The skull base is a complex osseous structure forming the floor of the calvaria. The anatomy of the skull base is often evaluated using CT and MRI in order to detect morphological abnormalities and pathological lesions. The basiocciput is the wedge-like segment of the occiput that lies anterior to the foramen magnum and joins the body of the sphenoid bone. There are anatomical variants of the basiocciput, and even though they are largely uncommon, their presence has significant diagnostic and clinical implications. One of these variants is the “fossa navicularis magna,” a notch-like defect in the clivus (Fig. 1) at the embryological synchondrosis fusion-junction of the body of the sphenoid bone with the basilar part of the occipital bone. It is suggested that a patent fossa navicularis magna could be a conduit for infection from the pharynx to the calvarial and intracranial structures.

We reviewed scientific databases—PubMed Central, EMBASE, Google Scholar, Scopus, Cochrane, and Science Research—for the years 1860–2018 using the key words “fossa navicularis,” “canalis basilaris medianus,” and “pharyngeal fossa.” We identified the papers in which these terms were used and described the distinctive features and clinical relevance of this distinctive skull base radiological finding. This will be the fourth case reported in the literature, and the defect was closed endoscopically via a transnasal route. This morphological skull base anomaly should be considered in the differential diagnoses for an unexplained skull base infective pathology.

Skull base surgeons should be aware of the existence of the fossa navicularis because of its clinical importance in rendering a prompt diagnosis and appropriate treatment.

https://thejns.org/doi/abs/10.3171/2018.5.PEDS18157

**KEYWORDS** skull base; clivus; anatomy; anatomical variant; bone defect; basiocciput; infection; congenital

**Case Report**

**History and Presentation**

A 9-year-old female was referred to our hospital. She initially presented with clinical signs suggesting meningitis and subsequently developed an isolated abducens nerve palsy that resolved after antibiotic therapy (co-amoxiclav). Clinical features included bitemporal throbbing headaches, left retroorbital pain, photosensitivity, neck stiffness, and fever (temperature 40.3°C). Her white cell count was 47 × 10⁹/L, platelet count was 557 × 10⁹/L, and C-reactive
protein level was 20 mg/L. Nine months later, she again presented to us with headache and cranial nerve (III and VI) palsies. No other neurological deficits were noted on examination. Fundal examination was normal. Her parents reported a previous medical history of sinusitis and recurrent meningitis. There were no symptoms suggestive of pituitary dysfunction. She was started on intravenous ceftriaxone. The cranial nerve palsies resolved within 3 weeks, and no other neurological deficit was noted during review.

Magnetic resonance imaging of the brain demonstrated enhancement of the basal meninges, particularly in the left perimesencephalic region. Fluid was also reported in the ethmoid and sphenoid sinuses. Lumbar puncture CSF showed no organisms. The CSF glucose was 3 mmol/L, and the CSF protein level was 57 mg/dl. There was no organism growth on blood cultures.

Repeat imaging—CT (Fig. 2) and MRI (Fig. 3)—was done following yet another admission with meningitic features and was reviewed by our multidisciplinary skull base team. A fossa navicularis magna was noted within the clivus with enhancement noted in the surrounding basiocciput. A small subperiosteal collection was also noted in the nasopharynx. Transient clinical improvement and radiological resolution was initially noted following antibiotic treatment for skull base osteomyelitis—intravenous ceftriaxone for 6 weeks (with intravenous metronidazole in the 1st week). This was later followed by a 6-week course of oral co-amoxiclav.

Operation and Postoperative Course

Because of further repeated episodes of infection and inflammation, the patient underwent endonasal endoscopic surgical removal of the infected clival tissue and fossa navicularis. Via a posterior septectomy approach, a wide sphenoidotomy was performed, and the floor of the sphenoid sinus was drilled down to expose the fossa navicularis and remove the diseased bone. Intraoperatively, a tract was apparent within the soft infected bone (Fig. 4). A concurrent adenoidectomy was performed to remove any reservoir of infective pharyngeal tissue. No obvious dural breach was noted.

Tissue specimens were obtained intraoperatively, and histological analysis demonstrated gliotic tissue of the macroscopically apparent tract within soft clival bone. No lymphoid tissue was seen, and the specimen primarily showed infiltrative inflammatory cells within the infected bone. Biopsy of the nasopharyngeal mucosa revealed normal mucosa, which cultured respiratory flora. Culture of the bone of the clivus did not yield an organism. The bone was friable and very vascular, but no purulent material was noted. Recovery was uneventful and there were no complications. The procedure was very well tolerated, and in the absence of antibiotic therapy, there had been no recurrence of symptoms at the 6-month follow-up review.

