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Variant Anatomy of the Jugular Foramen: An Osteological Study

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ABSTRACT
Background: Jugular foramen lesions are among the major complications of skull base surgery. Morphological variations in the structure are pertinent during interpretation of skull base radiographs and in surgical procedures within the foramen. This study therefore aimed at describing the morphology of the jugular foramen in a Kenyan population.

Methods: One hundred and five adult skulls from the Nairobi National Museums were used. Jugular foramen septation, dome and dimensions were studied extracranially. Statistical analysis was performed using SPSS (Version 21.1 IBM). Results: Septation was present in 202 (96.2%) jugular foramina, type I partial septation being the most common (78.7%). A dome was observed in 81 (38.6%) jugular foramina. Respectively, the mean right and left anteroposterior dimensions were 11.17 ± 2.05mm vs. 8.88 ± 2.30mm (p <0.001), mediolateral dimensions 17.47 ± 2.18mm vs. 15.30 ± 2.53mm (p <0.001), jugular dome depth 12.38 ± 2.64 mm vs. 11.25 ± 2.15 mm (p=0.054), posterior wall thickness 7.95 ± 2.20mm vs. 9.68 ± 1.98mm (p <0.001) and medial wall thickness 3.73 ± 1.10 mm vs. 3.73 ± 0.98mm (p = 0.992). Conclusion: Partial septation, asymmetry in dimensions and a wide range in the dome depth of the jugular foramen were frequent. Preoperative imaging of jugular foramen morphology is therefore recommended to avoid inadvertent injury to its contents and surrounding structures owing to variability.

Keywords: Jugular foramen, septation, jugular dome, jugular foramen dimensions.

INTRODUCTION
The jugular foramen (JF) transmits the internal jugular vein (IJV), inferior petrosal sinus, meningeal branch of ascending pharyngeal artery, glossopharyngeal, vagus and spinal accessory nerves. Lesions including paragangliomas, schwannomas, meningiomas, high jugular bulb and trauma may occur in the foramen, constituting one of the major challenges experienced in skull base surgery.

There is however paucity of data from the African population and lacking altogether among Kenyans. Additionally, the wall thickness, which may be important during access to the foramen has barely been described in literature. This study therefore set out to describe the morphology of the jugular foramen in a Kenyan population, with regards to septation, dome, anteroposterior dimension, mediolateral dimension and wall thickness.

MATERIALS AND METHODS
In this descriptive cross sectional study one hundred and five skulls (n=210 JF) obtained from the Nairobi National Museums of Kenya were studied. The museum osteological collection was from central Kenya (1950 - 1960). Approval for use of cadaveric material is provided in the Human Anatomy Act Cap 249(1967) and the Human Tissues Act Cap 252(1968) of the Laws of Kenya.
Skulls with normal morphology and those with erupted third molars (adults) were selected. The JF was identified extracranially. Presence or absence of septae - bony structures dividing JF into compartments and jugular dome - transverse bony plate within JF, were documented. When present the septation or bridging was classified as type I (one bridge), II (two bridges), III (three bridges) or IV (atypical fusion of intraforamina processes) according to Athavale.[11]

Morphometric data were taken using a pair of digital Vernier calipers (Sealey Professional Tools™, accurate to 0.01 mm) and a pair of adjustable compasses with a ruler for smaller measurements. Data were collected by a single observer. Intra-observer error was minimized by taking each measurement thrice and obtaining the average.

The measurements taken were: Anteroposterior (AP) dimension, the maximum sagittal dimension of JF; mediolateral (ML) dimension, the maximum transverse dimension of JF; depth of jugular dome, the height from the margin of the JF to the central part of the dome; medial wall thickness, the thickness of the osseous bar between JF and the hypoglossal canal and posterior wall thickness, the thickness of the jugular process at the level of the occipital condyles.

Data analysis was performed using SPSS version 21.1 (SPSS IBM). Means, standard deviations and range were obtained. The paired Student’s t test was used to determine the statistically significant differences in means between the right and left jugular foramina dimensions. P ≤ 0.05 was considered statistically significant at 95% confidence interval.

RESULTS

The jugular foramen varied in terms of septation types, presence of dome and side differences in wall thickness, anteroposterior and mediolateral dimensions.

Septation: Bony septation was present in 202 (96.2%) JF. Of these, type I partial septation was present in 159 (78.7%), type II partial septation in 8 (4%), type I complete septation in 28 (13.9%), type II complete in 1 (0.5%) and type II mixed septation in 5 (2.5%). Type IV or atypical septation was observed in only 1 (0.5%) JF. Bilateral septation was observed in 97 skulls of which type I partial was observed in 66 skulls (71%), type I complete in 7 (7.5%), type II partial in 2 (2.2%) while 22 skulls (22.7%) showed different septation types on the right and left sides [Figure 1].

