

My Approach to Echocardiographic Guidance During Percutaneous Balloon Mitral Valvuloplasty

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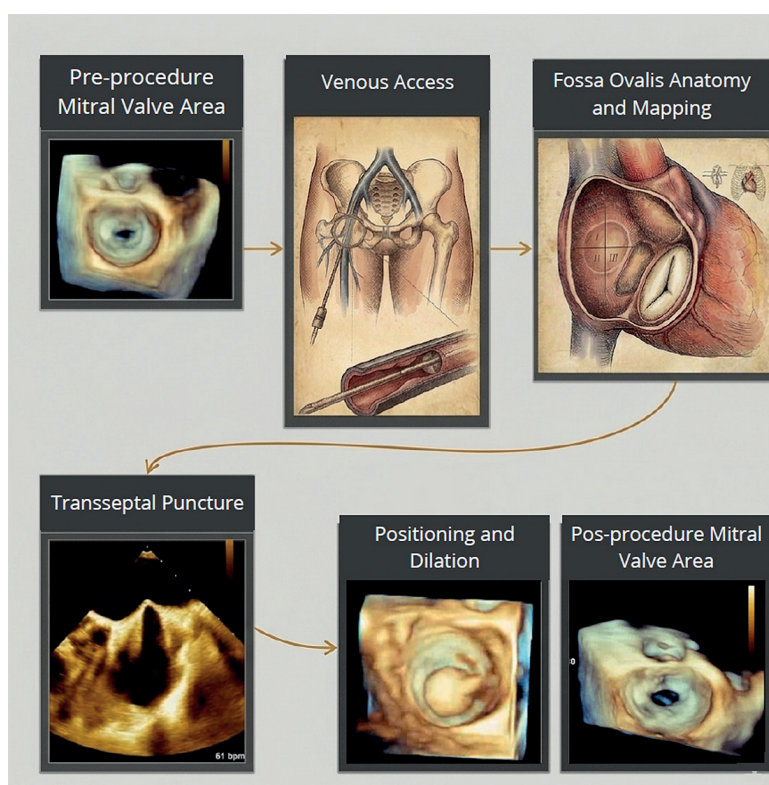
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Central Illustration: My Approach to Echocardiographic Guidance During Percutaneous Balloon Mitral Valvuloplasty



Arq Bras Cardiol: Imagem cardiovasc. 2026;39(3):e20260085

Keywords

Three-Dimensional Echocardiography; Transesophageal Echocardiography; Mitral Valve Stenosis; Rheumatic Heart Disease

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Manuscript received June 13, 2026, revised manuscript June 22, 2026, accepted June 25, 2026

Editor responsible for the review: Marcelo Tavares

DOI: <https://doi.org/10.36660/abcimg.20260085i>

Abstract

Rheumatic heart disease (RHD) remains a major global public health challenge because of its substantial morbidity and mortality, predominantly affecting the mitral valve. Although its prevalence is higher in developing countries, the disease continues to be diagnosed, albeit less frequently, in developed nations. Percutaneous balloon mitral valvuloplasty (PBMV) has become a highly effective therapeutic option for appropriately selected patients, with its technical and clinical success being strongly dependent on careful candidate selection. This article reviews the key aspects of

PBMV, ranging from the echocardiographic criteria used for patient selection to intraprocedural monitoring using transesophageal echocardiography (TEE).

Introduction

Rheumatic heart disease (RHD) remains one of the leading causes of cardiovascular disease worldwide and is considered the second leading cause of cardiovascular morbidity and mortality, surpassed only by atherosclerotic cardiovascular disease.¹ The prevalence of RHD remains high in developing countries; in Brazil and India, for example, it is estimated at 7 and 6 cases per 1,000 school-aged children, respectively. According to the Brazilian Institute of Geography and Statistics, approximately 10 million episodes of pharyngotonsillitis occur annually in Brazil, resulting in an estimated 30,000 new cases of acute rheumatic fever.^{2,3} Globally, approximately 30 million children and young adults are estimated to be living with the chronic form of the disease. In contrast, the incidence in developed countries is substantially lower, ranging from 0.1 to 0.4 cases per 1,000 school-aged children, as reported in the United States.⁴

In Brazil, the lack of effective rheumatic fever prevention programs places a substantial burden on the public healthcare system. This gap in care facilitates the progression to chronic valvular disease, among which mitral stenosis (MS) is the most common manifestation. Patients with severe symptomatic MS have a formal indication for intervention, which may be performed using either a percutaneous or a surgical approach.³

Historically, before the advent of percutaneous techniques, surgical commissurotomy was the standard treatment for MS. Initially, the procedure consisted of digital commissurotomy, in which the surgeon used their fingers to separate the fused valvular commissures. Subsequently, technical refinements led to the introduction of a mechanical dilator through the surgical incision, allowing more controlled dilation of the mitral valve. Closed surgical commissurotomy, introduced in the 1940s, was gradually replaced by open-heart surgery between the late 1960s and early 1970s, driven by the development of cardiopulmonary bypass. In 1982, Kanji Inoue performed the first percutaneous balloon mitral valvuloplasty (PBMV), with the original description published in 1984.^{5,6} Although alternative techniques, such as the double-balloon approach, were also developed, the Inoue balloon became the device of choice. When appropriately indicated, PBMV provides efficacy and long-term durability comparable to those of surgical commissurotomy, resulting in sustained hemodynamic and clinical improvement in both the short and long term, with an overall mortality rate of approximately 1%.⁷

Although the devices used in PBMV, such as balloon catheters, have undergone relatively modest technological changes over the past four decades, advances in cardiac imaging have profoundly transformed the procedure. Transesophageal echocardiography (TEE), particularly following the introduction of 3D imaging, has assumed a pivotal role. The high-quality images provided by TEE, combined with the expertise of the interventional

cardiologist, have made PBMV both safer and more effective. In the catheterization laboratory, the echocardiographer plays a crucial role, particularly in guiding transseptal puncture, thereby improving anatomical precision and reducing the risks associated with one of the most critical steps of the procedure.⁸

Preprocedural assessment and planning for PBMV

Appropriate patient selection for the procedure

TEE plays a pivotal role in the diagnosis, anatomical stratification, and careful selection of patients eligible for PBMV. The primary indications for the procedure include patients with severe MS and favorable valve anatomy (Class I, Level of Evidence B) as well as symptomatic patients with severe MS who are at high surgical risk (Class I, Level of Evidence C), provided that no thrombus is present in the left atrium (LA) or left atrial appendage (LAA).⁹

