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Case Report Open Access

Bilateral Duplication of the Foramen Spinosum: A Case Report with Clinical and Developmental Implications

Matthew J Zdilla*, Jillian M Laslo and Leah M Cyrus

Department of Natural Sciences and Mathematics, West Liberty University, West Liberty, West Virginia, USA

***Corresponding author:** Matthew J Zdilla, Department of Natural Sciences and Mathematics, West Liberty University, CSC 139; P.O. Box 295, West Liberty, USA, Tel: +1 304-336-8631; Fax: +1 304-336-8266; E-mail: mzdilla@westliberty.edu

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Abstract

In humans, the foramen spinosum (FS) is located within the sphenoid bone and transmits the middle meningeal artery (MMA). In species that evolutionarily predate humans, the FS exists within the temporal bone, the sphenosquamosal suture, or is absent altogether. It is therefore thought that, during the course of human evolution, the ossification of the posterior aspect of the greater wing of the sphenoid progressively developed around the MMA. The report documents the occurrence of a bilateral duplication of the FS in a male human skull. The report also discusses the clinical and developmental/anthropological significance. Because the foramen spinosum is utilized as a landmark for various surgical procedures involving the middle cranial fossa, the bilateral duplication of the foramen may be disorienting to the surgeon. Similarly, the dynamics of blood flow may be altered due to the bilateral bifurcation of the MMA. Because of the developmental significance of the FS, the occurrence of a bilateral duplication also has important anthropological implications.

Keywords: Anatomical variation; Cranium; Middle cranial fossa; Middle meningeal artery; Sphenoid

Introduction

In humans, the foramen spinosum (FS) is found within the sphenoid bone, posterolateral to the foramen ovale (FO) and, typically, along the posteromedial aspect of the greater wing. The FS allows communication between the middle cranial and infratemporal fossae. Usually, the foramen transmits the middle meningeal artery (MMA), middle meningeal veins, and the meningeal (recurrent) branch of the mandibular nerve (nervus spinosus) [1]. The lesser petrosal nerve, usually transmitted by the foramen ovale or, occasionally, the foramen petrosum (of Arnold), may also pass through the FS [1,2].

In species that evolutionarily predate humans, the FS exists within the temporal bone, the sphenosquamosal suture, or is absent altogether [3]. It is therefore thought that, during the course of human evolution, the ossification of the posterior aspect of the greater wing of the sphenoid progressively developed around the MMA [3]. Among extant great apes, the FS is absent much more frequently than in humans or fossil hominids [3]. Humans do, however, occasionally exhibit an absence or hypoplasia of the FS [1,4].

Conversely, unilateral duplication of the FS has been documented to occur among humans [4]. The duplication is thought to occur due to an early extracranial bifurcation of the MMA [4]. Unilateral duplication has been reported to occur in between 0% and 6% of human skulls [5-7]. However, despite the variety of reports identifying the unilateral duplication of the FS, no reports have yet to show a bilateral duplication. The case described herein documents the occurrence of a bilateral FS duplication.

Case Report

Inspection of the cranial base of an adult male skull of unknown age, held in the anatomical collection at West Liberty University, lead to the observation of a bilateral duplication of the FS. Each side of the cranium presented a FS located slightly anterolateral to another ipsilateral FS; however, the orientation of the foramina was not bilaterally symmetrical (Figure 1). Indeed, the spine of the sphenoid on the left side was located posterior to the left-sided FS, whereas the spine of the sphenoid on the right side was located intermediate to the right-sided FS. Each pair of FS, as well as the FO of each side of the skull, was measured by 1.) placing a digital caliper (Mitutoyo 0-8 in (0-203.2mm) ABSOLUTE™ digimatic caliper series 500, accuracy ± 0.001 in (0.025 mm)), opened and locked to a known distance of 50.00 mm, flush against the cranial base 2.) taking a high resolution macrophotograph of the cranial base with the caliper in the frame 3.) uploading the macrophotograph into ImageJ software (NIH) for analysis, 4.) calibrating the known caliper distance into pixels, and 5.) utilizing the built-in functions of ImageJ to determine foramen area, perimeter, maximum diameter, and minimum diameter.

For thorough documentation of the morphology, researchers also measured the distances from the posterior-most point of the ipsilateral greater wing of the sphenoid to the centroid of each respective ipsilateral foramina as well as distances from the centroid of each foramina to the midline of the skull. The midline of the skull was determined by dividing the breadth of the basilar process of the occiput. The angle formed between the line from the posterior-most point of the ipsilateral greater wing to the centroid of the foramen and the line from the centroid of the foramen to the midline was also recorded (Figure 2). Morphometric data can be found in Table 1.

