Review Article

My Approach to Agitated Saline Contrast Echocardiography in Pediatric Patients

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Abstract

Agitated saline contrast is a simple, safe, widely available echocardiography technique. It is particularly useful for evaluating right-to-left shunts and pulmonary vascular abnormalities in the pediatric population. This article presents a practical approach to using this technique in pediatric echocardiography. It reviews the underlying physiological principles, the technical aspects of preparation and image acquisition, and the main clinical applications.

What is agitated saline contrast?

Agitated saline contrast consists of the intravenous (IV) administration of normal saline that has been vigorously agitated, a process that promotes the formation of microbubbles from gases dissolved in the fluid under hydrostatic pressure. These microbubbles have a mean diameter greater than 9 μm, which prevents their passage through the pulmonary capillary bed under normal physiological conditions.[1]

After injection, immediate opacification of the right-sided chambers occurs. The microbubbles have a short half-life and dissolve rapidly as they pass through the pulmonary circulation. Therefore, in an intact cardiopulmonary system, they are not observed in the left-sided chambers.

The detection of microbubbles in the left atrium (LA) or left ventricle indicates diversion of blood flow beyond the pulmonary capillary bed, consistent with the presence of an intracardiac or intrapulmonary shunt. Under normal conditions, microbubbles (> 9 μm) do not traverse the pulmonary capillaries and dissolve within the lungs. Thus, any visualization of contrast in the left side of the heart is considered abnormal and indicates deviation from normal capillary flow.

Keywords

Ecocardiography; Contrast Echocardiography; Patent Foramen Ovale; Atrial Septal Defect; Hepatopulmonary Syndrome.

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Which echocardiographic view should be used?

For evaluation with agitated saline, the preferred echocardiographic view is the apical four-chamber view, as it provides optimal visualization of the interatrial septum, minimizes shadowing artifacts over the left-sided chambers, and facilitates identification of microbubble passage from the right atrium (RA) to the LA.

If an adequate apical window cannot be obtained, the subcostal four-chamber view is an appropriate alternative, particularly in the pediatric population, in which this window often provides superior image quality.

Image acquisition should begin before the arrival of microbubbles in the RA and be maintained for at least 10-20 heartbeats after opacification of this chamber, allowing proper temporal assessment of contrast appearance in the left-sided chambers. The use of harmonic imaging is recommended to increase diagnostic sensitivity.[2] In addition, when feasible, physiological maneuvers such as Valsalva or coughing should be synchronized with contrast arrival in the RA to enhance detection of right-to-left shunts.

How should the solution be prepared?

Preparation requires peripheral IV access in an upper limb (preferably the right one) and a standardized technique to ensure adequate microbubble formation.

