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ANATOMY OF THE JUGULAR FORAMEN IN DRY HUMAN SKULLS OF DIFFERENT GENDERS

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The purpose of the study was to examine certain morphometric parameters of the jugular foramen in dry adult human skulls classified by gender. The study was conducted on 77 "documented" dry skulls (38 male, 39 female), retrieved from the bone collection of the Anatomical Museum at the Department of Human Anatomy and Medical Terminology. Differences between the two groups were assessed using the non-parametric Mann–Whitney U test (PU). Descriptive t-test and Dispersion F-test (ANOVA) were also applied. A statistical significance of $p<0.050$ was considered sufficient to reject the null hypothesis. The study results showed that the oval shape of the foramen, in both males and females, was not associated with asymmetry (observed in 28.9 % of males and 20.5 % of females) and was more frequent in males. The least asymmetry was seen in dumbbell-shaped and kidney-shaped types. Comparative analysis of the area of the jugular foramen on both sides revealed that it was larger in males than in females, with a statistically significant difference observed on the left side ($P_U=0.040$). The medio-lateral dimension of the jugular foramen was found to be the same for both genders on both sides, with no statistically significant difference. Anterior-posterior measurements were also similar between genders on the right side (9.0±0.2 mm for both males and females), but differed significantly on the left side ($P_U=0.019$). Thus, we established that the jugular foramen can present in various shapes, with the oval form being the most common. Other shapes showed asymmetry – where one side had a narrower foramen and the opposite side a wider one – which, in our view, serves a compensatory function.

Key words: jugular foramen, gender differences, morphometry, skull anatomy.

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АНАТОМІЯ ЯРЕМНОГО ОТВОРУ НА СУХИХ ЧЕРЕПАХ У ЛЮДЕЙ РІЗНОЇ СТАТІ

Метою даної роботи було дослідження деяких морфометричних параметрів яремного отвору на сухих черепах дорослих людей, розділених за статевою ознакою. Дослідження проводилися на 77 «паспортизованих» сухих черепах (38 чоловічої, 39 жіночої статі), вилучених з кісткового сховища Анатомічного музею кафедри Анатомії людини та медичної термінології. Різниця між показниками для 2-х груп оцінювалася непараметричним методом U-Mann-Whitney (PU). Визначали Descript t-test, Disp F-test (ANOVA). При статистичній достовірності $p<0,050$ гіпотеза «0» заперечувалася. Результати дослідження показали, що овальна форма як у чоловіків, так і у жінок не має асиметрії (у чоловіків – 28,9 %, у жінок – 20,5 %) і більше спостерігається у чоловіків. Найменша асиметрія проявляється при гантелеподібній і бобоподібній формах. Порівняльний аналіз площі яремного отвору з обох боків показав, що він був більшим у чоловіків, ніж у жінок, і достовірно відрізнявся (PU=0,040) зліва. Медіо-латеральний розмір яремного отвору мав однакові значення у чоловіків і жінок з обох боків, між якими достовірних відмінностей не спостерігалося. Однакові показники між статями спостерігалися в передньо-задньому вимірі яремного отвору праворуч (у чоловіків і жінок склали 9,0±0,2 мм). Але параметри зліва мали достовірну різницю (PU=0,019). Таким чином, ми встановили, що яремний отвір має різні форми, серед яких найчастіше зустрічається овальна. Інші форми мають асиметрію – там, де на одному боці вузький отвір, а на протилежному боці розширений, на нашу думку, це має компенсаторне значення.

Ключові слова: яремний отвір, статеві відмінності, морфометрія, анатомія черепа.

The jugular foramen is located at the base of the skull and holds significant importance in otorhinolaryngology, radiology, and neurosurgical procedures involving the skull base and middle ear. Surgical access to this foramen is challenging [5]. It has complex anatomical relationships with critical neurovascular structures passing through it, including the glossopharyngeal and vagus nerves, the spinal portion of the accessory nerve, and the sigmoid sinus, which continues as the internal jugular vein [12].

As some authors have pointed out [3], intracranial or extracranial lesions can develop in this region of the skull, such as metastatic tumors, schwannomas, or intracranial meningiomas, as well as slow-growing glomus jugulare tumors, which can lead to multiple cranial nerve palsies, known as "jugular foramen syndrome" or Vernet's syndrome [3, 4, 6, 9].

