VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 64, No. 3, pp. 188–193

ISSN 0015–5659
www.fm.viamedica.pl

The morphology and morphometry of the foramina of the greater wing of the human sphenoid bone

Jerzy Reymond[1], Anna Charuta[2], Jarosław Wysocki[2]

[1]Department of Maxillofacial Surgery, Regional Specialist Hospital, Radom, Poland
[2]Department of Vertebrate Morphology Academy of Podlasie, Siedlce, Poland

[Received 28 May 2005; Revised 15 July 2005; Accepted 15 July 2005]

The greater wing of the human sphenoid bone is pierced by several foramina, which contain, as a main element, the venous anastomoses between the interior of the skull and the extracranial veins. Since data concerning these foramina are scarce in the literature, studies comprising the frequency of occurrence and morphology of the foramina of the greater wing of the human sphenoid bone were undertaken on 100 macerated skulls. We found that the foramen ovale *is divided into 2 or 3 components in 4.5% of cases. Moreover, the borders of the* foramen ovale *in some skulls were irregular and rough. This may suggest, on radiological images, the presence of morbid changes, which might be the sole anatomical variation. Concurrent with the* foramen ovale *are accessory foramina. The foramen of Vesalius and the cavernous foramen were present in 17% and 33% of cases, respectively. The foramen of Vesalius was always single and the cavernous foramen also occurred in multiple form. The* foramen spinosus *and the* foramen rotundum *occurred as permanent elements of the skulls studied. The mean area of the foramina measured, excluding the* foramen ovale, *was not considerable, which may suggest that they play a minor role in the dynamics of blood circulation in the venous system of the head.*

Key words: sphenoid bone, foramina, emissary veins, anatomy, human

INTRODUCTION

The greater wing of the human sphenoid bone is pierced by several foramina. Some of these are orifices of small diploic veins, while others connect infratemporal fossa with the middle cranial fossa and the orbit [3]. There are different foramina: the *foramen rotundum*, the *foramen ovale*, the *foramen spinosum*, and the inconstant foramen of Vesalius, as well as the inconstant meningo-orbital foramen (Hyrtl's channel). As their essential component, all foramina contain venous plexuses. The venous plexus of the *foramen ovale* connects the cavernous sinus with the pterygoid plexus [1, 3, 5–7, 12, 16]. The *foramen spinosum* also contains a venous component, the middle meningeal vein, connecting the cavernous sinus with the pterygoid plexus [1, 6]. The *foramen spinosum* is almost always present; absence of this foramen was found in 0.8% of skulls [2]. Beside the *foramen ovale*, a separate venous foramen, referred to as the foramen of Vesalius, is sometimes present [3, 9, 13, 15]. The Great Anatomist considered its presence in his anatomical description of the

Address for correspondence: Jarosław Wysocki, MD, PhD, Department of Vertebrate Morphology, Academy of Podlasie, Siedlce, Poland, ul. Prusa 14, 08–110 Siedlce, e-mail: jwysocki@ap.siedlce.pl

skull [16]. In most cases this foramen lies postero-medially from the *foramen rotundum* [2]. Sometimes the foramen of Vesalius is double [4, 17]. It should also be remembered that small venous foramina are located in the neighbourhood of the *foramen ovale*. These pierce the greater wing of the sphenoid bone in different places and might be mistaken for diploic veins. These foramina make up what is known as the lateral craniopharyngeal canal [13] or cavernous emissary [3]. The inconstant meningo-orbital foramen (Hyrtl's canal) pierces the greater wing of the sphenoid bone and also consists of a venous component. Hyrtl's canal has been the subject of a separate report by us [8]. The *foramen rotundum*, serving as a passage for the maxillary nerve, also contains the venous plexus, which surrounds the nerve and penetrates under its capsule [13]. This foramen links the cavernous sinus with the pterygoid plexus lying outside the skull [1]. The inconstant temporal foramen also belongs to the foramina piercing the greater wing of the sphenoid bone. The temporal emissary foramen pierces the sphenoid bone in the neighbourhood of the temporal fossa, on the lateral surface of the skull therefore, penetrating as a short channel with a diameter of about 1–2 mm [13].