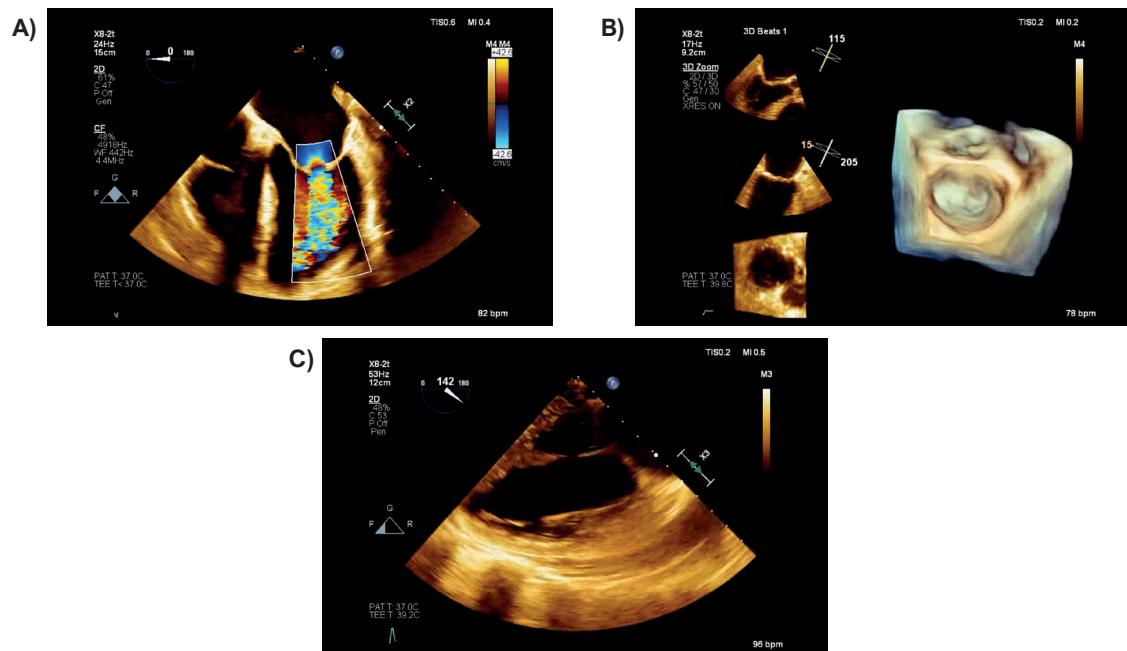
PBMV is also a safe, effective therapeutic option for pregnant women with severe MS and favorable valve anatomy, preferably after the 24th week of gestation. When performed with appropriate radiation protection, including lead shielding and minimal radiation exposure, the procedure is associated with low maternal and fetal morbidity and mortality.⁹

In contrast, mitral valve degeneration secondary to mitral annular calcification is not an indication for PBMV, as its underlying pathophysiology does not involve commissural fusion.

A systematic assessment of mitral valve anatomy and accurate measurement of the mitral valve area (MVA) constitute the cornerstone of PBMV indication. Currently, severe MS is defined based on MVA measurement, obtained using quantitative methods with 2D TEE or, more accurately, by direct planimetry with 3D TEE.¹⁰ Compared with the 2D technique, 3D planimetry provides greater accuracy and reproducibility by allowing more precise delineation of the valve orifice and complete visualization of the leaflets and commissures¹¹ (Video 1; Figure 1).

The anatomical evaluation should include a detailed assessment of leaflet morphology, including the degree of thickening and the presence of calcification, as well as commissural morphology. Characterization of the extent and symmetry of commissural fusion and the distribution of calcification is essential, given that the mechanism of PBMV is based on the mechanical separation of fused commissures, thereby increasing the MVA. The severity and pattern of commissural fusion are directly associated with the risk of clinically significant mitral regurgitation (MR) following the procedure.¹⁰ 3D TEE has revolutionized this assessment by enabling direct, real-time evaluation of the commissures from a single volumetric acquisition of the mitral valve displayed from the LA perspective (surgeon's view) (Video 1B; Figure 1B).

Assessment of the subvalvular apparatus is also mandatory. Acquisition of the 142° TEE imaging plane is recommended to quantify the degree of chordal thickening, fusion, and calcification (Video 1C; Figure 1D).



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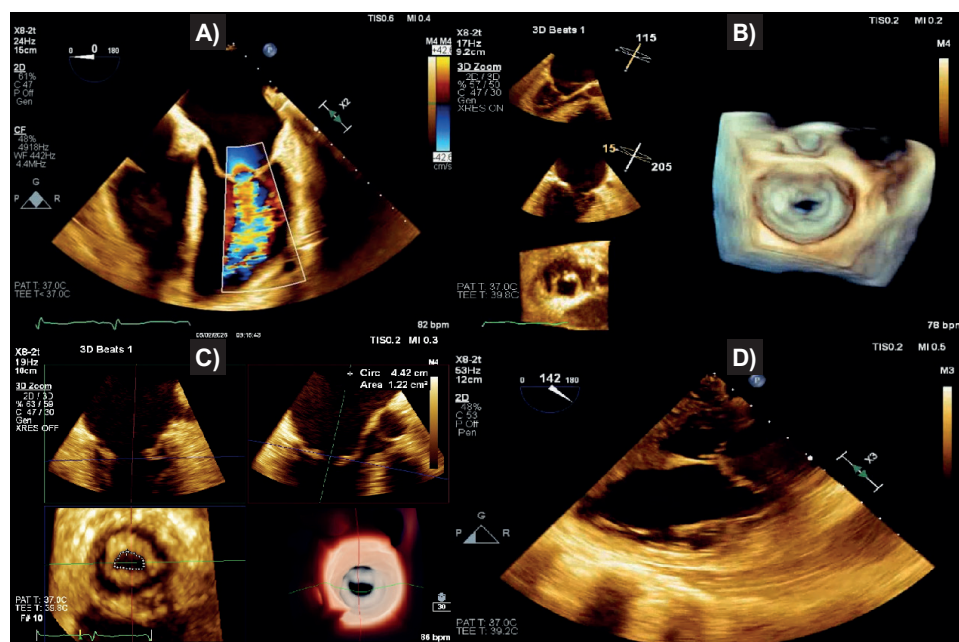


Figure 1 – Key echocardiographic findings in the preprocedural assessment for PBMV. A) Color Doppler demonstrating the PISA in a patient with isolated MS, without MR or valvular calcification. B) 3D reconstruction of the mitral valve from the LA perspective (surgeon's view), demonstrating nearly symmetrical commissural fusion. C) MVA measurement using multiplanar reconstruction (MultiVue) derived from the 3D dataset, yielding a value of 1.2 cm². D) Transgastric 142° view demonstrating the subvalvular apparatus and chordae tendineae for the assessment of thickening and calcification in patients with rheumatic involvement. LA: left atrium; MR: mitral regurgitation; MS: mitral stenosis; MVA: mitral valve area; PBMV: percutaneous balloon mitral valvuloplasty; PISA: proximal isovelocity surface area.

