The extracranial and intracranial venous systems.

Introduction

The foramen Vesalius is a variable foramen located at the skull base, anteromedial to the foramen ovale behind and lateral to the foramen rotundum. This foramen is also known as emissary sphenoidal foramen. The aim of the research was to determine the anatomical characteristics of the foramen Vesalius in adult human skulls and foramina classification according to their type, shape, and sex distribution. Material and Methods. The study included 26 dry adult human skulls of both sexes from the collection of the Department of Anatomy, Faculty of Medicine of the University of Novi Sad. The skulls were macroscopically analyzed according to the presence or absence of the foramen Vesalius. Results. The foramen Vesalius was found in 16 skulls (61.54%) and it was absent in 10 skulls (38.46%). The incidence of bilateral and unilateral foramen Vesalius was 87.5% (14 skulls) and 12.5% (2 skulls), respectively. The foramen Vesalius was found in 10 male skulls (62.5%) and in 6 female skulls (37.5%). Conclusion. Based on the morphological analysis of the skulls, the study showed that the foramen of Vesalius can be unilateral or bilateral. The bilateral foramen was more common and it was usually round and symmetrical. In regard to the sex prevalence, the foramen was more prevalent in male than in female skulls. The results of the study showed that foramen Vesalius is not an uncommon anatomical variation, and its presence and morphological appearance are important information for physicians in various fields.

Key words: Skull Base; Sphenoid Bone; Cranial Fossa, Middle; Anatomic Variation; Adult

Sažetak

Uvod. Vezalijusov otvor je varijabilan otvor koji se nalazi na bazi lozanje, ispred i unutra od ovalnog otvora, a spolja od okruglog otvora. Vezalijusov otvor je poznat još i po nazivu emisarni sfenoidalni otvor. Cilj ovog rada bila je morfološka analiza Vezalijusovog otvora na lozanji odraslog čoveka i klasifikacija otvora u odnosu na tip, oblik i polnu zastupljenost. Material i metode. U istraživanju je korističeno 26 suvih ljudskih lozana, koje pripadaju Zavodu za anatomiju Medicinskog fakulteta Novi Sad, Univerzitetu u Novom Sadu. Lozanje su makro-skopski analizirane na prisustvo ili odsustvo Vezalijusovog otvora. Rezultati. Vezalijusov otvor je bio prisutan na 16 (61,54%), a odsutan na 10 (38,46%) lozana. Incidencija odsutanog otvora bila je 87.5% (14 lozana), a jednostrano prisutnog 12,5% (dve lozana). Vezalijusov otvor je bio prisutan na 10 lozana muškog pola (62,5%) i šest lozana ženskog pola (37,5%). Zaključak. Na osnovu morfološke analize lozanja, studija je pokazala da Vezalijusov otvor može biti jednostrano i/ili obostrano prisutan. Otvor je bio češće prisutan obostrano i obično je bio okruglog i simetričan. Otvor je bio zastupljeniji kod lozana muškog nego kod lozana ženskog pola. Iz rezultata ove studije, može se zaključiti da Vezalijusov otvor nije retka anatomска varijacija, a njegovo prisustvo i morfološki izgled predstavljaju važne informacije za lekare iz različitih oblasti. Ključne reči: baza lozanja; sfenoidna kost; srednja kranijalna jama; anatomski varijacije; odsla osoba

Introduction

The greater wings of the sphenoid bone contain several openings that connect the middle cranial fossa to the pterygopalatine and infratemporal fossa. The permanent foramina of the sphenoid bone are foramen rotundum, foramen ovale and foramen spinosum, whereas the foramen of Vesalius (FV) and meningo-orbital foramen (Hyrtl’s canal) are inconstant openings. All permanent and inconstant openings of this region contain veins that connect the extracranial and intracranial venous systems.

