

ORIGINAL ARTICLE

ANTHROPOMETRIC MEASUREMENTS OF JUGULAR FORAMEN IN ETHIOPIAN DRIED ADULT SKULLS

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ABSTRACT

Introduction: The jugular foramen is a large irregular hiatus that lies on each side of the skull. It is subdivided into anterior, middle and posterior compartments. The shape and size of jugular foramen are related to the size of internal jugular vein and the presence or absence of a prominent superior jugular bulb.

Objective: The aim of the present study was to assess variations of jugular foramen in Ethiopian dried adult skulls. To our knowledge, this study is the first of its kind on Ethiopian skulls.

Methods and materials: Observation based descriptive study design was employed. The study was undertaken in 58 adult Ethiopian skulls. The diameters and areas of jugular foramen were determined using a sliding jaw vernier caliper. The presence of dome and septation were also examined.

Results: The mean anteroposterior and mediolateral diameters and the area of jugular foramen are larger on the right side. It has been observed that all the skulls had a jugular foramen bilaterally. Out of the examined 116 jugular foramina, a domed bony roof was present in 63.79% bilaterally, in 18.97% unilaterally on the right, in 9.90% skulls unilaterally on the left side, and it was absent bilaterally in 6.90% of skulls. The presence of bilateral partial bony septation was common and detected in 62.01% of the skulls.

Conclusions: The various measurements on the jugular foramen reported in our study sheds light on the size and shape of jugular foramen and provide a baseline for further research on the foramen in Ethiopian skulls.

Keywords: Skull, jugular foramen, morphological variation, dome, septation

INTRODUCTION

The jugular foramen (JF) is a long irregular shaped hiatus situated at the posterior end of petro-occipital suture at the base of the skull between jugular process of occipital bone posteromedially and jugular fossa of petrous part of temporal bone anterolaterally and posterolateral to the carotid canal [1, 2]. A domed bony roof may be seen in the JF indicating the presence of a prominent superior jugular bulb [1, 3]. Besides, the bony extension/separation may divide JF completely or partially.

The foramen is subdivided into three compartments: anterior, middle and posterior. Anterior compartment is a smaller venous cubicle (petrosal part) which contains inferior petrosal sinus. It is the main route of venous outflow from the skull. Sigmoid sinus continues as internal jugular vein in the posterior part of JF [4, 5]. The posterior compartment (sigmoid part) is a larger venous compartment. It contains sigmoid sinus and meningeal branch of occipital and ascending pharyngeal arteries [2, 3, 6]. The middle compartment, a neural compartment, on the other hand, contains three cranial

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nerves; glossopharyngeal, vagus and cranial accessory nerves.

