ORIGINAL RESEARCH

Topographic and Morphometric analysis of Foramen Spinosum in dry human skulls and its clinical implications

[1]Dr Pallavi Sharma,[2]Dr Srikant Pandey, [3]Dr Subodh Kumar, [4]Dr Rashmi Prasad

[1]Tutor, Department of Anatomy, Nalanda Medical College, Patna, Bihar, India
[2]Senior Resident, Department of Paediatrics, Nalanda Medical College & Hospital, Patna, Bihar, India
[3]Associate Professor, Department of Anatomy, Nalanda Medical College, Patna, Bihar, India.
[4]Professor and HOD, Department of Anatomy, Nalanda Medical College, Patna, Bihar, India.

Corresponding Author
Dr. Srikant Pandey
Senior Resident, Department of Paediatrics, Nalanda Medical College & Hospital, Patna, Bihar, India

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ABSTRACT

Background& Objectives: Foramen spinosum (FS) is located in base of skull in greater wing of sphenoid bone as part of middle cranial fossa and transmits the middle meningeal artery and meningeal branch of the mandibular nerve. FS serves as an easily recognizable landmark of great importance to neurosurgeons and radiologists. Complexity of FS anatomy and its neurovascular content can hinder many surgical procedures involving the middle cranial fossa. Thus, a more detailed understanding of the anatomy of the FS is of great interest in medical field, especially in neurosurgery, head & neck surgery and otolaryngology. **Methods:** The present study was conducted at Anatomy department of our medical college over three years from January 2019 to December 2022 on skulls of known sex and age with no apparent gross pathology, deformity, or traumatic lesions. Number, shape, morphological variations and dimensions of foramen spinosum in relation to different clinically important anatomical landmarks of Indian skull were studied on both sides of the skull. **Result:** Over the 3-year study period, 26 dry human skulls or 52 sides (right + left) were studied in detail. Estimated age of these skulls ranged between 40-60 years. Of these, 15 (57.7%) were of male sex and the rest 11 (42.3%) were of female sex. The FS was smaller than the foramen ovale and round shape was the most common (44.2%) followed by oval (32.7%). Mean antero-posterior diameter was 3.49 mm and 3.68 mm on right and left sides respectively. Mean FS transverse diameter was 3.04 mm on right and 3.12 mm on left side respectively. There was no statistically significant difference in AP and TD of FS between right and left sides. Mean distance between FO and FS was 3.04 ± 1.41 mm on right side and 3.19 ± 1.38 mm on left side respectively. There was some variation in FS diameter, length and FS–FO distance on right and left sides and the differences were more evident in females. However, this variation was not statistically significant. **Conclusion:** FS exhibits important anatomical variations in terms of its shape, diameter, and topography in relation to adjacent bone structures. Proper knowledge is important for better identification and preservation of neurovascular structures during surgical procedures involving the middle cranial fossa of the skul.

Key words: Anatomical variation, Foramen spinosum, Middle cranial fossa, Skull base, Sphenoid bone.

INTRODUCTION

Foramen spinosum (FS) was first described by Jakob Benignus Winslow in 18th century who called it ‘foramen spinosum’ due to its proximity to spine of sphenoid bone. It is located in base of skull in greater wing of sphenoid bone as part of middle cranial fossa and transmits the middle meningeal artery (MMA) and meningeal branch of the mandibular nerve or the nervous spinous which originates in the sensory portion of the trigeminal nerve. It is also a pathway for cerebral venous system as middle meningeal vein traverses through it and connects cavernous sinus with the pterygoid venous plexus. The greater wing of the human sphenoid bone harbours several foramina of anatomical importance that accommodate several vessels and nerves.[1] The FS is located posterolateral to foramen ovale (FO) and anteromedial to the spine of the sphenoid bone.[2] The FS is about 2–4 mm deep and its average diameter varies between 1.5-3.0 mm.[3]

