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ORIGINAL RESEARCH

An anatomical study of foramen ovale with clinical implications on dry adult human skull of north Indian population

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Abstract

Introduction: Foramen ovale which is present in the cranial cavity usually connects infratemporal fossa with the middle cranial fossa. This foramen is clinically quite helpful in several diagnostic and surgical procedures such as FNA through trans-facial approach which is supportive in the diagnosis of squamous cell carcinoma, meningioma and to evaluate the spread of many tumours.

Materials and Methodology: The present study is designed as a cross-sectional study which was undertaken on fully ossified skulls of north Indian population which constituted 75 dry, adult human skulls (39 males & 38 Females) obtained from Department of Anatomy at Index Medical College Hospital and Research centre, Indore, Madhya Pradesh. All the bones should be completely ossified and free from any congenital or pathological defects. Those bones which are deformed or malformed should be excluded from the study. The present study is designed as a cross-sectional study which was undertaken on fully ossified skulls of north Indian population which constituted 75 dry, adult human skulls (39 males & 38 Females) obtained from Department of Anatomy at Index Medical College Hospital and Research centre, Indore, Madhya Pradesh. All the bones should be completely ossified and free from any congenital or pathological defects. Those bones which are deformed or malformed should be excluded from the study.

Results: The bilaterally present foramen ovale was seen in almost all skulls. In this study the shape of the foramen ovale was oval in 56.70% cases while almond shaped in 28.65 % cases, round in 10.97%, irregular in 3.65% cases as tabulated in Table-1. Out of 75 skull the bilateral symmetric shape was seen in 35 skulls (70%) but the asymmetry in size i.e., dimensions in terms of length and width were bilaterally different in 100% of skulls. The 3.65% irregular foramen included one foramen showing confluence with the adjacently present foramen spinosum unilaterally on the left side. One of the skulls showed a confluence of the foramen ovale with the foramen spinosum and foramen lacerum bilaterally. The mean length and width of foramen ovale in male skulls was 7.561±1.123 and 7.640±1.194and 5.244±0.950 and 5.128±0.827 in the female skulls. However, the difference between the dimensions was statistically highly significant in the two sexes. (Table-2).

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Conclusion: To conclude, the shape of the foramen ovale was continuously variable, typically oval in most of the skulls (56.70%) followed by almond shaped. There was no significant difference in measurements of various metric parameters between right and left sides of foramen ovale ($p>0.05$) but highly significant difference was observed between male and female dimensions of all metric parameters. ($p<0.001$). The foramen ovale does not exhibit bilateral symmetry but sexual dimorphism is evident. The observed data might be helpful for surgical practices for references in the near future.

Keywords: foramina, ovale, cranial cavity, middle cranial fossa, neuralgia

Introduction

There are several foramina that are present in base of the skull. Out of which the foramen ovale is one of the most important foramina that is present in the greater wing of sphenoid bone.[1,2] It is usually present medial to foramen spinosum. Normally it connects the infra temporal fossa with the middle cranial fossa.[3] There are certain structures passing through it which are mainly the mandibular division of trigeminal nerve, accessory meningeal artery, lesser petrosal nerve, emissary veins connecting the pterygoid venous plexus in the infra temporal fossa to the cavernous sinus.[4]The foramen lies laterally and ventrally to the direction of the mandibular nerve when it is viewed along its longitudinal axis. And the study of this foramen is of great field of interest to the anatomist, anthropologist, radiologist and clinicians because of the greater impact on clinical and radiographic significance.

The foramen ovale is very helpful for various surgical and diagnostic procedures like fine needle aspiration via trans-facial approach in the diagnosis of squamous cell carcinoma, meningioma and the spread of the tumours.[5,6] It is also helpful for electroencephalographic (EEG) analysis of the patients affected with seizures, rhizotomy for trigeminal neuralgia by percutaneous approach.[7]Whenadministeringanaesthesia via mandibular nerve could also be done after a thorough knowledge of the morphometry obtained about the foramen ovale.[8] The percutaneous biopsy of the cavernous sinus reportedly been done through foramen ovale.[9]The foramen ovale is normally absent in the class reptiles and is theoretically acquired in mammals during the process of continuous evolution. When the mandibular nerve is entangled in the foramen ovale it causes the clinical condition called trigeminal neuralgia. Studies have recently shown that the right-side foramen ovale is usually narrower than the left this may be attributed to the cause that the trigeminal neuralgia usually develops on the right side.[10] The otic ganglion which lies immediately below this foramen in the infratemporal fossa[11]and this foramen serves a way through which the nasopharyngeal carcinoma might spread into the cranial cavity.[12]

Hence this study was conducted to define anatomical variations in foramen ovale which may serve as an important tool in the field of forensic, anthropological and surgical purpose and this study aims to highlight such events briefly.

