An Anatomical Study of the Jugular Foramen and Its Variations in Dried Adult Human Skulls in Sri Lanka

R Hasan [1], KA Salvin [2], EDPS Fernando [3], NADP Niwunhella [4], WMS Dilshani [5], WMRD Wijesundara[6], AAMMSL Perera[7]

[1234567]*Department of Anatomy, Faculty of Medicine - Ragama, University of Kelaniya, Sri Lanka*
[1]rizvi2003@gmail.com; [2]salvinka@gmail.com; [3]prasadth_f@hotmail.com; [4]dumind.niwunhella@gmail.com; [5]shashikadilshani@gmail.com; [6]risharawijesundara@yahoo.com, [7]lavindiperera@gmail.com

Abstract— *The jugular foramen has a wide ethnic variation in the anatomy and is a well known area for pathological lesions such as glomus tumours, Schwannomas etc, where such lesions are approached by drilling the bone around the jugular foramen. The authors intended to describe the morphometry and anatomical variations of the jugular foramen and the possible dimensional distinction between the jugular foramen and the jugular fossa. A descriptive study of 24 skulls was done regardless of the gender, to describe the mophometry of jugular foramen and jugular fossa along with scaled photographs. Comparisons between the right & left jugular foramen/ jugular fossa and comparison of jugular foramen & jugular fossa on the same side were done using the student t-test. We found that the jugular foramen was present bilaterally in all the skulls studied. The mean ML diameter of the jugular foramen was larger in the right 16.02(±2.46) mm than in the left 15.46(±2.68) mm, which is compatible with previous studies; the mean AP diameters of jugular foramen were 8.28(±1.70) mm on left side and 6.84(±1.76) mm on right side. Therefore the jugular foramen is mophometrically different from jugular fossa at least from the AP diameter (t<0.05 bilaterally) and should be considered as two distinct anatomical structures rather than fossa as a section of foramen. The rest of the variations are possibly due to constitutional, racial, gender related or genetic factors and supports previous established data on Jugular foramen.*

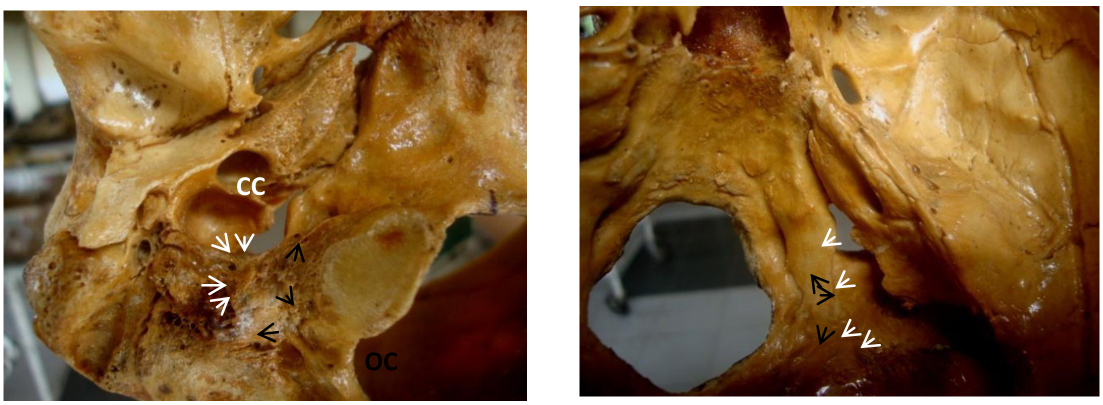
Keywords— Jugular foramen, Jugular fossa, septatio*n*

I. INTRODUCTION

The jugular foramen (J.Fr) is a fascinating skull opening or a bony channel consisting of a complex bony architecture which transmits many important neurovascular structures out of the base of the skull to the carotid space. The organization of the foramen is difficult to conceptualize because it varies in size and shape in different crania, from side to side in the same cranium, from its intracranial to extra cranial end in the same foramen, because of its complex irregular shape, its curved course, its formation by two bones, and the numerous nerves and venous channels that pass through it. (Hussain et al, 2010)