The principal aim of this work was the evaluation of the frequency of occurrence and morphology of foramina of the greater wing of the human sphenoid bone, primarily with regard to the variability of the *foramen ovale* and its surroundings, including the varied presence of foramen of Vesalius.

The presence of these foramina is important during clinical evaluation of radiological images of the diseased regions. This study was also motivated by the paucity of the literature, the incompleteness of textbook descriptions and the lack of proper illustrations showing these structures. This especially concerns the neighbourhood of the *foramen ovale*, which displays considerable variability, although this has not been treated separately in any publication.

MATERIAL AND METHODS

The investigations were performed on 100 macerated adult human skulls. After the sex of each skill had been determined, the foramina piercing the greater wing of the sphenoid bone were identified and their non-metric features analysed. To demonstrate the direct contact of the foramen under investigation with the cavity of the skull (which was obvious in the case of large foramina) a sounding of each foramen or channel leading to it was performed with a stiff steel wire of 0.1 mm in diameter. The variants in morphology of the foramina were described and photographed. The foramina studied were scanned and their areas measured using a computerised image analysis system (MULTISCAN). The *foramen rotundum* was not measured, since it was neither possible to open the integument of the skull, nor to prepare the skull to expose the foramen from the side of the pterygoid fossa. The data obtained, both metric and non–metric were analysed statistically. In order to evaluate the statistically significant differences of metric parameters between the same type of foramina (located on the left or the right side) we applied a pair-dependent test. For the remaining parameters Student's t-test as well as an analysis of variance (the distribution F — Snedecor) were used. The non-metric data were analysed with the χ^2 test. Pearson's test was applied for calculation of the linear correlation co-efficient of two variables.

RESULTS

The results of the evaluation of frequency of occurrence and morphology of the foramina studied are presented in Table 1. There were no statistically significant differences related to sex or the side of the skull on which a particular foramen was located.

Table 1. The frequency of occurrence and morphology of the selected foramina of the greater wing of the human sphenoid bone

Name of foramen/feature studied		Male skulls		Female skulls	
		Left side	Right side	Left side	Right side
Ovale	Single	48	46	49	48
	Multiple	2	4	1	2
of Vesalius	Unilaterally present	2	3	3	4
	Bilaterally present	3		2	
Cavernous		20	16	17	15
Temporal		3	1	4	3