In each clinical case, different surgical approaches to the jugular foramen are considered due to its anatomical variability. The anterior-posterior and medial-lateral dimensions are critical factors determining the vascular and neural content passing through this foramen. The variability and complexity of these neurovascular structures make each surgical intervention unique, highlighting the importance of anatomical knowledge [7].

There is a substantial body of scientific literature on the anatomy of the jugular foramen, though results are often contradictory. Of particular interest are studies focused on gender-related morphological differences in this foramen.

The purpose of the study was to establish certain morphometric parameters in dry adult human skulls, classified by gender.

Materials and methods. The study was conducted on 77 "documented" dry skulls (38 male, 39 female), taken from the bone collection of the Anatomical Museum at the Department of Human Anatomy and Medical Terminology (Fig. 1). Inclusion criteria included skulls of adult individuals with complete preservation of anatomical landmarks and reliable documentation of sex and age. Exclusion criteria comprised any evidence of cranial trauma, congenital anomalies, surgical interventions, pathological changes, or postmortem damage that could have affected cranial measurements. All procedures adhered to institutional and international ethical standards for research involving human skeletal remains. The study was approved by the Department of Human Anatomy and Medical Terminology's Ethical Committee.

All skulls were free of visible defects or deformations. The shape of the jugular foramina was visually assessed, and the maximum distances were measured in the anterior-posterior direction and between the furthest points in the medio-lateral direction (Figure 2), and the area was calculated. All linear measurements were performed using a digital caliper (electronic caliper) with an accuracy of 0.01 mm. Each measurement was taken three times, and the mean value was used for analysis to minimize random error. The area was calculated using the formula:

$$S=\pi\times\frac{L}{2}\times\frac{W}{2},$$

Where L is the maximal length, W is the maximal width, and $\pi\approx3.14$.

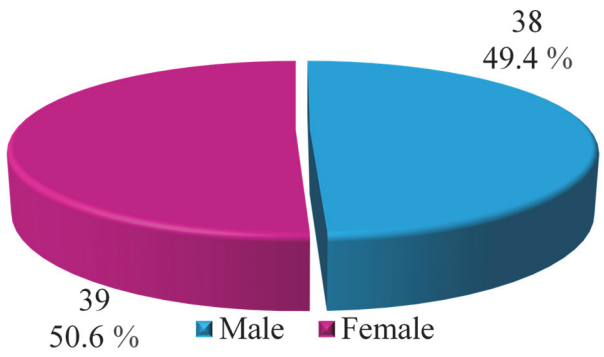

Fig. 1. Distribution of the studied material by gender.

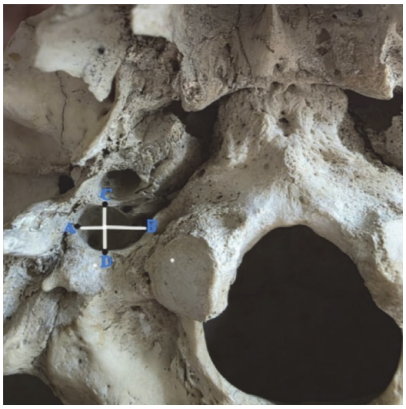

Fig. 2. Anteroposterior (C–D) and mediolateral (A–B) dimensions of the jugular foramen.

The results were recorded and analyzed statistically. For the variable groups, the following were calculated: arithmetic mean (M), standard error (±m), minimum and maximum values, median (Me), quartiles (Q1, Q3), and 95 % confidence interval (95 % CI). Differences between the two groups were assessed using the non-parametric Mann–Whitney U test (PU). Descriptive t-test and Dispersion F-test (ANOVA) were also applied. Statistical significance was considered at $p<0.050$ [11].

Results of the study and their discussion. As a result of the morphometric analysis conducted, gender differences were identified in the shape and size of the jugular foramen. The morphological spectrum of jugular foramen shapes included oval, triangular, dumbbell-shaped, kidney-shaped, pear-shaped, and round. The most frequently encountered shape in males was oval (28.9 %), with a similar trend in females, though at a lower frequency (20.5 %). Table 1 presents the frequency of observed jugular foramen shapes on both the right and left sides of male and female skulls.