Since 1500 A.D many researchers including Versalius were intrigued by the variations in shape and for the jugular foramen. Versalius (1543) in his illustrations of base of skull has mentioned compartmentation of jugular foramen. Several studies including osteological, radiological and microdisections were performed to solve the mystery of compartmentation and variations in the anatomy of jugular foramen, which led to conflicting observations (Shifan et al, 2013). Among these variations, it is well known that the jugular foramen varies considerably in size and shape of the jugular vein (Weber & Mckenna, 1994). An enlarged dome of the foramen forming the accommodation for the jugular bulb is another anatomical variation (Hatiboglu & Anil, 1992). Other than that, various intrinsic abnormalities, multiple 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 surrounding structures such as the middle ear might be contributing to these variations in jugular bony canal (Idowa, 2004). Surgical resection is the treatment of choice in the majority of these cases. Advances in Microsurgical techniques have made possible the removal of advanced jugular foramen lesions which were once assumed to be inoperable (Hussein et al, 2010). As neurosurgeons become bolder in 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 anteromedial compartment and posterolateral compartment, bipartite and tripartite divisioning, relations and bridging bony tissue in the foramen (Weber & Mckenna, 1994). Only a few similar studies were undertaken in Sri Lanka. Therefore the aim of this study was to describe the anatomy of the jugular foramen in Sri Lankan skulls with its clinically important anatomical variations as it could provide important information about the anatomy of the jugular foramen for reliable surgical interventions in this area.



ML diameterof J.Fr

Figure 1. (A) Right side, dry anatomic specimen photograph delineating the jugular foramen (black arrows) and the jugular fossa (white arrows). Outside – Inside view from the anterior perspective. (B) Right side, dry anatomic specimen photograph delineating the jugular foramen (black arrows) and the jugular fossa (white arrows). Inside - Outside view from the posterior perspective. Note the difference between two. (CC- carotid canal; OC – occipital condyle)

II. MATERIALS & METHODS

The study was conducted in the Department of Anatomy, Faculty of Medicine – Ragama. 48 Jugular Foramina from 24 dried adult human skulls of Sri Lankan origin were studied regardless of the male & female sex. 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

Healthy Skulls with intact base ((i.e: Well dried skulls, Non eroded base of the skull from inner and outer surfaces, non fractured base due to any injury)

B. Exclusion criteria

The Skulls that have been eroded and deformed

C. Osteometric parameters

Following parameters were studied:

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
4) Height: If *domed*, height is measured from the summit of the dome to the inferior border of the **fossa** (fig 4)
5) Dome: The bony roof is related to the presence of superior jugular bulb (fig 5)

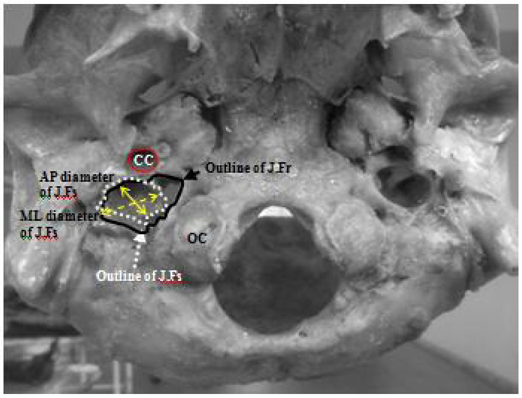


Figure 2. Outlining of J.Fs (dotted white line) and J.Fr (solid fill black line), measurements of jugular fossa: ML diameter (dashed double headed arrow) & AP diameter (Solid fill double headed arrow) OC - occipital condyle, CC - carotid canal