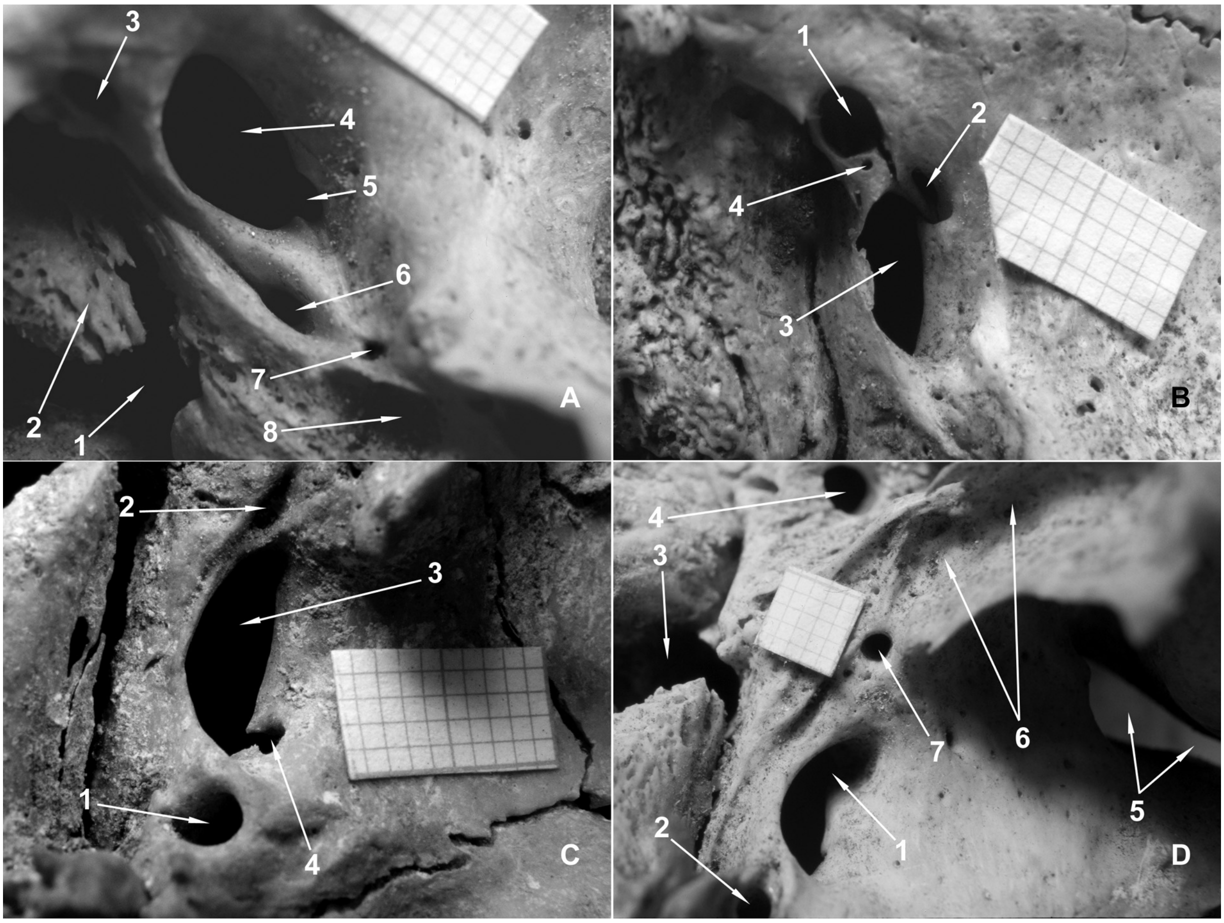

Figure 1. Morphology of the foramina of the greater wing of the sphenoid bone of the human skull. **A.** View of base of the skull on the right side. The *foramen ovale*, the foramen of Vesalius and the cavernous emissary; 1 — lacerated foramen, 2 — apex of pyramid of temporal bone, 3 —*foramen spinosum*, 4 — central part of *foramen ovale*, 5 — small compartment of *foramen ovale*, partially separated from the main part, 6 — foramen of Vesalius, 7 — cavernous emissary, 8 — scaphoid fossa; **B.** View of base of the skull on the right side. Anatomical variants of the *foramen ovale*; 1 — *foramen spinosum*, 2 — accessory *foramen ovale*, 3 — *foramen ovale*, 4 — innominate foramen located between the *foramen spinosum* and the *foramen ovale*; **C.** View of the base of the skull on the left side. The foramen of Vesalius is present. Separate component of the *foramen ovale* is visible, almost entirely isolated from it; 1 — *foramen spinosum*, 2 — foramen of Vesalius, 3 — main part of the *foramen ovale*, 4 — separate element of the *foramen ovale*; **D.** View of base of the skull on the left side. The cavernous foramen; also visible is the innominate foramen, situated medially to the former, in the close neighbourhood of the vomer, piercing the root of the pterygoid process of the sphenoid bone. The *foramen ovale* is banana-like in shape; 1 — *foramen ovale*, 2 — *foramen spinosum*, 3 — lacerated foramen, 4 — innominate foramen, 5 — inferior orbital fissure, 6 — pterygoid fossa, 7 — cavernous foramen.