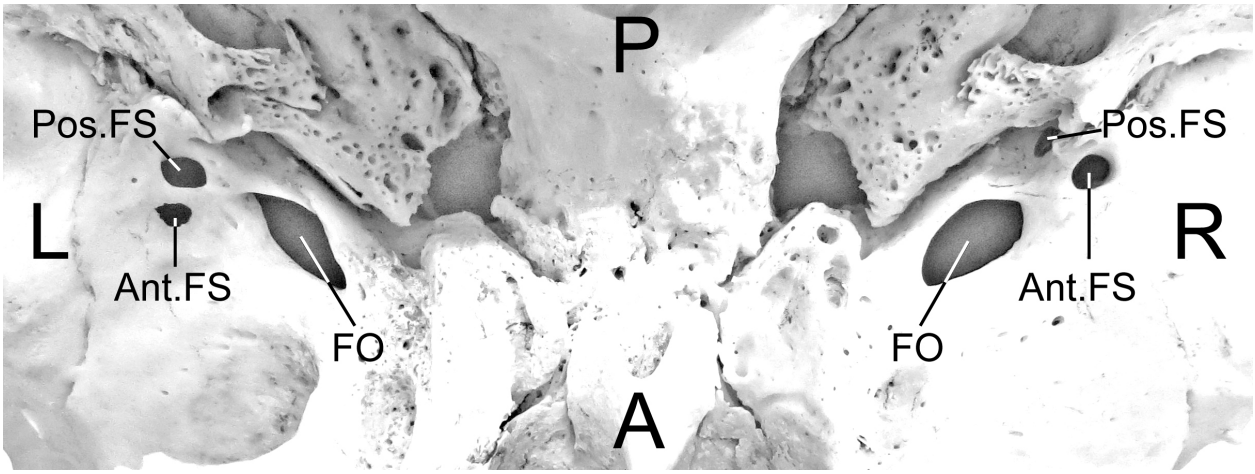

Figure 1: Inferior view of the skull base demonstrating a bilateral duplication of the foramen spinosum. (Pos.FS: posterior-most foramen spinosum; Ant.FS: anterior-most foramen spinosum; FO: foramen ovale).

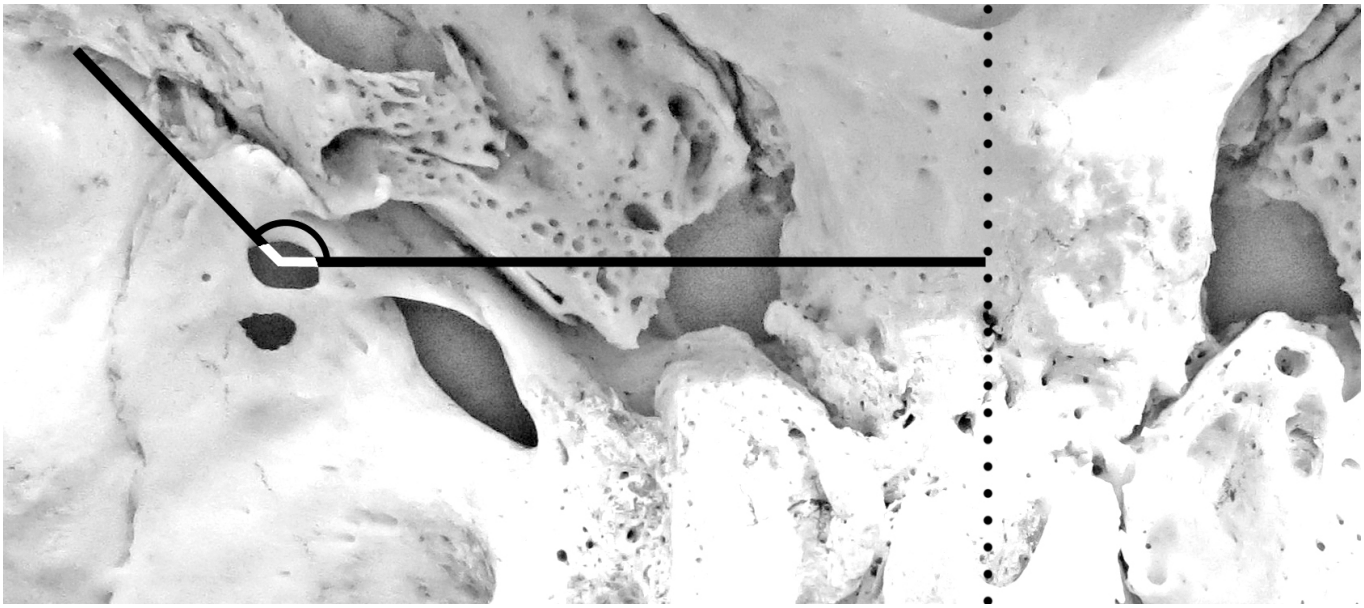

Figure 2: Inferior view of the left-side cranial base demonstrating the angle measured between the line from the posterior-most point of the ipsilateral greater wing of the sphenoid to the centroid of the foramen and the line from the centroid of the foramen to the midline. The midline, represented by the dotted line, was determined by dividing the breadth of the basilar process of the occiput.