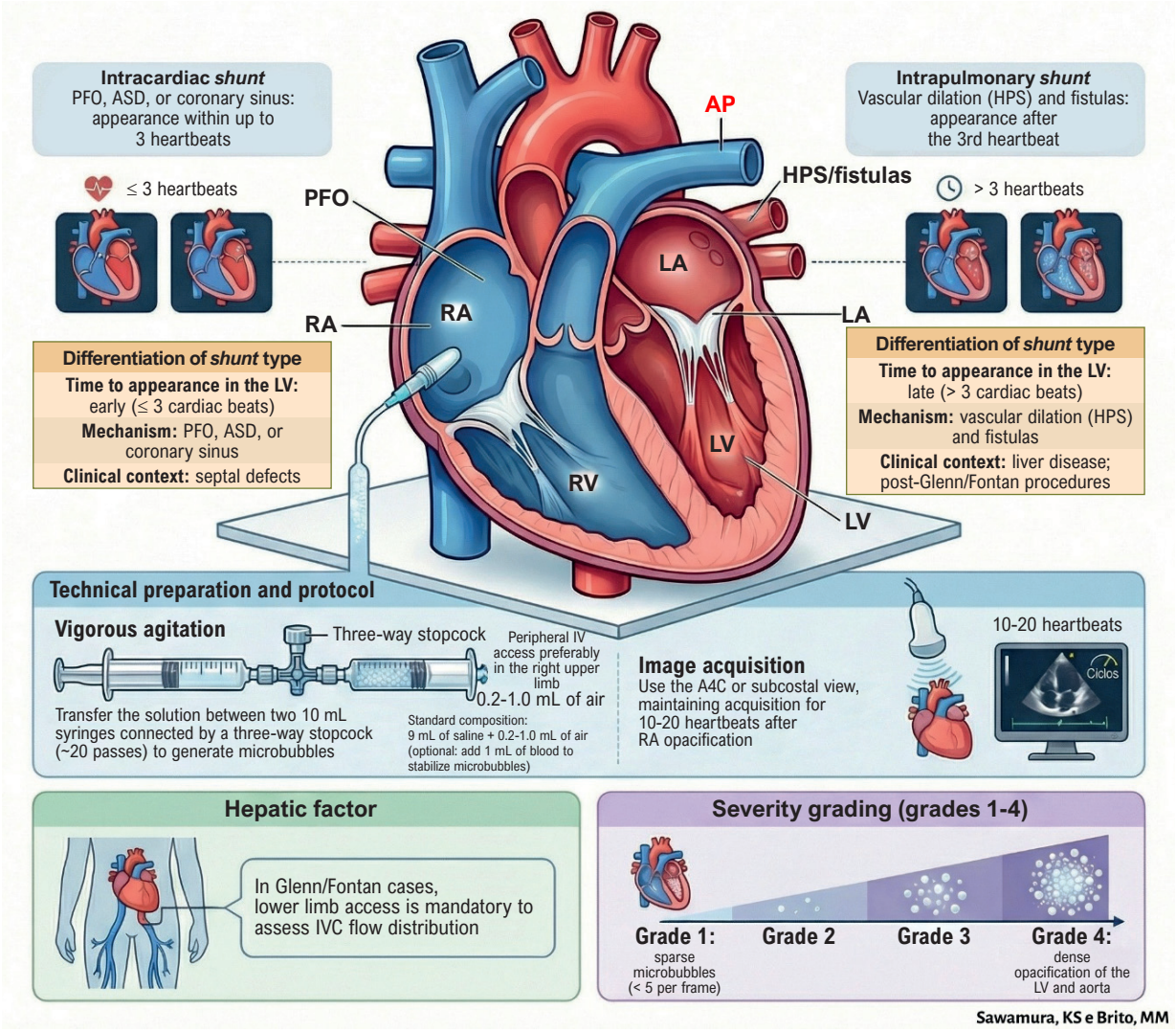
The technique consists of vigorous agitation by rapidly transferring the solution between two syringes connected by a three-way stopcock approximately 20 times, promoting appropriate microbubble formation (Central Illustration). Before IV administration, any visibly large air bubbles should be discarded to ensure procedural safety.

Injection should be performed immediately after agitation, as microbubbles have a short half-life.[1–3] On echocardiography, the contrast appears as hyperechoic material within the right-sided chambers, allowing dynamic assessment of its distribution and potential passage into the left-sided chambers. Recommended preparation options for pediatric use are described in Table 1.

Materials

- Peripheral IV access (preferably in an upper limb);
- Two 10 mL syringes;
- Three-way stopcock.

Central Illustration: My Approach to Agitated Saline Contrast in Pediatric Patients: Clinical Applications



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My Approach to Agitated Saline Contrast in Pediatric Patients: Clinical Applications. A4C: apical four-chamber view; ASD: atrial septal defect; HPS: hepatopulmonary syndrome; IVC: inferior vena cava; IV: intravenous; LV: left ventricle; PFO: patent foramen ovale; RA: right atrium; PA: pumonary artery.

Table 1 – Composition of agitated saline contrast for echocardiography

Option	Composition
A – Saline	9 mL of normal saline (0.9%) + 0.2-1 mL of air
B – With blood	8 mL of normal saline (0.9%) + 1 mL of blood + 0.2-1 mL of air

Before IV administration, any visibly large air bubbles should be discarded to ensure procedural safety.

Main indications in pediatric echocardiography

a) Investigation of intracardiac shunts

Agitated saline is widely used in pediatric echocardiography for the investigation and characterization of intracardiac shunts, particularly patent foramen ovale (Figure 1) and atrial septal defects, including coronary sinus-type defects (Figure 2).[2]

The key technical criterion for diagnosing an intracardiac shunt is the early appearance of microbubbles in the left-sided chambers, typically within the first 3 heartbeats after RA opacification. In sedated patients, brief abdominal compression may be applied to increase the sensitivity of the test.

