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Original Article

Morphological study of fossa ovalis and its clinical relevance

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ABSTRACT

Aims: Patent foramen ovale (PFO) has been implicated in the etiology of a number of different pathologies, including cryptogenic stroke, decompression sickness in divers, etc. It can act as a channel for paradoxical embolism. PFO is not an uncommon condition, with a probe-patency in 15–35% population.

The fossa ovalis (FOv) varies in size and shape from heart to heart; the prominence of annulus FOv also varies. The entire FOv may be redundant and aneurysmal. The anatomico-functional characterization of interatrial septum seems to be of paramount importance for both atrial septal defect (ASD) and PFO, not only for the device selection, but also for the evaluation of the outcome of this procedure.

Method: This study was conducted in 50 apparently normal hearts available in Department of Anatomy. After opening the right atrium, the shape of FOv was observed. The size was measured with the digital vernier caliper; the prominence and extent of limbus, and the redundancy or otherwise of FOv were noted; probe patency was confirmed.

Results: In the majority, FOv was oval (82%); average transverse diameter was 14.53 mm and vertical 12.60 mm. In 90%, the rim of the annulus was raised; in 20%, a recess was found deep to the margin of the annulus; and 18% showed probe patency.

Conclusion: As no study of this nature has been carried out in the Indian population, this provides pertinent information on the morphology of FOv, which may be useful for device selection in treating ASD and PFO.

1. Introduction

Fossa ovalis (FOv) is an oval depression of interatrial septum present toward the right atrium above and to the left of the orifice of inferior vena cava (IVC). It is formed by the contributions of septum primum and septum secundum in such a way that its floor is represented by septum primum and its limbus or margin is represented by septum secundum superoanteriorly and jointly by septum secundum and endocardial cushion posteroinferiorly[1–3] (Fig. 1).

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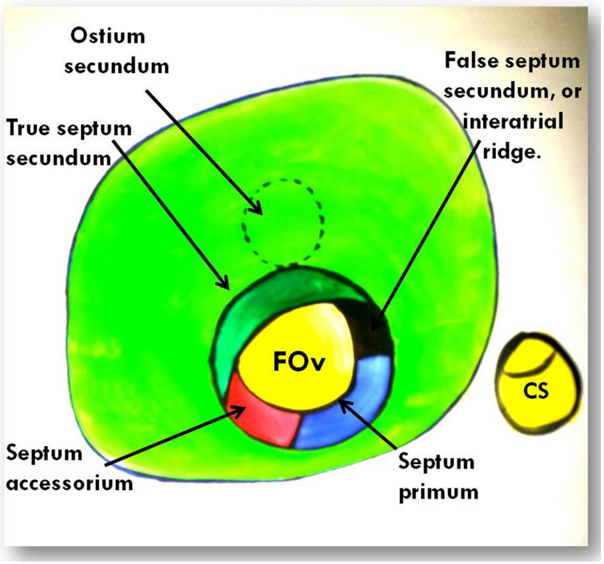

Fig. 1 – Schematic representation of various elements contributing to the formation of annulus FOv. FOv, fossa ovalis; CS, coronary sinus ostium.

During intrauterine life both these septae (primum and secundum) are opposed to each other such that they give rise to a flap valve, which acts like a shunt and the oxygenated blood is directed by Eustachian valve from IVC to the left atrium by way of foramen ovale (FO). This shunt or flap valve is closed by tight apposition of both septae shortly after birth because of increase in pressure in left atrium.[4,5]

There is presence of probe patency of FO in about 15–35% of general population. But sometimes FO persists to a varying degree, causing mixing of oxygenated and deoxygenated blood, which leads to a number of clinical and subclinical conditions like migraine, cryptogenic stroke, decompression sickness in divers, and platypnea orthodeoxia.[6] It may also lead to cerebral embolism. Transcatheter closure of patent foramen ovale (PFO) is indicated in these settings,[7] and prior to device selection, echocardiography is done to look for the dimensions of FOv and FO, its position along the limbus, redundancy, etc.

This study has been carried out with the aim to evaluate the gross anatomy of FOv including its annulus and floor because all these findings are of paramount importance in the selection of appropriate device for closure of FO.

2. Materials and method

The study was conducted on 50 apparently normal hearts available in Department of Anatomy. The hearts were collected from cadavers and also procured from forensic medicine department, and were preserved in 10% formalin.

