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A Comparative Study of the Anatomy of the Jugular Foramen and Its Variations in Dried Adult Human Skulls in Sri Lankan Population

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Abstract*—The jugular foramen known to have a wide variation among different ethnicities for its anatomical variations and is also a well known area for pathological lesions such as glomus tumours, Schwannomas etc. The treatment of such lesions often involves drilling the bony area around the jugular foramen. In this study the main intention of the authors are to describe the morphometry and anatomical variations of the jugular foramen and also explain the possible dimensional distinction between the jugular foramen and the jugular fossa. A descriptive study of 27 skulls was done regardless of the gender, to describe the morphometry of jugular foramen and jugular fossa along with scaled photographs. Comparisons between the right and left jugular foramen /Jugular fossa and comparison of jugular foramen and jugular fossa on the same side were done using the student t-test. The jugular foramen was present bilaterally in all the skulls studied. The mean ML diameter of the jugular foramen was larger in the right 12.62 mm than in the left 12 mm, which is compatible with previous studies; the mean AP diameters of jugular foramen were 7.62 mm on the left side and 6.92mm on the right side. It can be concluded from the above data that the jugular foramen is morphometrically different from the jugular fossa at least from the AP diameter ($t<0.05$ bilaterally) and should be considered as two distinct anatomical structures rather than the fossa being considered as part of the jugular foramen. The rest of the variations observed are possibly due to constitutional, racial, gender related or genetic factors which are supported by the data from previously performed studies.*

***Keywords*—** *Jugular foramen, jugular fossa.*

I. INTRODUCTION

The jugular foramen (J.Fr) is a skull opening or a bony channel consisting of a complicated bony architecture which transmits multiple significant neurovascular structures out of the base of the skull to the carotid space. The organization of the foramen is difficult to put into perspective because it varies in size and shape in different skulls, from one side to another side in the same skull, from its intracranial to extra cranial end in the same foramen, because of its complex irregular shape, its curves course, its formation by combining two bones, and the various nerves and venous channels that pass through it. (B.N et al., 2015)

Since the age of 1500 A.D many researchers including Vesalius were very intrigued by the variations in shape and form of the jugular foramen. Vesalius (1543) in his illustrations of the base of skull has mentioned about the compartmentation of the jugular foramen. Multiple studies including osteological, radiological and microdisections were performed to find the compartmentalization and variations in the anatomy of jugular foramen, which led to various conflicting observations. Most of the intracranial and extracranial lesions of posterior cranial fossa may have an effect on the structures in jugular foramen in addition to intrinsic abnormalities. Various Pathologies like meningiomas, paraganglionomas, schwanomas and other inflammatory lesions of inner ear are known to have an effect on the structures in jugular foramen. In radical dissection of neck, Internal jugular vein is ligated which is prone to infarctions and most of the researchers attribute it to the ligation of the dominant internal jugular vein. Since the field of neurosurgery has become bolder in approaching this region, so arises a need of familiarity with this region (Shifan et al., 2013). A well-known fact is the jugular foramen varies in shape and size in accordance to the jugular vein (Weber & Mckenna, 1994). Presence of an enlarged dome of the foramen which accommodates the jugular bulb is also a significant anatomical variation (Hatiboglu & Anil, 1992). In addition to that numerous intrinsic abnormalities, variations of adjacent vascular structures and pathological processes occurring in posterior cranial fossa such as intracranial meningiomas, paragangliomas, schwannomas, metastatic lesions and infiltrative inflammatory processes from the surrounding structures like the middle ear might be contributing to such variations in jugular bony canal (OE, 2019). Surgical resection is considered the main treatment of choice in the majority of the above mentioned cases. Jugular foramen lesions which were once considered inoperable are now being resected with the help of advanced microsurgical techniques (Hussain et al. 2010). As neurosurgeonS become bolder in the process of approaching this region, the need for familiarity with the detailed anatomy of this region becomes greater.

Several studies which were done elsewhere have described variation in size of the foramen, variation of certain compartments such as the antero-medial compartment, bipartite and tripartite divisioning of the foramen, relations and bridging bony tissue in the foramen (Weber & Mckenna, 1994). Only a few similar studies were undertaken in Sri

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Lankan adult skulls with its clinically important anatomical variations in view as it could provide important anatomical variations. It could also provide important information about anatomy of the jugular foramen for reliable neurosurgical interventions in this area.