This technique also assists in the characterization of venous anomalies, such as persistent left superior vena cava (SVC), unroofed coronary sinus, and arteriovenous fistulas.[4,5]

b) Hepatopulmonary syndrome (HPS) in pediatrics

HPS in pediatric patients occurs in the context of liver disease or portal hypertension and is characterized by intrapulmonary vascular dilation, partly mediated by increased nitric oxide production. This process leads to the formation of pulmonary microfistulas and disruption of the ventilation-perfusion relationship, allowing poorly oxygenated blood to enter the systemic circulation.

Diagnosis is based on the triad of underlying liver disease, evidence of intrapulmonary vascular dilation on echocardiography, and an increased alveolar-arterial gradient on arterial blood gas analysis. Clinically, it presents predominantly with hypoxemia of variable severity.[6,7]

On echocardiography, a delayed appearance of microbubbles in the left-sided chambers (> 3 heartbeats) is observed (Figure 3). This pattern differentiates HPS from intracardiac shunts, in which contrast appears early.[7]

c) Arteriovenous fistulas after Glenn/Fontan procedures

Following Glenn/Fontan surgeries, the development of pulmonary arteriovenous fistulas is related to the hemodynamic alterations inherent to single-ventricle physiology. The absence of pulsatile pulmonary flow, exclusion of hepatic flow with consequent deprivation of the so-called "hepatic factor," and chronically elevated central venous pressure promote endothelial dysfunction and pulmonary vascular remodeling, favoring microfistula formation.[2,8]

Clinically, these patients may present with persistent or progressive cyanosis. On agitated saline echocardiography, the characteristic finding is delayed appearance of microbubbles in the left-sided chambers, consistent with an intrapulmonary shunt pattern (Figure 4).

The origin of the shunt determines the site of contrast injection[9]:

- **Upper limb access (cephalic or basilic veins)** allows evaluation of SVC drainage into the pulmonary arteries and is useful for detecting pulmonary arteriovenous fistulas in cases of uneven flow distribution;

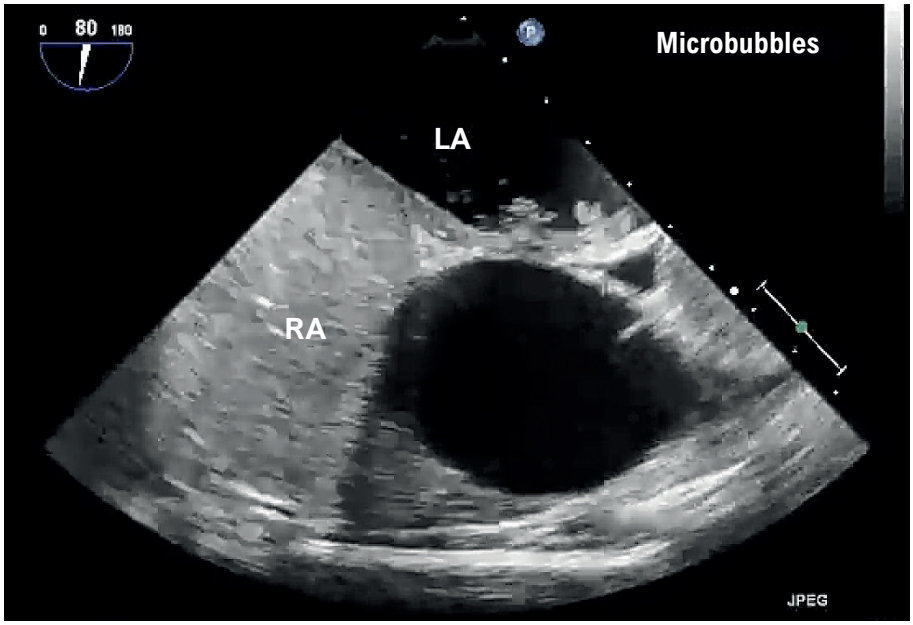

Figure 1 – *Transesophageal echocardiography demonstrating opacification of the RA after infusion of agitated saline contrast via peripheral IV access, with early passage of microbubbles into the LA through a PFO. IV: intravenous; LA: left atrium; PFO: patent foramen ovale; RA: right atrium.*

