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The Jugular Foramen and the Intracranial Volume; Are they Related?

¹S.A. Adejuwon, ²O.T. Salawu, ¹C.C. Eke and ¹R.S. Ajani

¹Department of Anatomy, College of Medicine, University of Ibadan, Nigeria

²Department of Zoology, University of Ibadan, Ibadan, Nigeria

Abstract: The study aimed to investigate the relationship between the size of a human skull foramen and the intracranial volume (skull capacity). A total number of 91 human skulls were studied to determine the volume of the foramina and the intracranial volume. The volumes of the foramina were determined by using the formula $\pi r^2 h$ (the geometrical formula of a cone-shaped figure) where 'r' is the radius of the effluent aperture, 'h' the depth of the foramen and π is a constant. The intracranial volume was determined indirectly by filling intracranial cavity with millets through the foramen magnum and then measuring the contained quantity in a volumetric jar. The mean values for the left and right foramina volume were 0.742 ± 0.25 and 1.049 ± 0.26 mL ($p < 0.05$), respectively. The Pearson Correlation Coefficients (r) established an insignificant negative correlation (inverse relationship) between the volume of the left and right jugular foramina [r-value = -0.201, p-value = 0.06 ($p > 0.05$)]. A significant negative correlation (direct relationship) [r-value = -0.225, p-value = 0.04 ($p < 0.05$)] was observed between the volume of left foramen and the Intracranial volume (skull capacity) and however, a weak significant positive correlation (direct relationship) between the volume of the right foramen and the skull capacity [r-value = 0.26, p-value = 0.02 ($p < 0.05$)] The study was able to demonstrate that the right jugular foramen is more voluminous than the left and that an inverse relationship exists between the intracranial volume and the volume of the left jugular foramen

Key words: Human, intracranial volume, jugular foramen, relationship

INTRODUCTION

The jugular foramen of the human skull is a complex bony canal, which transmits vessels and nerves from the posterior cranial fossa through the skull base into the carotid space (Chong and Fan, 1998). It is located between the temporal bone and the occipital bone. Its intracranial orifice is below the internal auditory meatus and superolateral to the intracranial orifice of the hypoglossal canal. It is situated with its long axis oriented from anteromedial to posterolateral parallel to the petroclival fissure, being configured around the sigmoid and inferior petrosal sinuses (Idowu, 2004).

Two out of every three jugular foramina exhibit asymmetry with the right being reportedly larger than the left (Wysocki *et al.*, 1999; Idowu, 2004). Racial and gender variations have been demonstrated in the size, height and volume of jugular foramen (Navsa and Kramer, 1998). However, documented evidence on the relationship between the intracranial volume and the volume of the jugular foramen is lacking in the population from which the samples under study is taken.

MATERIALS AND METHODS

The study was carried out between July and August, 2009 in the Department of Human Anatomy, University

of Ibadan, Ibadan, Nigeria. A total of 96 adult human skulls of unknown sex and age from collections in the Department of Anatomy of University of Ibadan, Nigeria were assembled; all the skulls were assumed from adult individuals because they all exhibit full dental eruption. The skulls were derived from the Southwestern Nigerian population, representing the Yoruba ethnic group of Nigeria. Ninety one pieces were suitable for our research purposes. With the aid of soft wire brush, the skulls were cleaned. The skulls were serially numbered with green 'Board Marker-B' manufactured by MonoAmi. Co. Ltd., of Thailand. The two jugular foramina were identified at the base of the skulls. Using a 1.5 mm cooper wire their depth were gauged and read on a Ruler that is graduated in millimeters. The diameter of the effluent aperture of the jugular foramina were gauged with aid of a Divider instrument and read on a Ruler. The readings were replicated three times and the mean values were recorded. The jugular foramen was adjudged to be 'cone-shaped' with the narrow apex towards the intracranial cavity. Its volume was calculated using $\pi r^2 h$ where 'r' is the radius of the effluent aperture, 'h' the depth of the foramen and π is a constant. To determine the skulls capacity, all the holes and foramina except the foramen magnum at the base of skull were plugged with cotton wool. Through the foramen magnum by means of a funnel, the skull cavity was filled with millets; the millets through a funnel were