II. Materials & Methods

The study was conducted in department of Anatomy, Faculty of Medicine – Ragama. 54 jugular foramina from 27 dried adult human skulls of Sri Lankan origin were studied regardless of the male & female sex, age and ethnicity. All skulls used did not have erosions in the measured area. A precisely calibrated, standard manual venire caliper (minimum reading of 0.02mm) and a divide were used for measurements. Scalded photographs were taken.

A. Inclusion Criteria

Skulls with intact base (healthy dried skulls, not eroded, non-fractured)

B. Exclusion Criteria

The skulls that have been eroded and deformed, having any fractures at the base of the skull or any deformed skulls.

C. Osteometric Parameters

Following parameters were studies

1) Side: Right or Left
2) Measurements in jugular foramina (J.Fr)(fig 1 & 3):
   2.1. Maximum anteroposterior diameter of the foramen
   2.2. Maximum mediolateral of the foramen
3) Measurements in jugular fossa (J.Fs)(fig 1&2):
   3.1. Maximum anteroposterior diameter of jugular fossa
   3.2. Maximum mediolateral diameter of jugular fossa

Height: if domed, height is measured from the summit of the dome to the inferior border of the fossa

III. Results

The Morphometric analysis of the study data revealed the following information, which was statistically analyzed and tabulated.

In all the skulls studied the jugular foramen was present bilaterally. On keen observation it was apparent that all jugular foramen were surmounted by an obvious bony roof and complete division of the foramen by bony septae were also not uncommon.

Table of measurements

Maximum AP diameter of the foramen		**Maximum ML diameter of the foramen**		**Maximum AP diameter of the jugular fossa**		**Maximum ML diameter of the jugular fossa**	
R(mm)	L(mm)	right (mm)	left(mm)	R(mm)	L(mm)	R(mm)	L(mm)
6.62	8.00	12.00	10.00	10.00	7.46	12.00	13.02
7.20	7.60	14.00	12.02	9.02	6.02	13.2	14
6.40	8.02	12.00	11.06	9.00	7.24	11.00	12.02
9.00	8.04	14.20	14.00	8.20	6.00	11.02	15
6.44	7.22	14.24	12.00	8.02	7.00	11.24	12.6
6.20	6.42	10.40	12.60	7.40	6.80	10.00	12.4
5.40	6.2	9.60	11.40	6.45	6.60	11.24	11.40
7.00	8.20	14.02	14.00	8.24	7.24	11.60	12.80
6.80	7.48	12.60	11.82	8.20	8.00	12.80	12.40
7.30	7.60	12.42	12.20	8.86	8.04	12.62	12.42
6.48	7.28	13.86	12.40	8.46	8.20	12.48	12.40
6.64	8.04	12.82	11.86	8.40	8.40	11.86	12.00
7.42	8.20	12.80	11.92	9.26	8.63	12.80	12.46
7.66	7.84	13.40	13.00	7.64	7.02	12.80	12.60
7.20	7.80	11.86	11.00	8.26	8.00	12.00	11.80
6.28	6.86	12.86	12.00	9.06	9.00	12.80	12.60
7.10	8.20	13.28	12.86	8.80	8.20	11.62	11.40
6.64	7.48	12.2	11.46	8.40	8.2	12.56	12.20
6.82	7.60	13.84	12.4	8.6	8.04	12.42	12.1
6.24	7.28	13.40	12.40	8.66	8.4	12.36	12.22
7.20	8.04	11.9	11.6	9.42	8.60	11.80	11.6
7.46	8.20	12.02	11.48	8.34	8.12	12.82	12.56
7.12	7.84	12.40	12.0	8.22	8.2	12.9	12.00
7.56	7.80	12.36	11.92	7.56	7.20	12.70	11.60
6.22	6.86	11.80	11.46	9.2	8.88	12.60	11.90
7.66	8.20	11.92	11.20	8.7	7.90	12.00	11.24

1. Jugular Foramen

- With Respect to the Jugular Foramen, Antero posterior diameter (AP) was 6.92(±0.7) mm on the right side and 7.62(±0.55) mm on the left side respectively. The comparison between right and left AP Diameter did not show any statistical significance.
- With respect to the Mediolateral (ML) Diameter, Mediolateral diameter (ML) was 12.62 (±1.12) mm on the right side and 12.00 (±0.86) mm on the left sides respectively. The comparison between right and left ML Diameter did not show any statistical significance

2. Jugular Fossa

- With Respect to the Jugular Fossa, Antero posterior diameter (AP) was 8.47(±0.72) mm on the right side and 7.74(±0.80) mm on the left side respectively. The

comparison between right and left AP Diameter did not show any statistical significance.
- With respect to the Mediolateral (ML) Diameter, Mediolateral diameter (ML) was 12.12(±0.76) mm on the right side and 12.33 (±0.79) mm on the left sides respectively. The comparison between right and left ML Diameter did not show any statistical significance.

