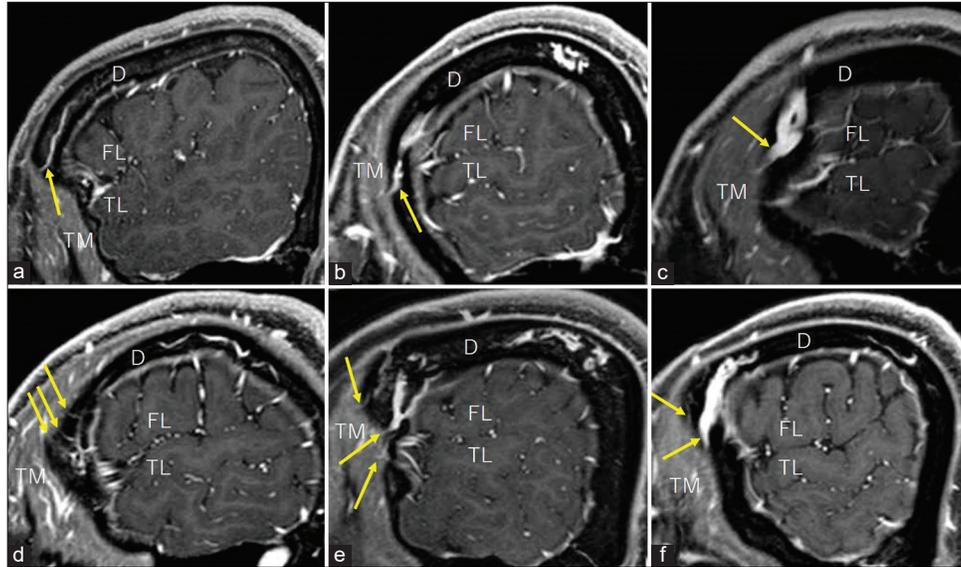


Figure 3: Postcontrast sagittal T1-weighted magnetic resonance images of different patients showing the diploic veins of the pterional area supplying branches coursing into the extracranial sites with varying diameter and number (a-f, arrows). D: Diploe; FL: Frontal lobe; TL: Temporal lobe; TM: Temporalis muscle. Upper row: Left side; lower row: Right side.

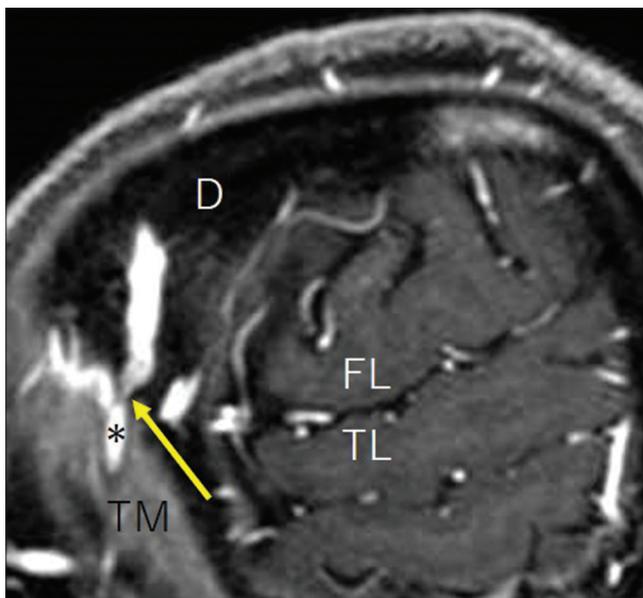


Figure 4: Postcontrast sagittal T1-weighted magnetic resonance image showing a diploic vein of the pterional area (arrow) that courses into an extracranial site and connected to a large vein (asterisk) distributing in the temporalis muscle (TM). D: Diploe; FL: Frontal lobe; TL: Temporal lobe.

