

# Jugular Foramen of Adult Human Skull and its Clinical Significance in Population of Eastern India: A Cross-sectional Study

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## ABSTRACT

**Introduction:** Jugular foramen is a complex irregular bony canal located at the base of the skull between the condylar part of occipital bone and petrous part of temporal bone. It allows passage of important nervous and vascular structures. These are ninth, tenth, eleventh cranial nerves, sigmoid sinus continued as the superior bulb of internal jugular vein and inferior petrosal sinus, meningeal branches of the ascending pharyngeal and occipital arteries. Jugular fossa has a septum and a dome. The dome lodges the superior bulb of internal jugular vein. The septum divides the foramen into two compartment, antero-medial and postero-lateral. There is a wide variation in shape, size and septation of jugular foramen in different regions of globe which have been studied by different authors in different periods of time. Many tumours may arise in this region causing compression of the vital structures passing through it. Surgery is the treatment of choice in these cases. Successful neuro surgeries involving this region require detailed knowledge about the anatomical variation of the jugular foramen.

**Aim:** To study and compare the morphology of jugular foramen, its various dimensions, shape, size and septation and its clinical significance related to internal jugular vein.

**Materials and Methods:** A cross-sectional descriptive study was carried out on 85 adult dry human skulls, collected from the

Anatomy Department as well as from the first year Bachelor of Medicine and Bachelor of Surgery (MBBS) students of different Medical colleges of West Bengal from September 2020 to June 2021. Presence of septa were observed and anteroposterior (AP), mediolateral diameter (ML diameter) were measured by using vernier calliper. Then the area was calculated. Data collected were compiled in tabular form. They were analysed by using Statistical Package for Social Sciences (SPSS) statistics version 20.0 and paired t-test and chi-square tests were applied.

**Results:** In the total 85 skulls studied, the area of jugular foramen was larger on right side in 91.76% and on left side in 8.24% of skull. The AP diameter was less than the ML diameter and areas in all cases. But both the diameters were significantly ( $p$ -value  $<0.001$ ) larger on right side than the left. Complete septation was present in right side of 34 foramina and in left side of 17 foramina. Partial or incomplete septation was present on right side of 51 foramina and left side of 68 foramina.

**Conclusion:** The study revealed variation in shape, size and septation in different skulls and also bilateral variation in same skull. It has immense value to radiologists, Ear Nose Throat (ENT) surgeons, neuro-surgeons and radiologists who deal with the diagnosis and management of space occupying lesions surrounding the jugular foramen.

**Keywords:** Base of the skull, Morphological variation, Occipital bone, Septation, Temporal bone

## INTRODUCTION

The jugular foramen is an irregular bony canal located in the floor of the posterior cranial fossa and formed after articulation of jugular notches of occipital bone with the petrous part of temporal bones. It transmits important neuro-vascular structures like Glossopharyngeal nerve (IX<sup>th</sup> cranial nerve) in a separate sheath, Vagus (X<sup>th</sup> cranial nerve) and Accessory nerve (XI<sup>th</sup> cranial nerve) in a common sheath of dura mater, Inferior petrosal sinus connecting the cavernous sinus with the superior bulb of internal jugular vein and sigmoid sinus continued as the superior bulb of internal jugular vein [1]. It is the main route of venous outflow from the skull.

The jugular foramen is related laterally with the styloid process. The axis is projected antero- medially and separated from hypoglossal canal by a thin bony bar. The margins are notched and extends to divide the foramen into two or three compartments. The most anterior part (sometimes completely separated by a spicule of bone called jugular process) also known as the petrosal part transmits the Inferior petrosal sinus, intermediate compartment giving passage to cranial nerves and the meningeal branch of ascending pharyngeal artery and the postero-lateral part also known as sigmoid part transmits sigmoid sinus as internal jugular vein [2,3].

