

Research Article

Morphometric Variations of Jugular Foramen in Pakistani Population: A Comparative Analysis with Clinical Implications

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Abstract

Background: The jugular foramen, an important structure at the base of the skull, transmits several vital neurovascular elements, including the internal jugular vein, cranial nerves IX, X, XI, meningeal branches of ascending pharyngeal artery and occipital artery, and the inferior petrosal sinus.

Objective: This study aims to conduct a comprehensive morphometric analysis of the jugular foramen in Pakistani skulls to highlight any population-specific variations and their potential clinical implications.

Methods: Forty-eight dry, undamaged skulls were observed for the parameters related to jugular foramen on right and left sides. Parameters were measured with the help of digital vernier caliper and measuring scale and values were noted in mm and cm. Data was entered into SPSS ver. 26. After checking normality, data analysis was done by Chi-square test, Independent Samples t-test and Mann Whitney-U test.

Results: Statistical analysis revealed greater distance between intrajugular process (peak) of temporal bone and jugular foramen on the right side (p value = 0.02) and increase in width of right sigmoid sinus at the posterior margin of jugular foramen (p value < 0.001). Rest of the parameters showed insignificant results.

Conclusion: Right-sided parameters related to jugular foramen showed significant difference from left side highlighting racial differences in skulls of Pakistani population. This can have possible clinical implications for local neurosurgeons.

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Introduction

The jugular foramen, an important structure at the base of the skull, transmits several vital neurovascular elements, including the internal

jugular vein, cranial nerves IX, X, XI, meningeal branches of ascending pharyngeal artery and occipital artery, and the inferior petrosal sinus.¹ It lies anterolateral to the foramen magnum and posterolateral to carotid canal. Petrous part of the temporal bone forms the anterior and lateral to the jugular foramen while occipital bone forms posteromedial boundary.² Variations in the morphology of the jugular foramen can significantly impact surgical approaches, radiological interpre-



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tations, and the understanding of certain neurological disorders.³ Familiarity with the jugular foramen's anatomy is crucial for neurosurgeons and ENT specialists.⁴ The complexity of the region necessitates precise anatomical understanding to avoid damaging vital structures during surgery.

Studies consistently indicate that the jugular foramen exhibits notable asymmetry, with the right side typically being greater in size than the left.^{5,6} The presence of osseous partitions within the jugular foramen was rare but could lead to additional considerations during surgery.² Complete septation within the foramen can complicate surgical access and necessitate tailored approaches based on individual anatomy.⁴ In addition, the presence of septa within the foramen varies, with complete septation observed more frequently on the right side.⁴ This asymmetry is not only prevalent in specific populations but has been observed across various ethnic groups, including Brazilian, Nigerian, and Indian populations.² Various clinical conditions may affect jugular foramen e.g. congenital disorders, vascular lesions and tumors which manifest in various clinical presentations.⁵ Glomus jugulare, paragangliomas, neuroma, meningioma, metastatic carcinoma, chondroma, nasopharynx carcinoma, carcinoma of the tympanic cavity, and infiltrating inflammatory processes are the commonest lesions that are seen by doctors in jugular foramen and its vicinity.²

The jugular foramen's dimensions influence surgical approaches to conditions like jugular foramen schwannomas, which can be challenging due to their proximity to vital structures. Surgical management often requires careful navigation around these anatomical variances to avoid complications such as nerve damage or vascular injury.⁷

Therefore, the jugular foramen presents considerable variability in size and morphology across different populations and genders. A thorough understanding of these variations enhances surgical precision and patient safety during procedures involving this critical anatomical structure. As ongoing research reveals more about these differences, it will further refine surgical techniques and improve outcomes for patients with conditions affecting the jugular foramen.

While many studies in the past have studied the morphological variations of the jugular foramen in different populations,^{1,8-10} there is a dearth of research

explicitly focusing on Pakistani individuals. Understanding the unique anatomical features of this population can provide valuable insights for clinicians and researchers. The results of this research will contribute to an improved understanding of the regional anatomical variations of the jugular foramen, aiding in surgical planning, radiological interpretation, and the management of neurological disorders. Furthermore, this study will provide a valuable reference for future anatomical and clinical research in the Pakistani population.

Methods

This study was descriptive and cross-sectional, conducted at Department of Anatomy, Services Institute of Medical Sciences, Lahore. The study was approved by the Institutional Ethical Committee of Services Institute of Medical Sciences, Lahore, Ref. no. IRB/2025/1528//SIMS. Sample size was calculated using values for width of sigmoid sinus at posterior margin of jugular foramen from a previous article.⁴ OpenEpiMenu gave the sample size of 50.