RESULTS

Examinations using contrast-enhanced MRI

The DVs draining into the extracranial sites were heterogeneously distributed over the skull. These DVs

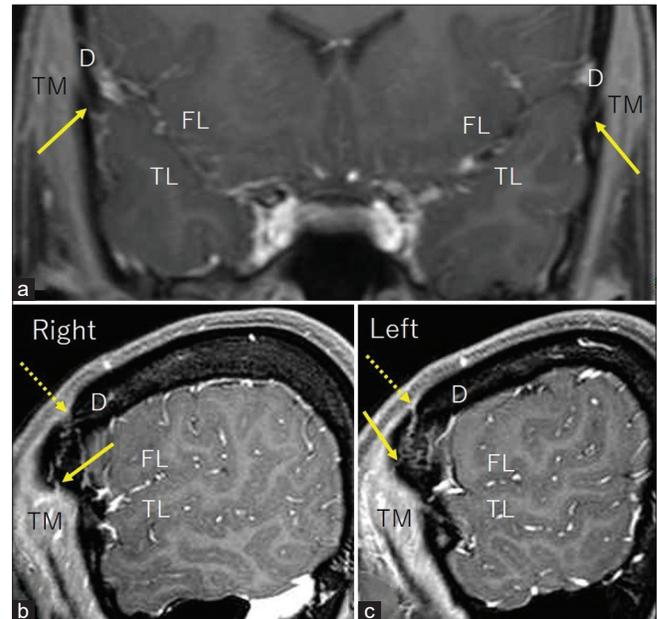


Figure 5: Postcontrast coronal (a) and sagittal (b and c) T1-weighted magnetic resonance images at the corresponding levels showing the diploic veins draining into the extracranial sites both in the frontal skull region (b and c, dashed arrow) and pterional area (a-c, arrows). D: Diploe; FL: Frontal lobe; TL: Temporal lobe; TM: Temporalis muscle.

were most frequently identified in the pterional area and were found in 38 of 88 patients (43%) on the right side and 35 (40%) on the left side. These DVs were found to drain directly into the temporalis muscle or supply extracranial

branches coursing into the muscle [Figure 2]. These DVs and their branches were highly variable in diameter and number and were characterized by the right-to-left asymmetry [Figure 3]. Their presence did not show any sex or specific age range predilections. The DVs were not identified in 31 (35%) patients. Furthermore, in 8 of 88 patients (9%), the DV of the pterional area was found to drain into an extracranial site and was connected to large venous channels distributed in the temporalis muscle [Figure 4]. In 15 (17%) patients, the calvarial DVs were found to drain into the extracranial sites in the frontal skull region, followed by 8 (9%) in the parietal,

2 (2%) in the occipital, and 1 (1%) in the temporal regions [Figures 5 and 6]. The identified DVs that were open to extracranial sites are summarized in [Table 1].

Cadaver dissection

On all dissected sides, part of the DVs injected with blue silicone was observed to course superficially in the diploe of the pterional area [Figure 7]. On one side, the DV in the area was exposed and open to the extracranial site [Figure 7f].

DISCUSSION

Despite investigations, connections between the intracranial and extracranial venous systems through calvarial DVs have not yet been documented.^[1,6,11-13] In this study, superficially lying DVs in the diploe were consistently observed in the pterional areas of the injected specimens. On contrast-enhanced MRI, the DVs connected to the extracranial sites were identified in >40% of the pterional area. In 9% of cases, these DVs were connected to large venous channels of the temporalis muscle. Furthermore, compared with the pterional area, the DVs open to the extracranial sites were less frequently found in other skull regions. Therefore, we assumed that part of the venous flow of DVs may drain out of

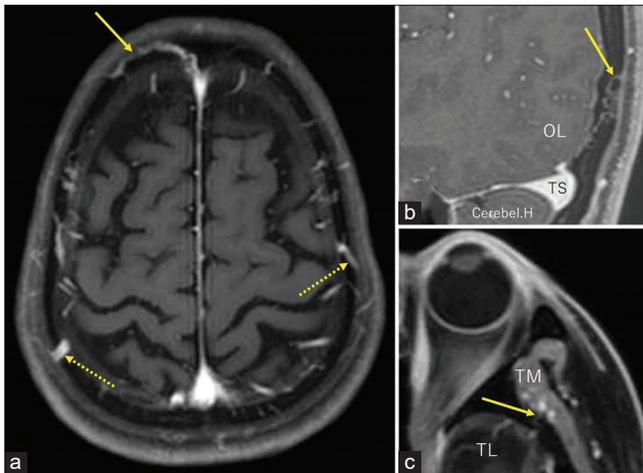


Figure 6: Postcontrast axial (a), sagittal (b), and axial (c) T1-weighted magnetic resonance images showing the diploic veins draining into the extracranial sites in the frontal (a, arrow), parietal (a, dashed arrows), occipital (b, arrow), and temporal (c, arrow) skull regions. Cerebel. H: Right cerebellar hemisphere; OL: Occipital lobe; TL: Left temporal lobe; TM: Temporalis muscle; TS: Transverse sinus.