Several echocardiographic scoring systems have been proposed to standardize preprocedural assessment. The Wilkins score, introduced in 1988, remains the most widely used model and evaluates four structural components: leaflet mobility, leaflet thickening, calcification, and subvalvular involvement. However, this score has important limitations as it does not incorporate commissural anatomy and has limited predictive value for long-term outcomes, including the development of acute MR.¹⁰

To address such limitations, Nunes et al. proposed a more comprehensive model incorporating additional variables, including MVA, apical leaflet displacement, commissural area ratio, and subvalvular involvement.^{12, 13} Long-term outcomes after PBMV have also been shown to be strongly influenced by patient age and the quality of the immediate procedural result.¹⁴

Another key component of the preprocedural evaluation is the exclusion of contraindications to PBMV, particularly the presence of greater than mild MR. In such cases, MR severity should preferably be quantified using the quantitative methods recommended in current guidelines, rather than relying solely on qualitative parameters⁹ (Figure 2).

Other contraindications to the procedure include extensive or bicommissural mitral valve calcification, MVA > 1.5 cm², concomitant severe aortic valve disease, coronary artery disease requiring surgical revascularization, significant tricuspid stenosis or regurgitation associated with tricuspid annular dilatation, the presence of thrombus in the LA or LAA, and the absence of commissural fusion.⁹

Exclusion of LAA and left atrial thrombus

Screening for thrombus within the LA, particularly the LAA, is a mandatory component of the preprocedural

assessment. This evaluation should be performed both during the outpatient TEE examination, together with MVA measurement and application of the eligibility scores, and immediately before the intervention. The identification of an intracavitary thrombus constitutes an absolute contraindication to PBMV, requiring cancellation of the procedure and immediate initiation of anticoagulant therapy.^{9,15}

To optimize LAA assessment, the use of the biplane (X-plane) imaging modality is recommended, as it enables the simultaneous acquisition of orthogonal planes and a more comprehensive evaluation of the structure, thereby increasing the sensitivity for thrombus detection (Video 2A).

In cases of diagnostic uncertainty, particularly when differentiating thrombus from sludge and imaging artifacts, ultrasound enhancing agents (UEAs) may be used. Although dedicated software for myocardial perfusion analysis with UEAs is not yet available for TEE, current guidelines recommend their use by adapting image acquisition settings through reduction of the mechanical index (MI < 0.3). Thrombi are characterized by the absence of UEA enhancement. In contrast, sludge, a condition reflecting blood stasis and a high thromboembolic potential, demonstrates complete LAA opacification, although with delayed contrast filling consistent with reduced LAA emptying velocities. Conversely, isolated spontaneous echocardiographic contrast is characterized by rapid and homogeneous opacification of the LAA following UEA administration.¹⁶

Once an LAA thrombus has been confirmed by TEE, full anticoagulation with a vitamin K antagonist, preferably warfarin, is recommended (Class I). The recommended duration of anticoagulation before repeat echocardiographic assessment varies among guidelines and published studies,

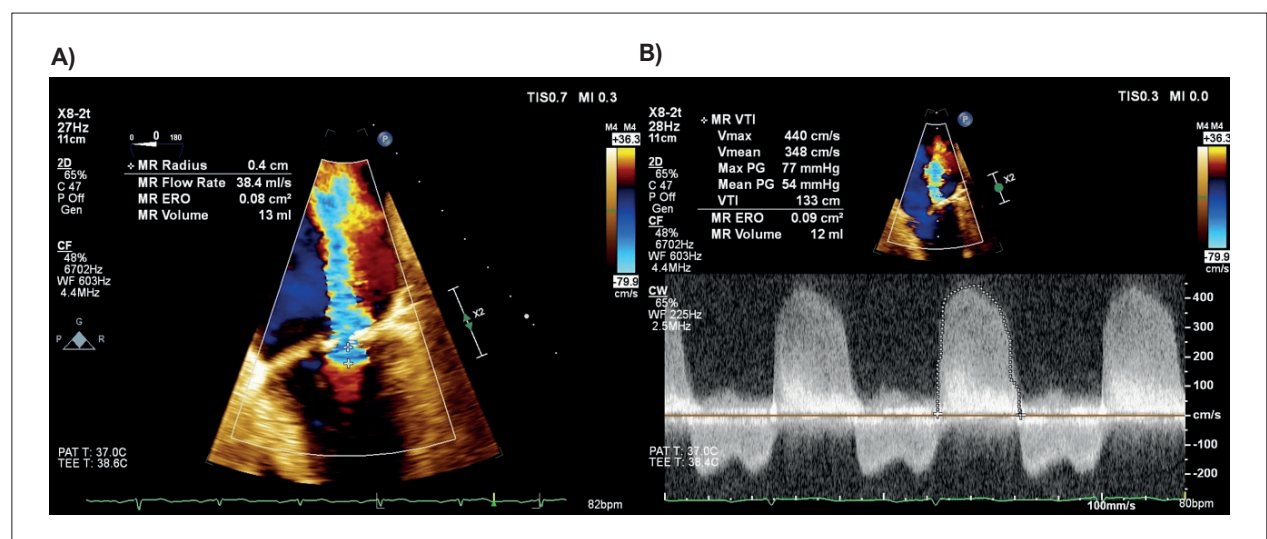
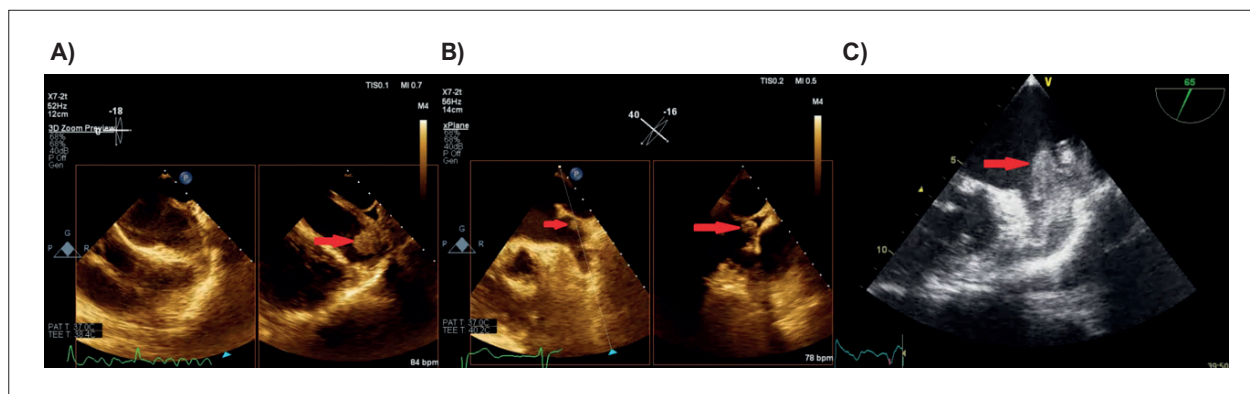


Figure 2 – Echocardiographic quantification of MR before PBMV. A) Quantification of MR using the PISA method. B) Quantification of MR using continuous-wave Doppler of the regurgitant jet, allowing calculation of the EROA and RV. The measured values (EROA = 0.09 cm² and RV = 12 mL) are consistent with mild MR. EROA: effective regurgitant orifice area; MR: mitral regurgitation; PBMV: percutaneous balloon mitral valvuloplasty; PISA: proximal isovelocity surface area; RV: regurgitant volume.