Dry, healthy and undamaged human skulls, irrespective of age and gender, available in the department, were observed. Damaged skulls were excluded from the study with the total count of available skulls, with all parameters, becoming 48. Parameters were taken from previous studies^{4,11}. All the parameters were measured using digital vernier calipers and measuring scale.

Data were analyzed using SPSS version. 26. Shapiro Wilks test was utilized to check the normality of the data. Chi-square test was applied to check association between side of skull and presence/ absence of septation in jugular foramen. Independent Samples t-test was used for normally distributed data to determine mean and standard deviation. In case of non-normal data, Mann-Whitney U test was used to determine median and interquartile range. Level of significance was decided at 0.05.

Results

Chi-square test showed that there was no significant association between presence/absence of septation in jugular foramen and side of the skull (Figure-1) with Fisher Exact test value of 0.501.

Some of the extracranial parameters were normally distributed, however, their analysis with Independent

Samples t-test gave insignificant results (Table 1).

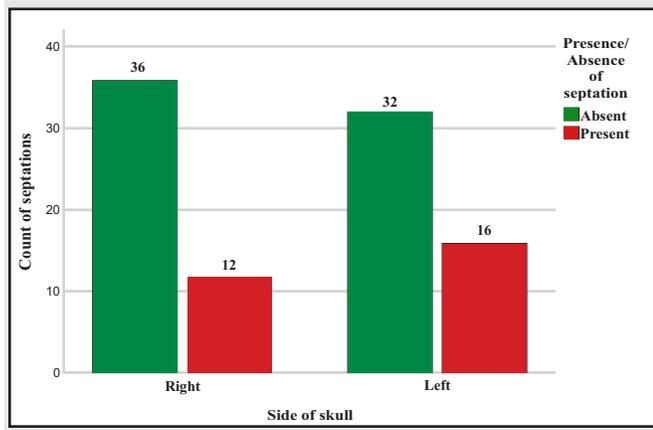


Figure-1: Bar graph showing the comparison of presence/ absence of septation in jugular foramen, between right and left sides of skull.

All the intracranial parameters and remaining extracranial parameters were not normally distributed. Their analysis by Mann Whitney-U test showed that the distance between the jugular foramen (posterior margin) and peak of intrajugular process of temporal bone was significantly more on right side of skulls than on the left side (p value = 0.02). In addition, the width of sigmoid sinus at jugular foramen (at the level of posterior margin) was also significantly more on the right side than the left side (p value < 0.001). The remaining analyzed

Table 1: Showing values of extracranial parameters (data normally distributed) in relation to jugular foramen as determined by Independent Samples t-test.

Morphometric parameter	Mean \pm SD		p value
	Right	Left	
Distance between midline of the medial pterygoid (inferior border) and JF (anterior border) (mm)	20 \pm 3	19.27 \pm 3.06	0.26
Distance between midline of the lateral pterygoid (inferior border) and JF (anterior border) (mm)	23.26 \pm 3.08	22.73 \pm 3.33	0.42
Distance between apex of the mastoid process and JF (outer border) (mm)	19.44 \pm 3.07	19.65 \pm 2.65	0.715
Distance between foramen magnum (midline) and JF (inferior border) (mm)	22.32 \pm 2.55	22.17 \pm 2.44	0.771

Level of significance is at < 0.05

parameters showed statistically insignificant differences between right and left sides of the skulls (Table 2).

Table 2: Showing values of extracranial and intracranial parameters (data not normally distributed) in relation to jugular foramen (JF) as determined by Mann-Whitney U test.

Morphometric parameter	Median \pm IQR ¹		p value	
	Right	Left		
Extracranial	Distance between base of vomer bone and JF (anterior border) (mm)	32.16 \pm 3.85	32.75 \pm 3.84	0.08
	Medio-lateral diameter of the JF from the medial end to the lateral end (cm)	0.70 \pm 0.28	0.60 \pm 0.30	0.05
	Distance between occipital condyles (midline) and JF (medial border) (mm)	8.52 \pm 6.79	8.80 \pm 6.29	0.62
Intracranial	Sagittal diameter of JF from anterior to posterior end (cm)	1.50 \pm 0.20	1.50 \pm 0.08	0.25
	Width: Transverse diameter of JF from medial to lateral end (cm)	0.55 \pm 0.20	0.50 \pm 0.17	0.34
	Distance between jugular foramen (posterior margin) and temporal bone (peak of intrajugular process) (cm)	01 \pm 0.30	0.90 \pm 0.30	0.02*
	Width of the sigmoid sinus groove (SSG) at jugular foramen (level of the posterior margin) (cm)	01 \pm 0.00	0.80 \pm 0.20	<0.001*