Materials and methodology

The present study is designed as a cross-sectional study which was undertaken on fully ossified skulls of north Indian population which constituted 75 dry, adult human skulls (39 males & 38 Females) obtained from Department of Anatomy at Index Medical College Hospital and Research centre, Indore, Madhya Pradesh. All the bones should be completely ossified and free from any congenital or pathological defects. Those bones which are deformed or malformed should be excluded from the study.

The observations were measured on both Right & Left sides in each skull. Thus 150 foramen ovale in 75 skulls were researched. The sex of the skull was also taken into account. The Non-Metric parameter studied were a)-Shape of the foramen ovale. The metric parameter studied were a) Length of the foramen ovale (mediolateral) and b) Width of foramen ovale

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(anteroposterior). The two dimensions of the foramen ovale measured were along its long and short axes respectively, measured with a vernier calliper with 0.1 cm precision. The data so revealed was statistically analysed for the morphometry as well as sexual dimorphism.

Results

The bilaterally present foramen ovale was seen in almost all skulls. In this study the shape of the foramen ovale was oval in 56.70% cases while almond shaped in 28.65 % cases, round in 10.97%, irregular in 3.65% cases as tabulated in Table-1. Out of 75 skulls the bilateral symmetric shape was seen in 35 skulls (70%) but the asymmetry in size i.e., dimensions in terms of length and widths were bilaterally different in 100% of skulls. The 3.65% irregular foramen included one foramen showing confluence with the adjacently present foramen spinosum unilaterally on the left side. One of the skulls showed a confluence of the foramen ovale with the foramen spinosum and foramen lacerum bilaterally.

The mean length and width of foramen ovale in male skulls was 7.561±1.123 and 7.640±1.194and 5.244±0.950 and 5.128±0.827 in the female skulls. However, the difference between the dimensions was statistically highly significant in the two sexes. (Table-2)

Table1: Variations in Appearance of Foramen Ovale.

Shape	Right(n=75)	Left(n=75)	Total(n=150)
Oval	43(58.53%)	41(54.87%)	84(56.70%)
Almond	26(29.26%)	21(28.04%)	47(28.65%)
Round	05(9.75%)	12(12.19%)	17(10.97%)
Irregular	03(2.43%)	03(4.87%)	06(3.65%)

Table2: The Foramen Ovale Dimensions

Variables	LTL	RTL	LTB	RTB	LTA	RTA
Mean	8.5	9.640	4.23	5.128	31.310	30.808
SD	1.123	1.294	0.850	0.827	8.262	6.545
Minimum	4.8	5.5	3.0	3.0	18.13	14.13
Maximum	11.0	12.0	7.0	7.8	57.38	54.95
Percentiles	4.745	5.560	4.000	4.000	15.860	17.238

LTL-left length, RTL-right length, LTB-left breadth, RTB-right breadth, LTA-left area, RTA-right area, SD-standard deviation

Table3: Mean, Standard Deviations (SD), tandP-Values for Foramen Ovale Parameters–Side

Parameters	Left Side (n=75) Mean ± SD (mm)	RightSide(n=75) Mean±SD (mm)	t	P
Length(L)inmm	7.561±1.123	7.640±1.194	0.438	0.662
Breadth(B)inmm	5.244±0.950	5.128±0.827	0.833	0.406
Area(A)inmm^2	31.310±8.262	30.808±7.545	0.406	0.685

P≤0.05isconsideredas significant value

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Table4: The Pearson Correlation Coefficient (r) and p-Value of the Continuous Variables

		LTL	LTB	LTA	RTL	RTB	RTA
LTL	rp	-	.301	.730	.610	.359	.574
		-	.006	.000	.000	.002	.000
LTB	rp	.305	-	.865	.225	.405	.382
		.002	-	.000	.030	.001	.000
LTA	rp	.750	.865	-	.462	.455	.556
		.000	.000	-	.001	.001	.000
RTL	R	.610	.217	.402	-	.227	.752
	p	.001	.050	.000	-	.046	.000
RTB	rp	.350	.404	.435	.225	-	.801
		.001	.000	.000	.039	-	.000
RTA	R	.525	.382	.565	.725	.805	-
	p	.000	.000	.000	.001	.000	-

LTL - left length, LTB - left breadth, LTA - left area, RTL - right length, RTB - right breadth, RTA - right area, r – Pearson correlation coefficient; $p \leq 0.05$ is significant.

