Review Article

My Approach to Transcranial Doppler Combined With Transthoracic and Transesophageal Echocardiography to Investigate PFO

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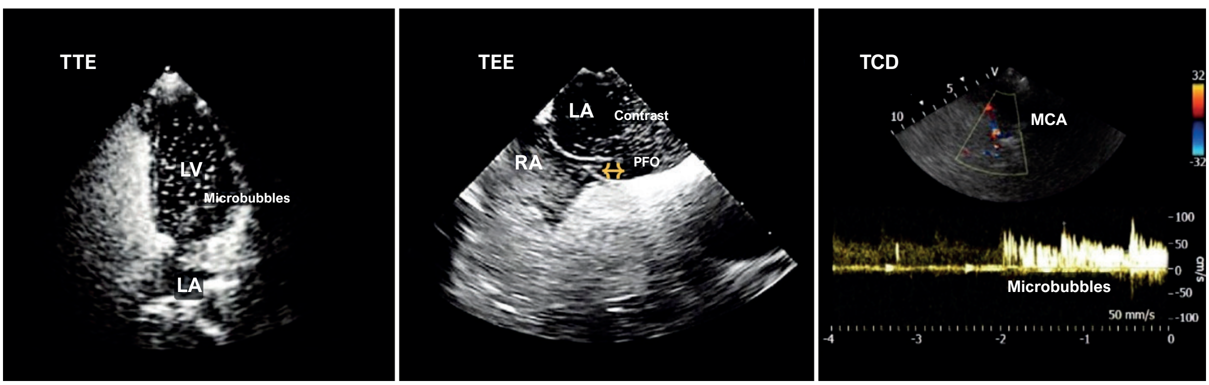
Central Illustration: My Approach to Transcranial Doppler Combined With Transthoracic and Transesophageal Echocardiography to Investigate PFO



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TTE in the apical 4-chamber plane showing the passage of microbubbles (right-to-left shunt). Contrast TEE through the PFO (arrow). TCD showing evident flow in the MCA with the presence of HITS after saline solution injection. TTE: transthoracic echocardiography; TEE: transesophageal echocardiography; LA: left atrium; RA: right atrium; PFO: Patent Foramen Ovale; TCD: Transcranial Doppler.

Abstract

This review article explores the combined use of Transcranial Doppler (TCD) with transthoracic (TTE) and transesophageal (TEE) echocardiography to investigate Patent Foramen Ovale (PFO), a condition found in approximately 25-27% of the adult population. PFO is a remnant of fetal circulation and the most common cause of interatrial shunt. It is associated with clinical complications such as platypnea-orthodeoxia syndrome, obstructive sleep apnea, migraine, and stroke.

PFO assessment is generally performed using TTE and TEE, but TCD, a highly sensitive and less used method, is also important. TCD indirectly detects shunts in awake patients and uses the microembolic signal (MES) grading score to classify shunt severity. This technique involves injecting a contrast solution into the antecubital vein during the Valsalva maneuver to detect intracardiac shunt by observing microbubble appearance in the first cardiac cycles.

The case report illustrates the effectiveness of TCD in the initial screening of a patient with suspected PFO using TTE, TCD and TEE. The conclusion highlights that TCD is a crucial diagnostic tool, particularly relevant for the therapeutic management of patients with cryptogenic stroke. Several scientific publications are referenced, providing a theoretical foundation for the combined use of TCD, TTE, and TEE in PFO investigation.

Keywords

Foramen Ovale; Transcranial Doppler Ultrasonography; Transesophageal Echocardiography; Stroke

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Introduction

Patent Foramen Ovale (PFO) is a fetal circulation remnant and the most common cause of interatrial shunt, affecting approximately 25 to 27% (1 in every 4 to 5 people) of adults. It is considered an anatomical tunnel-like variation, potentially associated with clinical complications such as platypnea-orthodeoxia syndrome, obstructive sleep apnea, migraine, and, notably, stroke due to paradoxical embolism. Diagnosis is particularly crucial in young stroke patients without apparent risk factors.[1,2]

Review Article

Assessment of PFO typically involves transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE). Another valuable but underutilized method among echocardiographers is transcranial Doppler (TCD). This method offers a noninvasive assessment of shunt presence in awake patients with high sensitivity,[3] using the microembolic signal (MES) grading score to classify the shunt severity. See Central Illustration below.

