

Echocardiography Detection of High-Risk Patent Foramen Ovale Morphology

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Abstract

Patent foramen ovale occurs in 25% of the general population. Several studies suggested that paradoxical embolism through a patent foramen ovale correlate with cryptogenic strokes (CS). Many epidemiological and clinical observational studies showed the association between CS and the presence of patent foramen ovale. There is still a controversy about whether patent foramen ovale should be closed. The information about patent foramen ovale morphology might be useful for the management of patent foramen ovale. This article discusses technical information about how echocardiography detects patent foramen ovale and identifies high-risk morphologies for the occurrence of patent foramen ovale related-stroke

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Introduction

Patent foramen ovale occurs in 25% of the general population.¹ Several studies suggested that paradoxical embolism through a patent foramen ovale correlate with cryptogenic strokes (CS). Many epidemiological and clinical observational studies showed the association between CS and the presence of patent foramen ovale. However, studies showing inconsistent result regarding whether patent foramen ovale closure reduces stroke recurrence in comparison with medical therapy. Earlier studies reported that patent foramen ovale closure did not significantly reduce a composite of death and neurological events^{2-4,2-4} More recent studies included some specific patent foramen ovale morphologies and showed the positive result of patent foramen ovale closure to reduce the outcome.⁵⁻⁸

Perhaps these specific morphologies for screening the candidate could explain the different result between the earlier and later studies. Further, Nakayama et al. recognized some patent foramen ovale features that might correlate with a higher incidence of neurological events and introduced a scoring system to predict.⁹ A meta-analysis showed that patients with cryptogenic stroke/ TIA and patent foramen ovale who have their patent foramen ovale closed, ischemic stroke recurrence is less frequent compared with patients receiving medical treatment. However, after patent foramen ovale closure, atrial fibrillation may occur quite frequent, though mostly transient.¹⁰ So, selecting a good candidate is important to get the most benefit of patent foramen ovale closure.

The information about patent foramen ovale morphology might be useful for the management of patent foramen ovale. Comprehensive information regarding patient characteristics, clinical features, imaging stroke pattern, and patent foramen ovale morphology is necessary to decide whether or not to close the patent foramen ovale.¹¹

This article discusses how echocardiography detects patent foramen ovale and identifies high-risk morphologies for the occurrence of patent foramen ovale related -stroke.

How to evaluate interatrial septum

Interatrial shunt occurs for approximately 6% -10% of congenital heart disease, with secundum atrial septal

defect (ASD) and patent foramen ovale are among the commonest lesion. However, patent foramen ovale is not a true interatrial defect because there is no septal tissue deficiency present. Foramen Ovale is a flap valve-like appearance between the septum primum and septum secundum called foramen ovale located in the anterosuperior portion of the atrial septum. Failure to close the foramen ovale after birth is called patent foramen ovale. It will potentially open if the right atrial pressure exceeds the left atrial pressure causing a shunt from the right atrium (RA) to the left atrium (LA).

Transthoracic echocardiography (TTE) or transesophageal echocardiography (TEE) can recognize the presence of patent foramen ovale by visualizing the interatrial septum (IAS). Some techniques used to ensure clear and good visualization of the IAS are as follows;

- We can visualize IAS from an apical 4 chamber view by TTE (fig. 1)
- Theoretically, subcostal view by TTE is a better view to show IAS, as it is perpendicular to the ultrasound beam. However, in an adult, the image quality of the subcostal view is not always adequate for comprehensive evaluation. (fig. 2) An off-axis apical 4 chamber view might shift vertical IAS to a rather diagonal position. This maneuver could improve the image quality of IAS.
- TEE is the reference modality for evaluating IAS. The image is clearer due to the proximity of the probe to the heart, and it shows IAS perpendicular to the ultrasound beam. (fig. 3) We need to scan through the IAS from 0° – 180° to get a full orientation of the IAS and the surrounding structures. This is the best way to evaluate patent foramen ovale morphology.

Using 3 D TEE, we can appreciate the patent foramen ovale and other structures next to it. At the superior orientation, there is superior vena cava (SVC), at the inferior is inferior vena cava (IVC), at the posterior is pulmonary veins and posterior wall of LA, and the aortic valve at anteriorly. (fig. 4)

How to evaluate patent foramen ovale

Foramen Ovale is formed from the septum primum and septum secundum and appears as the thin part of IAS. The common view to appreciate patent foramen ovale by TEE is from bicaval view at 90-110° (pic. 4).

