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Original Article

Anatomic variations of foramen ovale

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Abstract
Objectives: Foramen ovale is of great surgical and diagnostic importance in procedures like percutaneous trigeminal rhizotomy for trigeminal neuralgia, transfacial fine needle aspiration technique in perineural spread of tumour and electroencephalographic analysis for seizure. This study presents the anatomic variations in dimensions, appearance and number of foramen ovale. **Methods:** We studied 35 dried human skulls available in the Department of Anatomy, Manipal college of Medical Sciences, Pokhara, Nepal. Variations in appearance and number of foramen ovale were noted. Length and width of foramen ovale was measured. Comparison with other races and differences between right and left sides were also discussed. **Results:** Out of 70 sides in 35 adult skulls, mean length and width of foramen ovale was 7.46±1.41 mm and 3.21±1.02 mm on right side and 7.01±1.41 mm and 3.29±0.85 mm on left side. Shape of foramen ovale was typically oval in 43, (22 on right, 21 on left) almond shape in 24 (Fig.1, arrowhead; 11 right, 13 left), round in 2(1 right, 1 left) and slit-like in 1(Fig.1, arrow). Bilateral oval foramen was observed in 15 and bilateral almond was in 7. Out of 70 sides in 35 adult skulls 3 (2 left, 1 right) sides had spine on the margin of the foramen (Fig.2, arrow), 3 (2 left, 1 right) had tubercle protruding from the margin (Fig. 3, arrow), 2 (1 left, 1 right) sides had bridge like bony spur dividing the foramen into two compartments(Fig. 2, arrowhead), 9 (5 left, 4 right) had bony plate on the margin of foramen ovale (Fig. 4, arrow). Variant foramen ovale was observed in 24.2%. **Conclusion:** Anatomical variations in size and shape of foramen ovale could be explained by developmental reasons. Considering the immense surgical and diagnostic importance of foramen ovale, this study was worthwhile.

Key Words: Foramen ovale, skull, anatomical variation, tubercle, spine

The superior or cerebral surface of each greater wing of sphenoid bone forms part of the middle cranial fossa of the skull. In the posterior part of the greater wing is the foramen ovale, for the transmission of the mandibular nerve, the accessory meningeal artery, lesser petrosal nerve and an emissary vein. Foramen ovale opens into the infratemporal fossa through its other opening on the lateral surface of greater wing[1].

The venous segment of the foramen ovale may be separated from the remainder of the contents of the foramen by a bony spur; thus resulting in a so-called doubled foramen ovale. Such spurs are located anteriorly and medially according to Radiojevitc and Jovanovic cited by Lang[2]. They are present in 2.8% of subjects studied.

Developmental study in Japan showed an average maximal length of foramen ovale to be 7.48 mm and average minimal length to be 4.17 mm and difference between right and left side was not observed[3]. A German study showed length to be 7.2 mm and width to be 3.7 mm in adult skull[4]. Fluoroscopically-assisted laser targeting of the foramen ovale showed 6.9 mm on right side and 6.8 mm on left side. Average width on right side was 3.4 mm on right side and 3.8 mm on left side[5].

Anatomical variations in appearance and number of foramen ovale, is of great surgical importance. However, wide review of literature shows only very few studies on the anatomical variations of foramen ovale. So to establish some preliminary data on the dimensions and anatomical variation of foramen ovale we conducted the present study.

Material and methods

35 dried adult human skulls were studied. Out of these 35, 22 were of male sex and 13 were of female. These skulls were obtained from preserved sets of bones received at Department of Anatomy, Manipal

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College of Medical Sciences, Pokhara, Nepal. The posterior part of greater wing of sphenoid was carefully examined for existence of an oval aperture or foramina and foramen ovale was identified. Patency was confirmed by inserting a bristle through each. Skulls in poor conditions or skulls with partly damaged surroundings of the foramen ovale were not considered. Maximum length and width of foramen ovale was measured. Incidence of variation of shape of foramen ovale was evaluated and bony growth around the margins of the foramen was noted. Variation in right and left side and sex difference in length and width was calculated. Statistical analysis was done by using student's t test.