Video 2 – Different locations of thrombi within the LAA. A) Biplane (X-plane) TEE demonstrating a thrombus (red arrow) located within the body of the LAA. View: http://abcimaging.org/supplementary-material/2026/3903/ABCImag-2026-0085_AR_Video_2A.mp4. B) Example of a thrombus (red arrow) located at the LAA ostium, demonstrated using biplane (X-plane) imaging. View: http://abcimaging.org/supplementary-material/2026/3903/ABCImag-2026-0085_AR_Video_2B.mp4. C) Large thrombus (red arrow) involving both the body and the ostium of the LAA. View: http://abcimaging.org/supplementary-material/2026/3903/ABCImag-2026-0085_AR_Video_2C.mp4. LAA: left atrial appendage; TEE: transesophageal echocardiography.

generally ranging from 1 to 3 months. However, the therapeutic response is heterogeneous. Recent evidence has demonstrated that LAA morphology and thrombus location are important predictors of thrombus resolution. Cauliflower and chicken-wing morphologies, particularly when associated with thrombi located in the body or base of the LAA, are associated with a lower likelihood of resolution following anticoagulation. In contrast, cactus morphology and thrombi confined to the apical portion of the LAA are associated with higher rates of complete resolution within 3 months.^{17,18}

Assessment of interatrial septal anatomy

A thorough understanding of interatrial septal (IAS) anatomy is essential for the success and safety of transseptal puncture, a critical step in PBMV. First described in 1959, the transseptal puncture technique has become widely adopted with the expansion of percutaneous structural heart interventions, including PBMV. For this procedure, the ideal puncture site is the posteroinferior portion of the fossa ovalis (Figure 3).

TEE is indispensable for guiding transseptal puncture, reducing the risk of potentially serious complications, such as inadvertent perforation of the aortic root.²⁰

To ensure accurate needle positioning, the bicaval view (typically between 90° and 110°), combined with the biplane (X-plane) imaging modality, is particularly useful. This approach allows simultaneous visualization of the IAS and the ascending aorta in the short-axis view, providing the interventional cardiologist with anatomical landmarks that help maintain the needle-catheter assembly at a safe distance from this adjacent vascular structure²⁰⁻²² (Video 3A; Figure 4A).

During this stage, the echocardiographer should identify anatomical variations that may increase the complexity of transseptal puncture, such as a prominent Eustachian valve

or an IAS aneurysm. In the presence of an IAS aneurysm, excessive septal mobility may create the false impression that the needle has already entered the LA. However, fluoroscopy demonstrates that the needle remains within the right atrium, without complete traversal of the IAS.

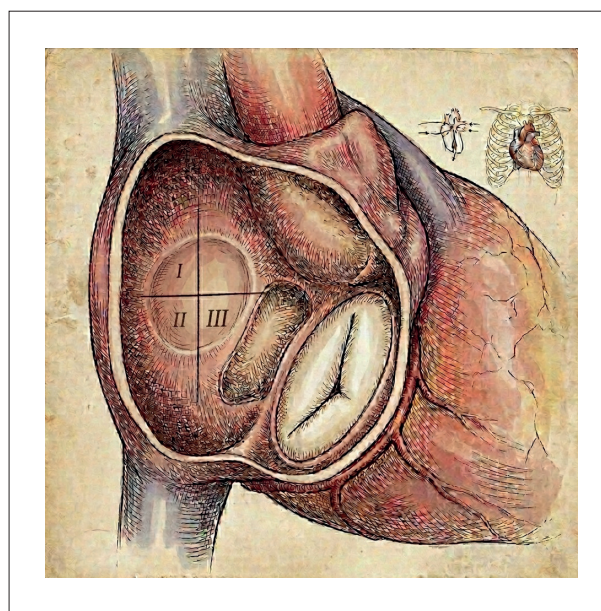
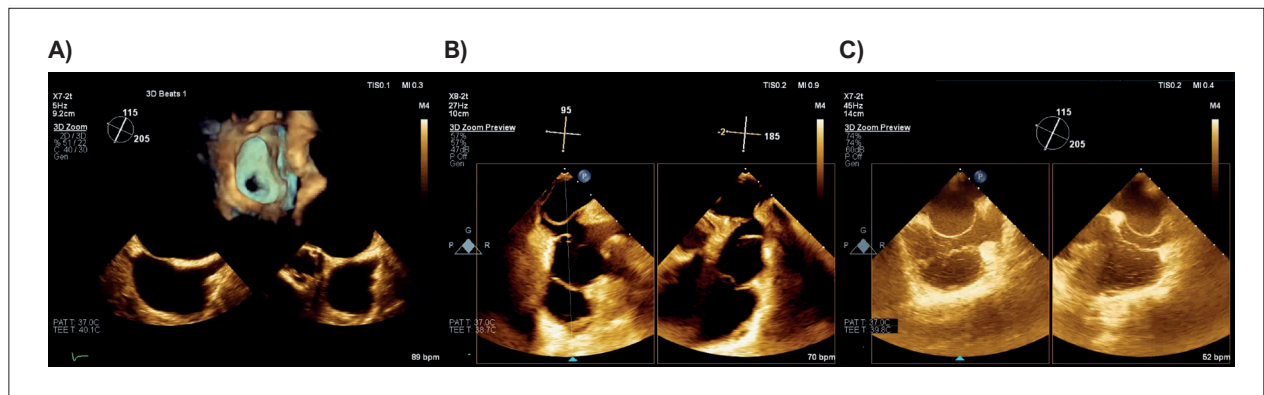


Figure 3 – Anatomy of the IAS and the principal transseptal puncture sites. Region I corresponds to the posterosuperior portion of the fossa ovalis and is preferentially used for procedures such as transcatheter mitral valve repair (MitraClip) and closure of paravalvular leaks. Region II corresponds to the posteroinferior portion of the fossa ovalis and is considered the ideal site for transseptal puncture during PBMV. Region III corresponds to the anteroinferior portion of the fossa ovalis and is typically used for pulmonary vein isolation procedures. IAS: interatrial septum; PBMV: percutaneous balloon mitral valvuloplasty.