The *foramen rotundum* was almost always present and its morphology did not show essential variability. The *foramen ovale* was also observed in all skulls studied and always had the shape of a more or less flattened oval (Fig. 1A, B). The borders of this foramen were in many cases irregular and sometimes incisures were visible on the edges. These often took the form of deep hollows, separated almost entirely from the main foramen (Fig. 1C, D). However, all such cases were assigned to the category of single *foramen ovale*. A multiple *foramen ovale*, divided into 2–3 separate components, was found in 9 cases. There were different morphological forms of this division. The most frequent was one in which 2–3 foramina were located within one common osseous niche. These foramina were usually the main *foramen ovale* and accessory foramen/foramina. Rarely, the *foramen ovale* was divided in two by a thin osseous trabeculum, forming anterior and posterior compartments (Fig. 2). The foramen of Vesalius was always an independent structure lying in the neighbourhood of the *foramen ovale*, forward from it and somewhat medially. The cavernous foramen was usually single, rarely multiple. In 3 cases (on 3 sides of skulls) we found numerous (2–3) cavernous foramina. The *foramen spinosum* was present on both sides of

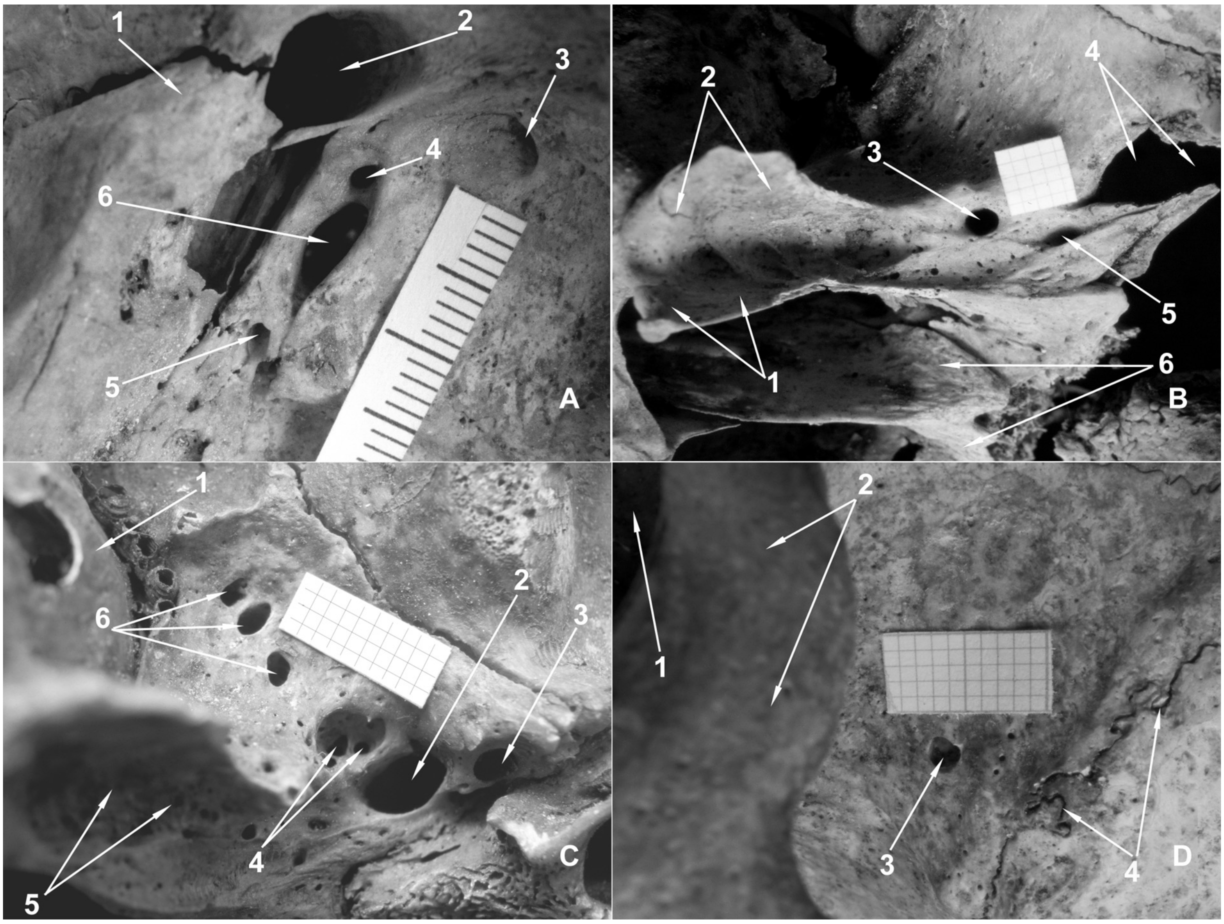

Figure 2. Morphology of the foramina of the greater wing of the sphenoid bone of the human skull, (on the skull base and on the lateral skull wall); **A.** View of the base of the skull on the right side (from inside). The *foramen ovale*, the foramen of Vesalius and the *foramen rotundum* are visible; 1 — apex of pyramid of temporal bone, 2 — lacerated foramen, 3 — *foramen rotundum*, 4 — foramen of Vesalius, 5 — *foramen spinosum*, 6 — *foramen ovale*; **B.** View of the base of the skull on the left side. The greater wing of the sphenoid bone partially damaged; 1 — medial lamina of the pterygoid process of the sphenoid bone, 2 — lateral lamina of the pterygoid process of the sphenoid bone, 3 — cavernous foramen, 4 — *foramen ovale* (partially damaged), 5 — foramen of Vesalius, 6 — vomeral wings; **C.** View of the base of the skull on the left side. Multiple cavernous foramina are present; 1 — maxillary tuber, 2 — *foramen ovale*, 3 — *foramen spinosum*, 4 — accessory *foramen ovale* (double), 5 — pterygoid fossa, 6 — triple cavernous foramen; **D.** View of lateral wall of the skull on the left side. The temporal emissary foramen piercing the greater wing of the sphenoid bone in the temporal fossa is visible; 1 — interior of left orbit, 2 — zygomatic bone, 3 — temporal emissary foramen, 4 — spheno-squamous suture.