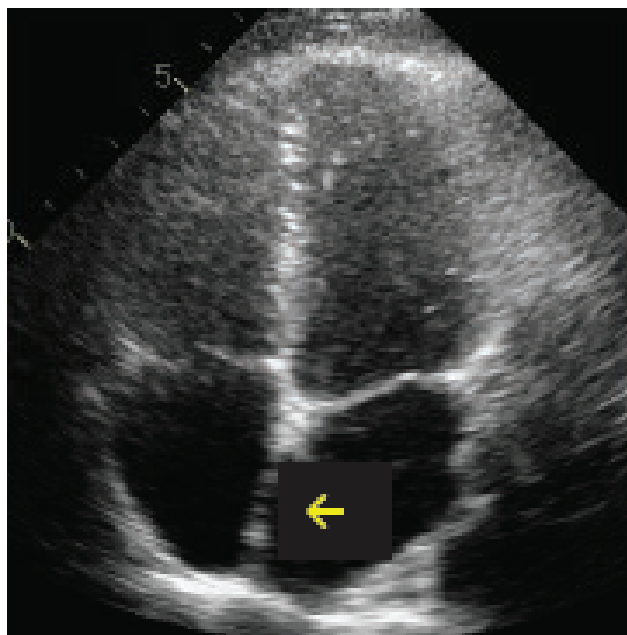


Figure 1. Transthoracic echocardiography showing 4 chamber view. Note that IAS (yellow arrow) is in a vertical position, parallel with the ultrasound beam.

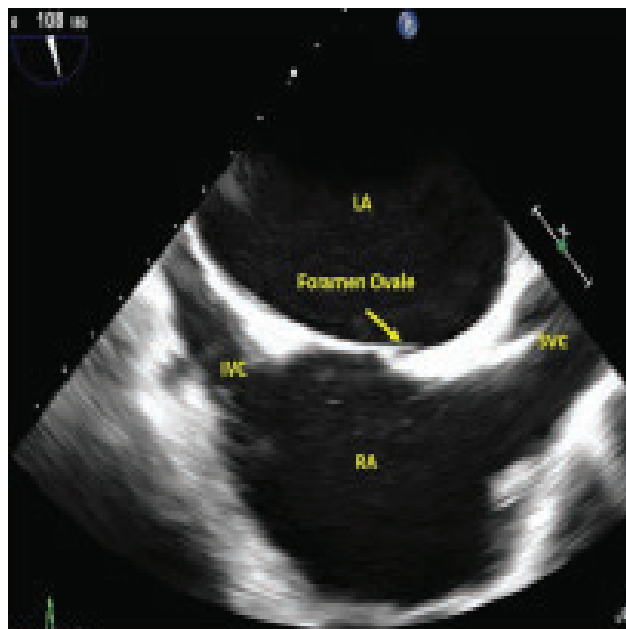


Figure 3. Bicaval view from trans-esophageal echocardiography shows a clear IAS and foramen ovale which is perpendicular to the ultrasound beam. LA; left atrium, RA; right atrium, IVC; inferior cava vein, SVC; superior cava vein.

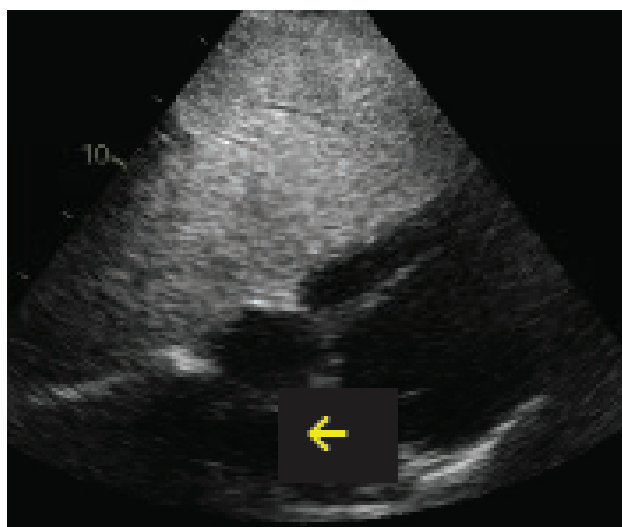


Figure 2. Transthoracic echocardiography showing the subcostal view. Note that IAS (yellow arrow) is almost horizontal, perpendicular to the ultrasound beam.