Video 3 – 3A) View: http://abcimaging.org/supplementary-material/2026/3903/ABCImag-2026-0085_AR_Video_3A.mp4. **3B)** View: http://abcimaging.org/supplementary-material/2026/3903/ABCImag-2026-0085_AR_Video_3B.mp4. **3C)** View: http://abcimaging.org/supplementary-material/2026/3903/ABCImag-2026-0085_AR_Video_3C.mp4.

Identification of a patent foramen ovale (PFO) is another important aspect of the preprocedural assessment. Although its presence may complicate transseptal puncture, a PFO may be used as an access route to the LA when this is the sole objective of the procedure. In contrast, in interventions such as MitraClip® implantation and percutaneous LAA closure, its use is not recommended, as its marked mobility and anatomical location frequently result in suboptimal positioning of the transseptal system²¹ (Video 3A; Video 3B; Figure 4).

Selection of the appropriate balloon size

Selection of the appropriate Inoue balloon size is a critical step in PBMV, as an inappropriate device size may result in inadequate commissural splitting or injury to the leaflets and subvalvular apparatus, leading to severe MR requiring surgical treatment. Traditionally, balloon diameter is estimated using the following height-based formula:

$$\text{Balloon diameter (mm)} = \text{height (cm)} / 10 + 10$$

However, the lack of a linear relationship between patient height and MVA must be emphasised^{24,25} (Figure 5A-C).

As an alternative to height-based formulas, balloon catheter size can be individualized using TEE. This approach is based on measurement of the mitral annular diameter in the apical four-chamber and two-chamber views, preferably during midsystole or end-systole. From an anatomical standpoint, the measurement obtained in the apical two-chamber view is particularly relevant because it corresponds to the largest intercommissural diameter of the mitral valve, providing a more reliable parameter for device selection and reducing the risk of overdilatation and severe MR.^{26,27}

Inoue balloons are available in different diameters, and initial selection may be guided by patient height:

- 24 mm balloon: dilation range of 20–24 mm; recommended for patients with a height ≤ 140 cm.

- 26 mm balloon: dilation range of 22–26 mm; recommended for patients with a height ≤ 160 cm.
- 28 mm balloon: dilation range of 24–28 mm; recommended for patients with a height of 160–180 cm.
- 30 mm balloon: dilation range of 26–30 mm; recommended for patients with a height > 180 cm.

Procedure

Objective

Successful PBMV is defined as achievement of an MVA > 1.5 cm² without induction of moderate or severe MR (grade > 2+). Achieving this outcome requires the echocardiographer to have a detailed understanding of all procedural steps and to maintain continuous communication with the interventional cardiologist throughout the procedure (Central Illustration).^{14,26}

Procedural steps

Step 1 – Image-guided transseptal puncture

The first step of PBMV is transseptal puncture, performed via femoral venous access. Using the biplane (X-plane) imaging modality in the bicaval TEE view, the echocardiographer guides the interventional cardiologist to puncture the posteroinferior portion of the IAS (Video 4A-B; Figure 6A-B). This puncture site is critical because it provides a safe distance from the aortic root, an adequate working height within the LA, and coaxial alignment of the delivery system with the mitral valve.

A pigtail catheter may be positioned in the aortic root to facilitate determination of the optimal puncture height, thereby reducing the risk of inadvertent aortic perforation. Subsequently, after being repositioned in the left ventricle (LV), the same catheter can be used to measure the transmitral pressure gradient following PBMV^{7,26} (Figure 6C).

Before transseptal puncture, the echocardiographer should identify and communicate any anatomical variations that may interfere with the procedure, such as an IAS aneurysm, PFO, or a prominent Eustachian valve. Successful traversal of the IAS is confirmed by visualization of the characteristic tenting of the fossa ovalis at the intended puncture site²⁰ (Video 4B; Figure 6B).

After successful transseptal puncture, the Inoue guidewire, featuring a pigtail-shaped distal tip, is advanced into the LA. The dilator is then introduced, followed by sequential advancement of the Inoue balloon across the IAS, minimizing the risk of injury to adjacent cardiac structures^{6,27} (Video 5A-B; Figure 7A-B).

Step 2 – Introduction of the balloon delivery system

After the appropriate balloon size has been selected, the Inoue balloon is prepared and assembled. The IAS is then

dilated using the 14-Fr rigid dilator included in the Inoue system, allowing advancement of the balloon into the LA^{6,27} (Video 5A-F; Figure 7).

Step 3 – Valve dilation and immediate echocardiographic assessment

Inflation of the Inoue balloon is performed in three sequential stages. Using a mixture of saline and iodinated contrast to increase radiopacity, the distal portion of the balloon is inflated first, followed by the proximal portion and, finally, the balloon waist (Video 5C-E; Figure 8C-E). The balloon waist remains positioned at the level of the mitral valve and represents the region of greatest radial force, responsible for separating the fused commissures.^{7,27}

More specifically, once the Inoue balloon has been positioned within the LA, approximately 2 mL of the saline-

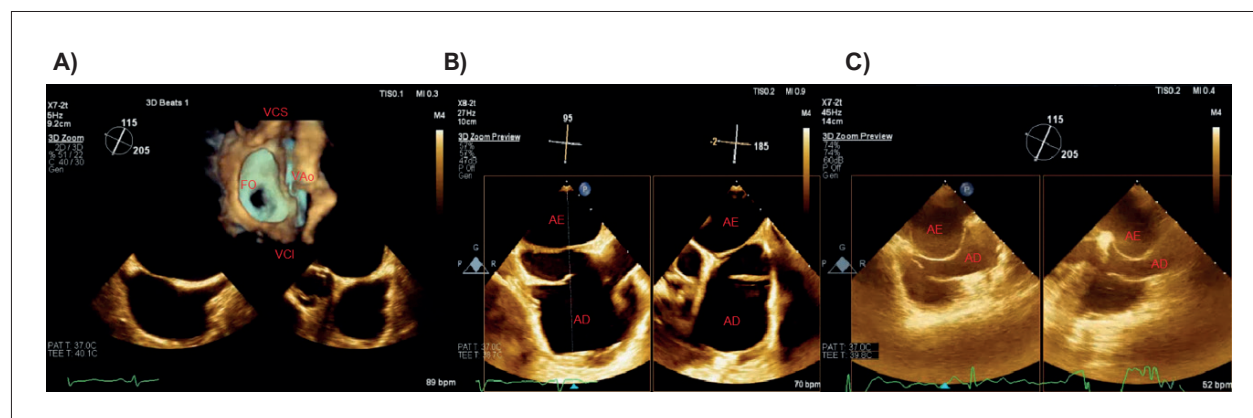


Figure 4 – Anatomical features of the IAS relevant to transseptal puncture. A) 3D reconstruction of the IAS obtained using the 3D Zoom acquisition mode from the RA perspective, demonstrating the normal anatomy of the fossa ovalis, represented by the dropout, as well as the AV, SVC, and IVC. B) Redundant Eustachian valve, an anatomical feature that may complicate transseptal puncture. C) IAS aneurysm, an important anatomical variant that should be identified before the procedure because it increases the technical complexity of transseptal puncture. AV: aortic valve; IAS: interatrial septum; IVC: inferior vena cava; RA: right atrium; SVC: superior vena cava.