Table 1

Frequency of observed shapes of the jugular foramen in male and female skulls

Gender	Side	Jugular Foramen Shape					
		Oval (n/ %)	Round (n/ %)	Bean-shaped (n/ %)	Triangular (n/ %)	Pear-shaped (n/ %)	Dumbbell-shaped (n/ %)
Male (38)	Right	11/28.9 %	1/2.6 %	7/18.4 %	9/23.7 %	6/15.8 %	4/10.5 %
	Left	11/28.9 %	2/0.05 %	12/31.6 %	6/15.8 %	3/0.08 %	4/10.5 %
Female (39)	Right	8/20.5 %	2/0.05 %	10/25.6 %	4/10.2 %	9/23.1 %	6/15.4 %
	Left	8/20.5 %	-	9/23.1 %	13/33.3 %	5/12.8 %	4/10.2 %

Notably, the oval shape in most cases was characterized by the absence of asymmetry, indicating a more symmetrical development of this structure in this form. Minimal asymmetry was identified in dumbbell-shaped and kidney-shaped forms of the jugular foramen. At the same time, maximum asymmetry was noted in the triangular form in females on the left side, reaching 33.3 %.

Overall, the round shape was very rare in both genders, which may indicate its anatomical and functional inexpediency or rarity in the population. The pear-shaped form was more often observed on the right side, both in males (15.8 %) and females (23.1 %), which may be related to anatomical features of the venous structures in this area.