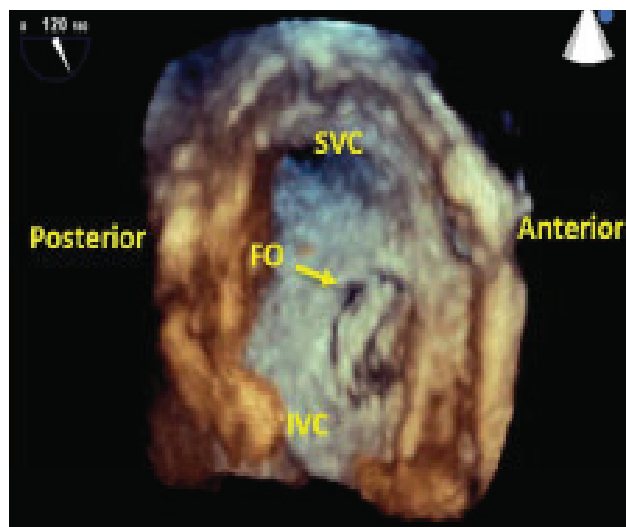


Figure 4. En face view of the IAS and foramen ovale by 3D TEE. IVC; inferior cava vein, SVC; superior cava vein, FO; foramen ovale.

patent foramen ovale will open if RA pressure exceeds LA pressure, resulting in a R-L shunt. With stretched patent foramen ovale, the L-R shunt may occur (fig.5) Using TTE, we cannot see patent foramen ovale as clear as by TEE. However, the bubble contrast test could help to confirm its presence.

We commonly use agitated saline contrast to confirm the presence of patent foramen ovale with a paradoxical shunt. The procedure can be done using either TTE or TEE. Below is how to perform an agitated saline bubble study;^{12,13}

- Preparing the patient;
 - o Intravenous access. Larger veins may guarantee better flow (brachial or femoral vein)
 - o Use 18-20 F gauge cannula connected to 3-way stopcock
- Preparing the contrast;
 - o Two 10 ml syringes
 - o 50 ml saline
 - o Mix 0.5 - 1 ml blood + 9 ml saline + just enough air (0.2 ml) in one syringe
 - o Connect that syringe to the other one with 3-way stopcock
 - o Prepare the solution by rapidly agitating between the two syringes several times until the fluid mixed homogeneously with very fine bubbles.
- Performing the test;
 - o Find the best echo view for patent foramen ovale visualization. TEE 90-110° or TTE the apical 4 chamber view with vertical IAS (avoid diagonal IAS, as it may create reverberation in the LA while contrast enter the RA)
 - o The solution is injected rapidly. Wait until it creates full opacification of RA. Then, evaluate whether some bubbles appear in the left heart.
 - o Ten beats acquire digital loop is to capture the process, from just before bubbles enter the RA.
 - o If Valsalva manoeuvre is to perform, the patient has to hold in strain phase until bubbles enter the RA, and release Valsava as bubbles fill the RA (and start counting the beats).

Positive bubble contrast test is considered when some bubbles occur in the left heart within three beats after opacification of the RA. The false-negative result may occur if the Valsalva manoeuvre is not adequate to

drain the bubble from the RA to the LA through patent foramen ovale. Because the preferential flow through the patent foramen ovale is coming from the IVC, performing bubble contrast from the femoral vein access might increase the sensitivity of the test and avoid the false-negative result. The false-positive result may occur if there is of pulmonary artery-venous malformation. If the bubbles appear in the left heart beyond 3 beats after the RA opacification, it is more likely that the bubbles cross through the pulmonary shunt, instead of the patent foramen ovale.