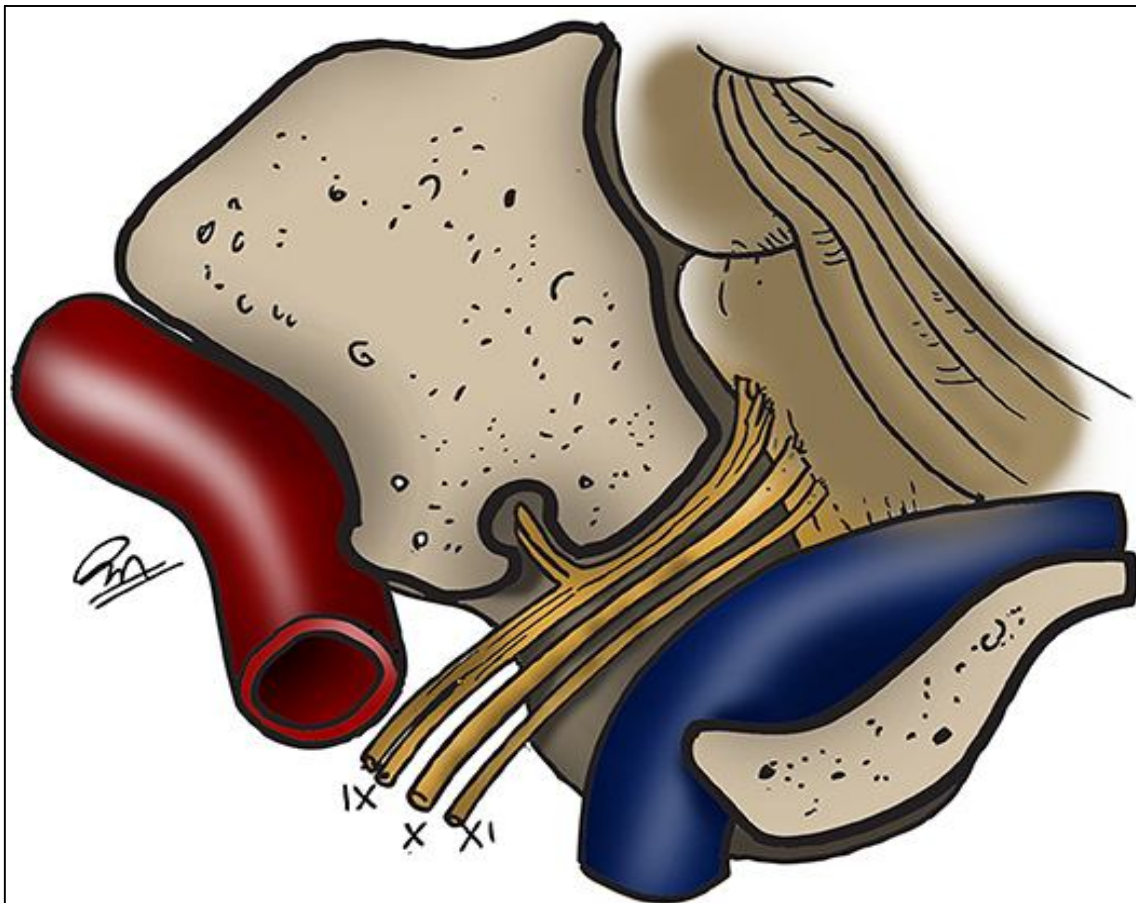


Figure 1: Schematic view of the structures of the jugular foramen in the middle and posterior compartment. Carotid artery in red, sigmoid sinus and jugular bulb in blue. IX: glossopharyngeal nerve. X, vagus nerve. XI, accessory nerve [7]

In the JF, glomic tumor, schwannoma, paraganglioma and other metastatic lesions may occur, which may require microsurgical interventions [8]. Therefore, the present study aims to study the normal range of different dimensions and variations, presence of dome and septation of JF in Ethiopian skulls which may provide valuable input for neurosurgeons working in Ethiopia as the foramen contains neurovascular bundles that are vulnerable to damage during surgical procedures.

The main objective of the present study is to assess morphological and morphometric variations of JF in dried adult Ethiopian skulls.

MATERIALS AND METHODS

Study Subjects: The study was conducted on 116 JF of 58 Ethiopian dry adult normal skulls procured from the Department of Human Anatomy, College of Medicine and Health Sciences, University of Gondar, Gondar, Ethiopia.

Inclusion and exclusion criteria: Only undamaged dried skulls with no sign of erosion were included in the study. All damaged skulls with unidentifiable features of JF were excluded from the study.

JF Measurement protocol: Each JF was labeled before the commencement of measurement. Then, the anteroposterior diameter (APD) and mediolateral diameter (MLD) was measured using sliding jaw vernier calipers (BETA UTENSILI S.P.A. and USA). The area of JF was calculated using the formula:

$$A = \frac{p \times APD \times MLD}{4} \quad [9]$$

In order to maximize the accuracy of results, each measurement was performed three times (in triplex) and the mean value was taken. The presence of dome and septation was also examined and photographed.

Data Analysis: All data were analyzed using SPSS version 20 statistical software. Descriptive analysis including, percentages and means were computed. Chi-square tests were performed to evaluate the association between the variables under investigation. P-values < 0.05 were considered as statistically significant.