Discussion

Unilateral duplication of the FS is an anatomical variant that has been reported to occur in between 0% and 6% of human crania [5-7]. The report described herein is the first documentation of a bilateral duplication of the FS. Unilateral duplication of the FS is of both clinical and developmental/anthropological significance and likewise, bilateral duplication of the FS is of similar importance, but warrants additional considerations.

Numerous disorders are known to occur bilaterally in the region surrounding the FS. The hallmark of neurofibromatosis Type 2 (NFT2) is the occurrence of bilateral vestibular schwannomas (VS) [8]. Treatment for bilateral VS includes bilateral surgeries for the resection of the tumors [9]. Similarly, bilateral aneurysms of the internal carotid artery (ICA) have been well documented [10,11]. Indeed, even in clinically unilateral aneurysm cases, the prevalence of bilateral ICA aneurysms warrants that angiography be performed bilaterally [10].

Side	Foramen	Area (mm2)	Perimeter (mm)	Maximum diameter (mm)	Minimum diameter (mm)	Posterior point of the ipsilateral greater wing to centroid distance (mm)	Midline to centroid distance (mm)*	Posterior point-centroid-midline angle (degrees)*
Left	Ant. spinosum	2.39	8.51	2.59	1.70	15.99	33.34	126
	Pos. spinosum	5.71	10.58	3.65	2.30	13.99	32.61	134
	Ovale	18.25	23.10	9.42	3.27	23.51	24.09	142
Right	Ant. spinosum	4.67	10.17	3.22	2.15	10.42	33.34	125
	Pos. spinosum	2.52	11.12	2.74	1.36	11.36	29.87	148
	Ovale	28.26	26.81	9.15	4.20	20.00	24.40	139
*: midline was determined by bisecting the basilar process of the occiput sagittally								

Table 1: Morphometric measurements of the foraminae spinosae and ovalae.

The spine of the sphenoid is an important surgical landmark that is utilized to locate the FS and middle meningeal artery [12]. Similarly, the sphenoidal spine is the most consistent and reliable extracranial landmark for the location of the ICA as it enters the temporal bone [13]. In this cranium, the spine of the sphenoid on the left side was located posterior to the left-sided FS whereas the spine of the sphenoid on the right side was located intermediate to the right-sided FS. Therefore, surgeons performing bilateral surgeries involving the ICAs in this region may be easily disoriented when utilizing the sphenoidal spines as surgical landmarks under the presupposition that the bone is bilaterally symmetrical.

The FS, similarly, acts as a landmark in numerous neurosurgical procedures of the middle cranial fossa [14]. Ustun et al. [15] performed an anatomical study through which the spinosum was exposed extradurally in the bypass of the middle meningeal artery (MMA) with the petrous internal carotid artery (ICA) for the treatment of high cervical vascular lesions or tumors occupying the high ICA. Ustun et al. [16] also reported an alternative to the anastomosis of the external carotid artery to the posterior cerebral artery (ECA-to-PCA) for the treatment of central vertigo and dizziness, commonly caused by vertebrobasilar insufficiency, by creating a bypass between the MMA and P2 segment of the PCA.

The latter of the aforementioned procedures notes that the MMA trunk must be transected immediately before the bifurcation of its anterior and posterior branch at the location inside the dura and over the FS [16]. The MMA typically bifurcates intracranially; however, in the case presented herein, both the left and right MMA bifurcated extracranially. Therefore, the described variant would complicate the MMA-PCA bypass, regardless of the side on which the surgery is performed.

Aristegui et al. [17] studied an alternative method of the middle fossa approach to the internal auditory canal (IAC) that could be used to treat VS, repair the facial nerve, and decompress neurovascular structures while preserving the anatomical structures in the nearby area. The MMA and branches of the trigeminal nerve have sections that pass through the FS. These sections would need to be elevated in order to properly expose the IAC for surgery [17]. Therefore, the bilateral FS described in this report may complicate the middle fossa approach to the IAC, particularly in the case of bilateral VS which are typical of NFT2.

Because the foramen spinosum is utilized as a landmark for various procedures involving the middle cranial fossa, the bilateral duplication of the foramen may be disorienting to the surgeon. Similarly, the dynamics of blood flow may be altered due to the bilateral bifurcation of the MMA. Surgeons utilizing procedures such as those mentioned in this study, or alternative middle cranial fossa approaches, must be aware of the possible anatomical variation presently described. Particular consideration for this specific variant must be taken in cases of bilateral VS typical of NFT2 and bilateral aneurysms of the ICA.

The report is the first documentation of bilateral duplication of the foramen spinosum occurring in a human and, therefore, should also be considered significant with regard to anthropology. The skull described herein is without adequate provenance to speculate on ancestral/racial morphology. Aside from being easily identifiable as an adult male, no other demographic information is known. Future reports of bilateral duplications of the FS should pay special attention to demographics. Demographic information accompanying future reports of bilateral duplication of the FS may have important anthropological implications.

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