the skull and in both sexes. The temporal foramen was always located within the greater wing of the sphenoid bone, on its temporal surface. The results of measurements of the area of the foramina studied are presented in Table 2. This data too showed no statistically significant differences dependent on sex or side of the body.

DISCUSSION

In the material studied, the *foramen ovale* was characterised by moderate variability. This foramen was described by Vesalius in his memorable work. He reported that the foramen was lying in the sphenoid bone, forward from the lacerated foramen [17], and mistakenly recognised its content, since he mentioned that 3rd and 4th cranial nerves cross in this way [17].

In the present studies we found that the borders of the foramen were in many cases irregular and cavernous. Those irregularities did not have the character of post-mortem damage, as their edges were smooth. In some cases it was possible to observe the incisures, often in the form of deep hollows, on the edge of the foramen. This data is in accordance with those obtained previously by Berlis et al. [2], in which considerable variability was found in the morphology of the *foramen ovale*. They also demonstrated that in 56.7% of cases this foramen is oval in shape, in 31.7% it has the shape of an elongated oval, and in 11.7% it is semicircular. However, these fea-

Table 2. The mean area of the studied foramina of the greater wing of the human sphenoid bone in relation to sex and body side (all data in mm^2). The results are presented as mean values (in bold, standard deviations (in brackets) and ranges (below)

Name of the foramen	Male skulls (n = 49)		Female skulls (n= 48)		All skulls (left and right)
	Left	Right	Left	Right	
ovale	17.39 (4.73) 10.3–25.3	19.43 (5.59) 11.4–31.2	17.66 (6.46) 10–34.2	20.92 (5.56) 12.7–32.4	26.4 (11.9) 10.9–62.2
spinosum	2.51 (1.21) 0.86–6.1	4.18 (1.71) 1–6.3	2.27 (1.23) 0.76–5.8	3.12 (1.28) 1.23–6.0	3.65 (2.62) 0.76–11.1
of Vesalius	1.60 (0.93) 0.56–3.26	2.49 (2.17) 0.23–6.5	2.81 (1.02) 2.15–3.98	2.86 (0.80) 1.78–3.65	2.55 (1.47) 0.23–6.5
cavernous	1.93 (1.61) 0.23–6.47	1.84 (1.04) 0.26–4.3	1.85 (1.30) 0.27–4.68	1.84 (1.62) 0.3–6.01	2.17 (1.63) 0.26–6.47
temporal	3.21 N = 3	2.06 N = 1	1.40 N = 4	1.83 N = 3	2.06 (0.73) 0.56–2.67

