

# Morphological Variations of Jugular Foramen in Dry Skulls of Central Indian Population: A Cross-sectional Study

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## ABSTRACT

**Introduction:** The jugular foramen is in close proximity with ninth, tenth and eleventh cranial nerves and the middle ear, it is the most common area for brain tumours like neurinomas and glomus tumours. A study of the morphological variations of the foramen would, therefore, be of immense help to Neurosurgeons and Otorhinolaryngologist.

**Aim:** To analyse the morphometric dimensions of jugular foramen and subsequent neurosurgical implications.

**Materials and Methods:** The present cross-sectional study accessed the anteroposterior diameter, mediolateral diameter and area of jugular foramen, width and depth of jugular fossa was studied in 50 dry adult skulls of central Indian population in Department of Anatomy, Amaltas Institute of Medical Sciences, Dewas, Madhya Pradesh, India, between February 2021 to June 2021. The presence of septations and dome was noted. The above data was recorded and analysed using Statistical Package For The Social Sciences (SPSS) version 20.0 (IBM Co., Armonk, NY, USA) and two-tailed Student's t-test ( $p < 0.05$ ).

**Results:** The mean anteroposterior dimension of jugular foramen was  $12.86 \pm 2.67$  mm on the right and  $10.57 \pm 2.32$  mm on the left. The mean mediolateral dimension of jugular foramen was  $14.92 \pm 2.46$  mm on the right and  $13.62 \pm 1.96$  mm on the left. The mean area of jugular foramen was  $175.45 \pm 48.23$  mm<sup>2</sup> on the right and  $140.53 \pm 42.23$  mm<sup>2</sup> on the left. The mean width of the jugular fossa was  $7.74 \pm 2.45$  mm on the right and  $6.26 \pm 2.89$  mm on the left. The mean depth of jugular fossa was  $12.64 \pm 4.87$  mm on the right and  $11.88 \pm 4.32$  mm on the left significant difference was noted between right and left side dimensions for anteroposterior diameter, mediolateral diameter and area of foramen, width and depth of fossa. Incomplete septations were observed in 62% foramen on right and 56% in left. A dome was observed in 68% foramen on right and in 32% foramen on left.

**Conclusion:** There was significant difference in the anteroposterior and mediolateral dimensions and area of the jugular foramen bilaterally and the right dimensions are more than the left. Further, the width of jugular fossa showed significant difference bilaterally. On statistical analysis, no significant difference was observed between the depth of both right and left jugular fossa.

**Keywords:** Jugular fossa, Morphometric, Neurosurgical implication, Norma basalis

## INTRODUCTION

A comprehensive understanding of jugular foramen anatomy is a prerequisite for surgeons resecting neurinomas, meningiomas or glomus tumours [1]. The foramen is located in posterior cranial fossa at the posterior end of petro-occipital suture. The petrous temporal bone is anterolateral and occipital bone is posteromedial [2]. The foramen has three compartments namely anterior, middle and posterior. The inferior petrosal sinus occupies the anterior compartment, glossopharyngeal, vagus and accessory cranial nerves occupy the middle compartment and sigmoid sinus occupies the posterior compartment. This compact arrangement can sometimes cause compression of the nerves resulting in jugular foramen syndrome or vernet syndrome [3]. The superior sagittal sinus often drains into right transverse sinus and therefore, right jugular foramen is often larger in size [4]. Similarly, the internal jugular vein on the right side is often larger than the left [5].

The variations in the size and bridging pattern of the foramina are studied by researchers in diverse ethnic groups [6]. Most authors attribute these variations to sex, age and stature rather than ethnicity [7]. Some authors observed variations in bridging pattern to be more on the right side and these variations significantly affect the course of glossopharyngeal, vagus and accessory cranial nerves [8]. Some authors have reported no partitions while others reported bridging in 20% and tripartite foramen in 0.7% [3,9]. The incidence of complete septation and partial septation is varied bilaterally [10]. Therefore, the jugular foramen has diverse morphology with bridges that can significantly compress the three major cranial nerves causing paralysis of muscles supplied. Tumours in this

region such as glomus jugulare and other brain tumour scan also compress sigmoid sinus and internal jugular vein, thus, impairing venous drainage of brain. Therefore, profound knowledge about variations in jugular foramen and fossa in central India population will be beneficial owing to recent advances in middle ear surgeries and other neurosurgeries around the foramen.