It can serve as an easily recognizable landmark of great importance to neurosurgeons and radiologists. Recognition of the foramen spinosum with structures that pass through it can help in distinguishing normal and abnormal anatomy during computed tomography or magnetic resonance imaging.[4] Vasodilation of the MMA and other

intracranial blood vessels has been implicated as a trigger of migrainous headaches. Therefore, it is prudent to have knowledge of anatomical variations associated with the morphology of the FS. Skull base fractures, epidural hematomas, pterygoid canal nerve surgery, and endovascular interventions of the internal maxillary artery are other clinical scenarios where success of the intervention is dependent on having a good idea of topography of the MMA. Anatomical knowledge of the FS and MMA is also important in cases where there is a possibility of creating a bypass from the MMA to the petrous portion of the internal carotid artery for the treatment of patients with high-flow cervical vascular lesions and infratemporal fossa tumors.[5] Differences in normal anatomy of the foramen spinosum, such as duplication and absence, are occasionally detected.[6] Its lack is commonly associated with the meningeal artery's atypical origin from the ophthalmic artery rather than from the maxillary artery.[7] This unusual origin of the middle meningeal artery is consistent with foramen spinosum (FS) agenesis.

To summarise, complexity of FS anatomy and its neurovascular content can hinder many surgical procedures involving the middle cranial fossa. Thus, a more detailed understanding of the anatomy of the FS is of great interest in the medical field, especially in neurosurgery, head and neck surgery and otolaryngology. Furthermore, such knowledge can contribute to the diagnosis of skull base traumas, epidural hematomas, and tumours. Despite such clinical relevance, data on dimensions and relative position of FS in Indian skull is scarce. Based on this background, the present study was conducted to study anatomical and morphometric analysis of foramen spinosum, including its anatomical variants in Indian skulls at a tertiary care level institute.

Aim and Objectives

To study number, shape, morphological variations and dimensions of foramen spinosum in relation to different clinically important anatomical landmarks of Indian skull.

MATERIALS AND METHODS

Study duration: three years from January 2019 to December 2022

Study setting: deptt of Anatomy of Nalanda Medical College, Patna, Bihar, India.

Study design: institution based descriptive study.

Study technique: Skulls of known sex and approximate age from Anatomy and Forensic Medicine department formed the study group. Only those skulls with no apparent gross pathology, deformity, or traumatic lesions were included in this study. Skulls with damage in the skull base and those of less than 18 years of age were excluded. Relevant parameters were measured in sagittal and transverse planes after stabilising the skull in Frankfurt horizontal plane. Antero-posterior diameter / Maximum diameter / (Length) or "L" & perpendicular to
this, transverse diameter / Minimum diameter / (width) or "W"/Breadth or "B" of the foramina
spinosum of the foramina spinosum of both sides were determined using Digital Vernier callipers with a precision of 0.1 mm. Each dimension was measured thrice and the mean figure recorded. The data collected was checked for errors prior to analysis. 4. Analysis of FS in relation to the foramen ovale (FO), spine of the sphenoid bone, the midpoint of the skull, and the pharyngeal tubercle was also done.

Statistical analysis: Information so collected was tabulated and entered in Microsoft excel sheet and further analysed by SPSS ver.20® software for Windows. Variables were expressed as mean, standard deviation, percentages, proportions or percentiles as appropriate. Pearson's chi-square test was used for comparison of categorical parameters and independent samples' t test for continuous parameters. P-value <0.05 was taken as significant.

RESULT

Over the 2-year study period, 26 dry human skulls or 52 sides (right + left) were studied in detail. Estimated age of these skulls ranged between 40-60 years. Of these, 15 (57.7%) were of male sex and the rest 11 (42.3%) were of female sex. Atleast a single FS was present on both sides in all these skulls. In one out of these 26 examined skulls (3.84%) and 1/52 sides (1.92%), the FS was duplicated. In one skull (3.84%) and 2/52 sides (3.84%), the confluence of FO and FS was noted. In all skulls except one, the FS was located in greater wing of the sphenoid in the middle fossa of the skull base, anteromedial to the mandibular fossa of the temporal bone and posterolateral to the FO, with the FS being completely separated from the FO. In one skull, the FS was located on on lateral lamina of the pterygoid process of the sphenoid bone, which was closer to the transition of the petrotympanic and petrosquamous sutures. An analysis of the morphology of the FS revealed four different shapes: round, oval, pinhole, and irregular. The FS was smaller than the FO, and round shape was the most common (44.2%) followed by oval (32.7%) as shown in table 1 below. An anatomical variation observed in one skull was the presence of the sphenoidal spine medial to the FS, whereas lateral position was the commonest and observed in most of the skulls. Symmetry of the right and left FS in relation to the median plane of the skull and pharyngeal tubercle was observed in all samples in the present study.

