Review Article

My Approach to Assessment of Mitral Paraprosthetic Leak

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Abstract

Mitral paraprosthetic leak is a common, often asymptomatic condition. When presented with clinical manifestations such as heart failure and/or hemolysis, interventional treatment is indicated. The transcatheter approach has become increasingly popular, requiring careful planning using imaging methods, particularly echocardiography. Echocardiography is crucial for assessing the severity, location, size, shape, and number of leaks. Once these variables are determined, the treatment approach is planned, typically using the transseptal route. The optimal puncture site depends on various factors, with precise puncture location being paramount. Intraoperative echocardiographic evaluation is essential for procedure success, guiding device positioning and adjustments while also identifying any potential complications.

Introduction

Paraprosthetic Leak occurs when a reflux appears around a valve prosthesis and can have several causes.[1-4] Most often, these are incidental findings, having clinical repercussions in only 5% of individuals. Related clinical manifestations include complaints such as heart failure in 85% of cases and/or clinically significant hemolysis in up to 47%.[1]

With a prevalence of up to 17%, the mechanism is diverse and sometimes poorly understood. A gap between the suture ring and the native valve ring may occur due to excessive calcification, an infectious event, or technical issues during surgery.[1,3] In mitral valve topography, this finding is seen in up to 15% of patients undergoing mitral valve replacement.[5]

According to recent guidelines,[2-4] leak repair is recommended for patients experiencing clinical heart failure or significant hemolysis.

Due to the risks associated with new surgical approaches, transcatheter treatment has become more prevalent in specialized centers for cases with favorable anatomies. However, complications such as interference with the prosthesis or nearby structures can occur.

Urgent surgery or death can occur in up to 4% of cases. In contrast, the composite outcome of adverse events within 30 days, including death, myocardial infarction, stroke, major bleeding, and emergency surgery, can reach up to 8.7%.[1,6]

The technical success rate of percutaneous closure was reported to be 86%, with an improvement in the functional class of up to 77%.[6] Ruiz et al.[7] reported long-term survival at 6, 12, and 18 months as 91.9, 89.2, and 86.5%, respectively. Sorajja et al.[8] found a survival rate of 75% for 1 to 2 years after percutaneous paraprosthetic leak closure and an estimated 3-year survival rate of 64.5%.

In screening by the Heart Team, relevant aspects of diagnostic imaging are fundamental for the therapeutic decision. A comprehensive investigation is mandatory, including transthoracic echocardiography with the identification and classification of the degree of reflux, as well as transesophageal complementation using three-dimensional (3D) imaging.[4,6]

Before planning a possible approach, local or systemic infectious conditions, as well as the presence of cavitary thrombi, must be excluded.[1,9]

Leak Image Assessment

Patient eligibility and scheduling for potential closure begins with obtaining high-quality images. Various methods are available to diagnose paraprosthetic leaks, including transthoracic echocardiogram (TTE), transesophageal echocardiogram (TEE), computed tomography (CT), and magnetic resonance imaging (MRI). Among these, there is no ideal diagnostic method, although echocardiographic imaging is the most commonly used and widely available method.

As an advantage, echocardiography allows for a direct comparison of pre-procedural images with intra-procedural results. However, echocardiography is susceptible to specific artifacts from acoustic shadows, which can complicate assessment. 3D complementation improves spatial definition, adding the ability to determine the path of a leak, which can often follow a serpentine-like course.[10]

On a superficial level, the first information to be checked and confirmed is the severity, location, size, shape, and number of leaks. Initially, the valve prosthesis is "scanned" through a systematic rotation of the echo probe, searching for the presence of dehiscence and/or paraprosthetic signs with the color Doppler.[1,4,6]

The type of prosthesis and the techniques employed for its implantation are fundamental during the imaging evaluation. The team must be aware of various factors, from the technique used for suturing to potential prosthetic materials like patches that aid in fixation.[1]

Evaluating a paraprosthetic leak requires consideration of multiple parameters and the patient's anatomical structure. The first step is assessing the movement of the device

Keywords

Mitral Valve; Heart Valve Prosthesis; Heart Valve Diseases.