The morphological variation of jugular foramen is an interesting topic to various research workers because of their clinical and racial significances. Most of the intra and extra-cranial lesions involving posterior cranial fossa and inflammatory lesions of inner ear may affect the structures around the jugular foramen. Management of the various space occupying lesions like intracranial meningiomas, paragangliomas, metastatic lesions adjacent to jugular foramen requires microsurgical approach [4]. In those surgeries, drilling is done around the foramen to expose the structures [5]. Anatomical variations of nerves and vessels around the foramen also increase the complexity. In radical neck dissection, internal jugular vein is ligated. So the knowledge regarding morphological variation is very much necessary to avoid the venous injury.

The present study was done to assess the dimensions like AP and ML diameter, area, septations (complete or partial) and compare the results with previous studies in view of safe surgical approach in this area. Though same type of study was done previously on eastern Indian population [6] but the numbers were less so present study was carried out to see whether the results were matching or not.

These morphological studies can also provide important information to anatomists, anthropologist, radiologists and surgeons [7].

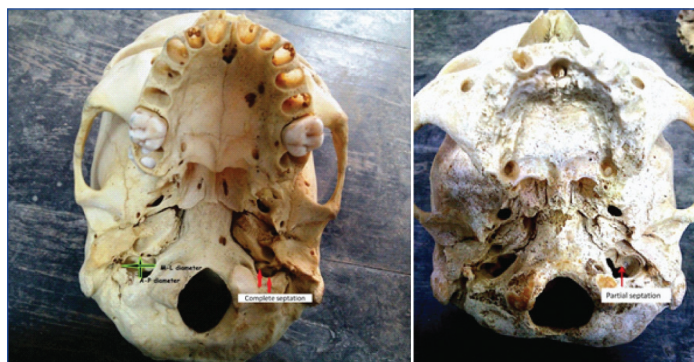
## MATERIALS AND METHODS

An observational cross-sectional study was done from September 2020 to June 2021, on 85 dried intact adult human skulls of unknown age and sex and without any malformation collected from Department of Anatomy of Medical College, Kolkata (MCK), Deben Mahata Government Medical College and Hospital, Purulia (DMGMCH) of West Bengal and also from first year MBBS students of Medical College, Kolkata and Institute of Postgraduate Medical Education and Research, Kolkata (IPGME & R). The students collected the bones for academic purpose from the senior students.

Among the 85 skulls 33 from MCK, 10 from DMGMCH and remaining 42 were taken from students. As skulls were obtained by the Doms from the donated bodies of the colleges of West Bengal so it was most likely that these skulls were of Eastern Indian origin. It took 10 months to complete the study (From September 2020 to June 2021) Ethical committee of concerned colleges (MCK, IPGME and R, DMGMCH) suggested to take verbal permissions from the Head of the departments of Anatomy to use the bones. The authors could collect 85 skulls from different sources and studied the similar type of works done previously by various researchers to decide the sample size. No formal sample size calculation was done because of the absence of an anatomically defined specification of large or small jugular foramen size in available literature. So no particular reference of the sample size was taken.

### Study Procedure

The foramina were observed with naked eye and using magnifying lens for the presence of septation of jugular foramen. The size of foramina of both sides was measured and their differences were also noted. Measurements were taken with the help of simple vernier calliper to compare the AP diameter and ML diameter of right and left sides. For measuring both AP and ML diameter, the points were taken in such a way that the distance between them was maximum. First these points were identified and marked with chalk then calliper was used to measure the distance. All the measurements were taken bilaterally and by three authors independently to eliminate the researchers' bias. All the diameter were measured twice and photographs [Table/Fig-1,2] were also taken.



[Table/Fig-1]: Photograph showing AP, ML diameters and complete septation;  
[Table/Fig-2]: Photograph showing partial septation. (Images from left to right)

## STATISTICAL ANALYSIS

Data collected were compiled in tabular form. The measured dimensions were found to be normally distributed. Data was analysed by routine descriptive statistics, namely mean and standard deviation for numerical variables and counts and percentages for categorical variables. Comparisons were done by paired t-test as applicable (for comparing diameter) and chi-square test was employed for categorical variables (for septations). Analyses were

two tailed and the level of statistical significance was set at  $p < 0.05$  for all comparisons. The software used for statistical analysis in this study was International Business Management (IBM) SPSS statistics version 20.0. All data were then compared with the studies of previous authors.