Discussion

The foramina present in the cranial cavity and their variations in their presence, number, size and location might have been leading to the research towards evolution which are of high clinical significance due to the neurovascular structures that commonly traverse through their narrow confines. Any trauma or space-occupying lesion in this confined area would naturally result in the application of compressive forces on the structures that traverse and related clinical manifestations as a consequence.[13] Therefore; adequate knowledge on the variations in the foramina precisely navigates the clinicians towards a proper positive interpretation of radiographs which helps in performing surgical procedures in the complicated region. *Hauser* and *De Stefano* (1989) further suggested that these cranial variants are the epigenetic factors which occur as a product of the genetically determined growth processes of other tissues likely muscles, vessels and nerves which could affect the physiologic osteosynthesis.[14]

The sphenoid bone ossifies physiologically through intramembranous and endochondral ossification process which can give rise to the basisphenoids (body), orbito sphenoids (lesser wings) and alisphenoids (greater wings). In lower class of mammals, a space is seen between the alisphenoid, the basisphenoid, and the periotic capsule or petrous bone which is known as the primitive foramen lacerum medius. *Shapiro* and *Robinson*(1967) found that in lower mammals, the mandibular nerve is sunken deeply in the foramen lacerum medius.[15]*Wood Jones* (1931) further elaborated that as the mandibular nerve sinks into the greater wing of the sphenoid bone between the internal carotid and stapedial arteries, gradually a groove, then a notch, and ultimately a true foramen ovale develops.[16] This transitional formation of the foramen ovale is clinically demonstrable in lower mammals and may explain some of the variants of this foramen is still observed in humans.[17] Thus, in humans, the foramen ovale develops from primitive foramen lacerum medius and the space persists as the foramen lacerum after formation of the carotid canal medially and the sphenopetrosal fissure posterolaterally. Foramen ovale is seen as a discrete foramen reportedly at around 22 weeks. The perfect ring-shaped formation of the foramen ovale has been reported in the 7th month of intrauterine life, as earliest and at 3 years after birth, the latest.[18]

In the present study, it has also been reported that the foramen ovale was present in all 75 skulls on both sides. In this study the shape of the foramen ovale was oval in 56.70% cases while almond shaped in 28.65 % cases, round in 10.97%, irregular in 3.65% cases as

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tabulated in Table-1. Out of 75 skulls the bilateral symmetric shape was seen in 35 skulls (70%) but the asymmetry in size i.e., dimensions in terms of length and widths were bilaterally different in 100% of skulls. The 3.65% irregular foramen included one foramen showing confluence with the adjacently present foramen spinosum unilaterally on the left side. One skull showed confluence of the foramen ovale with the foramen spinosum and foramen lacerum bilaterally. *Yanagi*, 1987, *Ray* et al (2005), *Sharma* and *Garud* (2011) have also reported variations in shape and size of foramen ovale. They reported Oval and Almond shape were the most common type for the foramen, less frequently might be in the shape of round and longitudinal.[18,19,20]*Wadhwa* et al (2012) in their study on 60 foramen found oval in 42 (70%), round in 6 (10%) and almond shaped in [10] (15%) cases and longitudinal in 3 (%).[21]*Patel* and *Mehta* (2014) in their study on 200 foramen found oval shaped in 119 (59.5%), round in 55 (27.5%) and Almond in 24 (12%) cases and slit like in 2 (%).[22]*John* and *Thenmozhi* (2015) reported 48 (60%) oval, 4 (6%) round, 7 (11.6%) almond shaped and 1 longitudinal / slit like foramen ovale out of 60 studied.[23] D shaped foramen as reported by us was also reported by *Diami* et al(2011) reported oval in 29.87%, D shaped 46.16%, Round 12.52%, Slit like 1.04%, but the incidence reported by them is much higher than us, moreover almond shaped foramen ovale was not found by them. The difference could be because of the ethnic variations.[24]

The mean length and width of foramen ovale in male skulls was 7.561±1.123 and 7.640±1.194and 5.244±0.950 and 5.128±0.827 in the female skulls. There was no significant difference between right and left sides in both sexes. However, the difference between the dimensions was statistically highly significant in the two sexes.(Table 3 and 4) The results are much in concordance with previous studies. In a study by *Ray* et al (2005)[19] the average length and width on the right side was 7.46 ± 1.41mm and 3.21 ± 1.02 mm, respectively, whereas on the left side it was 7.01 ± 1.41mm and 3.29 ± 0.85 mm, respectively. *Berlis* et al (1992)25, *Calcaterra* et al (1973)26. *Lindblom* K (1936)27 *Schelling* 197828, *Yanagi* (1987)18, *Patel* and *Mehta* et al (2014)22, Lang et al (1984)29 have reported the length varying in the range from 6.5 to 11.3 mm and width from 3.6 to 4.7 mm. They too did not observe any significant difference between right and left side in length and width ($p>0.05$).

Conclusion

To conclude, the shape of the foramen ovale was continuously variable, typically oval in most of the skulls (56.70%) followed by almond shaped. There was no significant difference in measurements of various metric parameters between right and left sides of foramen ovale ($p>0.05$) but highly significant difference was observed between male and female dimensions of all metric parameters. ($p<0.001$). The foramen ovale does not exhibit bilateral symmetry but sexual dimorphism is evident. The observed data might be helpful for surgical practices for references in the near future.

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