Discussion

Description and Nomenclature

The fossa navicularis is a notch-like defect located in
the exocranial portion of the clivus. Over the years, various authors have suggested a diverse number of names and/or descriptive terminologies: “fossa navicularis magna,” “medial basal fossa,” “fossa pharyngea,” “large pharyngeal fossa,” “canalis basilaris medius” (CBM), and “keyhole defect.” It has been regarded as an uncommon skull base foramen. Ginat et al. observed that even though several inconstant skull base foramina could be radiologically diagnosed as incidental findings, there could be significant clinical importance to such findings because of related anomalies and medical implications. Apart from the fossa navicularis, some of the other skull base foramina include the meningo-orbital foramen, palatovaginal canal, persistent craniopharyngeal canal foramen of Vesalius, canalicus innominatus, and CBM.

Currarino posited that the fossa navicularis is one of the six subtypes of the CBM and an incomplete form of CBM. Perna considered the fossa navicularis as a representation of the cephalic end of the CBM. Beltramello et al. offered a different viewpoint and described CBM as a persistent form of the chordal canal, and thus a disparate anatomical variant. However, Prabhu et al. consider the fossa navicularis and the CBM as similar anatomical findings. There have also been developmental links between the Thornwaldt (or Tornwaldt) cyst and fossa navicularis.

**Embryological Origin**

Two general theories have been suggested regarding the embryological origin of the fossa navicularis—a vascular origin and a notochordal origin. The vascular theory suggests that the notch-like defect is caused by the persistence and enlargement of several emissary veins passing through the clivus and therefore forms a bony aperture similar to the venous foramina in the vertebral bodies. Based on information about the embryological formation of the skull base in the fetal period, the vascular theory is plausible since the clivus would then be formed around its own emissary veins, leaving a passage in its center. This theory is supported by Prabhu et al., who suggested that the remnant vessels and lymphatics passing through the clivus give rise to the fossa navicularis.

The notochordal theory was first suggested by Perna, who reported that the fossa navicularis may be a remnant of the notochordal canal. The notochordal theory was supported by Beltramello et al., who considered that a remnant of the notochord in the roof of the pharynx prevents complete ossification of the clivus, therefore giving rise to the fossa navicularis. Thus, the remnant may represent a tract for infection to travel from the pharyngeal mucosa to the skull base and central nervous system.
Epidemiology

The reported incidence of the fossa navicularis in the anatomical literature is 0.9%–5.3%, with measurements ranging from 1.1 to 5.5 mm in depth and 1.5–8 mm in width.18

The finding was first reported in the early 19th century—Rossi reported it in 1.5% of the 3712 dried skulls he studied, Romiti reported it in 0.9% of 990 skulls,14 and Cankal et al.1 reported it in 0.9% of 990 skulls.14

Radiographic findings

CT: small fluid collection in nasopharynx just in front of clivus & a bony notch-like round defect; MRI: soft tissue swelling in nasopharyngeal & suboccipital areas; it internal jugular vein thrombus; connection b/w nasopharynx & skull base

Clinical presentation

Fever, HA, neck stiffness, Kernig’s & Brudzinski’s signs, It strabismus, altered consciousness, opisthotonus

Implicated organisms

Streptococcus. NA

Radiographic findings

XR: thickening of prevertebral soft tissues; CT: large retropharyngeal abscess w/ notch-like clival defect w/ associated osteolysis & cortical destruction; MRI: abnormal clival enhancement w/ collections w/ in longus colli bilaterally

TABLE 1. Literature summary of cases with clinical presentation, radiographic findings, treatment, and outcomes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Prabhu et al., 2009</th>
<th>Segal et al., 2013</th>
<th>Benadjiaoud et al., 2017</th>
<th>Alalade et al., 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case No.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>Present case</td>
</tr>
<tr>
<td>Age in yrs</td>
<td>5</td>
<td>12</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Sex</td>
<td>F</td>
<td>F</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Clinical presentation</td>
<td>Fever, reduced oral intake, neck stiffness, bilateral cervical lymphadenopathy</td>
<td>Fever, HA, neck stiffness, Kernig’s &amp; Brudzinski’s signs, It strabismus, altered consciousness, opisthotonus</td>
<td>HAs, fever, torticollis</td>
<td>HAs, fever, photosensitivity, neck stiffness, cranial nerve palsies</td>
</tr>
<tr>
<td>Radiographic findings</td>
<td>CT: fossa navicularis magna in basioccipit; MRI: clival osteomyelitis w/ associated retropharyngeal abscess &amp; C1–2 epidural enhancement</td>
<td>CT: fossa navicularis magna through clivus; MRI: fossa navicularis w/ clivus; rim-enhancing collection w/ clival; associated clival osteomyelitis</td>
<td>CT: fossa navicularis magna through clivus; MRI: fossa navicularis w/ clivus; rim-enhancing collection w/ clival; associated clival osteomyelitis</td>
<td></td>
</tr>
<tr>
<td>Implicated organisms</td>
<td>Group A Streptococcus</td>
<td>NA</td>
<td>Streptococcus intermedius, Fusobacterium spp.</td>
<td>NA</td>
</tr>
<tr>
<td>Treatment</td>
<td>Medical: initially IV ceftriaxone for 4 wks, followed by 4 wks oral amoxicillin; surgical: transoral incision &amp; drainage of retropharyngeal abscess</td>
<td>Medical: antibiotics* &amp; anticoagulants*</td>
<td>Medical: initially IV cefotaxime, metronidazole, gentamicin for 1st 7 days; IV co-amoxiclav after definitive culture results, followed by 3 mos oral pristinamycin; surgical: transnasal aspiration of retropharyngeal abscess</td>
<td>Medical: initially IV ceftriaxone for 6 wks (additional IV metronidazole for 1st wk), followed by 6 wks oral amoxicillin; surgical: endonasal endoscopic repair of defect</td>
</tr>
<tr>
<td>Outcome</td>
<td>Good, no sequelae</td>
<td>Resolution of strabismus &amp; partial resolution of venous sinus thrombosis</td>
<td>Good, no sequelae</td>
<td>Good, no sequelae</td>
</tr>
</tbody>
</table>