High-risk morphology of patent foramen ovale

Some patent foramen ovale morphologies might correlate with a higher incidence of neurological events, and TEE can recognize the features quite well. Nakayama et al. introduced a scoring system of patent foramen ovale morphology to predict the risk of CS (table 1). Using five variables with one point for each positive variable, they concluded that > 2 points were associated with the higher possibility of CS.⁹ A systematic review and meta-analysis evaluated the morphology of the patent foramen ovale as a risk factor for cerebrovascular accident.¹⁴

Table 1. High-risk patent foramen ovale score.

Variables	Point
Long-tunnel patent foramen ovale > 10 mm	1
Hypermobile interatrial septum	1
Eustachian valve or Chiari's network	1
Large Right -Left shunt during Valsalva maneuver	1
Low-angle patent foramen ovale < 10°	1
Maximal total point	5

A total point of > 2 is defined as a higher association with the cryptogenic stroke

Next is some echocardiography features of the high-risk patent foramen ovale morphology and best evaluated by TEE;

1. Long-tunnel patent foramen ovale > 10 mm

Using TEE at 90-110°, it is the maximum overlap between the septum primum and septum secundum (fig. 6)

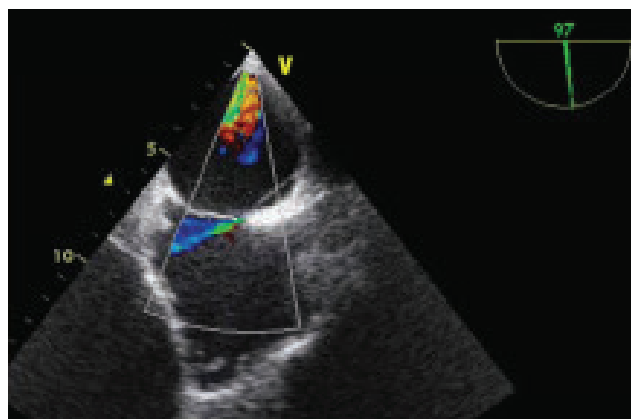


Figure 5. TEE showed stretched patent foramen ovale with L-R shunt.

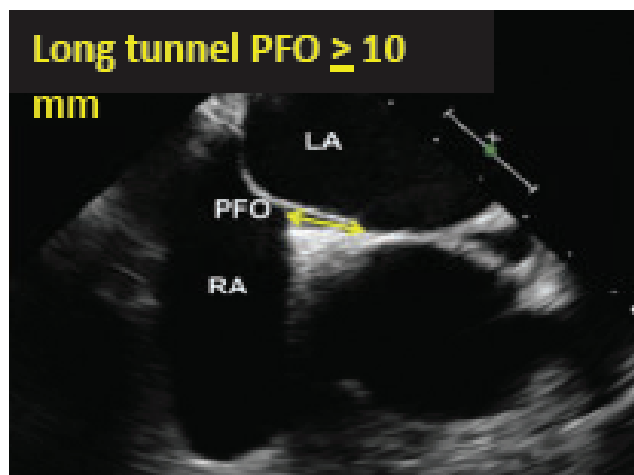


Figure 6. TEE showed long tunnel patent foramen ovale, which is one of the high-risk features associated with cryptogenic stroke. LA; left atrium, RA; right atrium, patent foramen ovale; patent foramen ovale. The picture was taken from reference ¹⁰.

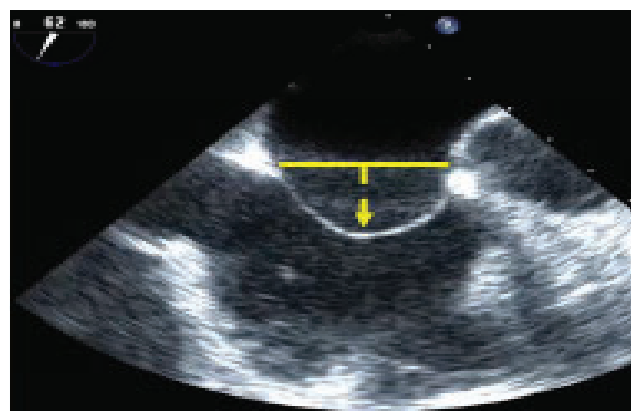


Figure 7. TEE showed atrial septal aneurysm (ASA) with > 10 mm septal excursion from the midline into the right atrium.