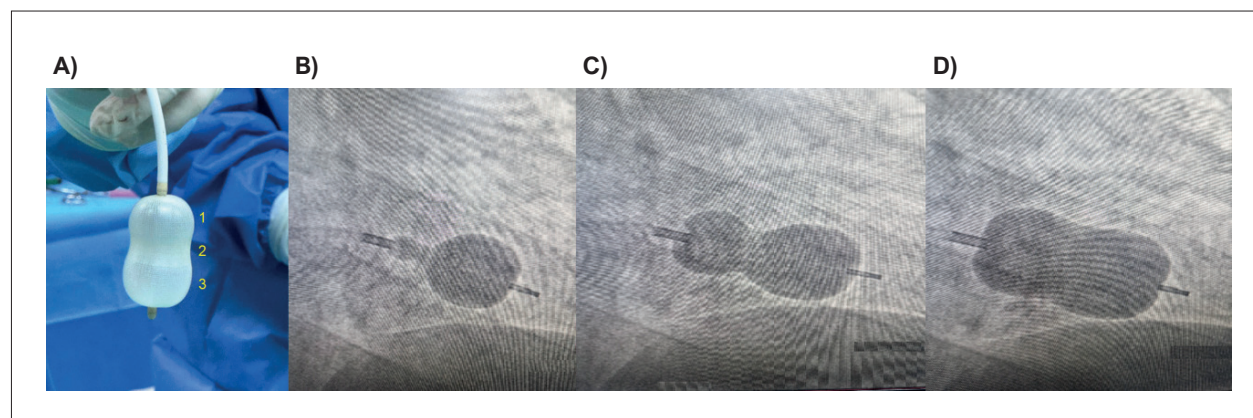


Figure 5 – Structure and inflation sequence of the Inoue balloon. A) Inoue balloon showing the proximal segment (1), the waist (2), and the distal segment (3). The waist corresponds to the region of greatest radial force and is responsible for commissural splitting during PBMV. B-D) Balloon inflation sequence during the procedure: the distal segment is inflated first, followed by the proximal segment and, finally, the waist, thereby producing commissural splitting. PBMV: percutaneous balloon mitral valvuloplasty.

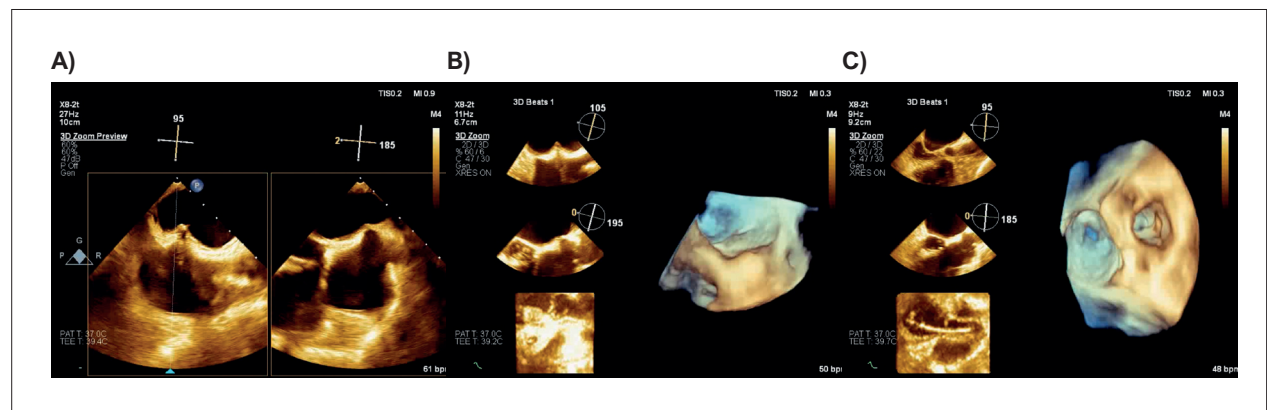
contrast mixture is initially injected to produce slight expansion of the distal balloon segment. This maneuver facilitates crossing of the mitral valve and reduces the risk of balloon entrapment within the chordae tendineae (Video 5D; Figure 7D).

After the balloon has crossed the mitral valve and has been positioned within the LV, the distal segment is fully inflated. At this stage, TEE guidance is essential. Failure of the distal segment to assume a fully spherical configuration should raise suspicion of significant resistance from the subvalvular apparatus or entrapment within the chordae tendineae. Once an appropriate spherical configuration has been confirmed, the balloon is gently retracted until the waist is positioned at the level of the mitral valve, after which full inflation is maintained for approximately 3-5 seconds (Video 5E; Figure 7E).

Following valve dilation, the balloon is repositioned in the LA, and immediate echocardiographic assessment of the

PBMV results is performed. This evaluation should include measurement of the MVA by 3D planimetry, assessment of valve and commissural morphology, characterization of the commissural splitting pattern (symmetric or asymmetric), detection of new or worsened MR, identification of its anatomical location, and evaluation for pericardial effusion, including its hemodynamic consequences. Although transmitral pressure gradients decrease immediately after the procedure, they should be interpreted with caution because they may increase during the subsequent hours as hemodynamic conditions normalize and the effects of anesthetic induction resolve. Therefore, the primary criterion for procedural success remains the achievement of an MVA $> 1.5 \text{ cm}^2$.^{26,21}

In routine practice, the initial balloon inflation is typically performed using a diameter 2-3 mm smaller than the



Video 4 – 4A) View: http://abcimaging.org/supplementary-material/2026/3903/ABCImag-2026-0085_AR_Video_4A.mp4. 4B) View: http://abcimaging.org/supplementary-material/2026/3903/ABCImag-2026-0085_AR_Video_4B.mp4. 4C) View: http://abcimaging.org/supplementary-material/2026/3903/ABCImag-2026-0085_AR_Video_4C.mp4.