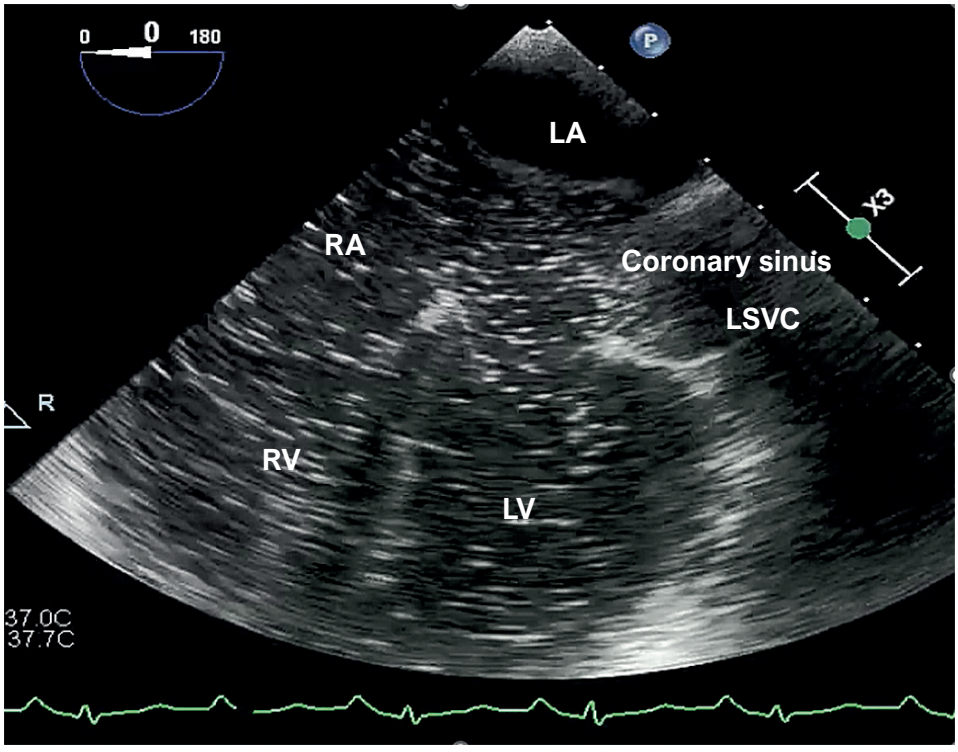

Figure 2 – *Transesophageal echocardiography in the four-chamber view after infusion of agitated saline contrast via peripheral IV access in the left upper limb, demonstrating opacification of the coronary sinus, the LSVC, and the LV, secondary to the presence of a coronary sinus-type ASD. ASD: atrial septal defect; LA: left atrium; LSVC: left superior vena cava; LV: left ventricle; RA: right atrium; RV: right ventricle.*

