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

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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
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 diplo-
ic veins. These foramina make up what is known as 
the lateral craniopharyngeal canal [13] or cavernous 
emissary [3]. The inconstant meningo-orbital fora-
men (Hyrtl’s canal) pierces the greater wing of the 
sphenoid bone and also consists of a venous com-
ponent. Hyrtl’s canal has been the subject of a sep-
arate report by us [8]. The foramen rotundum, serv-
ing as a passage for the maxillary nerve, also con-
tains 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 tem-
poral emissary foramen pierces the sphenoid bone 
in the neighbourhood of the temporal fossa, on 
the lateral surface of the skull therefore, penetra-
ting as a short channel with a diameter of about 
1–2 mm [13].

The principal aim of this work was the evalua-
tion of the frequency of occurrence and morpholo-
gy of foramina of the greater wing of the human 
sphenoid bone, primarily with regard to the variabi-
lity of the foramen ovale and its surroundings, 
including the varied presence of foramen of Vesalius.

The presence of these foramina is important dur-
ing 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 illus-
trations 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 mac-
erated adult human skulls. After the sex of each skull 
had been determined, the foramina piercing the 
greater wing of the sphenoid bone were identified 
and their non-metric features analysed. To demon-
strate the direct contact of the foramen under in-
vestigation 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 de-
scribed and photographed. The foramina studied 
were scanned and their areas measured using a com-
puterised 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 statisti-
cally. 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 re-
mainning 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 \( \chi^2 \) 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 oc-
currence 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**

<table>
<thead>
<tr>
<th>Name of foramen/feature studied</th>
<th>Male skulls</th>
<th>Female skulls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left side</td>
<td>Right side</td>
</tr>
<tr>
<td>Ovale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>48</td>
<td>46</td>
</tr>
<tr>
<td>Multiple</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>of Vesalius</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unilaterally present</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Bilaterally present</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Cavernous</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>Temporal</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
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
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-
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

### 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))

<table>
<thead>
<tr>
<th>Name of the foramen</th>
<th>Male skulls (n = 49)</th>
<th>Female skulls (n = 48)</th>
<th>All skulls (left and right)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left Left Right Right</td>
<td>Left Left Right Right</td>
<td></td>
</tr>
<tr>
<td>ovale</td>
<td>17.39 (4.73) 19.43 (5.59)</td>
<td>17.66 (6.46) 20.92 (5.56)</td>
<td>26.4 (11.9) 10.3–25.3 11.4–31.2</td>
</tr>
<tr>
<td>spinosum</td>
<td>2.51 (1.21) 4.18 (1.71) 0.86–6.1 1–6.3</td>
<td>2.27 (1.23) 3.12 (1.28) 0.76–5.8 1.23–6.0</td>
<td>3.65 (2.62) 0.76–11.1</td>
</tr>
<tr>
<td>of Vesalius</td>
<td>1.60 (0.93) 2.49 (2.17) 0.56–3.26 0.23–6.5</td>
<td>2.81 (1.02) 2.66 (0.80) 2.15–3.98 1.78–3.65</td>
<td>2.55 (1.47) 0.26–6.5</td>
</tr>
<tr>
<td>cavernous</td>
<td>1.93 (1.61) 1.84 (1.04) 0.23–6.47 0.26–4.3</td>
<td>1.85 (1.30) 1.84 (1.62) 0.27–4.68 0.3–6.01</td>
<td>2.17 (1.63) 0.26–6.47</td>
</tr>
<tr>
<td>temporal</td>
<td>3.21 N = 3 2.06 N = 1</td>
<td>1.40 N = 4 1.83 N = 3</td>
<td>2.06 (0.73) 0.56–2.67</td>
</tr>
</tbody>
</table>
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 sphenoparietal 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**