MORPHOLOGICAL CHARACTERISTICS OF FORAMEN VESALIUS IN DRY ADULT HUMAN SKULLS

MORFOLOŠKE KARAKTERISTIKE VEZALIJUSOVOG OTVORA SUVIH LOBANJA ODRASLIH OSOBA

Miloš MALETIN, Miloš VUKOVIĆ, Milan SEKULIĆ and Vanja DRLJEVIĆ TODIĆ

Summary

Introduction. The foramen Vesalius is a variable foramen located at the skull base, anteromedial to the foramen ovale behind and lateral to the foramen rotundum. This foramen is also known as emissary sphenoidal foramen. The aim of the research was to determine the anatomical characteristics of the foramen Vesalius in adult human skulls and foramina classification according to their type, shape, and sex distribution. Material and Methods. The study included 26 dry adult human skulls of both sexes from the collection of the Department of Anatomy, Faculty of Medicine of the University of Novi Sad. The skulls were macroscopically analyzed according to the presence or absence of the foramen Vesalius. Results. The foramen Vesalius was found in 16 skulls (61.54%) and it was absent in 10 skulls (38.46%). The incidence of bilateral and unilateral foramen Vesalius was 87.5% (14 skulls) and 12.5% (2 skulls), respectively. The foramen Vesalius was found in 10 male skulls (62.5%) and in 6 female skulls (37.5%). Conclusion. Based on the morphological analysis of the skulls, the study showed that the foramen of Vesalius can be unilateral or bilateral. The bilateral foramen was more common and it was usually round and symmetrical. In regard to the sex prevalence, the foramen was more prevalent in male than in female skulls. The results of the study showed that foramen Vesalius is not an uncommon anatomical variation, and its presence and morphological appearance are important information for physicians in various fields.

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Introduction

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Andreas Vesalius [1] first described and drew this opening, which was named after him “foramen of Vesalius” (foramen venosum Vesalii, sphenoid emissary foramen, canaliculus sphenoidal). The FV is a small, non-permanent opening, with the upper end located on the cerebral surface of the greater wings of the sphenoidal bone, anterior and medial to the foramen ovale and lateral to foramen rotundum. Its lower end is located on the upper part of the lateral pterygoid plate, inferior and lateral to the scaphoid fossa.

The FV can be unilateral or bilateral. The mean diameter of the foramen is 1 mm in infants, while

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in adults it is 1.4 – 2 mm [2]. Anthropological studies have shown that there are numerous disagreements among authors about the presence of the FV, which range from 25 – 100% in the population [3].

According to Wood-Jones [4], the FV is a characteristic of the human race and it is an indicator of the complex cranial venous system in humans. The FV does not exist in any primate other than humans.

The emissary vein passes through the FV and it was named as the foramen itself, i.e. Vesalius vein, which establishes communication between the cavernous sinus and the pterygoid plexus. Along with the emissary vein, the accessory meningeal artery also passes through the foramen [5]. The FV is sometimes divided with a bony septum, reducing the space for the emissary veins and artery, resulting in vascular compression.

Since there is poor information on the presence and characteristics of the FV in our population, in comparison with the data in different populations, this study represents a morphological analysis of the adult skulls that show the FV. The aim of the research was to determine the anatomical characteristics of the FV in adult skulls and their classification according to the type, shape, and sex distribution.

Material and Methods

The study included 26 dry adult skulls (13 male and 13 female) that belong to the Osteological Collection of the Department of Anatomy of the Faculty of Medicine, University of Novi Sad. Only skulls without visible deformities and damage were examined.

The skull sex determination was done using the sex-modified visual determination protocol modified by Ferembach [6] and Buikstra [7].

The examined skulls were photographed with an Olympus camera (18 x optical zoom) and the images were then transferred to the magnetic medium of the computer system.

Abbreviations

FV – foramen of Vesalius

Based on the macroscopic appearance and shape of the FV, the skulls were morphologically analyzed and divided into basic groups.

The incidence of bilateral and unilateral FV was calculated and presented in relation to the sex distribution. The obtained results were graphically presented.

Results

In a sample of 26 dry adult skulls, presence of the FV, their shape on the internal and external surface of the base of the skull, as well as sex distribution, were analyzed. Based on the morphological characteristics, foramina were classified into two main groups: bilateral and unilateral.