Results

Present study was conducted on a total of 70 sides in 35 dry adult skulls. Mean length of foramen ovale was 7.46±1.41 mm on right side 7.01±1.41 mm on left side (Table-1A). Mean length of foramen ovale in male was 7.27±1.39 mm. and in female was 7.16±1.51 mm (Table-1B). Maximum and minimum length observed was 10.2 mm, 5.1 mm and 10.4 mm, 4.9 mm on right and left sides respectively (Table-1A). Maximum length in male was in 10.4 mm. and in female was 10.2mm.and minimum length was 5mm. in male and 4.9mm. in female skulls (Table-1B). Difference between the length of right and left side and the two sexes was not statistically significant (p>0.05).

Maximum width of foramen ovale was 5.0 mm on both right and left sides (Table-1A).Maximum width in 5 mm. in both sexes (Table-1B). Minimum width was 1.0 mm on right side and 2.2 mm on left side (Table-1A).Minimum width in male was 1 mm. and 2 mm. in females (Table-1B). Mean width on right side was 3.21±1.02 mm and 3.29±0.85 mm on left side (Table-1A). Mean width in male was 3.33±0.84 mm. and 3.13±1.15 mm in females (Table-1B). Difference between the width of right and left side (p >0.05) and between male and female was not statistically significant (p>0.05)

Shape of foramen ovale was also observed. Foramen ovale was typically oval in 43 sides (table-2, 22 right, 21 left), almond in 24 sides (Fig.1, arrowhead;table-2;11 right, 13 left), round in 2 sides (Table-2;1 right, 1 left) and slit like in 1 (Fig.1 arrow; Table-2; right side). Bilateral oval foramen was observed in 15 sides (68.1% right; 71.4% left of total oval shaped foramina) & bilateral almond was observed in 7 sides (63.6% right; 53.8% left of total almond shaped foramina). Incidence of oval, almond, round and slit like foramen were 61.4%, 34.3%, 2.9%, 1.4% respectively.

In 3 (2 left, 1 right) cases out of 70 had spine on the margin of foramen (Fig. 2, arrow), 3 (2 left, 1 right) had tubercle protruding from margin (Fig. 3, arrow). 2 cases (1 left, 1 right) had bridge like bony spur dividing the foramen into two compartments, a larger medial and smaller lateral both unilaterally (Fig. 2, arrowhead). In 9 (4 right, 5 left) cases bony plate protruding from margin of the foramen ovale was seen (Fig. 4, arrow). 7 out of 8 cases of foramen associated with either spine, tubercle, spur were seen in oval shaped foramen.

Table 1A: Dimensions of foramen ovale in right and left side

Values	Length(Right)	Length(Left)	Width(Right)	Width(Left)
Maximum	10.2	10.4	5.0	5.0
Minimum	5.1	4.9	1.0	2.2
Mean	7.46	7.01	3.21	3.29
Standard Deviation	1.41	1.41	1.02	0.85
P value	>0.05		>0.05	

Table 1B: Dimensions of foramen ovale in male and female

Values	Length(Male)	Length(Female)	Width(Male)	Width(Female)
Maximum	10.4	10.2	5	5
Minimum	5	4.9	1	2
Mean	7.27	7.16	3.33	3.13
Standard Deviation	1.39	1.51	0.84	1.15
P value	>0.05		>0.05	

Table 2: Variations in appearance of foramen ovale

Shape	Right (n=35)	Left(n=35)	Total(n=70)
Oval	22(62.8%)	21(60%)	43(61.4%)
Almond	11(31.4%)	13(37.1%)	24(34.2%)
Round	1(2.8%)	1(2.8%)	2(2.8%)
Slit	1(2.8%)	0	1(1.4%)

Fig 1. Right foramen ovale shows presence of raised leading to a slit-like foramen ovale (arrow). Left foramen is almond-shaped (arrowhead).

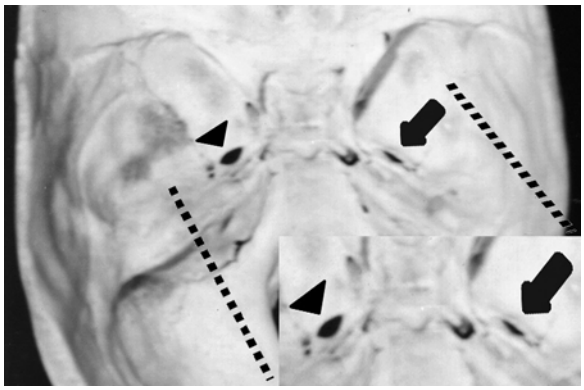


Fig. 2 Right foramen ovale shows presence of spine (arrow) on the anterior margin of foramen ovale. Right foramen ovale shows a bridge like bony spur dividing the foramen into a smaller medial part (arrowhead) and a larger lateral part.