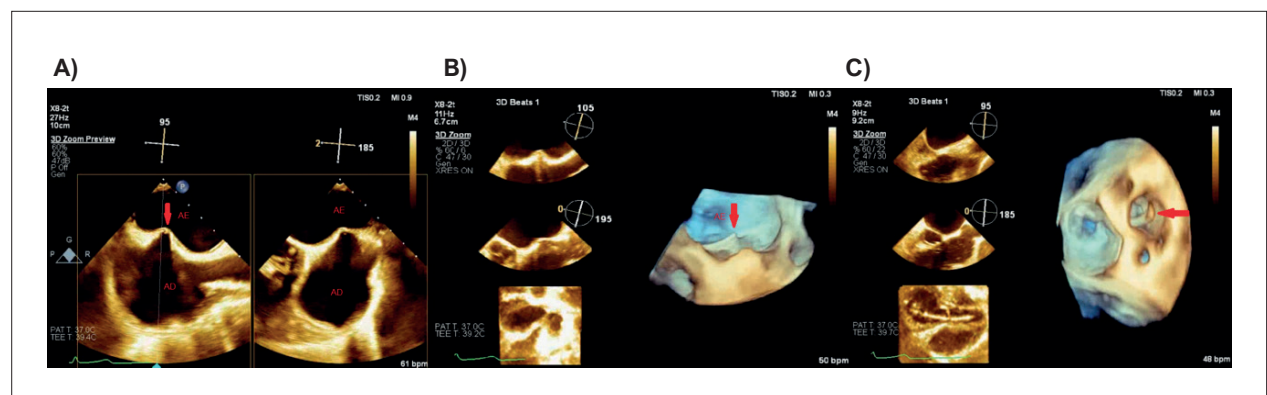
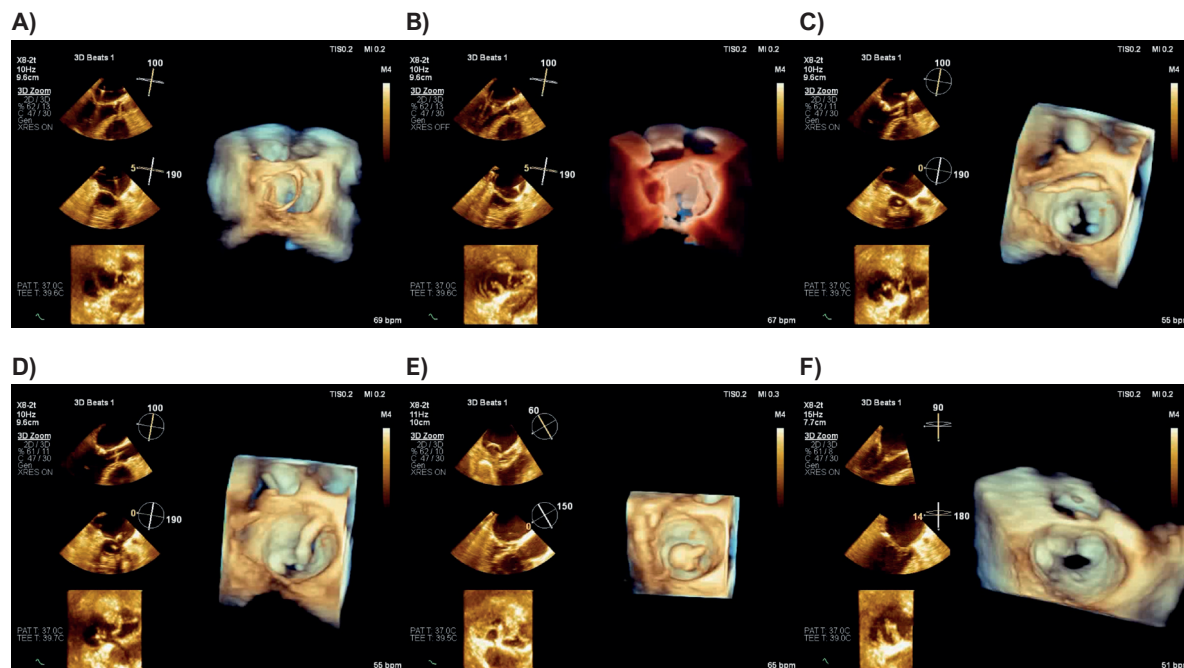


Figure 6 – Echocardiographic guidance of transseptal puncture during PBMV. A) Bicaval view combined with the biplane (X-plane) imaging mode, allowing simultaneous visualization of the IAS and the AA in orthogonal planes. This approach assists the interventional cardiologist in directing the puncture toward the posteroinferior portion of the IAS, away from the AA and toward the IVC (red arrow). B) 3D reconstruction (3D Zoom) demonstrating tenting of the IAS caused by the transseptal needle immediately before septal traversal (red arrow). C) 3D reconstruction (3D Zoom) demonstrating the pigtail catheter positioned in the AA (red arrow), serving as an anatomical landmark during transseptal puncture. AA: ascending aorta; IAS: interatrial septum; IVC: inferior vena cava; PBMV: percutaneous balloon mitral valvuloplasty.



Video 5 – 5A) View: http://abcimaging.org/supplementary-material/2026/3903/ABCIImag-2026-0085_AR_Video_5A.mp4. 5B) View: http://abcimaging.org/supplementary-material/2026/3903/ABCIImag-2026-0085_AR_Video_5B.mp4. 5C) View: http://abcimaging.org/supplementary-material/2026/3903/ABCIImag-2026-0085_AR_Video_5C.mp4. 5D) View: http://abcimaging.org/supplementary-material/2026/3903/ABCIImag-2026-0085_AR_Video_5D.mp4. 5E) View: http://abcimaging.org/supplementary-material/2026/3903/ABCIImag-2026-0085_AR_Video_5E.mp4. 5F) View: http://abcimaging.org/supplementary-material/2026/3903/ABCIImag-2026-0085_AR_Video_5F.mp4.