## MATERIALS AND METHODS

A cross-sectional study was conducted in Department of Anatomy, Amaltas Institute of Medical Sciences, Dewas, Madhya Pradesh, India, between February 2021 to June 2021. A total of 50 human dry skulls were taken for study, thus, making the sample size of 100 jugular foramina and fossa.

**Inclusion and Exclusion criteria:** Adult skulls with intact jugular foramen and norma basalis was included. Skulls with morphological deformities in the jugular foramen and deformed norma basalis were excluded.

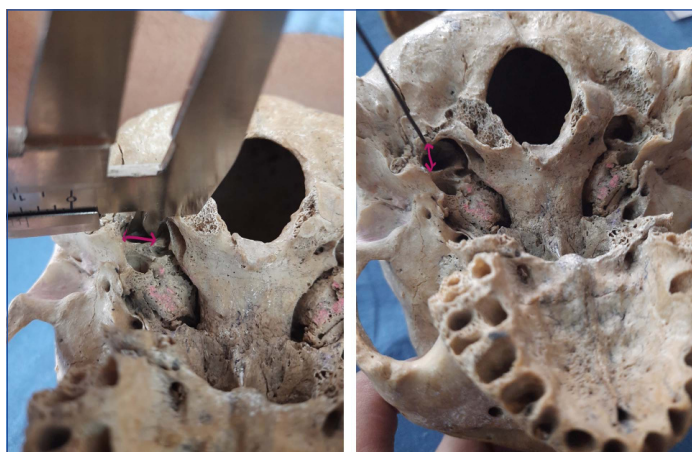
### Parameters Measured

Side of foramen, anteroposterior diameter of the foramen, maximum mediolateral diameter of the foramen, area of the jugular foramen [Table/Fig-1,2]. Bridging patterns: complete or incomplete septa, number of compartments formed, presence or absence of a domed bony roof, if dome present then depth of jugular fossa from summit of dome to lower border of fossa was measured (marking on a probe and then reading taken by calliper) and maximum width of jugular fossa were noted [Table/Fig-3,4].

Sliding digital calliper (Lianying 0005, Zhejiang, China) graduated to the last 0.01 mm was used and the variations in the size of jugular



[Table/Fig-1]: Measurement of anteroposterior diameter of jugular foramen.  
 [Table/Fig-2]: Measurement of mediolateral diameter of jugular foramen.  
 (Images from left to right)



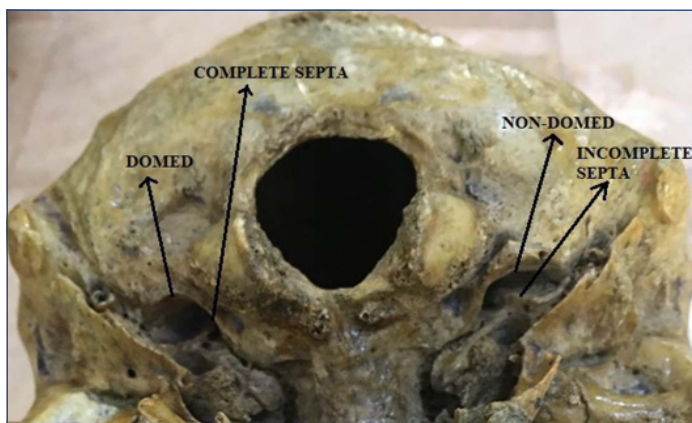
[Table/Fig-3]: Measurement of width of jugular fossa.  
 [Table/Fig-4]: Measurement of depth of jugular fossa. (Images from left to right)

foramen (anteroposterior, mediolateral diameter, area) and fossa (width and depth) was studied. Area of foramen was calculated using Radinsky's formula ( $A=1/4 \times \pi \times t \times s$ ) [11].

t= transverse diameter (mediolateral)

s= sagittal diameter (anteroposterior)

A foramen with complete septa and a domed jugular fossa is shown in on the left side [Table/Fig-5]. A foramen with an incomplete septum and a jugular fossa without a dome is shown in on the right side [Table/Fig-5]. No other associated accessory foramen in relation to jugular foramen was noted.



[Table/Fig-5]: Domed fossa with complete septa on left and a non domed fossa with incomplete septa on right.

### STATISTICAL ANALYSIS

Statistical Package for Social Sciences (SPSS) version 20.0 (IBM Co., Armonk, NY, USA) and two-tailed Student's t-test ( $p<0.05$ ) were used to analyse statistically the measured dimensions. The mean, standard deviation, area, bridging variations and presence and absence of dome was analysed.