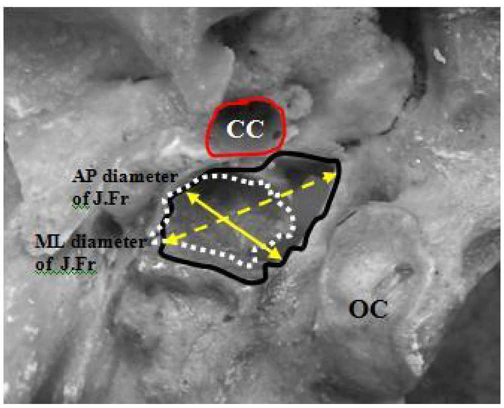


Figure 3. Outlining of J.Fr (dotted white line) and J.Fr (solid fill black line), measurements of jugular foramen: ML diameter (dashed double headed arrow) & AP diameter (Solid fill double headed arrow) OC - occipital condyle, CC - carotid canal

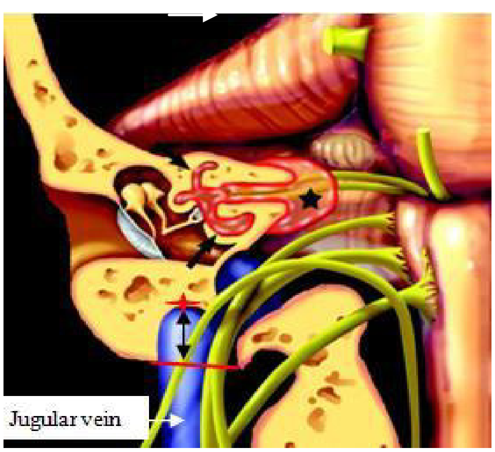


Figure 4. Coronal section through J. Fr. Height of the J.Fs from inferior border of the fossa ( ) to summit of the dome can be measured using the depth measuring stick of the venire calliper and a glass slide can be used to mark the inferior surface of the fossa. The bony roof is related to the presence of superior jugular bulb.

Figure 5. Presence of an obvious dome (black arrow)

6) Septations/bridging: Bony bridges dividing the foramen into compartment

6.1. Presence or absence

6.2. Bipartite/ tripartite form of the jugular foramen

6.3. Complete or incomplete [fig 6 (A, B)]

7) Separate foramina for inferior petrosal sinus: A well defined opening with bony circumference present in the J.Fr. (fig 7)

8) Laterality: from fixed bony demarcations (mid point of anterior margin of the foramen magnum to most medial point of inlet to jugular fossa/ foramen). (fig 8)

III. RESULTS

The mophometric analysis of the current study revealed the following. The data were statistically analysed and tabulated.

The jugular foramen was present bilaterally in all the skulls studied. On examination it became apparent that most of the foramina were surmounted by an obvious bony roof and complete division of the jugular foramen by bony septations were not an uncommon finding.

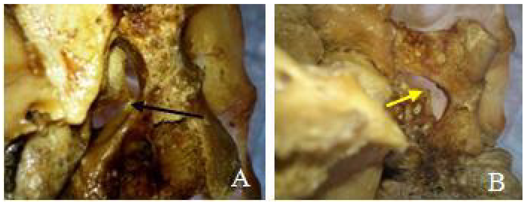


Figure 6. (A) Complete septation in J.Fr (completion of the bony septum is shown by the black arrow); (B) Incomplete bony septation in J.Fr (incomplete bony septum is shown by the yellow arrow)

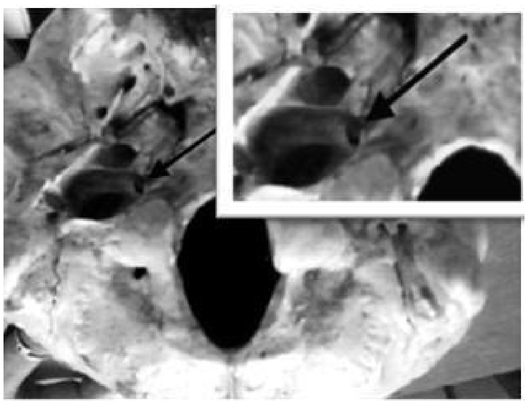


Figure 7. Showing separate foramen for IPS (inferior petrosal sinus)