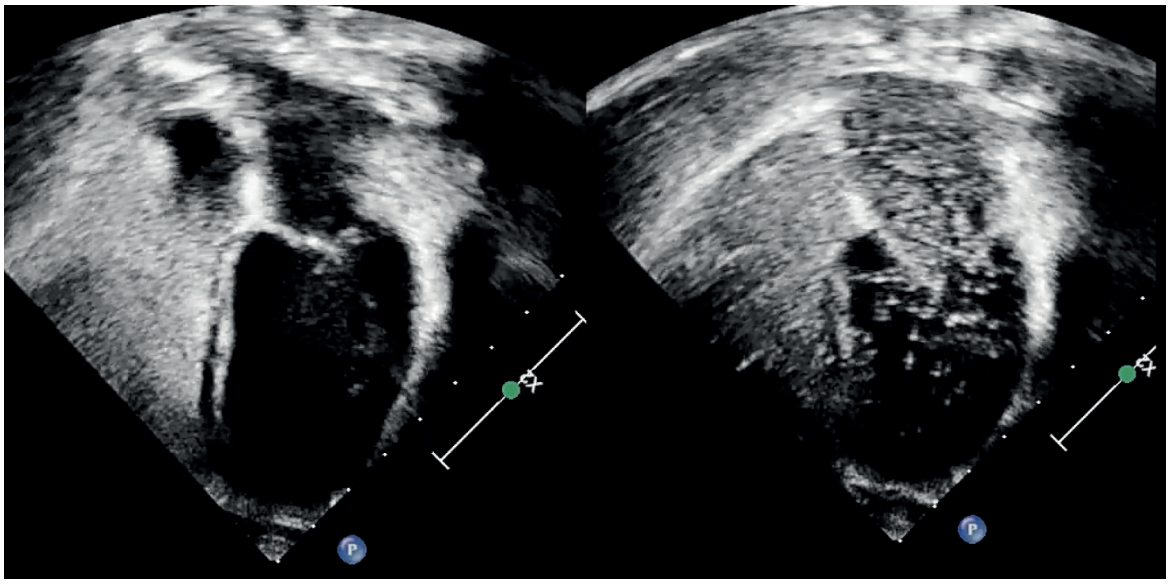

Figure 3 – *Transthoracic echocardiography in the apical four-chamber view demonstrating delayed appearance of microbubbles (> 3 heartbeats) in the left-sided chambers after infusion of agitated saline via peripheral IV access. IV: intravenous.*

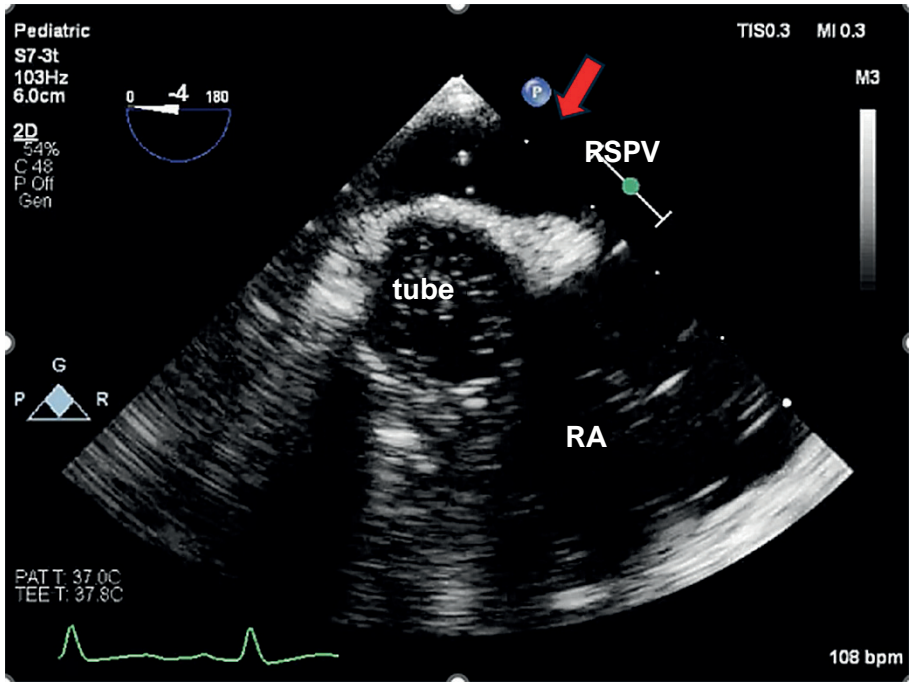

Figure 4 – *Transesophageal echocardiography in a patient following extracardiac Fontan surgery. The arrow indicates the RSPV, where microbubbles are observed after injection of agitated saline via peripheral IV access, which suggests the presence of pulmonary microfistulas. IV: intravenous; RA: right atrium; RSPV: right superior pulmonary vein.*

- **Lower limb access (saphenous or femoral veins)** is mandatory to assess the distribution of the hepatic factor. Early appearance of microbubbles in the left-sided chambers after injection via the inferior vena cava confirms the presence of an intrapulmonary shunt.

d) Pericardiocentesis

Agitated saline injection can be used during pericardiocentesis to confirm, under echocardiographic guidance, correct positioning of the needle or catheter within the pericardial space, particularly when the aspirate is bloody or there is uncertainty regarding instrument location.