### RESULTS

Mean of all the parameters studied is shown in [Table/Fig-6]. On statistical analysis, right and left anteroposterior dimensions of the

foramen showed significant difference with  $p=0.0001$  ( $p<0.05$ ). The right and left mediolateral diameter of the foramen also showed significant difference with  $p=0.0268$  ( $p<0.05$ ). Even right and left area of the foramen had significant difference with  $p=0.0003$  ( $p<0.05$ ) [Table/Fig-7].

Dimension measured	Mean±SD (mm)		
	Right	Left	Total
Anteroposterior diameter of jugular foramen	12.86±2.67	10.57±2.32	11.71
Mediolateral diameter of jugular foramen	14.92±2.46	13.62±1.96	14.27
Area of jugular foramen	175.45±48.23	140.53±42.23	157.99
Width of jugular fossa	7.74±2.45	6.26±2.89	7.0
Depth of jugular fossa	12.64±4.87	11.88±4.32	12.26

[Table/Fig-6]: Mean of all parameters.

Parameters	Anteroposterior (mm)		Mediolateral (mm)		Area (mm <sup>2</sup> )	
	Right	Left	Right	Left	Right	Left
Mean	12.86	10.57	14.92	13.62	175.45	140.53
Standard Deviation	2.67	2.32	2.46	1.96	48.23	42.23
p-value	0.0001 ( $p<0.05$ )		0.0268 ( $p<0.05$ )		0.0003 ( $p<0.05$ )	

[Table/Fig-7]: Dimensions of the jugular foramen.

The right and left jugular fossa showed a mean width of 7.74±2.45 mm and 6.26±2.89 mm respectively and on statistical analysis there was significant difference between the right and left jugular fossa width with  $p=0.0003$  ( $p<0.05$ ) [Table/Fig-8].

Parameters	Width (mm)		Depth (mm)	
	Right	Left	Right	Left
Mean	7.74	6.26	12.64	11.88
Standard deviation	2.24	1.82	2.52	2.41
p-value	0.0003 ( $p<0.05$ )		0.028 ( $p>0.05$ )	

[Table/Fig-8]: Dimensions of the jugular fossa.

The incomplete septations were found in 62% foramen and complete septations was 38% foramen on the right. Similarly, on the left, the percentage of incomplete septations was 56% and complete septations was 44%. A dome was observed in 68% foramen on right and in 32% foramen on the left.

### DISCUSSION

The dimensions and morphology of the jugular foramen has immense clinical implications due to its proximity to vital structures. Jugular foramen is in close relation with middle ear. Several brain tumours such as glomus jugulare, metastatic tumours, schwannomas and inflammatory processes can compress glossopharyngeal, vagus and accessory cranial nerves. The tumours can also compress the sigmoid sinus and the internal jugular vein affecting the venous drainage of the brain. Tumours can invade middle ear resulting in hearing loss and paralysis of the cranial nerves. Accessory foramen in the wall of the foramen can result in communicating between sigmoid sinus and occipital extracranial veins resulting in infection spread to venous sinuses and subsequent thrombosis. Therefore, the authors believe, that, the current study on morphology of jugular foramen has profound significance in neurosurgeries in this region and of middle ear surgeries [12].

The comparison of dimension of foramen of the present study with the studies of different ethnic groups has been shown in [Table/Fig-9] [13-18]. In the present study, the anteroposterior, mediolateral dimensions and area on statistical analysis showed significant difference bilaterally ( $p<0.05$ ). Gupta C et al., in their study found significant difference only in anteroposterior dimension and area with  $p=0.0001$  ( $p<0.05$ ) and observed no significant difference

Authors	Anteroposterior measurement (mm)		Mediolateral measurement (mm)		Area (mm <sup>2</sup> )		Width of jugular fossa (mm)		Depth of jugular fossa (mm)	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Gupta C et al., [13]	11.22	9.52	16.52	16.02	187.34	153.2	6.83	5.69	11.75	11.13
Vijisha P et al., [14]	17.33	15.3	12.13	9.27	210.87	141.93	-	-	-	-
Khanday S et al., [15]	10.06	8.9	14.6	13.9	118	90	-	-	-	-
Osunwoke EA et al., [16]	15.76	13.39	9.34	7.54	437.4	419.48	-	-	-	-
Idowu OE [17]	13.90	14.11	10.22	9.57	-	-	-	-	-	-
Singla A et al., [18]	9.32	7.34	15.67	14.85	-	-	8.99	7.54	11.11	11.04
Kamath VG et al., Present study	12.86	10.57	14.92	13.62	175.45	140.53	7.74	6.26	12.64	11.88

**[Table/Fig-9]:** Comparison of dimensions of foramen as reported in studies in other ethnic groups [13-18].

in mediolateral dimension [13]. Vijisha P et al., did not find any statistical significance in any of the dimensions bilaterally [14].