3. *Depth of Jugular Fossa*

- These research parameters were in similar range and the mean depth had closer values. The right side being 10.2 mm on the right side and 9.97mm in the left side. There is no statistical significance found between the two.

IV. DISCUSSION

Jugular foramen is located between the petrous portion of the temporal bone and occipital bones, posterior to the carotid canal and it connects the posterior cranial fossa and the jugular fossa. It lies in an oblique position, from the lateral aspect posteriorly towards the medial aspect anteriorly (kenan & Ossama). From inner surface of the skull base outwards, it courses anteriorly, then going laterally and finally inferiorly through the base of the skull. Anteriorly it is separated from the inferior carotid opening by the bony ridge, the carotico jugular spine. The jugular foramen is located lateral to the hypoglossal canal and the two are separated from each other by an osseous bar and it serves as a passage for the glossopharyngeal, vagus and accessory cranial nerves, internal jugular vein, two dural sinuses and the meningeal branches of the occipital and ascending pharyngeal arteries (Shifan et al, 1975; Linn et al, 2009).

- A neural compartment (Pars nervosa), containing the glossopharyngeal nerve;
- A large venous compartment (pars vascularis – sigmoid part), containing the sigmoid sinus
- A smaller venous compartment (pars vascularis – petrosal part), containing inferior petrosal sinus.

The sigmoid and the petrosal parts are anatomically separated by bony processes namely the intrajugular processes, which originate from the opposing surfaces of the temporal and occipital bones, and also by a dural septum, which connects these two bony structures. The smaller pars nervosa is relatively more consistent in size when compared to the larger and more clearly variable pars vascularis. Contrary to what the name suggests not all the cranial nerves pass through the pars nervosa. Only the glossophryngeal nerve goes through the pars nervosa together with the inferior petrosal sinus. The vagus and accessory nerves travel with the jugular vein in the pars vascularis. Within the jugular foramen the glossopharyngeal nerve gives off the glomus bearing tympanic branch called the nerve of Jacobson (Hussain et al., 2010)

However, the jugular foramen is difficult to understand in three dimensional form and even difficult to assess surgically; the difficulties in exposing this foramen is created due to its deep location and the presence of surrounding structures such as carotid artery anteriorly, the facial nerve laterally, hypoglossal nerve medially and vertebral artery inferiorly (Shifan et al., 2013). The size and shape of the jugular foramen is related to the size of internal jugular vein and the presence or absence of a prominent superior jugular bulb. Standard text books suggest that the superior saggital sinus being drained into the right transverse sinus, thus the right foramen is usually larger than the left, but there is a wide variation in the anatomy of the intra cranial venous sinuses which accounts for the variation in size and shape of jugular foramen (Woodhall, 1939). According to Padget (1957), the difference in size of the two internal jugular veins is already visible in the human embryo at the 23mm stage and probably results from the differences in the pattern of development of the right and left brachiocephalic veins.

A study which looked in to these variations by Pereira et al (2010) mentions the mean AP diameter of the jugular foramen to be 9.21 ± 1.95mm and 8.65 ± 1.57mm and ML diameter to be 15.82 ± 2.67mm and 15.86mm ± 2.64mm on right and left sides respectively in Southern Brazilian population. They also mention that the AP diameter on the J.Fr is significantly larger on right side and which may be related to prominent superior bulb of internal jugular vein. In an another study, Idowu (2004) reported that the mean AP diameter to be 10.02mm and 9.57mm and mean ML diameter 13.9mm and 14.11mm on right and left side respectively. Current study gave slightly lesser mean diameters bilaterally AP dimensions, than above studies. Also, in contrast to Pereira et al, AP diameters of left & right did not have a statistically significant difference. However, the ML diameters in current study were bigger than the measures by Idowu (2004) bilaterally and right ML diameter in Pereira et al.; Left side ML diameter of Pereira et al. (2010) is almost equal with current study.