Table 1: Mean and standard deviation of the volumes of the foramina

Foramina	No.	Mean volume (mL)	S.D.	S.E.
Left(V1-Lt)	91	0.742	±0.247	0.026
Right(V2-Rt)	90	1.049	±0.258	0.027

The mean volume of the right jugular foramen is significantly greater than that of the left ($p < 0.05$)

Table 2: Pearson correlation coefficient analysis of foramina volume and intracranial volume

	V1-Lt	V2-Rt	V1+V2	ICV
V1-Lt	1.000	-0.201	0.593*	-0.225*
p-value		0.06	<0.0001	0.04
V2-Rt	-0.201	1.000	0.623*	0.259*
p-value		0.06	<0.0001	0.017
V1-V2	0.593*	0.623*	1.000	0.065
p-value	<0.0001	<0.0001		0.560
IC-V	-0.225*	0.259*	0.065	1.000
p-value	0.039	0.02	0.560	

V1-Lt = left foramina volume; V2-Rt = right foramina volume; V1+V2 = total foramina volume; IC-V = Intracranial volume; *: Significant difference

poured into a graduated volumetric jar where the reading was then taken.

RESULTS

A pair of foramina, which were the largest and were responsible for the direct flow into the internal or external jugular veins were acknowledged as main venous foramina of the skull. The foramina were always characterized by smaller or greater asymmetry in favour of one body side. Therefore it was possible to indicate the left foramen (V1-Lt) and the right foramen (V2-Rt) from each pair. Similarly, the sum of the volume of the two jugular foramina was indicated as (V1+V2). The result of the measurements of the foramina volume was summarized in Table 1. The mean volumes of the left and right foramina are 0.742 ± 0.247 and 1.049 ± 0.258 ml respectively. The mean volume of the two foramina are significantly different ($p < 0.05$). 76.7% of the jugular foramen showed right-sided size dominance while 21.1% showed left-sided size dominance. The remaining 2.2% showed no size dominance. The Pearson Correlation Coefficients (r) statistical analysis showed an insignificant negative correlation between the volume of the left and right jugular foramina [r-value = -0.201, p-value = 0.06 ($p > 0.05$)]. A negative significant correlation [r-value = -0.225, p-value = 0.04 ($p < 0.05$)] was observed between the volume of left foramen and the intracranial capacity, and however, a weak significant positive correlation between the volume of the right foramen and the intracranial capacity [r-value = 0.26, p-value = 0.02 ($p < 0.05$)]. The summary of the results of Pearson correlation coefficient analysis were presented in Table 2. The graphs of the relationships between the volume of the jugular foramina and the intracranial capacity are presented in Fig. 1, 2 and 3.

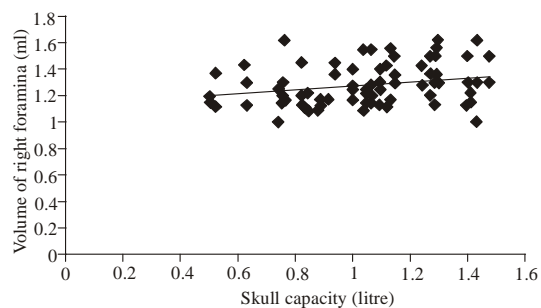


Fig. 1: The relationship between the right foramina volume and the intracranial/skull capacity