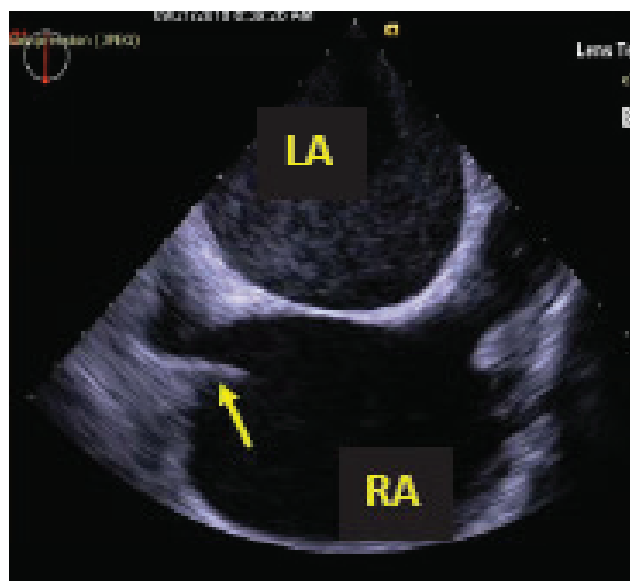


Figure 8. From TEE, yellow arrow showed Eustachian Valve.

2. *Hypermobility of interatrial septum*

Atrial septal aneurysm (ASA) is defined when septal excursion from the midline into either the RA/ LA is > 10 mm, or the total excursion between the RA to LA > 15 mm. While hypermobile IAS was defined as the excessive motion and floppy IAS with an excursion of each heartbeat reaches > 5 mm (fig.7).

3. *Presence of Eustachian valve or Chiari's network*

This feature is one of the scoring variables and considers positive if seen as > 10 mm protrusion within the RA (fig 8 and fig 10).

4. *Large R-L shunt during Valsalva maneuver*

Using an agitated saline contrast test with or without Valsalva maneuver, we visualize the LA's bubble appearance within 3 beats after full opacification of the RA. The large RL shunt was defined as > 20 microbubbles. The result can be detected by TTE (fig 9a) or TEE (fig 9b). For the detailed procedure, refer to the above information about how to perform a bubble contrast test.

5. *Low-angle patent foramen ovale < 10°*

Using TEE from bicaval view (at around 90-110 °), we can measure the angle between IVC and patent foramen ovale flap on and < 10° was defined as low-angle patent foramen ovale (fig 10).