The interior of the right atrium was exposed by an incision made parallel to atrio-ventricular groove, further extending along the upper margin of right auricle up to superior vena cava orifice (SVC). Following observations were made:

- Shape of FOv was observed (circular, oval, or elliptical) and recorded. [Circular where the two diameters were equal and oval or elliptical where one of the diameters was longer than the other.]
- Size of FOv was measured (in mm) with the help of digital vernier caliper.
- Extent and location of limbus were noted.
- Redundancy of FOv was observed (aneurysmal, redundant) and recorded.
- Probe patency was confirmed.
- Right surface of interatrial septum was photographed.

3. Result

This work was carried out in 50 apparently normal hearts available in the department.

A. **Size of FOv:** In the present study, the average transverse diameter FOv was 14.53 mm (range 5.69–29.83 mm) and

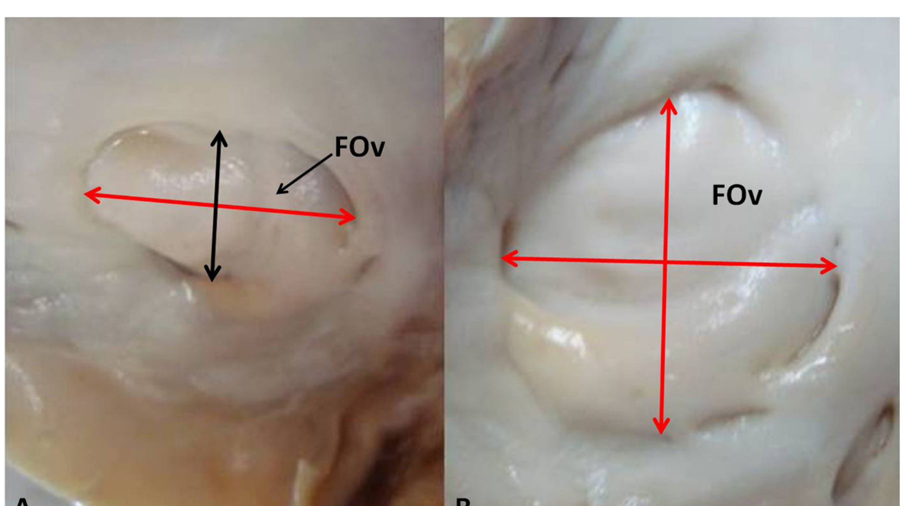

Fig. 2 – Shapes of fossa ovalis (FOv). (A) Oval and (B) circular. Double-headed red arrow indicates the long axis.

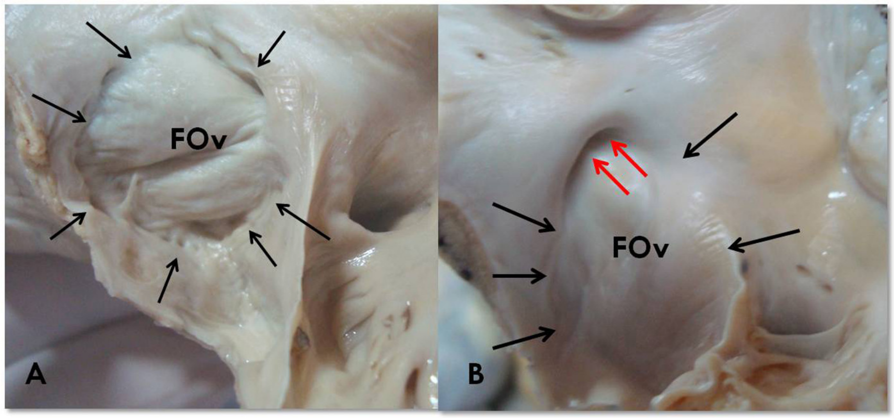

Fig. 3 – Annulus fossa ovalis. (A) The annulus is raised along the whole circumference (black arrows). The fossa ovalis show redundancy. (B) The annulus is flat except in its upper part which shows a prominent recess (red arrows). Fossa ovalis is aneurysmal bulging towards right atrium. FOv, fossa ovalis.

average vertical diameter was 12.60 mm (range 5.75–23.92 mm).

B. **Shape of FOv:** was variable: it was oval in 41 cases (82%), circular in 7 cases (14%), and elliptical in 2 cases (4%) (Fig. 2).

C. (i) *Annulus*: annulus or limbus FOv was found to be flat or raised at the margin. Annulus was raised in 46 cases (92%) and flat in 4 cases (8%) (Fig. 3).