The FV was found in 16 skulls (61.54%), while in 10 skulls (38.46%) it was absent (Graph 1).

Bilateral FV is located on the right and the left sides of the skull (Figure 1), while unilateral foramen is located only on the right or left side (Figure 2). In the sample of 16 skulls, bilateral FV was found in 14 skulls (87.5%) and unilateral in 2 skulls (12.5%).

Graph 1. Percentage of skulls with and without foramen of Vesalius

Graphik 1. Procena lobanja sa prisutnim i odsutnim Vesalijusovim otvorom

Figure 1. Bilateral foramen of Vesalius on the internal (A) and external surface (B) of the base of the skull (arrows)

Slika 1. Obostrano prisutan Vesalijusov otvor na unutrašnjoj (A) i spoljašnjoj (B) strani baze lobanje (strelica)

Figure 2. Unilateral foramen of Vesalius (arrow) on the internal surface of the base of the skull

Slika 2. Jednostrano prisutan Vesalijusov otvor (strelica) na unutrašnjoj strani baze lobanje
All the examined cases presented with a foramen on the internal and external surface of the base of the skull, so it could be called the Vesalius canal. In our sample, all the foramina were open. The upper end of the canal was behind and lateral to the foramen rotundum and in front and medial to foramen ovale. The lower end of the canal was located below and lateral to the scaphoid fossa. Closed canals at either end, or double foramina were not detected. Asymmetric FV was found in 5 skulls. In 11 cases, foramina were small and round; in 5 cases on one side they were larger, oval and elongated (Figure 3). The FV were present in 10 male skulls (62.5%) and 6 female skulls (37.5%) (Graph 2).

**Discussion**

In our study, FV was observed in 61.54% of skulls (Table 1), which corresponds to the findings of Lanzieri [8], Romalha [9], and Raval [10]. The most common foramen is bilateral, round and symmetrical, found in 87.5% of the skulls. Our results differ from the findings of other authors [5, 11–19], where the presence of foramina is lower (Table 1). According to most authors, the presence of the foramina is lower than ours, but when comparing the results of different authors of the same nationality, we may notice that their data also differ (Table 1). The FV in our sample was bilateral in 87.5% and unilateral in 12.5% of cases, which corresponds to the findings of Kodama [20], Nayak [17] and Kale [21]. Most authors reported approximately equal distribution of bilateral and unilateral foramina [5, 10–12], while some studies showed that unilateral openings were more frequent [14, 16, 18].

### Table 1. Incidence of the FV in different populations (%)

| Author and year | Nation            | Sample number | Incidence of the foramen Vesalius (%) |
|-----------------|-------------------|---------------|---------------------------------------|
| Boyd (1930)     | England/Engleska  | 1500 skulls/lobanja | 36.5%                                |
| Lanzieri (1988) | America/Amerika   | 50 CT scans/skenova | 64%                                  |
| Ginsberg (1994) | America/Amerika   | 123 CT scans/skenova | 80%                                  |
| Kodama (1997)   | Japan/Japan       | 400 skulls/lobanja | 21.75%                               |
| Gupta (2005)    | India/Indija      | 35 skulls/lobanja | 42.90%                               |
| Ramalho (2007)  | Brazil/Brazil     | 80 skulls/lobanja | 71.87%                               |
| Kaplan (2007)   | Turkey/Turska     | 10 skulls/lobanja | 100%                                 |
| Shaik (2007)    | India/Indija      | 125 skulls/lobanja | 36%                                  |
| Shinohara (2010)| Brazil/Brazil     | 400 skulls/lobanja | 33.5%                                |
| Raval (2015)    | India/Indija      | 150 skulls/lobanja | 60%                                  |
| Murlimanju (2015)| India/Indija    | 78 skulls/lobanja | 37.2%                                |
| Bayrak (2018)   | Turkey/Turska     | 317 CBCT scans/skenova | 28.1%                                |
| Costa do Nascimento (2018) | Brazil/Brazil | 194 skulls/lobanja | 18.55%                                |
| Nayak (2018)    | India/Indija      | 30 skulls/lobanja | 30%                                  |
| Leonel (2019)   | Brazil/Brazil     | 170 skulls/lobanja | 45.2%                                |
| Kaplan (2019)   | Turkey/Turska     | 350 CBCT scans/skenova | 41.1%                                |
| Our study (2020)| Serbia/Srbija     | 26 skulls/lobanja | 61.54%                                |