A clinically meaningful diagnosis of PFO requires both anatomical characterization and physiological assessment of potential right-to-left shunting.

Traditionally, TTE serves as the primary imaging method for PFO screening due to its widespread availability and cost-effectiveness. At the same time, TEE with agitated saline enhancement remains the gold standard for demonstrating shunts through PFO and providing morphological details of the interatrial septum.

TCD with agitated saline (microbubbles) has increasingly played a role in diagnosing transient shunts by enabling real-time analysis of the presence of High-Intensity Transient Signals (HITS) in the cerebral arterial circulation, offering a semi-quantitative assessment of venous-arterial shunt severity.[4,5]

Technique

The 3-to-5 Mhz sectoral ultrasound transducer is generally the most suitable and it is recommended to use the transcranial factory preset. Then, the transducer is positioned in the temporal window, with the transducer index pointed to the patient's right, anterior to the tragus of the ear and moving in small steps, until the flow signal towards the transducer is recorded by adjusting the frequency (2.0 MHz and 2.5 MHz), gain and depth (35-60mm) settings to obtain clear images of the middle cerebral artery (MCA) (Figures 1A, 1B, 1C).

In detail, the contrast agent ideally consists of 8 mL of normal saline combined with 1 mL of air and 1 mL of the patient's blood. The presence of red blood cells in the agitated saline solution enhances ultrasonic wave reflection, thereby improving visibility of microbubbles in TCD. The mixture is then vigorously shaken approximately 10 times using a system comprising two 10 mL syringes connected by a 3-way stopcock. The stirred solution is then administered into the antecubital vein via an 18 gauge, preferably.

During the procedure, the patient is instructed to perform the Valsalva maneuver, which involves forced expiration against a closed glottis for at least 10 seconds (strain phase), followed by relaxation (release phase). Hemodynamically, this maneuver causes a sudden increase in blood volume in the right atrium, exceeding the flow from the pulmonary veins to the left atrium, thereby promoting flow through the shunt.[6,7]

Simultaneously, in an insonation of the curve is conducted using Pulsatile Doppler on the middle cerebral artery (MCA), with reduced scanning speed to allow continuous recording for 60 seconds from the start of the Valsalva maneuver. During this time period, spikes of microbubbles will be visualized, being evidenced as HITS due to reflection of the ultrasound signal (Figure 1C).

The test is considered positive when at least one early hyperintense signal is detected (up to 10 seconds after microbubble infusion). In tachycardic patients, counting cardiac cycles may be a more accurate approach, as it considers the patient's individual heart rate.[8] The detection of microbubbles within the first 3-5 cardiac cycles indicates an intracardiac shunt, whereas their appearance after the fifth cardiac cycle suggests a pulmonary shunt.[9]

The number of embolic spikes (HITS) recorded provides critical information; a higher number of microbubbles correlates with a larger foramen ovale passage size.[10,11] Such data is essential for determining the hemodynamic significance of PFO according to the Spencer logarithm scale (adapted from Table 1 and Figure 2).[12,13]

Clinical case

Case report demonstrating the value of TCD in the initial screening of a patient with suspected PFO. J.R.C., a 56-year-old male patient, without comorbidities, but with sequelae of ischemic stroke. The 24-hour Holter did not show atrial fibrillation. The patient sequentially underwent TTE, TCD and TEE associated with the Valsalva maneuver to evaluate the cardioembolic source.