tures of the *foramen ovale* were not the object of present investigations, in which we evaluated, first of all, the presence of a single or a divided foramen. According to Berlis et al. [2], the *foramen ovale* is divided in 12.5% of cases by the osseous bridge, and in 0.8% of cases is completely double. Such partition, without cases of multiplicity, was also observed in the present investigations (Table 1). The mean area of the *foramen ovale*, in relation to sex and side of the body, ranged from 17.39 mm^2 to 20.92 mm^2. We did not find any relevant data in the available literature. The linear dimensions of the *foramen ovale* presented by other authors are 2.4–6.7 × 6.5–11.3 mm, with an average of 3.9 × 4.7 [2, 5, 10, 13]. Converting these linear dimensions to area, using the formula for the area of an ellipse, we obtained values ranging from 25.24 mm^2 to 115.31 mm^2, with an average of 28.8 mm^2. These values, therefore, are very close to our data. According to Schelling [13], in 55% of cases the left *foramen ovale* prevails, in 27.5% the right one, and in 17.5% of cases equilibrium is preserved. In addition, in our material the left foramen predominated, although the difference was not statistically significant.

The foramen of Vesalius [17] was found in our material in 17% of the skulls. If the occurrence of the foramen at least on one side is taken into account, a result is obtained of 22% of the number of skulls. According to other authors, this foramen is present unilaterally in 12.5–35% of skulls [2, 4, 13]. The result of our assessment falls therefore within this framework of values. However, the frequency of the bilateral occurrence of this foramen in our studies (5% of the skulls) is considerably lower than that reported by Boyd [4] (14.7% of the skulls).

It is noteworthy that Vesalius [17] described the presence of this foramen as a rare phenomenon, and mentioned that, although it may sometimes be found unilaterally, it very seldom occurs bilaterally. The mean area of the foramen of Vesalius ranged in our material from 1.6 to 2.86 mm^2, depending on the sex and the side of the body. However, its asymmetry was not statistically significant, which is not in agreement with the data obtained by Lanzieri et al. [9]. According to Boyd [4], in 65% of skulls the foramen of Vesalius has a diameter of 0.5–1 mm, in 5% of the skulls a diameter of 1–2 mm, and only very rarely a diameter of 2.5 mm. The linear dimensions of this foramen, according to Berlis et al. [2], are 1–2 × × 1–3.5 mm, with an average of 1.3 × 1.8 mm. Schelling [13] reported that the diameter of this foramen was 1.32 × 1.22 mm on the left side and 1.24 × × 1.16 mm on the right side. By transforming the data of Schelling, which are mean linear values, into values for area, applying the formula for an ellipse, we obtained a value of 2.58 mm^2 for the left and 2.26 mm^2 for the right side. The data are thus in close agreement.

We found the cavernous foramen in 36 male and 32 female skulls. Therefore, taking these values together, it was present in 68% of the skulls studied. Our data indicate that this seemingly unimportant foramen, often ignored in descriptions of the skull, is quite often present. Moreover, its characteristic feature is great variability, including a high incidence of multiple forms. Schelling [13] observed the presence of cavernous foramina in 5% of skulls. These had diameters of up to 2.5 mm and were, according to him, varieties of diploic vein. Bochenek and

Reicher [3] devoted little attention to this foramen in his textbook, only mentioning that its occurrence is a rare variant. It may be caused by fact that foramina of the diploic veins are frequently present in this region, which might be mistaken for the cavernous foramen.

Only careful sounding enables the real venous emissary to be distinguished from the diploic veins. The small values of the area of the cavernous foramen (1.84–1.93 mm^2, depending on sex and the side of the body) rank it among the smaller emissaries of the skull.