Dome: Jugular dome was present in 81 (38.6%) of the jugular foramina. Unilaterally, right dome was observed in 32 skulls (30.5%) [Figure 2A] and left dome in 7 skulls (6.7%) [Figure 2B]. Bilateral presence of the dome was seen in 21 skulls (20%) [Figure 2C] and bilateral absence in 45 skulls (42.9%). The dome was always posterolateral in the foramen. The mean depth of the right dome was 12.38 ± 2.64 mm and the left 11.25 ± 2.15 mm (P = 0.054). A wide range in the depths was obtained, the maximum depth being 18.6 mm and the minimum depth 6.11 mm.
ASETA ET AL; VARIATIONS OF THE JUGULAR FORAMEN

Anteroposterior and mediolateral dimensions: Both mean AP and ML dimensions were greater for the right JF than the left JF. The mean AP dimension was 10.03 ± 2.46mm, right and left JF 11.17 ± 2.05mand 8.88 ± 2.30 mm respectively (p< 0.001). The mean ML dimension was 16.38 ± 2.59mm, right and left JF 17.47 ± 2.18mm and 15.30 ± 2.53mm respectively (p< 0.001) [Figure 3]. The right JF showed larger dimensions than the left JF in 86 skulls (81.9%) for the AP dimension and 82 skulls (78.1%) for the ML dimension.

Posterior and medial wall thicknesses: The mean posterior wall thickness was greater in the left JF than the right JF with the difference being statistically significant (9.68 ± 1.98mm vs. 7.95 ± 2.20mm, p<0.001). The mean thickness of the medial wall for the right and left JF was 3.73 ± 1.10mm and 3.73 ± 0.98mm respectively (P=0.992) [Figure 3].

DISCUSSION

The jugular foramen was bilaterally present in all cases as conventionally described [1]. The foramina septation, dome and dimensions showed variations from some populations, which may be of clinical relevance.

Septation

The high prevalence (96.2%) of JF septation is concordant with Kumar et al [10] but at variance from other literature [Table 1]. The most common type is partial septation, in agreement with reports from other populations [7,10,12,13]. Data on complete septation is close to the findings of Kumar et al [10] and Roma et al [13] but differs largely from other studies [7-9]. Complete septation was higher in the left compared to the right JF as opposed to the results of Kumar, Hatiboğlu and Roma et al. Likewise, partial septation was higher in the left than right JF, similar to some reports in literature [7,10,12]. The variations in frequency of septation are genetic or developmental [6,14]. For foramina with partial septation, they may be completed in the living by a fibrous septum [15]. Compartmentation may have implications during surgical access to the lesions within the foramen [15]. The high frequency of septation calls for prudence during planning to ensure safe access and accurate interpretation of posterior cranial fossa radiographs [15].

Dome

The 30.5% frequency of unilateral right JF dome is akin previous descriptions [7,10,13] but differs from...
Hatiboğlu et al. [12] among the Turkish [Table 2]. The 6.7% frequency of unilateral left dome is similar to the studies by Sturrock [7] and Hatiboğlu et al. Bilateral presence of dome showed a lower frequency (20%) similar to the findings of Roma et al [13] while bilateral absence was highest for the present study [Table 2]. The mean depth of jugular foramen dome is comparable to the results of Singla et al [14] who studied skulls in an Indian population and obtained 11.11 mm and 11.04 mm for the right and left JF respectively. Gupta et al [18] reported a depth of 11.75 mm for the right JF and 11.13 mm for the left JF, these too correspond to the present study. The ranges of the depths do not exhibit such a wide population difference compared to other JF dimensions. A study by Anson et al [19] nevertheless seems to differ from this. They reported most of the domes being less than 7 mm in depth. The difference may be methodological.