Table 1: Shape of FS on both sides of skull

Shape	On right side (n=26) (Number, Percentage)	On left side (n=26) (Number, Percentage)	Total (n=52) (Number, percentage)
Round	12, 46.2%	11, 42.3%	23, 44.2%
Oval	8, 30.8%	9, 34.6%	17, 32.7%
Pinhole	4, 15.4%	4, 15.4%	8, 15.4%
Irregular	2, 7.7%	2, 7.7%	4, 7.7%

Mean AP diameter was 3.49 mm and 3.68 mm on right and left sides respectively. Mean FS TD was 3.04 mm on right and 3.12 mm on left side respectively. There was no statistically significant difference in AP and TD of FS between right and left side. Mean distance between FO and FS was 3.04 ± 1.41 mm on right side and 3.19 ± 1.38 mm on left side respectively. There was some variation in FS diameter, length and FS–FO distance on right and left sides and the differences were more evident in females. However, this variation was not statistically significant. In the skulls of female skeletons, the diameter of the FS ranged from 1.76 to 4.42 mm (with a mean of 3.47 mm on the right side and 3.54 mm on the left side). Length of the FS ranged from 5.92 to 13.65 mm (with a mean of 7.59 mm on the right side and 8.61 mm on the left side). The FS–FO distance ranged from 1.29 to 5.08 mm (with a mean of 2.95 mm on the right side and 3.06 mm on the left side). The maximum value of all measurements was found on the left side. In male skulls, diameter of the FS ranged from 1.88 to 3.78 mm (with a mean of 3.52 mm on the right side and 3.61 mm on the left side). Length of the FS ranged from 6.17 to 13.77 mm (with a mean of 7.62 mm on the right side and 8.74 mm on the left side). In contrast to female skulls, higher values of the measurements were not consistently observed on the left side. Regarding FS–FO distance in male skulls, the values ranged from 0.93 to 3.64 mm (with a mean of 3.05 mm on the right side and 3.11 mm on the left side). As observed in female skulls, most of the measurements were higher on the left side. There was no statistically significant difference in the distance of FS to the midpoint of the skull base or pharyngeal tubercle between the right and left sides in either gender.

Table 2. Morphometry of FS w.r.t important anatomical landmarks on right side of skull in both sexes

Female	**Minimum**	**Maximum**	**Mean**
Diameter	1.76 mm	3.94 mm	3.47 mm
Length	5.92 mm	10.82 mm	7.59 mm
FS–FO distance	1.29 mm	3.51 mm	2.95 mm
FS–SM distance	8.44 mm	10.88 mm	9.73 mm
FS–PT distance	9.19 mm	12.39 mm	10.81 mm
Male	**Minimum**	**Maximum**	**Mean**
Diameter	1.88 mm	3.42 mm	3.52 mm
Length	6.17 mm	13.77 mm	7.62 mm
FS–FO distance	0.93 mm	3.64 mm	3.05 mm
FS–SM distance	8.60 mm	10.92 mm	9.84 mm
FS–PT distance	9.31 mm	11.93 mm	10.85 mm

(FS: foramen spinosum, FO: foramen ovale, SM: midpoint of skull base, PT: pharyngeal tubercle)

Table 3: Morphometry of FS w.r.t important anatomical landmarks on left side of skull in both sexes

Female	**Minimum**	**Maximum**	**Mean**
Diameter	2.10 mm	3.78 mm	3.61 mm
Length	6.60 mm	13.65 mm	8.74 mm
FS–FO distance	0.69 mm	5.08 mm	3.11 mm
FS–SM distance	8.23 mm	10.96 mm	9.82 mm
FS–PT distance	9.23 mm	12.58 mm	10.97 mm
Male	**Minimum**	**Maximum**	**Mean**
Diameter	1.99 mm	4.43 mm	3.61 mm
Length	6.26 mm	13.88 mm	8.74 mm
FS–FO distance	0.93 mm	5.76 mm	3.11 mm
FS–SM distance	8.14 mm	11.08 mm	9.90 mm
FS–PT distance	8.83 mm	12.66 mm	11.08 mm