## RESULTS

On examining the total 85 skulls, it was found that 75 foramina (88.23%) of right side and 9 (10.58%) of left side showed greater AP diameter. There was one skull whose AP diameter was same on both sides. The ML diameter was more in case of 81 (95.29%) foramina of right side and only 4 (4.71%) of left side. The area of jugular foramina was more in right side in 78 cases (91.76%) and on left side in 7 (8.24%) cases [Table/Fig-3]. [Table/Fig-4] shows that both AP and ML diameter was more on the right side than left ( $p$ -value  $< 0.001$ ).

Parameter	Greater on right side	Greater on left side	Equal on both sides
Area (mm <sup>2</sup> )	78 (91.76%)	7 (8.24%)	0
AP diameter (mm)	75 (88.23%)	9 (10.58%)	1 (1.17%)
ML diameter (mm)	81 (95.29%)	4 (4.71%)	0

[Table/Fig-3]: Comparing areas and various diameters of jugular foramen of both sides.  
AP: Anteroposterior; ML: Mesiolateral

Parameters	Right jugular foramen		Left jugular foramen		p-value (t-test)
	Range (mm)	Mean±SD	Range (mm)	Mean±SD	
AP diameter (mm)	7.2-12.23	9.42±1.22	6.55-11.22	8.80±1.14	<0.001
ML diameter (mm)	9.45-18.45	14.38±2.33	8.25-17.35	11.90±2.27	<0.001
Area (mm <sup>2</sup> )	68.04-212.89	137.54±35.39	56.74-170.89	106.11±29.01	<0.001

[Table/Fig-4]: Comparing various dimensions of jugular foramen of both sides by paired t-test.  
SD: Standard deviation; bold p-values are significant

The incidence of bony bridging of a foramen revealed that the complete septation affected 34 jugular foramina on right side and 17 on left side, whereas 51 foramina had partial septation on the right and 68 on the left. Frequency of complete septation was higher on the right side but the difference between the number of septation of both sides was not statistically significant ( $p$ -value  $> 0.05$ ) [Table/Fig-5].

Side	Septation		p-value (Chi-square test)
	Complete n (%)	Partial n (%)	
Right	34 (40%)	51 (60%)	0.09
Left	17 (20%)	68 (80%)	

[Table/Fig-5]: Comparing septation of jugular foramen by Chi-square test.

## DISCUSSION

The present study was conducted to understand the complex anatomy of the Jugular Foramen. Though the sample size was not very large as the skulls were collected only from Eastern India, so generalised conclusions were not obtained. The shape and size of jugular foramen is related with size of internal jugular vein. In the present study, in 78 skulls, right foramen was larger than the left and in seven skulls left foramen was larger than right counterpart. The dimensions of jugular foramen of the right side was significantly more than left side that corresponds well with the fact that the right internal jugular vein is larger than left in most of the individual. The superior sagittal sinus is also larger than the inferior sagittal sinus. The superior sagittal

sinus is continuous with right transverse sinus, then right sigmoid sinus and then which continues as the right internal jugular vein. The inferior sagittal sinus continues as straight sinus, left transverse sinus, left sigmoid sinus. From this left internal jugular vein begins. Wide variation in the anatomy of intra cranial venous sinuses may be the cause of variation in size and shape of jugular foramen [8]. The difference in the size of the two internal jugular vein is already visible in human embryo at 23 mm stage. It probably occurs because of the differences in the development of right and left brachiocephalic vein [9].

In a previous study done by Sturrock RR reported out of 156 skulls, 68.6% had larger right foramen, 23.1% had larger left foramen and in rest (8.3%) size was bilaterally same [10]. Hatiboglu MT and Anil A had studied the area of 300 Anatolian skulls and reported that in 61.6% right foramen were larger than left counterpart and in 26% left was larger than right. In the remaining right and left foramina were equal in size [11]. Patel MM and Singel TC studied 91 adult Indian skulls from Saurashtra region and observed that in 60.4% cases, right foramen was larger and in 15.4% left foramen was larger, while in 24.2% they were equal on both sides [12]. Another study done by Hussain SS et al., on south Indian population reported similar results. They observed that the area of right jugular foramen was greater than the left in 64.8% cases. In 24.8% cases left was larger than the right. And in only 10.4% of cases they were equal on both sides [8]. Similar studies were also done by Khanday S et al., on South Indian population, by Vijisha P et al., and Amudha G et al., on Tamil Nadu population. In all cases the size of the foramen was larger on the right side [13-15]. [Table/Fig-6] shows comparison of the area of Jugular foramen with previous authors [8,10-15].