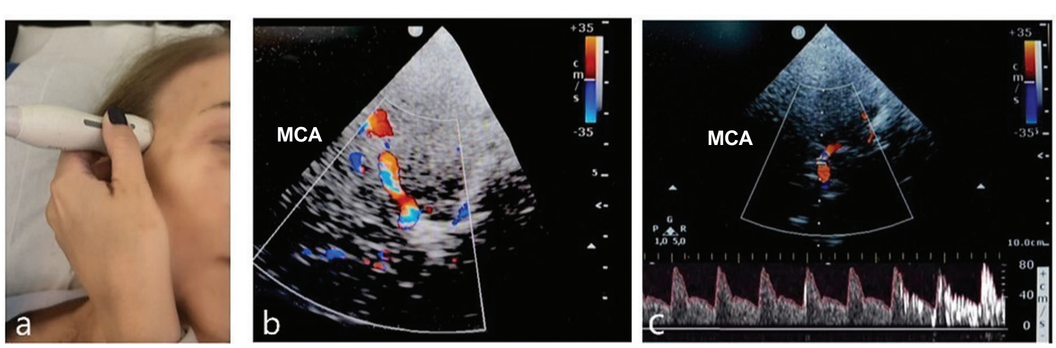

Figure 1 – *The sector probe is positioned in the time window. TCD shows evident flow in MCA with HITS after injection of saline solution. MCA: middle cerebral artery.*

The TTE showed an aneurysm of the interatrial septum with the early detection of a large amount of saline contrast in the left atrium (Figure 3A). TEE was performed to adequately visualize the characteristics of the interatrial septum and PFO, aiming for percutaneous closure (Figures 3B and 3C). Using the MCA spectral Doppler, a number of severe HITS were detected during the first three cardiac cycles, defining the presence of an important venous-arterial shunt (Figure 4).

Table 1 – The magnitude of the shunt is classified according to the Spencer grading scale

SPENCER'S LOGARITHMIC SCALE		
GRADE 0	Absence of HITS	Absence of shunt
GRADE 1	1 to 10 HITS	Intermittent shunt (during Valsalva only)
GRADE 2	11 to 30 HITS	Small shunt
GRADE 3	31 to 100 HITS	Moderate shunt
GRADE 4	101 to 300 HITS	Significant shunt
GRADE 5	> 300 HITS	Very large shunt, continuous appearance of hits ("curtain effect")

HITS: High-Intensity Transient Signals.

Conclusion

Diagnosing PFO can pose significant challenges due to various factors that can influence and result in inconclusive studies. False negatives can occur due to the presence of a redundant Eustachian valve, obstructing saline solution from reaching the interatrial septum and false positives such as pulmonary venoarterial shunts.[14]

TCD represents an additional, straightforward, and non-invasive diagnostic tool with high sensitivity, being particularly essential in the initial evaluation of patients with cryptogenic stroke, especially in those where identifying a right-to-left shunt through PFO may be crucial for therapeutic management.[15]

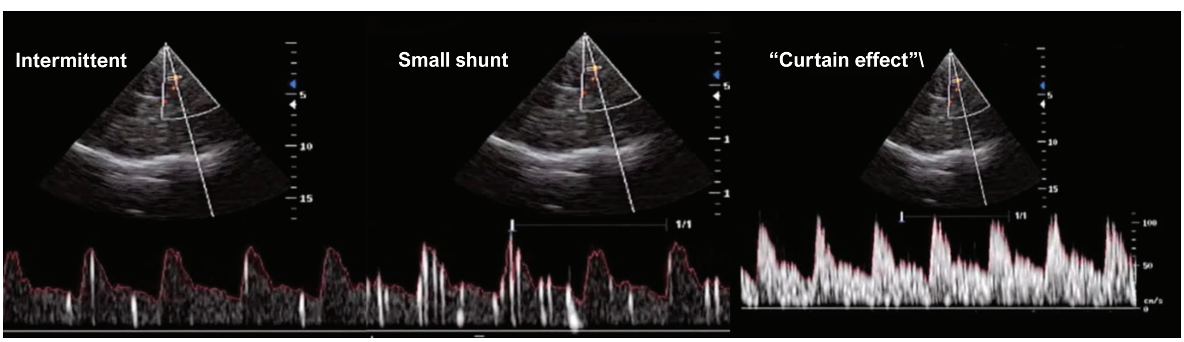

Figure 2 – *Doppler showing flow in the MCA with the presence of HITS after the injection of agitated saline solution, graded according to the Spencer logarithmic scale.*