The appearance of microbubbles in the pericardial space after the injection of 3–5 mL of agitated saline allows differentiation between the pericardial space and the cardiac chambers, as shown in Figure 5, reducing the risk of inadvertent puncture of intracardiac structures.[10]

Classification

Severity grading:[9]

- **Grade 1:** sparse microbubbles in the LA (< 5 bubbles per frame);
- **Grade 2:** 5-25 microbubbles in the LA;
- **Grade 3:** > 25 microbubbles without complete cavity opacification;
- **Grade 4:** dense LA opacification, similar to right-sided chambers, with contrast visible in the systemic ventricle and aorta.

Technical differentiation between intracardiac and intrapulmonary shunts

The distinction is based on the timing of microbubble appearance in the left-sided chambers (Table 2).

Conclusion

Agitated saline contrast is a simple, safe, highly useful technique in pediatric echocardiography. It enables the identification and differentiation of intracardiac and intrapulmonary shunts, the characterization of systemic venous anomalies, the assessment of alterations related to single-ventricle physiology, and procedural support, such as image-guided pericardiocentesis.

When applied judiciously and with appropriate monitoring, it improves diagnostic accuracy, enhances procedural safety, and reduces the need for invasive or higher-cost methods, thereby optimizing clinical decision-making.

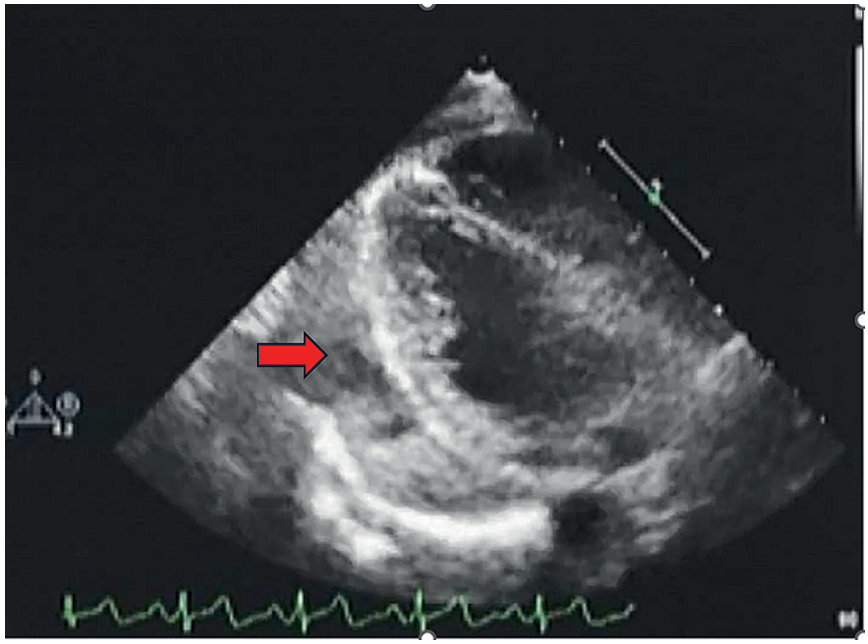

Figure 5 – *Transthoracic echocardiography with infusion of agitated saline into the pericardial space to confirm correct needle positioning during puncture.*

Author Contributions

Conception and design of the research, acquisition of data, analysis and interpretation of the data, writing of the manuscript, and critical revision of the manuscript for intellectual content: Sawamura KSS, Brito MM.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Table 2 – Technical differentiation between intracardiac and intrapulmonary shunts

Characteristic	Intracardiac shunt	Intrapulmonary shunt
Time to appearance in the LV	Early (≤ 3 heartbeats)	Late (> 3-6 heartbeats)
Mechanism	Intracardiac communication	Pulmonary vascular dilation, microfistulas
Clinical example	PFO, ASD	HPS, post-Glenn/Fontan

ASD: atrial septal defect; HPS: hepatopulmonary syndrome; PFO: patent foramen ovale.

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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.

Use of Artificial Intelligence

During the preparation of this work, the authors used NotebookLM to create the central figure. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Availability of Research Data

The underlying content of the research text is contained within the manuscript.

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