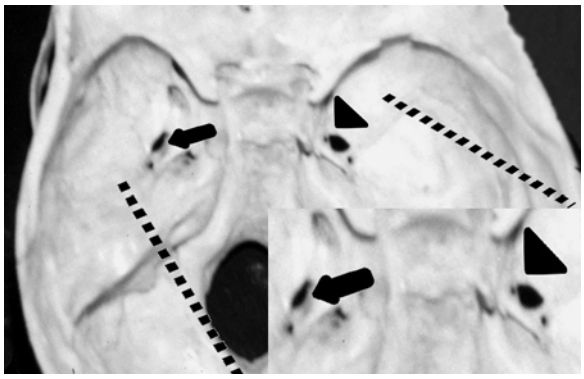


Fig.3 Left foramen ovale shows presence of tubercle (arrow) on the left margin foramen ovale

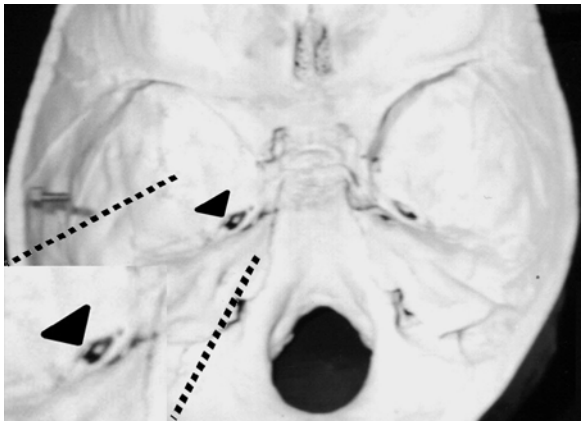
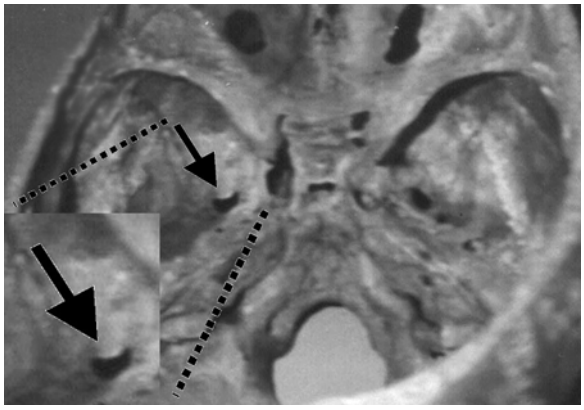


Fig. 4 Right foramen ovale shows presence of bony plate (arrow) on the anterior margin of foramen ovale (arrow).



Discussion

Foramen ovale is one of the important foramina situated at the transition zone between intracranial and extracranial structures. Therefore, it is used for various invasive surgical as well as diagnostic procedures. Electroencephalographic analysis of seizure by electrode placed at foramen ovale is done. FO electrode technique provided good neurophysiological information in candidates for selective amygdalohippocampectomy[6]. Therefore knowledge of the exact topography and morphometry of the FO electrodes is required for a more precise anatomo-electro-clinical correlation of seizures. Knowing the anatomic variations of FO is important because surgical treatment of trigeminal neuralgia is most commonly accomplished by microvascular decompressioner by percutaneous trigeminal rhizotomy done through FO[7,8]. In a study conducted in India, forty patients of trigeminal neuralgia were treated with percutaneous trigeminal ganglion balloon compression. In all patients except one, the needle could be introduced easily. The only exception was the patient with foramen ovale stenosis, in whom, the needle just fitted in the foramen[9]. Moreover, the accuracy of percutaneous biopsy of cavernous sinus tumours through the foramen ovale is 84%[10] and it is important before making any decision to indicate open surgical, radiosurgical or radiotherapeutic treatment. Nasopharyngeal carcinoma (NPC) frequently spreads intracranially and most common route of spread is through the foramen ovale (34%) was reported by Chong VF in 1996[11]. The technique of CT-guided transfacial fine needle aspiration technique through FO to diagnose squamous cell carcinoma, meningioma, Meckel cave's lesions allows biopsy of deep lesions that would otherwise require open surgical biopsy or craniotomy[12,13]. This results in decreased patient morbidity and significant cost reduction.