**Legend/Legenda:** * CBCT - cone-beam computed tomography/Kompjuterizovana tomografija na bazi koničnih zraka

All the examined cases presented with a foramen on the internal and external surface of the base of the skull, so it could be called the Vesalius canal. In our sample, all the foramina were open. The upper end of the canal was behind and lateral to the foramen rotundum and in front and medial to foramen ovale. The lower end of the canal was located below and lateral to the scaphoid fossa. Closed canals at either end, or double foramina were not detected. Asymmetric FV was found in 5 skulls. In 11 cases, foramina were small and round; in 5 cases on one side they were larger, oval and elongated (Figure 3). The FV were present in 10 male skulls (62.5%) and 6 female skulls (37.5%) (Graph 2).

**Figure 3.** Bilateral asymmetric Vesalius foramina (arrows), foramen ovale (FO), foramen spinosum (FS), foramen lacerum (FL) on the internal surface of the base of the skull

**Slika 3.** Obostrano prisutan asimetričan Vezalijusov otvor (strelice), ovalni otvor (FO), otvor bodlje (FS), proderani otvor (FL) na unutrašnjoj strani baze lobanje

**Graph 2.** Percentage of male and female skulls with Vesalius foramina

**Grafikon 2.** Procent lobanja muškog i ženskog pola sa prisutnim Vezalijusovim otvorom
In our sample, the FV was more common in male subjects, unlike Gupta [11] and Rossi [22], who reported that it was more common in females. Kodama [20] did not detect a difference between sexes after examining 400 skulls.

The incidence of variable FV is probably due to evolutionary and adaptive skeletal responses to local biomechanical stimuli. The FV represents the communication between the extracranial and intracranial spaces of the skull. When present, it contains an emissary vein that connects the venous sinus of the skull and the venous vessels of the head, particularly the cavernous sinus with the pterygoid plexus. Through this channel, pathological processes and infections can pass from the extracranial into the cranial space (causing thrombosis of the cavernous sinus and intracranial infection). Given that the mandibular nerve and the corresponding blood vessels of the middle cranial fossa are nearby, pathological changes can affect the neurovascular elements and lead to certain symptoms [23–25]. The surgical significance of this foramen is that during percutaneous trigeminal rhizotomy, the needle may pass through this non-permanent opening and lead to cavernous sinus puncture and intracranial hemorrhage, which can be a life-threatening condition [23, 24].

Asymmetry of the FV was observed in 5 cases and in most cases it was likely the result of a pathological process than a normal variant. The occurrence of asymmetry, i.e. an enlarged foramen on one side is most often the result of an acquired abnormality caused by an invasion of nasopharyngeal melanoma, angiofibroma, carotid-cavernous fistula, and neurofibromatosis [8].

Based on the results, it can be concluded that variations of FV are not rare anatomical phenomena as previously thought. The presence of several foramina, given that it is more frequent, should be suspected during the radiological diagnostic examination of the middle cranial fossa [23]. The finding of FV, its shape, symmetry, and asymmetry, provides important information for anatomists, radiologists, neurosurgeons, and maxillofacial surgeons.

**Conclusion**

In this study, the macroscopic examination of skulls showed that foramen of Vesalius can be unilateral or bilateral. The incidence of bilateral foramen was much higher than unilateral, and it was mostly round and symmetrical. With regard to gender prevalence, the foramen was more frequent in male than in female skulls. From this, it can be concluded that foramen Vesalius is not an uncommon finding, and its presence and morphological appearance represent important information for physicians in various fields.

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