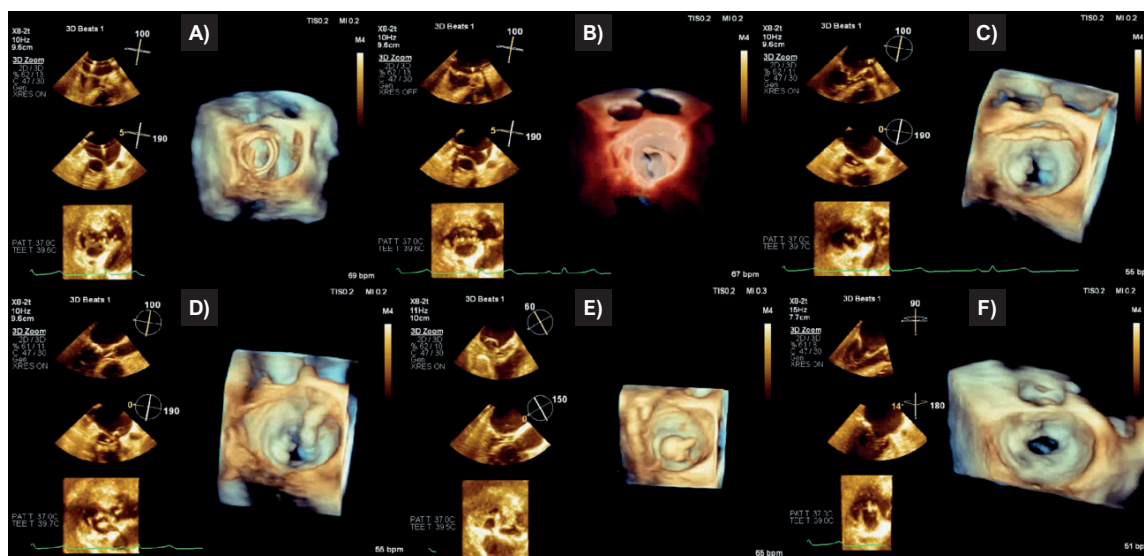


Figure 8 – Steps of Inoue balloon advancement and positioning during PBMV. A) Inoue guidewire with a pigtail-shaped distal tip designed to minimize the risk of LA injury. B) Withdrawal of the guidewire after positioning the Inoue balloon within the LA. C) Advancement of the balloon system toward the mitral valve. D) Positioning of the Inoue balloon with the waist at the level of the mitral valve. E) Inflation of the proximal segment of the balloon within the LA. F) Final appearance of the mitral valve after PBMV, demonstrating an increase in MVA compared with Figure 1B. LA: left atrium; MVA: mitral valve area; PBMV: percutaneous balloon mitral valvuloplasty.

patient's estimated final balloon diameter. Two or three additional inflations are then performed with progressive increases in balloon volume until the planned diameter is reached, while MR severity is reassessed after each inflation. The development of new or significant worsening of MR constitutes an indication for immediate termination of the procedure, and additional inflations with larger balloon volumes are not recommended.^{20,27}

Significant MR following PBMV may occur in up to 15% of patients, depending on the diagnostic criteria adopted. According to its anatomical location, MR can be classified into four patterns:

- Isolated commissural: 34.4% of cases.
- Commissural MR associated with posterior leaflet involvement: 25.0% of cases.
- Central MR resulting from extensive valve opening: 17.0% of cases.
- Central MR secondary to rupture or flail of the A2/P2 scallops: 23.4% of cases.²⁸

Acute MR is one of the most serious complications of PBMV and may result from inadequate commissural splitting, leaflet perforation, or papillary muscle rupture, frequently requiring surgical intervention. On TEE, the regurgitant jet is often eccentric, potentially leading to underestimation of MR severity. Furthermore, it is important to recognize that the criteria used to quantify chronic MR should not be applied to the assessment of acute MR.¹⁴

The most accurate measurement of MVA is obtained by direct planimetry using 3D TEE. Pressure half-time-derived MVA should not be used immediately after PBMV because acute changes in atrial and ventricular compliance compromise its accuracy. Accordingly, this method becomes more reliable approximately 48-72 hours after the procedure.^{14,27,28}

At the end of the intervention, the echocardiographer monitors balloon withdrawal to exclude iatrogenic injury and performs a repeat assessment of the IAS to identify residual atrial septal defects resulting from transseptal puncture as well as the presence of pericardial effusion. Small IAS defects with left-to-right shunting are frequently detected by TEE immediately after PBMV and, in most cases, decrease in size progressively or close spontaneously within 6-12 months. In contrast, right-to-left shunting is generally associated with significant pulmonary hypertension and may persist temporarily until pulmonary pressures decline following the procedure.^{7,14,27-29}

Outcomes

Immediate procedural success rates following PBMV are high, exceeding 90% when patients are appropriately selected. Echocardiographic and hemodynamic success is classically defined as the achievement of a final MVA ≥ 1.5 cm² in the absence of moderate or severe MR (grade ≥ 2 +).^{11,34} Procedure-related mortality is remarkably low (0%-3%).⁸

Improvements in MVA and hemodynamic status are generally sustained in patients with favorable valve anatomy, particularly younger individuals. In this subgroup, event-

free survival at 5, 10, and 15 years reaches 89%, 79%, and 43%, respectively.³¹⁻³³ In contrast, older patients or those with unfavorable valve anatomy, particularly in developed countries, experience less favorable long-term outcomes, with event-free survival rates of 56% at 10 years and 30% at 20 years.

The incidence of periprocedural complications has declined substantially over recent decades. This reduction reflects increasing operator experience, advances in cardiac imaging, and the continuous involvement of the echocardiographer throughout the procedure. The most common complications include cardiac tamponade (0.5%-12%) and embolic events, including stroke (0.5%-5%). Acute myocardial infarction occurs less frequently and is generally attributable to inadequate anticoagulation or embolization to the right coronary artery during the procedure. Structural complications include leaflet laceration, perforation of the cardiac chambers (LA or LV), and rupture of the subvalvular apparatus involving the chordae tendineae and papillary muscles. However, severe MR remains the most clinically significant complication, with an incidence of up to 15%.^{28,33}

Conclusion

Careful patient selection, combined with favorable valve anatomy, is the principal determinant of immediate procedural success and favorable long-term outcomes following PBMV. In this context, a thorough understanding of mitral valve anatomy, with particular attention to the commissures, together with objective assessment of MR severity, is essential for appropriate procedural planning and intraprocedural guidance.

The presence of the echocardiographer in the catheterization laboratory is essential for enhancing procedural safety, particularly during transseptal puncture guidance. Furthermore, immediate echocardiographic assessment after each balloon inflation allows evaluation of commissural splitting, measurement of the MVA, and early detection of new or worsening MR, the principal complication of PBMV.

In developing countries such as Brazil, where RHD remains highly prevalent, PBMV continues to play an established role in the management of rheumatic MS by relieving valvular obstruction, improving quality of life, and, in many cases, delaying the need for surgical intervention.

Author Contributions

Conception and design of the research: Gripp EA, Lourenço BN, Carestiato LR, Côrtes LA, Rabischoffsky A; acquisition of data: Gripp EA, Lourenço BN, Carestiato LR, Ribeiro ML, Rabischoffsky A; analysis and interpretation of the data: Gripp EA; writing of the manuscript: Gripp EA, Lourenço BN, Carestiato LR, Ribeiro ML, Côrtes LA, Rabischoffsky A; critical revision of the manuscript for intellectual content: Gripp EA, Lourenço BN, Ribeiro ML, Côrtes LA, Rabischoffsky A.

Potential Conflict of Interest

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

Sources of Funding

There were no external funding sources for this study.

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 Gemini 1.5 to create an artistic representation of the fossa ovalis depicted in Figure 4 and the Central Illustration (atrial septal aneurysm and fossa ovalis). After using this tool, the authors reviewed and edited the content as necessary 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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