(ii) *Segment of the annulus that was prominent*:
- All around the margin in 11 cases (22%).
- Superior and anterior in 8 cases (16%).
- Superior, anterior, and inferior in 14 cases (28%).
- Superior and inferior in 4 cases (8%).
- Superior, inferior, and posterior in 4 cases (8%).

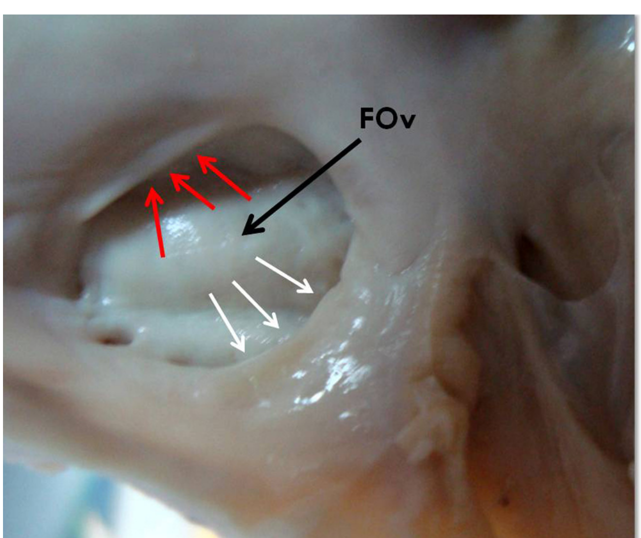

Fig. 4 – Raised margin of annulus in its whole circumference. In the upper part, it shows a deep recess (red arrows) and slit-like recess in the lower part (white arrows). Also seen are 2 openings in the posterior part at the annulus. Fossa ovalis is seen bulging in the right atrium. FOv, fossa ovalis.

- Anterior and inferior in 3 cases (6%).
- Anterior in 2 cases (4%).

(iii) *Recess in relation to annulus*: deep recess, which was 5–10 mm in depth, was found in 10 cases (20%), whereas it was merely slit-like in 4 cases (8%), and in another 4 cases (8%), pouch or pocket was present deep to annulus (Fig. 4).

D. **Floor of FOv:** The floor was flat in 35 cases (70%). Aneurysmal in 7 cases (14%), out of which 4 cases (8%) had bulging towards right atrium, and 3 cases (6%) had aneurysmal bulging towards left atrium. The floor was redundant or lax in 8 cases (16%) out of which in 6 cases (12%) it was folded towards right atrium; in 1 case (2%) it was folded towards left atrium and in 1 case (2%) it was folded toward both atria (Figs. 3 and 4).

E. **PFO:** 2 cases (4%) showed PFO, whereas 9 cases (18%) had only probe patency (Fig. 5).

F. In the present study, one of the specimen showed the presence of fibrous strands of approximately 0.5–1.0 cm in length arising from the right surface of FOv from about its middle and were directed to the anteroinferior part of the limbus (Fig. 6). The branching and anatomizing of the strands formed a network in FOv.

4. Discussion

4.1. *Development of FOv*

At the end of the fourth week of intrauterine life, a sickle-shaped crest grows from the roof of common atrium into the lumen. This crest is the first portion of the septum primum. The opening between the lower rim of the septum primum and the endocardial cushions is the ostium primum. The ostium primum becomes progressively smaller and disappears as the septum primum fuses with the fused endocardial cushions to form primordial AV septum. Before closure is complete, however, cell death produces perforations in the upper portion

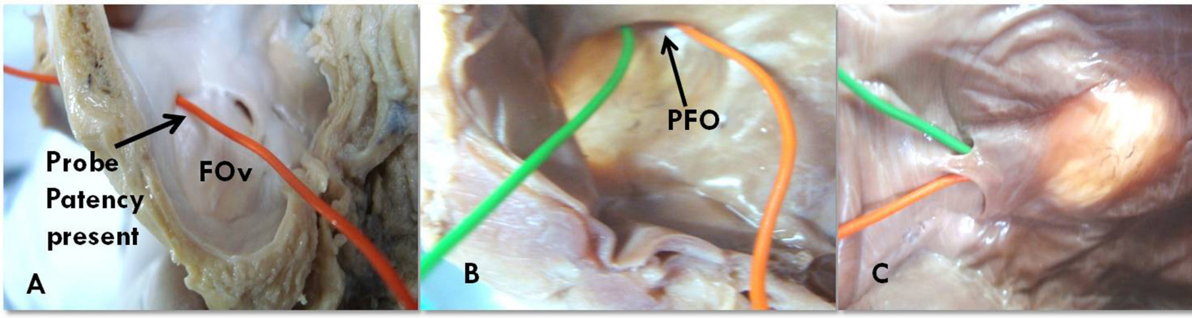

Fig. 5 – (A) Probe patency where orange probe has been negotiated through the right atrium (black arrow) to emerge through the left atrium. (B) 2 probes being passed through patent foramen ovale (PFO) via the right atrium. (C) The emergence of the probes into the left atrium and they are separated by a strand. FOv, fossa ovalis.