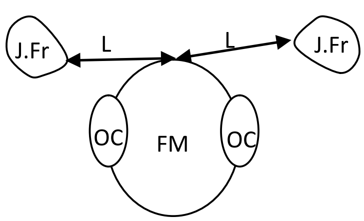


Figure 8. The metric measurement of laterality. (J.Fr- Jugular foramen; OC- Occipital condyle; FM- Foramen magnum; L- Laterality)

A. Jugular foramen

1) Antero posterior (AP) diameter: The mean AP diameters were 8.28(±1.70) mm on left side and 6.84(±1.76) mm on right side respectively. It was found that 67% of total foramina were having AP diameter between 5 and 10mm. A few of them, i.e. 16.5% of them had AP diameters less than 5mm; all of these narrow foramina were belonged to the left side, 16.5% were having AP diameter more than 10mm. However, the comparison between right and left AP diameter did not show any significant difference. A slit like Foramina was observed in one skull on the left side with AP diameter of 4.66mm and the ML diameter was 19.96mm.

2) Mediolateral (ML) diameter: The mean ML diameter was 16.02 (±2.46) mm in right side and 15.46 (±2.68) mm in left sides and no statistically significant difference was observed between the two sides. ML diameters ranged from 10.68mm to 21.18mm and most of the foramina, i.e. 77% were found to have a ML diameter between 13 to 19mm, 15% between 10 to 13mm and 8% were noted to have more than 19mm.

B. Jugular fossa

1) Anteroposterior (AP) diameter: The mean AP diameters were 6.85mm on left side and 8.3mm on right side respectively. The AP diameters ranged from 3.86mm to 16.12mm and 72.5% of total foramina were having AP diameter between 7 and 13mm. A few of them, i.e: 15% of them had AP diameters less than 7mm; all of these narrow foramina were belonged to the left side; the rest of the fossae were having AP diameter more than 13mm. Diameters on left and right did not show significant difference(t>0.05).

2) Mediolateral (ML) diameter: The observed mean values were 11.6mm on the left side and 12.6mm on the right and the diameters ranged 8mm on left and 8.3mm right.

C. Jugular foramen vs. jugular fossa

The AP diameter of the jugular fossa depicted significant difference from AP diameter of the jugular foramen (t<0.05 bilaterally). ML diameters of them did not depict such difference.

D. Height/ depth of jugular fossa

These measurements ranged in a similar manner bilaterally and mean values had closer values, i.e. 11.6mm on left and 11.9mm on right, with no significant difference between them.

E. Dome of the jugular fossa

The prominent dome was noticed bilaterally in 7(29.16%) & unilaterally in 14(58.3%) skulls; out of unilateral prominent dome, 12(86%) were seen in right side.

F. Presence of septa

Usually the jugular foramen is partially divided to three compartments by two marked constrictions. Complete partition is not a common feature (Singla et al, 2012). In the current study, all the observed 48 foramina had at least one septation, either complete or incomplete. Bilateral complete septation of jugular foramen were found in 3 skulls (12.5% of 24 skulls). Another 6 skulls (25 %of 24 skulls) had complete unilateral septation and 84% of them were on the left side. Out of all the jugular foramina, 37 (77%) foramina had either a complete or an incomplete single septa. 10 (21%) foramina were observed to have 2 septae regardless of completeness while 1 foramina showed 3 incomplete septae, dividing the foramina in to 4 incomplete compartments.

G. Separate foramina for inferior petrosal sinus (IPS)

A separate opening for IPS was observed in bilaterally in 3 skulls (12.5%) & unilaterally in 7(29.16%) skulls. Out of the latter category, 5(71%) separate IPS openings were observed on the left side.

H. Laterality

The observed mean laterality in current study were surprisingly, exactly similar up to the second decimal, i.e. 22.69mm on both sides and the values ranged 9.6mm on left and 11.7mm on right.