<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Sample size</th>
<th>Complete Septation (%)</th>
<th>Partial Septation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sturrock (1988)</td>
<td>British</td>
<td>156</td>
<td>3.2</td>
<td>3.2</td>
</tr>
<tr>
<td>Hatiboğlu et al (1992)</td>
<td>Turkish</td>
<td>300</td>
<td>5.6</td>
<td>4.3</td>
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<tr>
<td>Pereira et al (2010)</td>
<td>Brazilian</td>
<td>111</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Kumar et al (2014)</td>
<td>Indian</td>
<td>68</td>
<td>16.7</td>
<td>8.82</td>
</tr>
<tr>
<td>Roma et al (2014)</td>
<td>Indian</td>
<td>100</td>
<td>16.5</td>
<td>14</td>
</tr>
<tr>
<td>Present Study</td>
<td>Kenyan</td>
<td>105</td>
<td>13.3</td>
<td>14.3</td>
</tr>
</tbody>
</table>

The bilateral differences in presence of a dome may be attributed to difference in size between the right and left superior jugular bulbs the larger forming a dome. [20] The population differences are genetic or ethnic based. [10,18,21] Jugular dome suggests a prominent superior jugular bulb which should not be mistaken for a tumor or a mass during radiography. Where the dome is so high that it reaches above the internal acoustic meatus, it is indicative of a high riding jugular bulb. [22] During preoperative planning for inner ear surgeries, presence of a dome with its jugular bulb should be considered as an important relation since injury to the bulb can be devastating. [23] The wide range of depth obtained in the current study (6.1 mm - 18.6 mm) suggests variable positions of the superior jugular bulb which should be considered during surgery.

**Anteroposterior and mediolateral dimensions**

The present study demonstrated larger AP and ML dimensions for the right JF compared to the left JF in line with literature reports. [19,17,25-27] Idowu obtained a similar trend for the AP dimension but had almost equal left and right ML dimension. [8] The 11.17 mm and 8.88 mm right and left AP dimensions from the current study are comparable with most literature. [8,9,17,27] but differ largely from those reported by Saheb [25] and Sundika [26] et al [Table 3]. The 17.47 mm and 15.3 mm right and left ML dimensions are akin to findings among Nigerians [27] and Brazilians [9] and are at variance from the other reports [Table 3]. The right dimensions were larger than the left dimensions in about 80% of the skulls, a value higher compared to about 67% reported as standard literature. [28] This observation however corresponds to that by Singh et al [21] who reported a high of 88.3% larger right than left JF. The AP and ML dimensions of JF are indicative of the size of the IJV. The larger superior sagittal sinus preferentially drains into the right sigmoid sinus and therefore the right IJV is larger than the left IJV. [29] Intracranial variations in venous sinuses, different developmental patterns, genetic or...
ethnic differences contribute to the asymmetry.\[30\] Knowledge of jugular foramen dimensions may be important in the diagnosis of JF stenosis or widening. The right JF dimensions are greater than the left’s, suggestive of right IJV ‘dominance’ in most of the study population. This may provide guidance in selecting the IJV to ligate or catheterize.\[31,32\]

### Table 3: A-P and M-L dimensions from different study populations.

<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Sample Size</th>
<th>AP Dimension (mm)</th>
<th>MI Dimension (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td>L</td>
</tr>
<tr>
<td>Pereira et al. (2010)</td>
<td>Brazilian</td>
<td>111</td>
<td>9.21 ± 1.95</td>
<td>8.65 ± 1.57</td>
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<tr>
<td>Singla et al. (2012)</td>
<td>N.W. Indian</td>
<td>50</td>
<td>9.32 ± 2.04</td>
<td>7.34 ± 2.04</td>
</tr>
<tr>
<td>Osunwoke et al. (2012)</td>
<td>S. Nigeria</td>
<td>120</td>
<td>9.34 ± 2.00</td>
<td>7.54 ± 2.17</td>
</tr>
<tr>
<td>Present study</td>
<td>Kenyan</td>
<td>105</td>
<td>11.17 ± 2.05</td>
<td>8.88 ± 2.30</td>
</tr>
</tbody>
</table>

### Posterior and medial wall thicknesses

The thicker left than right JF posterior wall may be related to the presence of a smaller left JF compared to right JF. The medial wall separating JF from the hypoglossal canal was a thin plate (3.73 mm) with no significant side differences. To the best of our knowledge, there is paucity of data on these dimensions from the available literature. Variability in posterior wall dimension may be crucial in the posterior approach to the jugular foramen by drilling the jugular process.\[33\] A very thin process may result in inadvertent injury to JF structures. Image guided procedure is therefore imperative. For the medial wall, the thin bony plate is prone to laceration when resecting lesions within the jugular foramen. Caution is therefore essential during such procedures to avoid penetration of the osseous septum and inadvertent injury to the hypoglossal nerve in the adjacent hypoglossal canal.

### CONCLUSION

Partial septation, asymmetry in dimensions and a wide range in the depth of jugular dome were a frequent occurrence. Preoperative imaging of jugular foramen morphology is therefore recommended to avoid inadvertent injury to its contents and surrounding structures owing to variability.

### Limitation

Most of the skulls were not sex-categorized.

### Acknowledgements

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### REFERENCES