Fossa navicularis in a pediatric patient: anatomical skull base variant with clinical implications

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The fossa navicularis is an anatomical variant of the skull base thought to be a rare finding. It represents a bony depression in the skull base. The authors here report the case of a fossa navicularis magna in a 9-year-old female who had been treated for recurrent episodes of meningitis.

A literature review was also done to highlight the unique features and clinical importance of this distinctive radiological skull base finding. The literature search covered papers from the 19th century up to 2018. Earlier authors described "fossa navicularis" as a very rare skull base finding. So far, only three cases of fossa navicularis with associated clival or intracranial infection have been reported in the literature. This is the fourth reported case, 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.

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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.⁸ 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.² 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.

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 $47 \times 10^9/L$, platelet count was $557 \times 10^9/L$, and C-reactive

ABBREVIATIONS CBM = canalis basilaris medianus.

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FIG. 1. Illustration showing the fossa navicularis within the clivus in three axes. Note the notch-like defect posterior to the nasopharyngeal wall. **A:** The fossa navicularis in a coronal view of the clivus. **B:** Fossa navicularis in the sagittal view. **C:** Notch-like defect (fossa navicularis) shown in the axial view. Copyright Holt Illustration. Published with permission. Figure is available in color online only.

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

FIG. 2. Sagittal bone window CT scan demonstrating an aperture (fossa navicularis, arrow) through the clivus.

FIG. 3. I: Sagittal fat-saturated Gd-enhanced T1-weighted MR image demonstrating fossa navicularis magna within the clivus. II: Sagittal T2-weighted MR image showing dural thickening (A) posterior to the clivus with associated enhancement. There is a rim-enhancing collection/abscess (B) within the canal in the body of the clivus. Enhancement of the marrow of the clivus (C) is greater than in the marrow elsewhere, e.g., of the odontoid process (D), in keeping with an associated osteomyelitis. III: Coronal MR image demonstrating involvement of the cavernous sinus.

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 medianus” (CBM), and “keyhole defect.”¹⁷ It has been regarded as an uncommon skull base foramen. Ginat et al.⁶ 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, canaliculus innominatus, and CBM.

Currarino⁵ posited that the fossa navicularis is one of the six subtypes of the CBM and an incomplete form of CBM. Perna¹² considered the fossa navicularis as a representation of the cephalic end of the CBM. Beltramello et al.² 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.¹³ 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.^{3,5,9,16}

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.¹³ Based on information about the embryological formation of the skull base in the fetal period,⁸ 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.,¹³ 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,¹² who reported that the fossa navicularis may be a remnant of the notochordal canal. The notochordal theory was supported by Beltramello et al.,² 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.

FIG. 4. Photograph obtained via an endonasal endoscopic approach, showing the fossa navicularis defect on the anterior wall of the clivus. Figure is available in color online only.

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

Parameter	Prabhu et al., 2009	Segal et al., 2013	Benadjaoud et al., 2017	Alalade et al., 2018
Case No.	1	2	3	Present case
Age in yrs	5	12	7	9
Sex	F	F	M	M
Clinical presentation	Fever, reduced oral intake, neck stiffness, bilat cervical lymphadenopathy	Fever, HA, neck stiffness, Kernig's & Brudzinski's signs, lt strabismus, altered consciousness, opisthotonus	HAs, fever, torticollis	HAs, fever, photosensitivity, neck stiffness, cranial nerve palsies
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	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; lt internal jugular vein thrombus; connection btwn nasopharynx & skull base	CT: fossa navicularis magna in basiocciput; MRI: clival osteomyelitis w/ associated retropharyngeal abscess & C1–2 epidural enhancement	CT: fossa navicularis magna through clivus; MRI: fossa navicularis w/in clivus; rim-enhancing collection w/in canal; associated clival osteomyelitis
Implicated organisms	Group A <i>Streptococcus</i>	NA	<i>Streptococcus intermedius</i> , <i>Fusobacterium</i> spp.	NA
Treatment	Medical: initially IV ceftriaxone for 4 wks, followed by 4 wks oral amoxicillin; surgical: transoral incision & drainage of retropharyngeal abscess	Medical: antibiotics* & anticoagulants*	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	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
Outcome	Good, no sequelae	Resolution of strabismus & partial resolution of venous sinus thrombosis	Good, no sequelae	Good, no sequelae

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

* Name not provided.

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.¹⁶

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 Rizzo reported it in 2.1% of 335 skulls.² More recently, Cankal et al.⁴ looked at 492 dry skulls and the CT images of 525 patients to determine the incidence of fossa navicularis. They found the variant in 5.3% of the dry skulls examined (2.4% were less than 2 mm deep, and 2.9% were deeper than 2 mm). From the CT evaluation, they found that 3.0% of the patients had a fossa navicularis. As the CT sections were 2 mm (and would not highlight defects smaller than that), the authors suggested that the incidence of fossa navicularis was similar in their population and more frequent than previous studies had suggested.

As high-resolution skull base imaging is increasingly available, we propose that a detailed evaluation of the skull base is useful in determining the real incidence of this anatomical variant and will aid prompt diagnosis of the etiological factor in relevant infective scenarios. It is highly likely that the incidence may be higher than previously reported.

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 (hypoactive marrow with a homogeneous hypoactive 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 spheno-occipital synchondrosis usually completely fuses at 18 years.¹ 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.

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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. Critically 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.

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