IV. DISCUSSION

Jugular foramen is located between the petrous portion of temporal bone and occipital bones, posterior to carotid canal and it connects the posterior cranial fossa and the jugular fossa. It lies in an oblique position, from the lateral aspect posteriorly toward the medial aspect anteriorly (Kenan & Ossama). From inner surface of the skull base to outwards, it courses anteriorly then laterally and finally inferiorly through the skull base. Anteriorly it is separated from the inferior carotid opening by a bony ridge, the caroticojugular spine. The jugular foramen is lateral to the hypoglossal canal and the two are separated 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, 2013).
According to Rhoton, the jugular foramen can be divided into 3 compartments (Rhoton et al, 1975; Linn et al, 2009);

1) A neural compartment (pars nervosa), containing the glossopharyngeal nerve;

2) A larger venous compartment (pars vascularis - sigmoid part), containing the sigmoid sinus and;

3) A smaller venous compartment (pars vascularis - petrosal part), containing the inferior petrosal sinus.

The sigmoid and the petrosal parts are separated by bony processes: the intrajugular processes, which originate from the opposing surfaces of the temporal and occipital bones, as well as by a dural septum, which connects these 2 bony structures. The smaller pars nervosa is relatively more consistent in size compared with the larger and more variable pars vascularis. Not all the cranial nerves pass through the pars nervosa as the name suggest. Only the glossopharyngeal 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 three dimensionally and difficult to access surgically; the difficulties in exposing this foramen is created by its deep location and the 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 the internal jugular vein and the presence or absence of a prominent superior jugular bulb. Standard text books suggests that the superior sagittal sinus being drained into the right transverse sinus, thus the right foramen is usually larger than the left, but there is a very wide variation in the anatomy of the intra cranial venous sinuses which accounts for 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 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 15.86±2.64mm on right and left sides respectively in Southern Brazilian population. They also mention that the AP diameter of 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 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 on 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 right and 26% were larger on left. The current study observed 75% skulls with larger J.Fr on the right side and in the rest it was larger on left.

An unusual slit-like J.Fr on the left side with AP and ML 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 4.66mm 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 J.Fr. 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 a 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 (fig 4). In the neurosurgical literature, and even in extensive anatomic studies, both the jugular foramen and the jugular fossa often are referred to by the term "jugular foramen." This use of the term may be the result 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 comparing the dimensions of J.Fr and J.Fs. However, this fact could be strengthened statistically during the current study as the authors observed that the mophometric dimensions of J.Fr was significantly different than the 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 J.Fr.

The depth of the J.Fs was measured as given in fig 4 and they were almost similar to the values observed by Singla et al, 2012. Although Singla et al (2012) has named this dimension as 'the depth of the foramina', the author prefers the term 'the depth of jugular fossa' for this measurement as it includes the dome which makes up the J.Fs. However, 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 – 15mm (82%of fossae with obvious domes). Authors also observed a deep tunnel like fossa which measured a depth of 19.62mm on right side, where as Singla et al (2012) mentions 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 Singel (2007) who found this feature in only 29% of the skulls.

Vlajkovic et al (2010) observed bipartite form of J.Fr domination and had 24% of skulls out of 50 skulls with complete bridging. Meanwhile Sturrock (1988) and Hatiboglu and Anil (1992) observed right side complete bony septation in 5.6% and 3.2% skulls respectively. Pereira et al observed the bilateral complete septation in 0.9% of cases. Singla et al (2012) observed complete bilateral and unilateral septum in 8% and 4% cases respectively. The current study gave different values than all of the above studies, observing complete bilateral and unilateral septations of 12.5% and 25% respectively.

V. CONCLUSION

The mean dimensions of the J.Fr were larger in the right side than in the left side and is compatible with previous regardless of local variations. J.Fr is mophometrically 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 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 seems to be more room for further systematic studies in Sri Lanka to verify the spatial organization of the Jugular foramina and its internal anatomical variations precisely, using imaging techniques including high resolution CT/ MR angiography with the purpose of providing reliable anatomical information, to understand precise anatomical variations which will be important in neurosurgery and to add literature regarding the foramina in Sri Lankan population.