In the present study mean length of FO was7.46+\-1.41mm on right side and 7.01+\-1.41mm on left side. Though right foramen ovale was longer than left but no significant difference was observed between the two sides $p>0.05$ .In a developmental study conducted in Japan an average maximal length of foramen ovale was7.48 mm and average minimal length was 4.17mm and difference between right and left side was not observed which is similar to present study[3]. A German study showed length to be 7.2mm[4] and a fluoroscopically-assisted laser targeting of the FO conducted in New York showed length to be less compared to present study. They reported 6.9mm on right side and 6.8mm on left side with range length - 5.0_10.0mm; left, 6.0_9.0mm; right[5].

According to present study maximum width of foramen ovale was 5.0mm on both right and left sides while minimum width was 1.0mm on right side and 2.2mm on left side. Mean width on right side was 3.21+\-1.02mm and 3.29+/-0.85mm on left side. Difference between the width of right and left side was not statistically significant ($p > 0.05$). Similar findings were observed by a German study where average width was 3.7mm in adult skull[4]. Average width on right side was 3.4mm and 3.8mm on left side was reported in a study conducted by fluoroscopically- assisted laser targeting of foramen ovale in New York.

In the present study difference between the length and width of foramen ovale in male and female sex was not statistically significant ($p>0.05$). Similar was the observation by Yanagi[3].

Variations in the shape of foramen ovale showed maximum number of foramen to be ovale shaped; 61.4% followed by almond shaped, round and slit like incidence of which were 34.3%, 2.9%, and 1.4% respectively. Similar findings were observed in developmental studies conducted in Japan They reported majority of the foramen ovale to be ovale shaped and observed that they ware irregular in shape compared with the other foramen in human spheroid bone[3].

Variation in the dimension and shape of foramen ovale can be explained by developmental reasons. Foramen ovale is situated at the posterior border of greater wing of sphenoid. The sphenoid bone consists of the body (formed by the presphenoid and postsphenoid centres, with a contribution from the medial crus of the orbitosphenoid), the paired lesser wings (orbitosphenoids), and the greater wings (alisphenoids). Postsphenoids is the part with which are associated the greater wings and pterygoid processes. The first ossific nuclei to appear are those for the great wings (ali-sphenoids). One makes its appearance in each wing between the foramen rotundum, ovale and spinosum. At 22 weeks 3 days the foramen ovale and spinosum are seen as discrete openings and are contained in an area of unossified cartilage[14]. Ossification takes place around the large trunk of mandibular nerve and other structures passing through the foramen ovale in later life. Foramen ovale of man is enclosed by membrane bone, derived from a medial process associated with the scaphoid fossa[15]. The earliest perfect ring-shaped

formation of this foramen is observed in the 7th foetal month and the latest in 3 years after birth[3]. Spine, tubercle, bony plate, spur, leading to double foramen ovale and raised margin, all these variations indicate bony overgrowth during developmental process, between age of its first appearance at eighth week in utero and its perfect ring shaped formation. Various inconstant patterns of grooves and foramina in the vicinity of the foramen ovale can be interpreted as arising from the interplay of various parts of membrane bone and the emissary venous plexus from the middle meningeal veins to the pterygoid plexus[15]. An accessory or ectopic foramen ovale can develop in the process when those inconstant foramina disappear leaving behind foramen ovale as one large oval opening.

Certain earlier workers have reported bony overgrowth also. A bony spur is located anteriorly and medially according to Radiojevitc and Jovanovic (1956) cited by Lang[2]. Spur was present in 2.8% of subjects studied. In the present study 12.8% sides showed such a bony plate protruding from the margin and 4.2% cases showed spine at the margin of foramen ovale. 4.2% had tubercle protruding from margin A slit like foramen ovale was found in 1.4% cases. Perfect oval and almond shaped foramen were found in 61.4% and 34.2% cases.

So from the present study we found 25.7% (18 in 70 sides) of foramina ovale may be variant due to developmental reasons either have a spine, tubercle bony plate or a bridge like spur or a slit like narrow shape which may seriously hamper diagnostic and therapeutic procedures through the foramen ovale.

Conclusion

Variant foramen ovale was found in 24.2% (17 cases-3 spine, 3 tubercle, 2 spur, 9 plates) of cases in the present study. Out of which 16 foramina showed spine, tubercle, bony plate and leading to a slit like foramen ovale signifying over-ossification during developmental process.

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