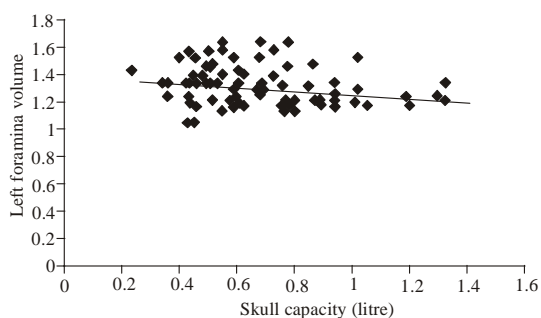


Fig. 2: The relationship between left foramina and the intracranial/skull capacity

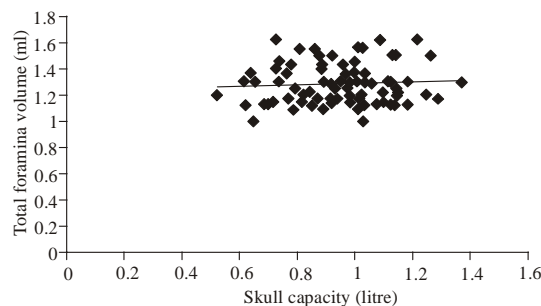


Fig. 3: The relationship between the total foramina volume and the intracranial/skull capacity

DISCUSSION

The dural venous sinuses constitute the principal venous outflow of the cranial cavity and its contents. These sinuses terminate via the sigmoid and inferior petrosal sinuses as the bulb of the internal jugular vein. Thus blood flow through the jugular foramina is considerable and the rate will be contributory to the caliber of the internal jugular vein.

This study demonstrated a statistically significant asymmetry in the volumes (size) of the foramina with the right being more voluminous. This finding is in consonance with previous but similar studies (Wysocki et al., 1999; Idowu, 2004). This asymmetry may account

for the slight difference in the calibre of the right and left internal jugular veins. However, the predominance of right jugular foramen over its left counterpart in 76.7% of the skulls under evaluation is considerably higher than any other value that has been previously reported (Rhoton, 1975; Sturrock, 1988; Hatiboglu *et al.*, 1992; Adams *et al.* 1997; Idowu, 2004; Wysocki *et al.*, 2006). Hatiboglu *et al.* (1992) reported 61.6%, Adams *et al.* (1997) 65%, and Wysocki *et al.* (2006) 54%.

The 21.1% of the skulls with left-sided size dominance reported in this study is lower than 32.5 and 27% of Schelling (1978) and Wysocki *et al.* (2006), respectively.

Several works showed the relationship between the area of the jugular foramen and skull capacity. There is however, paucity of reports relating foramina volume with the intracranial volume (skull capacity). Wysocki *et al.* (2006) reported that the skull volume is significantly related to the area of the jugular foramen and hypoglossal canal, indicating that these two are most important venous foramina of the human skull.

The insignificant weak positive relationship observed between the total jugular foramen and the intracranial volume (skull capacity) may suggest that variations exist in the intracranial venous blood flow rates amongst Nigerians. This assertion may have relevance in the aetiopathogenesis of intracranial angiopathies. The significant direct relationship between the mean right jugular foraminal volume and the mean intracranial volume (skull capacity) indicates that this foramen receives more load than its left counterpart (which showed a significant inverse relationship). Thus it will not be out of place to assert that the right jugular foramen plays greater role than the left jugular foramen in the venous drainage of the cranial cavity and its contents.

CONCLUSION

Though, relationships exist between the intracranial volume and the right and left jugular foraminal volumes; further studies utilizing larger sample size or highly sophisticated techniques (Computed Tomographic Scanning or Magnetic Resonance Imaging) may be needed to clarify these incongruent relationships.

ACKNOWLEDGMENT

The authors wish to thank the Department of Human Anatomy, College of Medicine, University of Ibadan, Nigeria, for their kind support in providing cadaveric bone specimens for the study. Also, we wish to thank the Departmental Chief Technologist, Mr. Adeniyi for his help in sourcing the skulls and providing historic information on the samples. Authors thanks to the management of Maxwell Scientific Organization for financing the manuscript for publication.

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