Number	Author	Larger on the right side (%)	Larger on the left side (%)	Equal on the both sides (%)
1.	Hussain SS et al., [8]	64.8	24.8	10.4
2.	Sturrock RR [10]	68.6	23.1	8.3
3.	Hatiboglu MT and Anil A [11]	61.6	26	12.4
4.	Patel MM and Singel TC [12]	60.4	15.4	24.2
5.	Khanday S et al., [13]	70	24	6
6.	Vijisha P et al., [14]	76.6	10	6.6
7.	Amudha G et al., [15]	55	35	20
8.	Present study	91.8	8.2	0

[Table/Fig-6]: Comparison of the area of the jugular foramen [8,10-15].

In the present study, it was observed that the jugular foramen had either partial or complete septation. Complete septation was more in the right but partial septation was more in left side. Similar findings were reported in the study done by Hussain SS et al., on Southern Indian population [8]. They observed that complete septation was more in the right than left, but partial septation was more in the left [Table/Fig-7]. Another study done by Sturrock RR observed that the incidence of complete septation was found to be similar in both right and left side but partial septation was more in left side [10]. But Khanday S et al., also reported the presence of complete as well as partial septation more in the right side [13]. The findings from similar studies done by Hatiboglu MT and Anil A, Patel MM and Singel TC, Vijisha P et al., and Amudha G et al., supported the present study [11,12,14,15]. [Table/Fig-7] [8,10-15] showed the comparison of septation of Jugular foramen with other authors.

Number	Author	Complete septation		Partial septation	
		Right	Left	Right	Left
1.	Hussain SS et al., [8]	20.8	16.8	45.6	58.4
2.	Sturrock RR [10]	3.2	3.2	1.3	10.9
3.	Hatiboglu MT and Anil A [11]	5.6	4.3	2.6	19.6
4.	Patel MM and Singel TC [12]	23.0	17.6	49.5	59.3
5.	Khanday S et al., [13]	13	4	24	7
6.	Vijisha P et al., [14]	10	6.7	63.3	70
7.	Amudha G et al., [15]	10	3	90	99.7
8.	Present study	40	20	60	80

[Table/Fig-7]: Comparison of the complete and partial septation among jugular foramen in percentage Skull in Eastern India [8,10-15].

### Limitation(s)

The sample size was small as skulls were collected only from three medical Colleges of West Bengal because of the ongoing corona pandemic. Here data was not robust enough to draw generalised conclusions.

### CONCLUSION(S)

In present study, the right jugular foramen was larger than the left and the complete septation was more in the right but partial septation was more on the left side. There were some variations observed in the parameters of jugular foramen when compared with the previous studies which may be due to various factors like racial, geographic or genetic. As the location of jugular foramen is deep, it is not directly accessible for clinical evaluation. So the knowledge of variations of different parameters is necessary to avoid any unintentional outcome during skull micro surgery for neurosurgeons, radiologists and also for anthropologists, since the foramen is related to many important vessels and cranial nerves. So the knowledge regarding these variations is very much important. More future studies with larger sample size with more morphological variations of the Jugular foramen in Eastern India would help in drawing generalised conclusions.

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**PLAGIARISM CHECKING METHODS:** [Jan H et al.]

- Plagiarism X-checker: Aug 10, 2021
- Manual Googling: Sep 20, 2021
- iThenticate Software: Nov 25, 2021 (21%)

**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: **Jul 08, 2021**  
Date of Peer Review: **Sep 09, 2021**  
Date of Acceptance: **Sep 27, 2021**  
Date of Publishing: **Jan 01, 2022**