ACKNOWLEDGMENT

The authors thank Mr. Pantalin Perera for supplying us with well preserved skulls during the study.

REFERENCES

Hatiboglu MT, Anil A. Structural variations in the jugular foramen in human skull. J Anat. Feb 1992;180 (pt1):191-196

Hussain Saheb S, Mavishetter G F, Thomas S T, Prasanna L C, Muralidhar P. A Morphometric study of the jugular foramen in human adult skulls of south India. J Biomed Sci and Res., Vol 2 (4), 2010,240-243.

Idowu OE. The jugular foramen- a morphometric study. Folia Morphol 2004;63:419-22.

Kawabe K, Sekine T, Murata K, Sato R, Aoyagi J, Kawase Y, et al. A case report of vernet syndrome with varicella zoster virus infection. J Neurol Sci 2008;270:209-10.

Kenan IA, Ossama AM. Jugular fossa lesions <Jugular fossa lesions pdf, google> (sited on 20.05.2014).

Linn J, Peters F, Moriggl B, Naidich TP, Bruckmann H, Yousry I. AJNR Am J Neuroradiol. Jan 2009;30:34–41.

Padget DH. The development of cranial venous system in man, from the view point of comparative anatomy. Acontributions to Embryology 1957;36:79-140.

Patel MM, Singel TC. Variations in the structure of the jugular foramen of the human skull in Saurashtra region. J Anat Soc India 2007;56(2): 34-37.

Pereira GAM, Lopes PTC, Santos AMPV, Krebs WD. Morphometric aspects of the jugular foramen in dry skulls in adult individuals in Southern Brazil. J Morphol Sci 2010;27(1):3-5

Rastogi R, Budhiraja V. Slit like J.Fr due to abnormal bone growth at J.Fs-a case report. IJAV 2010;3:74-75.

Rhoton AL, Buza R. Microsurgical anatomy of the jugular foramen. J Neurosurg 1975;42:541–550. [7].

Shifan Khanday, Ramesh Kumar Subramanian, Melani Rajendran, Ashfaq Ul Hassan, Sajad Hamid Khan**.** Morphological and morphometric study of jugular foramen In south Indian population. International Journal of Anatomy and Research, Int J Anat Res 2013, Vol 1(3):122-27. ISSN 2321- 4287

Singla A, Sahni D, Aggarwal A, Gupta T, Kaur H. Mophometric study of the jugular foramen in Northwest Indian population. J pg medicine, 2012;46(4):165-175.

Sturrock RR. Variations in the structure of the jugular foramen of the human skull. J Anat. 1988 Oct; 160:227-30.

Vlajkovic S, Vasovic L,Stankovic S, Popovic J, Chkuranovic R. Human bony jugular foramen: Some additional morphological and mophometric features. Med Sci Monit. 2010 May; 16(5):BR140-6

Weber AL, McKenna MJ. Radiologic evaluation of the jugular foramen. Anatomy, vascular varients, anomalies and tumors. Neuroimaging Clin N Am 1004 Aug;4(3):579-96.

Woodhall B, Anatomy of the cranial blood sinuses with particular reference to the lateral. Laryngoscope. 1939;49: 966-1010

BIOGRAPHY OF AUTHORS

[1]Dr. Rizvi Hasan, Senior Lecturer, MBBS, PhD; [2] Dr. K A Salvin, Senior Lecturer, MBBS, MD, FRCS; Senior Lecturer, [3]Dr. E D P S Fernando, Senior Lecturer, MBBS, DFM, MPhil, MRCGP: [1,2,3] Department of Anatomy, Faculty of Medicine, Ragama.

[4]N A D P Niwunhella, [5]W M S Dilshani, [6]WMRD Wijesundara, [7]A A M M S L Perera, [4,5,6,7]Research assistant - Department of Anatomy, Faculty of Medicine – Ragama.