In the present study, the authors observed that the size of the jugular foramen in the right side is more than left. Das SS et al., studied 114 dry adult human skulls (63 males and 51 females). On statistical analysis, Chi-square test and Student's t-test, it was observed that all the parameters of jugular foramen were greater on the right side than on the left side [12].

Studies in Nigerian ethnicity by Osunwoke EA et al., [16] and Idowu OE [17] show that the Nigerian jugular foramen dimensions are larger than Indian dimensions. The dimensions reported by authors like Gupta C et al., [13], Singla A et al., [18], and Khanday S et al., [15] in Indian skulls are similar to those observed in the present study. Further, the area of the foramen reported by studies in Indian ethnicity by Vijisha P et al., [14], Gupta C et al., [13] and the present study are more or less similar. This shows that the jugular foramen do exhibit both ethnic similarity and variations. In recent studies, it showed that anatomical knowledge of jugular foramen is of utmost importance because of its wide implication in neurosurgical procedures. Anatomical variations of jugular foramen are dependent on constitutional, racial or genetic factors. A thorough knowledge of these variations while doing neurosurgical procedures will widely reduce the mortality and morbidity [19-21].

In the present study, on the right side the percentage of incomplete septations was 62% and complete septations was 38%. In the study by Gupta C et al., [13], on the right side the percentage of incomplete septations was 56% and complete septations was 44%. Similarly, on the left side the percentage of incomplete septations was 56% and complete septations was 44% in the present study. In the study by Gupta C et al., on the left side it was 58% incomplete and 42% complete septations [13]. Vijisha P et al., have reported 73.3% incomplete septations on right and 80% incomplete septations on the left side [14]. It is clear from the above mentioned studies that on both sides the percentage of incomplete septations in the jugular foramen are more than the percentage of complete septations.

In present study, a dome was observed in 68% cases on right side and in 52% cases on the left side. In the study by Gupta C et al., in 74% cases a dome was observed on right and in 58% cases on the left [13]. Khanday S et al., observed that the dome was in 40% cases in the right side and 29% cases in the left. [15].

In present study the width of right and left jugular fossa showed a significant difference with  $p=0.0003$  ( $p<0.05$ ), unlike the depth of right and left jugular fossa which showed no significant difference with  $p=0.28$  ( $p>0.05$ ). A similar observation was made by Gupta C et al., [Table/Fig-9] [13].

The present study proves the fact, that morphology of jugular foramen differ in different races and indicate racial differences. The knowledge of variations of jugular foramen is of utmost importance for surgeons while performing crucial surgeries. This is a preliminary study and further more research is necessary.

## Limitation(s)

The current study was restricted to north India confined to one ethnic group with small sample size. Study was conducted on dry human skulls, so values show variations when compared to studies done on live patients. Also, the study was limited by fact that no information on the gender, age, cause of death or presence of any diseases related to the skulls.

## CONCLUSION(S)

There was significant difference in the anteroposterior and mediolateral dimensions and area of the jugular foramen bilaterally and the right dimensions are more than the left. Further the width of jugular fossa showed significant difference bilaterally. The percentage of incomplete septations was found to be 62% on right and 56% on left. The incomplete septations were more than complete septations bilaterally. A dome was observed in 68% foramen on right and in 52% foramen on the left. The foramen is closely related to the middle ear and brain tumours such as glomus jugulare, metastatic tumours and schwannomas can compress the internal jugular vein affecting the venous drainage of the brain. Therefore, the authors believe that the study on morphology of jugular foramen has profound neurosurgical implications.

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**PLAGIARISM CHECKING METHODS:** [\[Jain H et al.\]](#)

- Plagiarism X-checker: Feb 21, 2022
- Manual Googling: Mar 02, 2022
- iThenticate Software: May 25, 2022 (6%)

**ETYMOLOGY:** Author Origin**AUTHOR DECLARATION:**

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? No
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Feb 19, 2022**Date of Peer Review: **Mar 3, 2022**Date of Acceptance: **May 18, 2022**Date of Publishing: **Jul 01, 2022**