Ethical Considerations: This study was done from 26th Februar to 20th April 2016, after ethical clearance and getting approval from the Ethical committee of the School of Medicine, College of Medicine and Health Sciences, University of Gondar (Reference SOM 794/08 E.C. dated February 26 2016). It was conducted using 58 Ethiopian dry

adult normal skulls and intact adult human skulls of unknown sex and age, which were obtained from the anatomical museum in the Department of Human Anatomy, School of Medicine, College of Medicine and Health Sciences, University of Gondar, Ethiopia. The skulls were collected for teaching purpose from unclaimed cadavers.

RESULTS

A total of 116 JF from 58 dried adult skulls of unknown sex were used for the present study. All of the skulls that were examined during the study had JF bilaterally.

Dimension of JF: The mean APD of the 116 JF examined was 11.02 ± 1.50 mm on the right side and 10.08 ± 1.77 mm on the left side. There was a statistically significant difference between the two sides of JF ($p=0.029$). The mean MLD of JF was 17.63 mm on the right side and 16.06 mm on the left side. MLD of the right JF was significantly larger than the left ($p=0.010$; Table 1).

Area of JF: The mean area of JF was greater on the right side (157.25 ± 2.42 mm²) than on the left side (128.31 ± 3.73 mm²). There was a statistically significant difference between the areas of the two sides of JF ($p=0.004$; Table 1).

Table 1: Anteroposterior and mediolateral diameters and area of jugular foramen

Parameters	Right JF		Left JF		P-value
	Range	Mean ± SD	Range	Mean ± SD	
Anteroposterior diameter (mm)	9 - 14.75	11.04 ± 1.50	6 - 14	10.08 ± 1.77	0.029
Mediolateral diameter (mm)	13.50 - 28	17.63 ± 3,26	14 - 20.5	16.06 ± 1.77	0.01
Area of JF (mm²)	95.42 - 252.9	157.25 ± 2.42	77.75 - 219.91	128.31 ± 3.73	0.004

Side dominance: The JF was larger on the right side in 75.86%, on the left side in 17.24% and equal on the right and left sides in 6.90% of the cases (Figure 2 A-C).

Jugular domed bony roof: Out of 58 examined skulls, jugular domed bony roof was present bilaterally in 36 (62.01%): on the right side only in 12 (18.97%), on the left side only in 6 (10.34%), and absent in 4 (6.90%) (See, Figure 3 and Table 2). However, Pearson chi-square test showed no statistically significant difference between the right and left sides of the JF ($p=0.345$).

Septation: As it is presented in Table 3, complete separation by the septation was identified in 9 (15.52%) subjects on the right side and 11 (18.96%) subjects on the left side. A partial separation was seen on the corresponding right side in 40 (69%) and left side in 42 (72%) of the skulls. On the other hand, septation of JF was absent in 12 (20.69%) on the right and in 12 (20.69%) of the left side. The bony septum was absent bilaterally only in 4 skulls (Figure 4 B).