of the septum primum. Coalescence of these perforations forms the ostium secundum, ensuring free blood flow from the right to the left primitive atrium.[4,5]

A new crescent-shaped fold appears. This new fold, the septum secundum, never forms a complete partition in the atrial cavity. When the left venous valve and the septum spurium fuse with the right side of the septum secundum, the free concave edge of the septum secundum begins to overlap the ostium secundum. When the upper part of the septum primum gradually disappears, the remaining part becomes the valve of FO. The passage between the two atrial cavities consist of an obliquely elongated cleft, FO, through which blood flows from the right atrium to the left side.[4,5]

After birth, when lung circulation increases and pressure in the left atrium rises, the valve of the FO (i.e. septum primum) is pressed against the septum secundum, obliterating the oval foramen and separating the right and the left atria. In about 20% of cases, fusion of the septum primum and septum secundum is incomplete, and a narrow oblique cleft remains between the two atria. This condition is called probe patency of oval foramen; it does not allow intracardiac shunting of blood.[5]

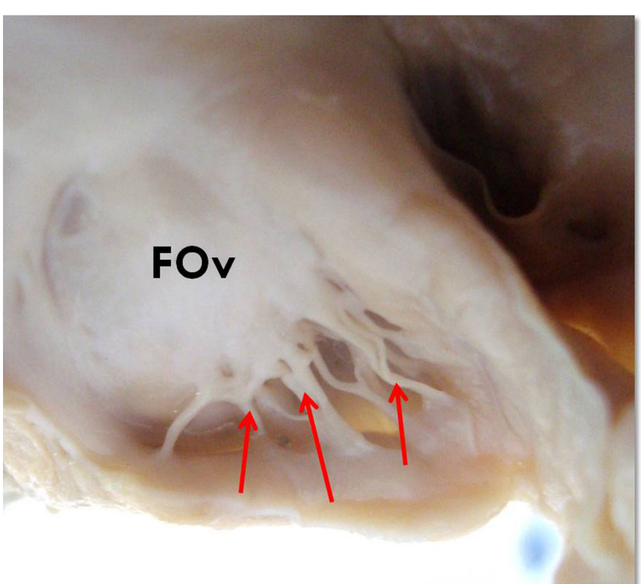

Fig. 6 – Photograph showing a large number of fibrous strands (red arrows) in the anteroinferior part of fossa ovalis (FOv).

4.2. *Molecular basis*

Genes regulating cardiac development are being identified and mapped, and mutations that result in heart defects are being discovered. For example, mutations in the heart-specifying gene *NKX2.5* on chromosome 5q35 can produce atrial septal defects (ASDs – secundum type). Mutations in the *TBX5* gene result in Holt–Oram syndrome, characterized by preaxial limb abnormalities and ASDs.[5]

Occasionally, the FO closes during intrauterine life. This premature closure of the FO leads to massive hypertrophy of the right atrium and ventricle and underdevelopment of the left side of heart. Death usually occurs shortly after birth.[5]

Kydd et al.[8] reported dimensions of FOv: anteroposterior – 17 mm and superoinferior – 19.4 mm, whereas in the present study, average transverse diameter was found to be 14.53 mm and average vertical diameter was 12.60 mm. This difference can be accounted for by the method used (trans esophageal echocardiography, TEE) by them, as also to the set of European population. Although in the present study the hearts were normal, it also showed wide variations in size and shape of FOv. No attempt was made in the present study to correlate the weight and size of heart with the various dimensions of FOv. In this context, it is important to mention the work of Reig et al.,[9] wherein they have found a positive correlation between heart weight and thickness of anterior limbus of FOv and the area of FOv, and concluded that in the individuals with high cardiac weight, the area of FOv is larger than those who have low cardiac weight.