Table 1: Diploic veins draining out of the extracranial sites in different skull regions.

Pterional area	Right: 43% (38/88) Left: 40% (35/88)
Frontal skull region	17% (15/88)
Parietal skull region	9% (8/88)
Occipital skull region	2% (2/88)
Temporal skull region	1% (1/88)

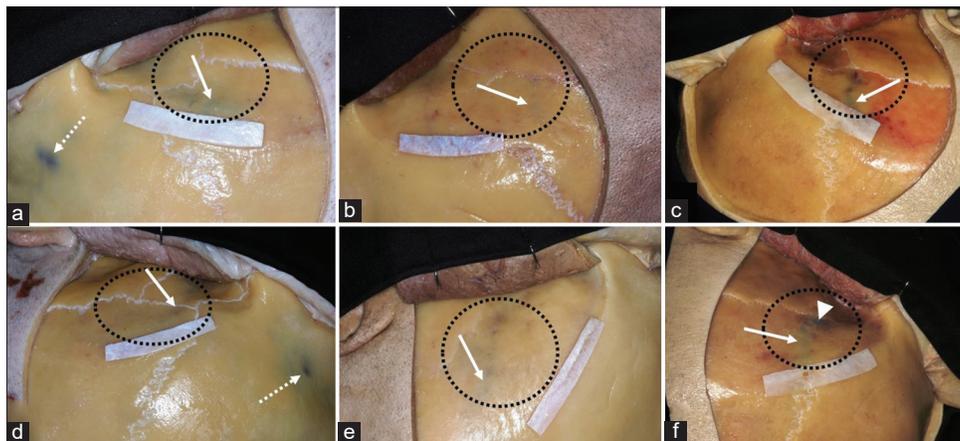


Figure 7: (a-f) Six sides of three injected cadaver heads, after reflection of the scalp flaps for performing conventional frontotemporal craniotomies, showing the diploic veins coursing superficially in the diploe (arrow) of the pterional area (within dashed circle). On one side, a diploic vein in the area is open to the extracranial site (f, arrowhead). Dashed arrow: Diploic vein in the frontal bone; upper row: Right side; lower row: left side.

the extracranial sites in the pterional area. In addition, these findings indicate that the pterional area may be an important interface between the intracranial and extracranial venous systems. However, the clinical implications of the connections and reasons for high frequency in the pterional area remain elusive. Given that this area has been documented as one of the most frequent skull regions involving well-developed and thick DVs, it may play a pivotal role in the entire system of calvarial DVs.^[1,6,11] Sinus pericranii, subepicranial varix mimicking sinus pericranii, and diploic venous sac have been documented as rare venous lesions involving the DVs.^[2,7,8] The calvarial DVs draining out of the extracranial sites identified in this study may be associated with the development or enlargement of these venous abnormalities.

This study had several limitations. The cohort for MRI examinations consisted of patients with an inhomogeneous age distribution and uneven sex ratio. The patients were retrospectively evaluated and not randomly assigned. Furthermore, the DVs coursing through the pterional area were assessed using thin-sliced, contrast-enhanced MRI and a few dissected specimens. In contrast to a previous study describing ontogenetic changes in calvarial DVs, this study did not find such changes in DVs coursing in the pterional area or their branches connected to the extracranial venous system.^[10] Therefore, a well-controlled study is necessary to validate the outcomes of our study in a large population with a homogeneous age distribution. Despite these limitations, we believe that the results of this study will improve our understanding of DVs in pterional areas.

CONCLUSION

The study showed that part of the diploic venous flow drains extracranially in the pterional area. This area may provide an important interface between the calvarial DVs and the extracranial venous system.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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