(FS: foramen spinosum, FO: foramen ovale, SM: midpoint of skull base, PT: pharyngeal tubercle)

DISCUSSION

Occurrence of anatomical variations in cranial foramina in terms of diameter, symmetry, presence or absence, and unilateral or bilateral presentation is an intriguing phenomenon. This information is essential because of advancements in diagnostic imaging

methods used to assess pathological conditions that affect these foramina and their neurovascular content. In the present study, FS was located in greater wing of the sphenoid bone in majority of the skulls. However, there are reports of the presence of this foramen in the squamous part of the temporal bone or in the sphenosquamosal suture.[8]Atleast a single FS was present on both sides in all these skulls in the present study. Other studies conducted on various populations reported FS absence in 2-8% skulls.[9,10] The absence of the FS can be explained by a difference in the middle meningeal artery's origin and course. In this study, we noted unilateral duplication of FS in single skull which corresponds to the Indian study of Somesh et al.[11] However Naqshi et al have reported a high prevalence of bilateral FS duplication.[12] FS duplication can be related to the early division of the middle meningeal artery or a small bony growth plate that separates the foramen. There is an important relationship between the FS and the spine of the greater wing of the sphenoid, which is usually located posterolateral to this foramen. Such variations can affect the course of the middle meningeal vessels and can cause damage to the auriculotemporal or chorda tympani nerve. In the present study, 98% of the FS were located in this anatomically usual position which is comparable to the findings of Desai et al[13] and Khairnar et al.[14]. In this study, foramen ovale and foramen spinosum overlapped in 3.84% of the skull which is similar to the study conducted by Gupta et al.[15] Various shapes of FS was observed in this study. In the present report, various shapes of the FS were also observed. Round shape (44%) followed by oval (32.7%) were the most common shape of foramen spinosum, which is comparable to the Indian study of Anju et al.[16]

In the present study, mean AP diameter was 3.49 mm and 3.68 mm on right and left sides respectively. Mean FS transverse diameter (TD) was 3.04 mm on right and 3.12 mm on left side respectively. There was no statistically significant difference in AP and TD of FS between right and left sides. These values are somewhat higher than the findings from skulls studied in south Indian and Chinese populations.[17,18] The mean area of foramen spinosum presented in the present report was larger than that reported by Gupta et al.[15] We also investigated the relationship between FS and FO. This information is important for certain surgeries, such as percutaneous trigeminal rhizotomy and percutaneous biopsy of cavernous sinus tumors, because their procedures can cause damage to the neurovascular structures of the FS due to its proximity to the FO.FS is usually located approximately 3 mm posterolateral to the FO. Regarding the FS–FO distances obtained in the present study, differences were observed between women and men, with greater mean distances in the latter. However, this difference was not statistically significant. Similar finding was reported by Rai et al.[19]

In view of the above findings, it is prudent to state that knowledge of complex anatomy of the FS and of surrounding bone and neurovascular structures directly influences clinical, radiological, and surgical interventions that explore the skull base. The FS is thus an important landmark in middle cranial fossa surgeries since surgical approaches are technically more difficult without this knowledge. Furthermore, detailed knowledge of the FS for radiologists is essential for the interpretation of abnormal foramina on radiological images.

CONCLUSION

FS exhibits important anatomical variations in terms of its shape, diameter, and topography in relation to adjacent bone structures. Such knowledge is important for better identification and preservation of neurovascular structures during surgical procedures involving the middle cranial fossa of the skull, and they contribute to the clinical anatomical knowledge of physicians, dentists, and anatomists.

Limitations

First limitation is that our is a single centre study. Second limitation is the small sample size. As skulls are a scarce resource for assessment of foramen spinosum, data collection was constrained by the limited number of skulls. It was also challenging to perform different statistical tests because of the limited sample size. Thus, our data cannot be extrapolated to the general population.

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Conflict of interest: None to declare.

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