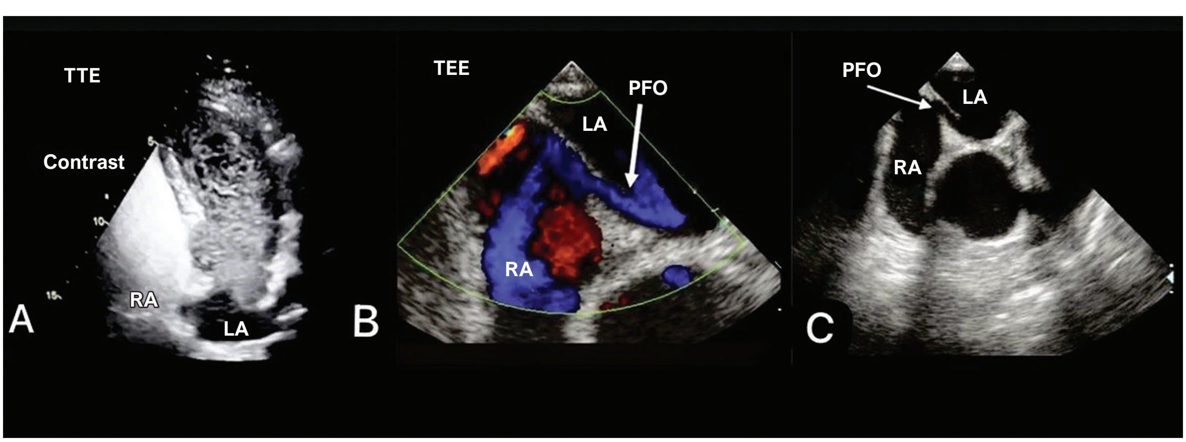

Figure 3 – *TTE shows an aneurysm of the interatrial septum with saline contrast in the left atrium. TEE reveals a large and long PFO allowing spontaneous right-to-left flow. MCA Doppler reveals a significant venous-arterial shunt with severe HITS. TTE: transthoracic echocardiography; TEE: transesophageal echocardiography; LA: left atrium; RA: right atrium; PFO: Patent Foramen Ovale.*

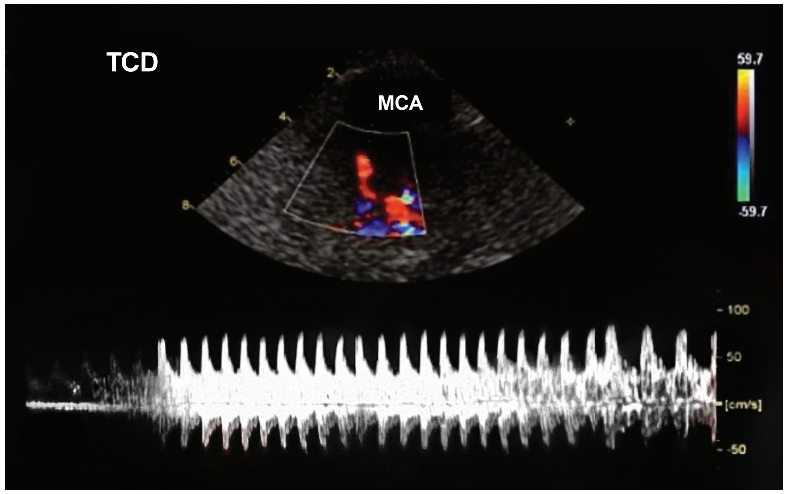

Figure 4 – *Doppler of the MCA reveals a significant arteriovenous shunt with a continuous appearance of HITS ('curtain effect'). TCD: Transcranial Doppler; MCA: middle cerebral artery.*

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Author Contributions

Conception and design of the research, acquisition of data and writing of the manuscript: Barros G; critical revision of the manuscript for intellectual content: Costa PV.

Potential Conflict of Interest

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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