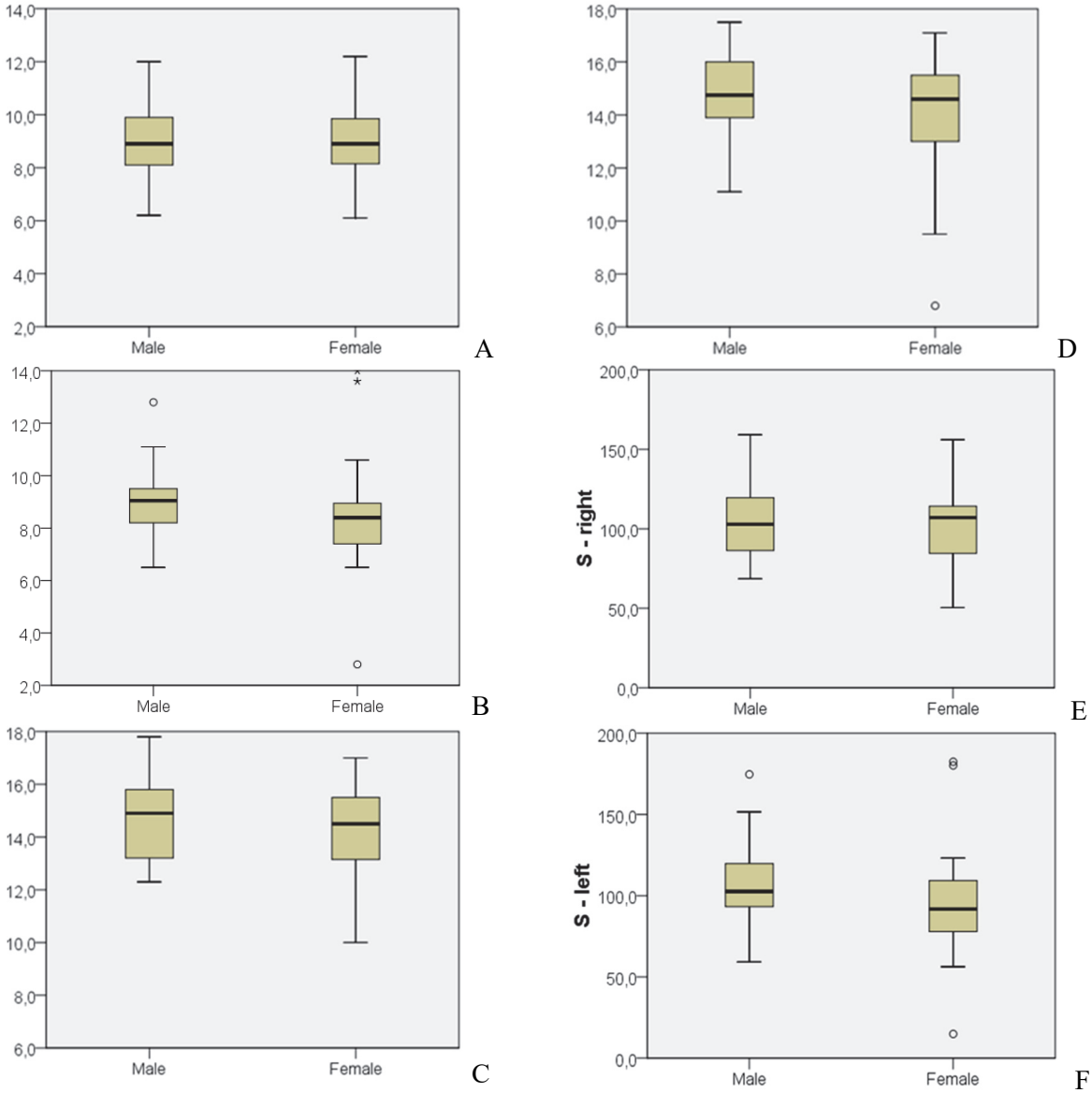

Fig. 3. Statistical analysis of the anteroposterior dimension of the jugular foramen in males and females on the right side (a) and left side (b), mediolateral dimension of the jugular foramen in males and females on the right side (c) and left side (d), the area of the jugular foramen in males and females on the right side (e – right) and the left side (f – left).

On the right side, this parameter was comparable between genders: the mean value was 9.0±0.2 mm in both groups, with no statistically significant difference ($p>0.05$). This indicates a high degree of symmetry in the development of the right jugular foramen in the anteroposterior direction (Fig.3A, B), which may be related to the functional necessity of stable venous outflow through the right internal jugular vein, which is known to be more commonly dominant. On the left side, however, a statistically significant difference between genders was observed ($P_U=0.019$). In males, the mean value was 9.0±0.2 mm (range: 6.5–12.8 mm; median - 9.1 mm; 95 % confidence interval – 8.6–9.4 mm; Q1 = 8.2 mm, Q3 = 9.5 mm), while in females it was 8.4±0.3 mm (range: 2.8–14.0 mm; median – 8.4 mm; 95 % CI – 7.8–9.0 mm; Q1 = 7.3 mm, Q3 = 9.0 mm). Despite some overlap in the confidence intervals, the difference between the groups was statistically significant, indicating gender dimorphism on the left side. It can be assumed that the increased anteroposterior diameter in males is associated with more pronounced venous outflow or with constitutional and anatomical features of the male skull, such as a generally larger cranial volume and a more developed venous network. A wider anteroposterior lumen may also reflect adaptive or compensatory features that ensure adequate venous drainage in males. In contrast to the anteroposterior direction, the mediolateral dimension (Fig.3C-D) did not show statistically significant differences between genders on

either the right or the left side ($p > 0.05$). In males, the average size was: right – 14.6±0.3 mm, left – 14.8±0.3 mm. In females, the corresponding values were slightly smaller: right – 14.3±0.3 mm, left – 14.1±0.3 mm.

Despite the slight difference in absolute values, statistical analysis did not reveal any significant differences, which may indicate a relative conservativeness of the transverse (frontal) dimension of the jugular foramen regardless of gender. It is possible that this parameter is less affected by gender and individual characteristics, or that it ensures structural stability for the passage of anatomical structures (the internal jugular vein, cranial nerves IX, X, and XI) in the transverse direction.

Overall, the observed asymmetry and gender dimorphism were primarily related to the anteroposterior dimension on the left side. These findings are essential for planning neurosurgical and vascular interventions, interpreting CT and MRI data, and comparative anatomy.

The literature supports the results of this study. For example, in the study by Thunyacharoen S. and Mahakkanukrauh P. [13], the anteroposterior diameter of the jugular foramen was reported as follows: right – 8.67±1.57 mm, left – 7.59±1.55 mm; and the mediolateral diameter – 14.66±2.61 mm on the right and 14.25±2.36 mm on the left. In the work of Jain SRL, Kushwah RS. [10]., similar parameters were found: right – 9.32±2.04 mm (anteroposterior), 15.67±2.28 mm (mediolateral); left – 7.34±2.04 mm and 14.85±2.89 mm, respectively.