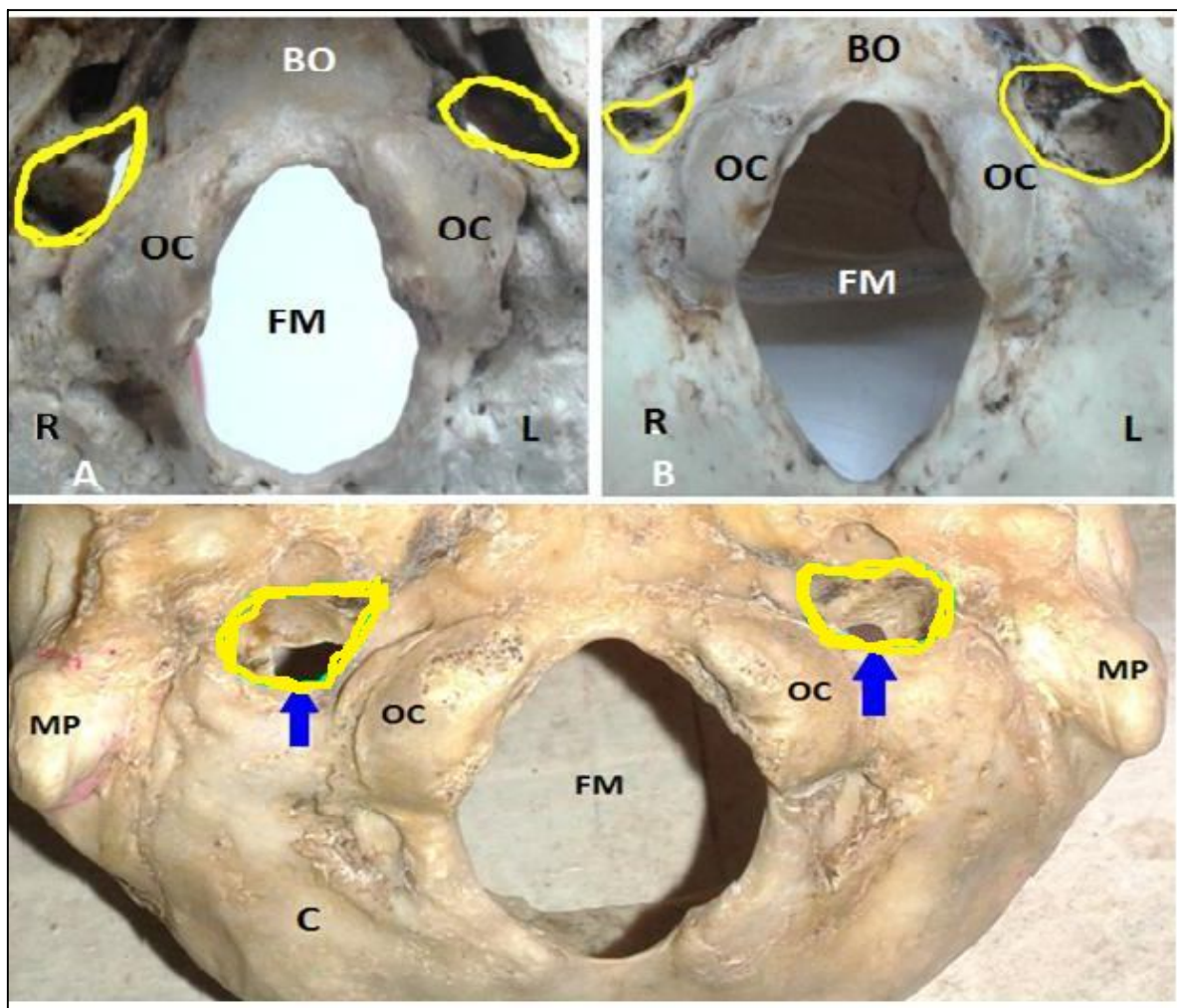


Figure 2: Pictures taken from Ethiopian dried skull specimens (A), (B) and (C) in 2015 illustrating side dominance of JF; exo-cranial view of posterior aspect of base of a skull (A): Larger right foramen (B): Larger left foramen (C): Equal right & left side of JF (BO-Basi-occiput, OC-Occipital condyle, FM- Foramen magnum, MP- Mastoid process, R-Right, L- Left)