HA = headache; IV = intravenous; NA = not applicable; XR = radiography.

* Name not provided.

Anatomy

The fossa navicularis is a small round medio-sagittal bony aperture in the anterior surface of the clivus, more specifically, in the basilar part of the occipital bone. It lies close to the nasopharynx and the sphenoidal sinuses.4 It is superior to the pharyngeal tubercle and is parallel to the carotid canals.2 The fossa navicularis tends to be located at the exit site of the notochord in early fetal life at the base of the anterior basiocciput.5

Histology

Beltramello et al.2 reported in their case study that the fossa navicularis was filled by lymphoid tissue of the pharyngeal tonsil. Their patient was diagnosed with a prominent fossa navicularis following evaluation for sinusitis. This finding was supported by Prabhu et al.,13 who identified lymphoid tissue from the pharyngeal tonsil around the fossa navicularis. In a more recent study, Sheikh et al.16 found the overlying tissue to be composed of loose connective tissue with a mixture of collagen, elastic fibers, and vascular matrix. They reported no glandular, lymphoid, or notochordal tissue in the histologically analyzed tissues. Our histopathological assessment revealed gliotic tissue within the visible tract, which represents a new finding.
Clinical Importance, Diagnosis, and Treatment

The fossa navicularis has been considered a benign anatomical variation of the clivus until recently; cases reported in the literature are shown in Table 1. Other anatomical variants in the basiocciput do not seem to be associated with a similar risk of infection. Even most cases of fossa navicularis do not seem to be associated with intracranial infection. Syed et al.17 reported 4 cases of fossa navicularis diagnosed incidentally. Longer follow-ups in these cases would be necessary for the assessment of recurrent infection, and surgical exploration should be considered as the optimal mode of treatment in these cases.

The MRI features of bone marrow in the clivus have been seen to vary with age.7,10,11 In childhood, the bone marrow is rich in hematopoietic tissue and the clivus is homogeneously hypointense. This is referred to as “stage I” clivus bone marrow as opposed to stage II (intermediate stage with fatty infiltration of the marrow and the clivus has a heterogeneous appearance) or stage III (hypointense marrow with a homogeneous hypointense clivus). Olcu et al.10 found in their study that the stage III features were not noted in the age group of 0–9 years. In cases in which unexpected MRI clival changes are noted, as was the case with our patient, there is most likely an underlying pathology.

The synchondroses at the skull base are important for craniofacial development, and the sphenoid-occipital synchondrosis usually completely fuses at 18 years.7 However, this joint is different from the fossa navicularis as the fusion begins superiorly and progresses inferiorly, through the five stages described by Bassed et al.1 In stages II and III, when partially fused, it is typically visible as a linear partition between the sphenoid and occiput rather than the notch-like defect appearance of the fossa navicularis.

Conclusions

The fossa navicularis is a defect in the ossification of the exocranial clivus. Physicians should be aware of its existence because of its role in intracranial infections. As high-resolution CT and MRI become increasingly accessible, we propose that careful scrutiny of the skull base will be beneficial for determining the real incidence of this anatomical variant and will aid prompt diagnosis of the etiological factor in relevant infective scenarios. Our review suggests that the incidence may be higher than previously reported.

References

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Alalade, Briganti. Acquisition of data: Alalade, Briganti, McKenzie. Analysis and interpretation of data: Alalade, Briganti, McKenzie, Gandhi. Drafting the article: Alalade, Briganti, McKenzie. Critical revising the article: Alalade, Gandhi, Amato, Panizza, Bowman. Reviewed submitted version of manuscript: Alalade, Amato, Panizza, Bowman. Approved the final version of the manuscript on behalf of all authors: Alalade. Administrative/technical/material support: Alalade.

Correspondence

Andrew F. Alalade: Princess Alexandra Hospital, Brisbane, Australia. andrew.alalade@nhs.net.