Shape of FOv is variable and it may be circular, oval, or elliptical. In the present study, the shape was oval in 41 (82%) cases, circular in 7 (14%) cases, and elliptical in 2 (4%) cases. The literature reviewed does not mention the variations of the shape of FOv and hence our findings cannot be compared with that of other workers.

In the year 1963, George A. Christie gave a detailed description of the development of limbus FOv, wherein he has described that adult limbus is derived from embryologically distinct structures, being formed dorso-cranially by the true septum secundum, dorso-caudally by the septum accessorium, ventro-caudally by the thickened portion of the septum primum, and ventro-cranially by the false septum secundum, or interatrial ridge[10] (Fig. 1).

Annulus FOv was raised in 90% cases, and flat in remaining 10% cases in the present study. It is raised all round the margin in 11 (22%) cases, along superior and anterior margin in 8 (16%) cases, and along superior, anterior, and inferior margin in 14 (28%) cases. In the literature reviewed, we did not find the detailed study of this parameter.

In the present study, deep recess was found in 10 (20%) cases in relation to annulus which had a depth ranging from 5 to 10 mm, it was merely slit-like in 4 (8%) cases, and in another 4 (8%) cases, pouch or pocket was present deep to annulus ranges from 5 to 8 mm in depth. No other study elaborates the presence of deep recess or slit deep to annulus.

As described by Anthony Pearson et al., atrial septal aneurysm is a localized out-pouching of the FOv region of the atrial septum with criteria: (1) base width ≥1.5 cm with; (2) ≥1.1 cm excursion into either the left or the right atrium or a sum of the total excursion into the left or right atrium ≥1.1 cm. They found aneurysmal FOv in 1% of autopsies but by TEE, it was found to be 8%.[11] Gianluca et al. found it to be aneurysmal in 0.22–4% in general population but it rises to 8–15% in patients with stroke.[12] Kydd et al. observed atrial septal aneurysm in 12%.[8] Floor was flat in 70%, aneurysmal in 14%, and redundant in 16% in the present study. This higher incidence may indicate that these individuals are more prone to thromboembolic phenomenon.

Anthony Pearson et al. (1991) quoting the work of Silver and Dorsey (1978) reported an incidence of probe patency as 50%[10] and Marelli et al. have reported an incidence of 25% in general population.[13] Rana et al. have reported an incidence of 25–35%.[7] Davison et al. found it in 15–35%.[6] Bergman et al. have also mentioned its incidence as 25%.[14] In the present study, it was found in 18% of the hearts examined.

Shirani et al. reported PFO in 70% cases who had aneurysm of FOv[15] and Fisher et al. reported an incidence of 9.2%,[16] whereas in the present study, it was 4%. It is possible that in cases with aneurysmal FOv, the incidence is much higher. Such high incidence reported may be due to inclusion of PFO with the probe patency.

The presence of fibrous strands in FOv was observed in one of the specimen studied. This unique feature of fibrous strands in FOv has not been reported in the literature reviewed. The strands present in the FOv do not resemble Chiari network described in the literature. In such cases, difficulty may be encountered in transcatheteric closure of PFO.

Babaliaros et al.[17] have given the average area of FOv being from 1.5 to 2.4 cm^2 and have stated that in approximately two-third of the patients, fossa is paper-thin. They have advocated the role of transseptal (TS) catheterization by needle, radiofrequency (RF) energy, and excimer laser catheter to puncture the septum, this being utilized for ablation of accessory pathways for AV nodal reentrant tachycardia (AVNRT) and percutaneous repair of ASD and PFO. The aneurysm may lodge the tip of catheter preventing the cannulation. They have also described its use in LA appendage closure.[17]

Thus, the morphological study of FOv assumes greater significance due to its clinical relevance.

5. Conclusion

PFO is implicated as a channel for paradoxical embolism. It can act as a mechanism for cerebral ischemic events, as emboli can pass paradoxically from the right to left-sided circulation. Transcatheter closure of PFO is indicated in these settings.[7] An increasing number of FOv membrane aneurysms (FOMA) are diagnosed by echocardiography. Higher frequencies of such aneurysms have been reported in patients with embolic stroke.[18] The modality of TS catheterization emphasizes further the importance of morphology of FOv.[17]

Thus, the accurate rim length measurements and other parameters of FOv remain mandatory in evaluating every case of ASD suitable for transcatheter closure and are becoming important also in selecting the proper device in PFO patients. So the findings of the present work, in the central Indian population, should be of immense value to the cardiologists and interventionists of this area.

Conflicts of interest

The authors have none to declare.

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