It should be noted that according to some authors, gender-related differences in the size of the jugular foramen are evident on both the right and left sides. However, in our study, a statistically significant difference between genders was observed only on the left side. This may reflect anatomical variability associated with individual, racial, constitutional, or population-specific characteristics. Some sources report a predominance of an enlarged jugular foramen on the right side (enlarged in 58.18 % of cases), while it is less frequently enlarged on the left side (21.82 %). In contrast, in our study, a larger foramen was observed on the left side in males, highlighting the need to consider variation across populations and samples. The morphometric analysis of the jugular foramen revealed significant anatomical variability in both shape and size, as well as distinct sexual dimorphism, which aligns with previously published findings. Aseta et al. [2], in their osteological study, emphasized that the jugular foramen demonstrates a wide spectrum of morphological forms – including oval, pear-shaped, triangular, dumbbell-shaped, and others – and that these forms may present either symmetrically or asymmetrically. Our study confirmed that the oval shape was the most frequent in both sexes and typically showed minimal asymmetry, whereas the triangular form, particularly on the left side in females, demonstrated the greatest asymmetry (33.3 %). These findings support the observations of Das et al. [3], who highlighted not only the morphometric diversity of the jugular foramen but also the influence of gender and individual variation on its dimensions. Notably, the anteroposterior diameter of the left jugular foramen showed a statistically significant difference between males and females (P_U=0.019), with males having larger measurements. Additionally, the foraminal area was significantly greater on the left side in males (P_U=0.040). These findings are consistent with Das et al. [3], who also reported sex-based differences and emphasized their importance in clinical anatomy and surgical planning, especially during skull base surgeries. The mediolateral diameter, however, did not differ significantly between sexes, suggesting a conserved transverse structure required for the safe passage of critical neurovascular elements, including cranial nerves IX, X, and XI, and the internal jugular vein. Fan et al. [4] underscore the clinical significance of understanding this anatomy, particularly in the context of pathological processes – such as cranial nerve involvement due to varicella-zoster virus reactivation – which may impact structures passing through the jugular foramen in immunocompromised patients.

Overall, the asymmetry is often presented as narrowing on one side with compensatory widening on the other, possibly reflecting a functional adaptation for venous drainage. These anatomical variations, supported by both our findings and prior literature, underscore the need for individualized anatomical assessment in radiological diagnostics and neurosurgical interventions.

Asymmetry of most forms manifested as narrowing of the foramen on one side with a corresponding widening on the opposite side, which we interpret as a possible sign of a compensatory mechanism for venous outflow. Next, a quantitative assessment of the area of the jugular foramen was conducted. Comparative analysis showed that the area of the jugular foramen (Fig. 3E, F) was larger in males than in females, with a statistically significant difference on the left side (P_U=0.040). In males, the average left-side area was 105.3±3.8 mm² (range: 59.3–174.7 mm²; 95 % confidence interval: 97.6–113.1 mm²; median: 102.7 mm²; Q1: 93.3 mm²; Q3: 119.8 mm²), whereas in females it was 95.0±4.8 mm² (range: 49.0–182.5 mm²; 95 % CI: 85.2–104.8 mm²; median: 91.8 mm²; Q1: 77.6 mm²; Q3: 110.6 mm²).

Thus, the data obtained demonstrate statistically significant differences in the area and dimensions of the jugular foramen between genders, predominantly on the left side. The identified asymmetry in shape and the variability in morphometric characteristics indicate a high degree of anatomical variation in this structure, which is of critical importance for clinical anatomy, neurosurgery, and radiological diagnostics. According to Kerimzade G.E. [9], the distance between the stylomastoid foramen and the jugular foramen in skulls of different cranial shapes shows a high level of statistically significant variation in terms of width. No marked differences were found between the right and left sides; however, the values differed significantly depending on the cranial index. The most significant distance was observed in dolichocranic skulls compared with brachycranic and mesocranic skulls.

Conclusion

The presented morphometric study of the jugular foramen is valuable for determining surgical approaches. Awareness of anatomical variations can help reduce the risk of error during surgical procedures, particularly in neurosurgery. Understanding the different shapes of the foramen, their gender differences, and accounting for asymmetry contributes to the protection of neurovascular structures.

Moreover, gender dimorphism of the skull requires thorough evaluation based on morphological features. Gender dimorphism may correlate with the endocrine system and developmental patterns. This study provides new morphometric data to clarify anatomical variations and expand current knowledge of the jugular foramen.

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