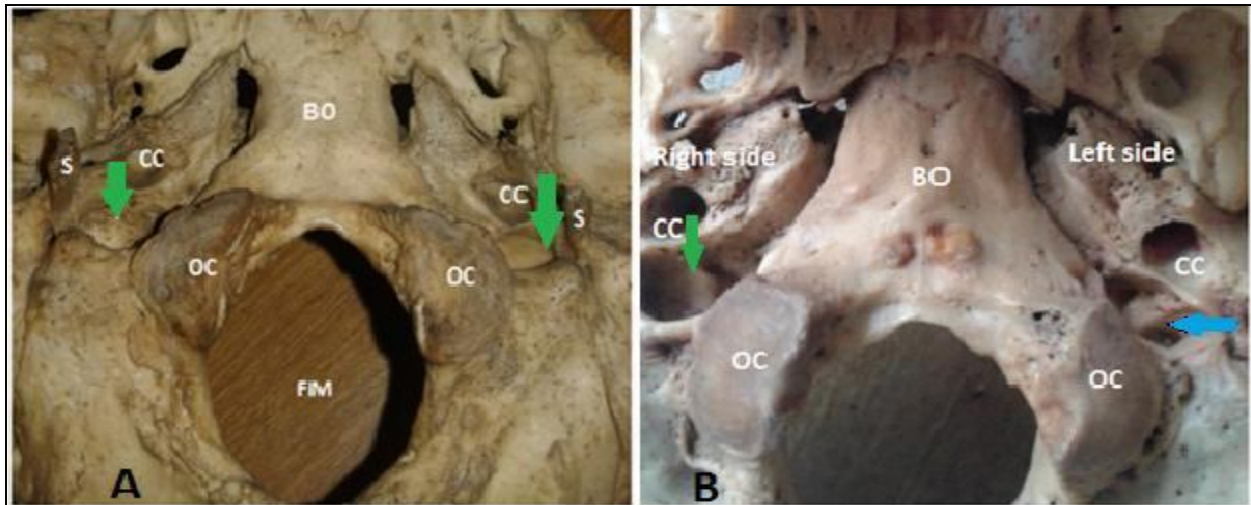


Figure 3: Pictures taken from Ethiopian dried skull specimen (A) and (B) in 2015 illustrating dome of JF; exo-cranial view of posterior aspect of base of a skull (A): Bilateral dome of JF; right and left side green down arrows indicate domed bony roof. (B): Absence of dome on the left side; green down arrow indicates presence of dome while left blue arrow points absence of dome. (BO-Basi- occiput, CC-Carotid canal, OC-Occipital condyle, S-Styloid process, FM- Foramen magnum)

Table 2: Presence or absence of domed bony roof

Presence of dome	Number (%)
Bilateral presence	36 (62.01%)
Only on the right side	12 (18.97%)
Only on the left side	6 (10.34%)
Bilateral absence	4 (6.90%)

Table 3: Septation or Compartment of JF

Separation of compartments	Body side	Number (%)
Complete separation	Right	9 (15.52%)
	Left	11 (18.96%)
Partial separation	Right	41 (70.69%)
	Left	39 (67.24%)
Without separation	Right	8 (13.79%)
	Left	8 (13.79%)