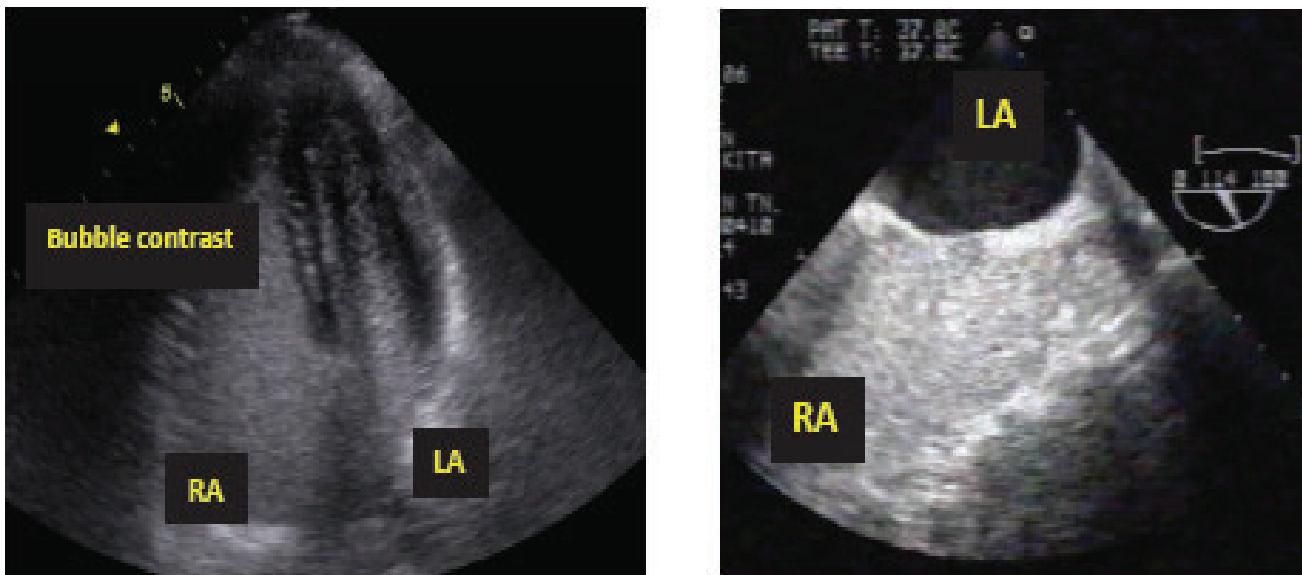


Figure 9. This picture shows a bubble contrast test performed in two different patients. Noted the full opacification of the RA. TTE visualizes a positive bubble contrast test with a large right-left shunt in the 1st patient (fig 9a.), and the negative result showed from TEE in the 2nd patient (fig 9b) .

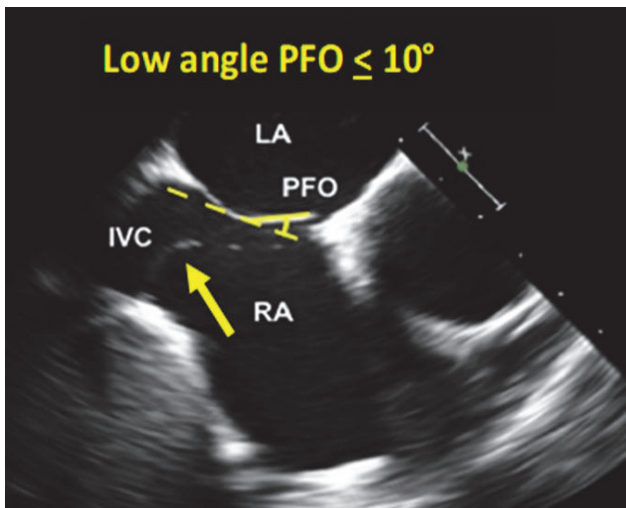


Figure 10. TEE showed low angle patent foramen ovale – IVS. Noted yellow arrow showed Chiari's network. LA; left atrium, RA; right atrium, patent foramen ovale; patent foramen ovale, IVC; inferior cava vein. The picture is taken from reference. ¹⁰

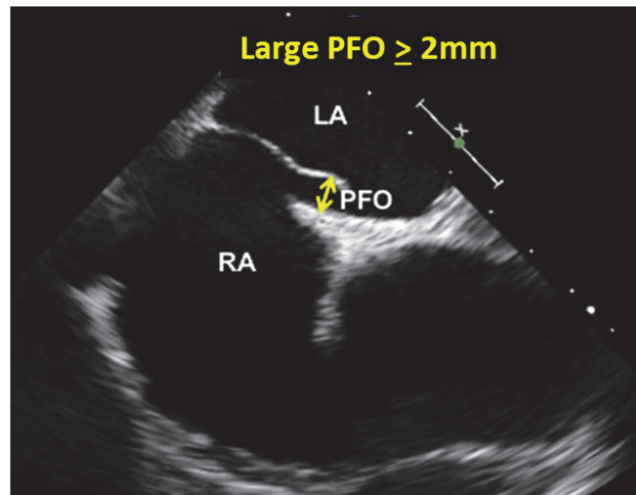


Figure 11. TEE showed a large separation of both primum and secundum septum, creating a wide gap. LA; left atrium, RA; right atrium, patent foramen ovale; patent foramen ovale. The picture is taken from reference. ¹⁰

6. Large-size patent foramen ovale, > 2 mm

This feature was not included in the score, but still an important feature that might correlate with the risk of CS. Using TEE, large-size patent foramen ovale is defined when the maximum separation between the septum primum and septum secundum reaches > 2 mm, at the end-systolic frame (fig.11).

Summary

As discussed above, patent foramen ovale is a relatively common condition in the general population. There are still controversies regarding its correlation with CS and whether it should be closed in all patent foramen ovale cases. Some studies recognized some patent foramen ovale features that might correlate with CS. Using echocardiography, we can identify the presence of patent foramen ovale and appreciate the high-risk morphology of patent foramen ovale.

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