¹ Interquartile range

*Level of significance is at < 0.05

Discussion

Jugular foramen and surrounding structures show considerable variations in different ethnic groups, as already reported in previous studies.^{1,2,5,8} Our study showed a statistically insignificant difference between the right and left sides of the skulls, based on the presence or absence of septation in the jugular foramen. Septation was absent in most of the skulls examined; this is similar to other studies that documented the absence of or partial septation in

most of the observed skulls.¹²⁻¹⁵

Our study showed a larger anteroposterior diameter of jugular foramen compared to other studies^{16,17} while the width of jugular foramen in our research was less than that documented in the Central Indian and West Bengal populations.¹⁷

Our study documented that the width and anteroposterior diameters of the jugular foramina of the right sides of the skull were slightly greater than those of the left side, however, the difference was statistically insignificant; this contrasts with previous studies which documented significantly larger jugular foramina on the right sides.^{5,9}

In our study, we found that the distance between the medial pterygoid plate and jugular foramen was less (20mm) than that documented by another study done on the South African population (25mm),¹¹ however, the distance between jugular foramen and lateral pterygoid plate was almost similar in both our study and the one done on South African skulls.¹¹ There was no statistically significant difference between the right and left sides for both parameters. Our study also found that the distance between the mastoid process and jugular foramen was less (19mm) than that documented in the Indian population in a previous study (21mm).⁴ There was no difference in the distance between foramen magnum midpoint and jugular foramen, between the right and left sides of the skulls, in our study. Previous studies also documented the same finding.¹¹

When observed intracranially, the peak of the intrajugular process of the temporal bone on the right side, lay significantly far away from the posterior margin of the jugular foramen; this contrasts with a previous South African study that also showed that the right side had higher values, however, their results were not statistically significant.¹¹

Our research showed a statistically significant wider sigmoid sinus on the right side, at posterior margin of the jugular foramen. Similar results were documented by researchers in studies conducted in Brazil and Serbia.^{18,19} This contrasts with a South African study that showed no difference between the sigmoid sinus width of the right and left sides.¹¹ This can probably be explained by the different racial structures of the analyzed skulls.

These results indicate that even though there was no significant difference between size of jugular foramina between two sides of the skulls, the distance between the jugular foramen and intrajugular process

of temporal bone, and the width of sigmoid sinus at the entry point into jugular foramen were significantly greater on the right side showing a predominance of right sided venous vasculature as is generally accepted due to frequent drainage of superior sagittal sinus into right sided transverse sinus, and then sigmoid sinus, leading to larger width of right sigmoid sinus, and hence a larger right internal jugular vein.⁹

These findings are of clinical importance because of the proximity of various neurovasculature within and outside the foramen. Pathologies affecting the structures within and outside the jugular foramen may not only involve the surrounding structures, but these may also affect decision-making about surgical approaches to treatment options. The commonest tumor affecting the jugular foramen is paraganglioma, followed by schwannomas.²⁰ A careful approach to resection of tumors is extremely important to maintain the function of cranial nerves in the vicinity. Different surgical approaches are employed to access tumors or pathologies affecting jugular foramen depending upon tumor location and extension and hence understanding the intricate anatomy of the skull base with precise knowledge of variations, particularly variations among various races can be crucial to avoid unintentional damage to nerves and vessels leading to complications. Thus, the surgical approach to jugular foramen tumors is highly individualized, depending on a combination of tumor characteristics, anatomical considerations, and the goals of minimizing morbidity while achieving total tumor removal.

Various studies were performed on other populations of the world to document variations in the morphometric features of the jugular foramen and surrounding structures. To the best of our knowledge, our study is the first one to document a detailed description of variations, in skulls of Pakistani origin, from other races, and these findings can help neurosurgeons and otorhinolaryngologists in making decisions regarding the approach towards the lesions surrounding jugular foramen while treating the local population.

Limitations: Our study had a moderate sample size of 48 skulls. A multicenter study involving medical colleges in other provinces of Pakistan, with access to larger number of skulls belonging to different ethnic groups, may provide a more accurate picture of the variations in Pakistani population particularly compared to findings in other races.

Conclusion

Neurosurgeons and otolaryngologists in Pakistan should be aware of the anatomical variations in the jugular foramen morphometrics in Pakistani ethnic groups compared to other races. Different surgical approaches for treatment, depending upon the race of the population, should be considered, as following routine practices might result in unpredictable complications.

Ethical Approval: The Institutional Review Board, Services Institute of Medical Sciences, Lahore approved this study vide letter Ref No. IRB/2025/1528/SIMS.

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Author Contribution

YB: Conception & design, acquisition of data, drafting of article, final approval.

TM: Conception & design, analysis & interpretation, drafting of article.

TF: Drafting of article, critical revision of the article, final approval of the version to be published.

HA: Analysis & interpretation of data.

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