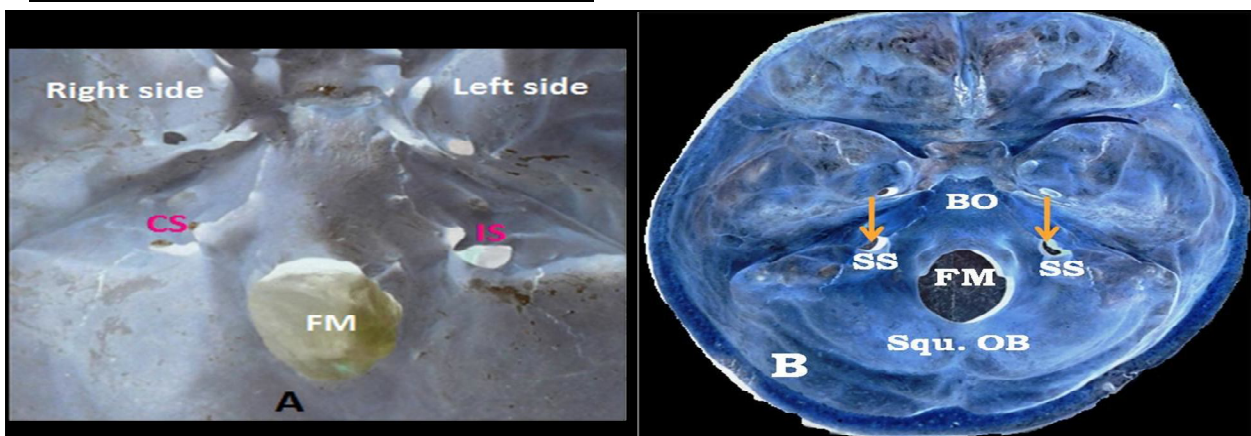


Figure 4: Pictures taken from Ethiopian dried skull specimen (A) and (B) in 2015 illustrating JF septation; endo-cranial view of posterior aspect of base of a skull (A): left side complete and right incomplete septum; CS on the right side shows a completed septum dividing the JF into two compartments, while in the left side IS shows incomplete bony septum. (B): Bilateral absence of septation; blue down arrows show a non-separated right and left JF. (CS- Complete septation; IS – Incomplete septation; BO-Basiocciput; SS-groove for sigmoid sinus; FM- Foramen magnum, Squ. OB – Squamous part of occipital bone)

DISCUSSION

The mean APD of JF was 11.04 ± 1.50 mm and 10.08 ± 1.77 mm, respectively, on the right and left sides obtained in the present study are comparable to previous report by researchers [10, 11]. The study by Idowu [10], using Nigeria skulls reported the mean value of the right side APD to be 10.22 mm and the left APD to be 9.57 mm. Similarly, a study conducted on JF in 50 Indian skulls found the mean value of APD to be 11.2 ± 2.47 mm on the right and 9.52 ± 1.55 mm and left JF, respectively [11]. However, the present study reported a larger value of right and left APD as compared to the reports in Sir Lanka and Turkey 6.84 ± 1.76 mm and 8.28 ± 1.70 mm [12], 8.3 ± 2.2 mm and 7.3 ± 1.4 mm [13], on the right and left sides of JF, respectively.

The mean value of the MLD found in the present study (17.63 ± 3.26 mm – right JF and 16.06 ± 1.77 mm- left JF) is in agreement with results reported by Gupta and collaborators in Indian skulls 16.52 ± 2.03 mm on the right and 16.02 ± 2.20 mm on the left side [11]. However, research conducted in North India using 100 dried adult skulls presented a larger mean value of MLD on the right (17.63 mm vs 23.62 mm) and left side (16.06 mm 22.86 mm) [2]. In line with our study, a morphometric study conducted using 111 Southern Brazilian dry adult skulls reported the mean MLD of 15.86 ± 2.64 mm on the left side. However, the MLD on the right side is found to be smaller (15.82 ± 2.67 mm) [14].

The mean area of JF which is 154.22 mm² on the right side and 126.42 mm² on

the left side in the present study shows relatively wider JF as compared to the recent reports 118 mm² and 90 mm² [16], 99.19 mm² and 68.93 mm² [9] accordingly. On the other hand, Idowu found the mean area of the jugular foramen of Nigeria adult skulls on the right was between 437.4 and 210.87 mm² and that on the left was between 419.48 and 141.93 mm² [10]. A morphological and morphometric study conducted on the jugular foramen of dry India skulls revealed the mean area of 187.34 ± 55.62 mm² on the right and 153.20 ± 35.80 mm² on the left sides [11]. This JF area difference with Ethiopians' may be due to sex, nutrition or racial variation.

The size and shape of JF are related to the size of internal jugular vein and the presence or absence of a prominent superior bulb. The right JF is usually larger than the left. The difference in size of the two internal jugular veins is already visible in the human embryo at the 23 mm stage and probably results from differences in the developmental pattern of right and left brachiocephalic veins [15].