Considering the examined J.Fr, Sturrock (1988) states that the right J.Fr to be larger in 69% of skulls whereas Hatoboglu & Anil (1992) found that 61.6% were larger on the right and 26% were larger on left. The current study observed 75% skulls with larger J.Fr on the right side in the rest it was larger on left.

An unusual slit-like jugular foramen on the left side with antero-posterior and Medio-lateral dimensions of 2.47mm and 7.74mm respectively was reported by Rastogi and Budhiraja (2010). In current study authors observed a slit like foramina in one skull on the left side with AP diameter of 4.6mm and the ML diameter was 19.96mm which is well more than twice the size of the ML diameter than reported by Rastogi and Budhiraja (2010). According to Kawabe et al. (2008), due to narrowing of foramen IX, X and XI cranial nerves may get involved resulting in Vernet's syndrome. It might cause the neurovascular symptoms which can mimic the symptoms of jugular meningiomas or a glomus jugular tumor.

The jugular fossa is the other structure located in close relationship, hence confused due to the same reason, with the Jugular foramen. It is located at the inferior aspect (inferior surface) of the petrous part of the temporal bone as a deep bony depression, the size of which varies from skull to skull. It communicates with the posterior cranial fossa via the jugular foramen. It lodges the jugular bulb which continues into the jugular vein inferiorly. In the neurosurgical literature, and even in extensive anatomic studies, both the jugular foramen and jugular fossa often are referred to by the term ''jugular

foramen.'' This use of the term may be the result of either of simple error or the user's wish to provide a broader anatomic description of the area, and this confusion may be the underlying reason for current lack of agreement regarding the internal anatomic organization of ''the jugular foramen'' as well. Regardless of the reasons of this mix up, the jugular foramen and the jugular fossa are two distinct anatomic formations, although they are intimately related (Kennan & Ossama). No previous studies have been done to assess this fact could be strengthened statistically during the current study as the authors observed that the morphometric dimensions of the J.Fs at least from their AP diameters ($t<0.05$ bilaterally), hence should be considered as two distinct anatomical structures rather than J.Fs as a part of the jugular foramen.

The depth of the jugular fossa was measured and they were almost similar to the values observed by Singla et al., 2012. Although Singla et al. (2012) named this dimensions as 'the depth of the foramina', the author prefers the term 'the depth of jugular fossa'. Regardless of the given name, measurements in current study depicted no statistically significant difference between left and right sides. Most of the fossae had a depth between 5 – 15 mm. Authors also observed a deep tunnel like fossa which measured a depth of 19.62mm on right side, where Singla et al. (2012) mention about a similar fossa of 24.23mm on right side.

The incidence of bilateral domed bony roof in current study was 29.16% which is much lesser than the percentages given by Pereira et al. (2010) who reported bilateral roof in 68.5%; Sturrock (1988) reported the domed roof bilaterally in 53.9% and Singla et al. (2012) observed 66%. But our values were closely related to the study by Patel and single (2007) who found this feature in only 29% of the skulls.

While Sturrock (1998) and Hatiboglu and Anil (1992) had observed that the right side had complete bony septation in 5.6% and 3.2% of the Skulls respectively. Pereira et al. observed the bilateral complete septation in 0.9% of cases. Singla et al. (2012) had commented on the complete bilateral and unilateral septum in 8% and 4% cases respectively.

V. Conclusion

The mean dimensions of the J.Fr were larger in the right side than in the left side and compatible with previous regardless of local variations. J.Fr. is morphometrically different from J.Fs at least from the AP diameter and should be considered as two distinct anatomical structures rather than J.Fs as a section of the J.Fr. The rest of the variations are possibly due to constitutional, racial, sexual or genetic factors and supports previous established data of J.Fr. knowledge of the observed variations is important for neurosurgeons, ENT surgeons, radiologists & Anthropologists.

VI. Recommendations

Considering this research as a pilot trial, there is scope for conducting extensive research with respect to the exact anatomical variations in the spatial organization of the jugular foramina and its anatomical variation with respect to age, gender and ethnicity. Research tools such as CT/MRI can be employed in gathering more precise information which would aid immensely in neurosurgical procedures related to jugular foramen.

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