We found the temporal foramen in 5.5% of the skulls studied. This foramen, usually in the form of a short channel, pierced the greater wing of the sphenoid bone at its temporal surface. In some anatomical descriptions it is mistakenly classified as the foramen of the anterior temporal diploic vein, which is observed in about 14% of skulls [13]. The temporal emissary proper is, according to data from the literature, present in 1–1.5% of the skulls as a large anastomosis with the middle meningeal vein and the spheno-parietal sinus [1, 13, 14]. Engel called this connection the temporal emissary (Engel 1859, cited after Schelling [13]). The results of our evaluation indicate a slightly higher incidence. However, discussion of them is difficult because of a lack of comparative data in the literature. The data reported by Schelling are probably closer to the true values, since he investigated a large number of the skulls. The discrepancy in the results may also be caused by differences in population, including its racial make-up, skulls from Poland not being included in Schelling's studies [13].

The *foramen spinosum* was a permanent structure of the skull in our material. It is present only in higher Primates [11]. Its incidence is 98.5% in man, 89.4% in the chimpanzee, 58.7% in the gorilla, and 9.2% in the orang-utan [18]. Vesalius described this foramen as lying rearwards from the *foramen ovale*, attributing to it as content a small venous branch, which then joins the internal jugular vein [17]. The mean area of the *foramen spinosum* in our material is 3.65 mm^2, which is consistent with the data given by other authors, if linear dimensions (2.1×2.6 mm) given by them [2] are converted to area value. It is also in agreement with Schelling's investigations, according to which the mean diameter of this foramen is about 1.5 mm [13].

CONCLUSIONS

1. In rare cases the *foramen ovale* is multiple in form.
2. Irregularities of the edge of the *foramen ovale* are present in normal conditions and are not an expression of a morbid process.
3. The cavernous foramen is a frequent element of the greater wing of the sphenoid bone.

REFERENCES

1. Bekov DB (1965) Atlas venoznoi sistemy golovnogo mozga tscheloveka. Medicina, Moskwa.
2. Berlis A, Putz R, Schumacher M (1992) Direct CT measurements of canals and foramina of the skullbase. Br J Radiol, 65: 653–661.
3. Bochenek A, Reicher M (1993) Anatomia człowieka. Vol. 3, Ed. 6. PZWL, Warszawa.
4. Boyd G I (1930) The emissary foramina in the cranium of man and anthropoids. J Anat, 65: 108–121.
5. Calcaterra TC, Cherney EF, Hanafee WF (1973) Normal variations in size and neoplastic changes of skull foramina. Laryngoscope, 83: 1385–1397.
6. Dołgo-Saburov BA (1956) Anastomozy i puti okolnogo krovoobraschtschenija u tschczeloveka. Izd 3, Medgiz, Leningrad.
7. Krmpotić-Nemanić J (1978) Anatomie, Variationen und Mißbildungen der Gefäse im Kopf- und Halsbereich. Arch Oto-Rhino-Larying, 219: 1–91.
8. Kwiatkowski J, Wysocki J, Nitek S (2003) The morphology and morphometry of the so called "meningo--orbital" foramen in humans. Folia Morphol, 62: 323–325.
9. Lanzieri CF, Duchesneau PM, Rosenbloom SA, Smith AS, Rosenbaum AE (1988) The significance of asymmetry of the foramen of Vesalius. Am J Neuroradiol, 9: 1201–1204.
10. Lindblom K (1936) A roentgenographic study of the vascular channels of the skull. Acta Radiol, 30: 211–223.
11. Poplewski R (1935) Anatomia ssaków. Układ kostnostawowy. Vol. 2. Komitet Wydawniczy Podręczników Akademickich, Warszawa.
12. Rouviére H, Cordier G (1954) Anatomie humaine. Thiéme édit ol 1, Masson, Paris.
13. Schelling F (1978) Die Emissarien des menschlischen Schädels. Anat Anz, 143: 340–382.
14. Sreseli MA, Bolsakow OP (1977) Klinitschno-fizjologiczeskije aspekty morfologii sinusov tviordoj mozgovoj obolotschki. Medicina, Leningrad.
15. Thiéme G (1988) Terminologia anatomica. New York, Stuttgart.
16. Testut L (1948) Traite d'anatomie humaine. O Doin, Paris.
17. Vesalius A (1543) De humani corporis fabrica libri septem. Bruxelle, Reprint.
18. Žedenov VN (1962) Sravnitelnaja anatomija primatov. Gos Izd Vysšaja Škola, Moskwa.