Morphometric study of the jugular foramen of South Gujarat region, India on 100 dry skulls reported that 75% of the foramen was larger on the right side and 23% was larger on the left side [4]. Besides, a morphological and morphometric study of jugular foramen in South Indian population conducted using 648 JF reported larger right JF in 70% and in 24% left side of the foramen is larger [16]. These observations went in line with the present study.

As to domed bony roof presence in the JF, the results of the present study are similar to the study by Kumar and colleagues, who reported 57.35% bilat-

eral presence, 29.4% on the right side, 8.82% on the left side, and bilateral absence of dome in 4.41% of the foramen [3]. However, a recent study reported the bilateral presence of dome in a much lower percentage (23%) of skulls and more frequent bilateral absence (36%) [4].

The absence of domed bony roof indicates that the superior jugular bulb is poorly developed or absent in

such cases and may not form the floor of middle ear cavity. In addition, a study conducted in Indian (Saurashtra region) using 91 skulls observed the dome as the special feature of JF was present in 21% bilaterally, in 38.5% on the right side, in 14.3% on the left side and in 25.3% bilateral absence [17]. Another study on 55 Bangladesh dried adult skulls reported the bilateral presence of dome of JF in all examined skulls [18] (Table 4).

Table 4: Comparison of dome of JF of the present study with other studies in percent (%)

Authors	Dome symmetry			
	Bilaterally	Right unilaterally	Left unilaterally	Absent
Roma and Mehta, 2014	23	30	11	36
Kumar et al., 2014	57.35	29.4	8.82	4.41
Patel and Single, 2012	21	38.5	14.3	25.3
Hussain et al., 2010	49.6	27.2	8.8	14.4
Akram et al, 2012	100	0	0	0
Hatibgu and Anil, 1992	49	36	6	10.3
Sturrock, 1988	53.9	30.1	6.4	9.6
Sharma and Garud, 2011	58	28	8	6
Present study	63.79	18.97	10.34	6.9

The JF is usually divided into a variable number of compartments by a bony septum projecting from the opposing surfaces of the petrous temporal bone and squamous occipital bone either partially or completely. The compartmentalization of the foramen could be the logical reason for compression on the last four cranial nerves, causing varied symptoms grouped as Vernet's Syndrome besides glomus jugulare and glomus vagale tumors [8].

In the present study, the complete bony separation of JF on the right side was 17.24%. Our study is supported by a study conducted in India (16.17%) [3]. However, our finding is smaller than Ak-

ram, et al., (76.36%) [18] and Roma and Mehta (68%) [4] and greater than the findings of Hatiboglu and Anil (5.63%) [19] and Sturrock (3.2%) [15]. The present study revealed a slightly higher percentage of partial septation of right and left JF compared to other studies [15, 17, 18]. Most of the studies reported common right side complete separation of JF than the left and common left side partial separation than the right [5, 6, 11].

CONCLUSION AND RECOMMENDATION

The anthropometric measurements of JF of Ethiopian dried skulls were significantly larger on the right sides than the left. And, bilateral partial septation and presence of dome of JF were detected. To our knowledge, the present study is the first of its kind conducted on Ethiopian skulls. Thus, our research finding provides a baseline for further research on the JF in Ethiopian skulls. The jugular foramen has constantly fascinated Ear, Nose, and Throat specialists, radiologists, and neurosurgeons because of modern advances in surgical procedures involving skull base and middle ear. Tumors in this area such as schwannoma, meningioma, glomus jugulare, and chordoma can produce multiple cranial nerve palsies. Most of the approaches for resection for these tumors such as retrosigmoid, transjugular craniotomy require partial petrosectomy traversing the jugular fossa. Thus, the knowledge of anatomical details and dimensions of jugular foramen would be a great help to these surgeons while approaching this area.

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Conflicts of Interests: None

Authors' Contributions:

MJ: conception of the research idea, study design, conducts research, data collection, analysis and interpretation, and reviewed the manuscript.

YA: interprets the data and reviewed the manuscript.

AM: conducts research, data analysis and interpretation, and draft the manuscript.

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