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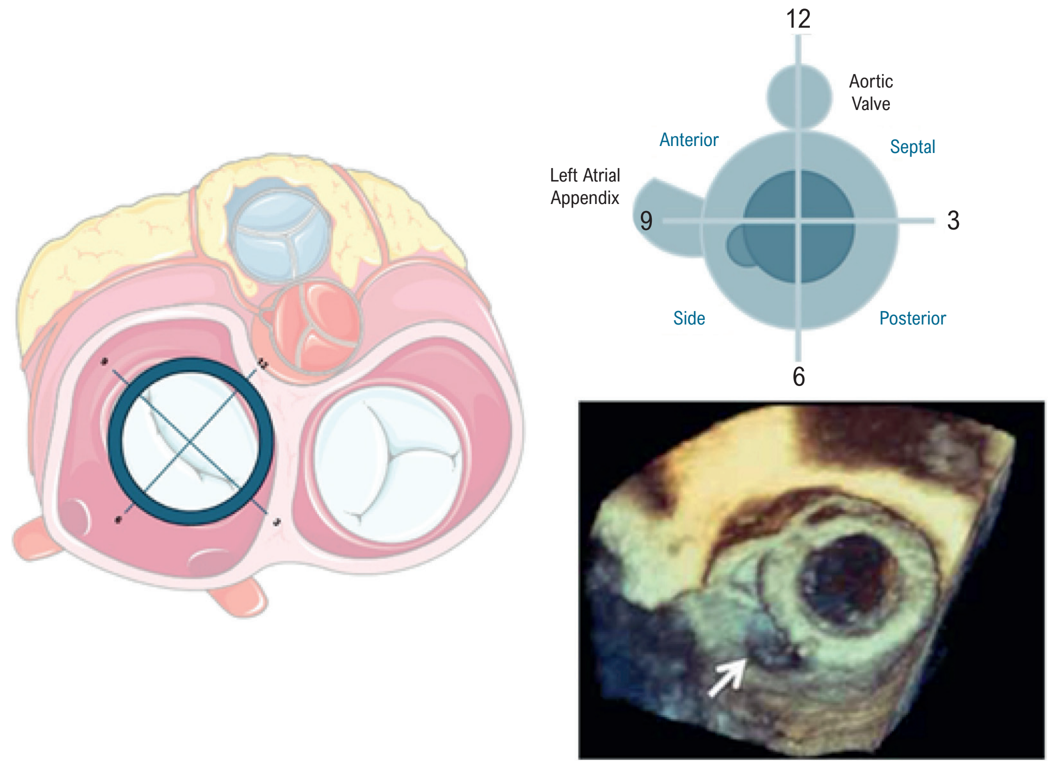
Central Illustration: My Approach to Assessment of Mitral Paraprosthetic Leak



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Schematic drawing of the paraprosthetic leak location and orientation in a mitral prosthesis.

relative to the native ring. Displacements of the device, known as "Rock Motion," indicate significant dehiscences affecting more than 40% of the ring. In some cases, this hypermobility may result from adjacent tissue mobility due to infectious events. In such cases, a transcatheter approach is contraindicated, and prompt evaluation for conventional surgery is necessary (Video 1).[6,10]

Once this complication has been ruled out, the Doppler parameters need to be evaluated, as in Table 1.

The first step is to grade the intensity of the regurgitation, as well as its hemodynamic repercussions. Parameters commonly used in the echocardiographic classification of native valve lesions can be extrapolated with caution to the assessment of paraprosthetic leaks.[1,10]

Assessments of Doppler curves of the pulmonary veins in mitral topography leaks and that of the ascending aorta in aortic topography seem useful at first. The observation of high transprosthetic gradients, even with normal aspects of the leaflets or mobile elements, also signals the possibility of hyperflow and important paraprosthetic leak.[1]

Signs of progressive eccentric hypertrophy also make up the diagnosis of regurgitation severity, signaling significant volume overload.[1,10]

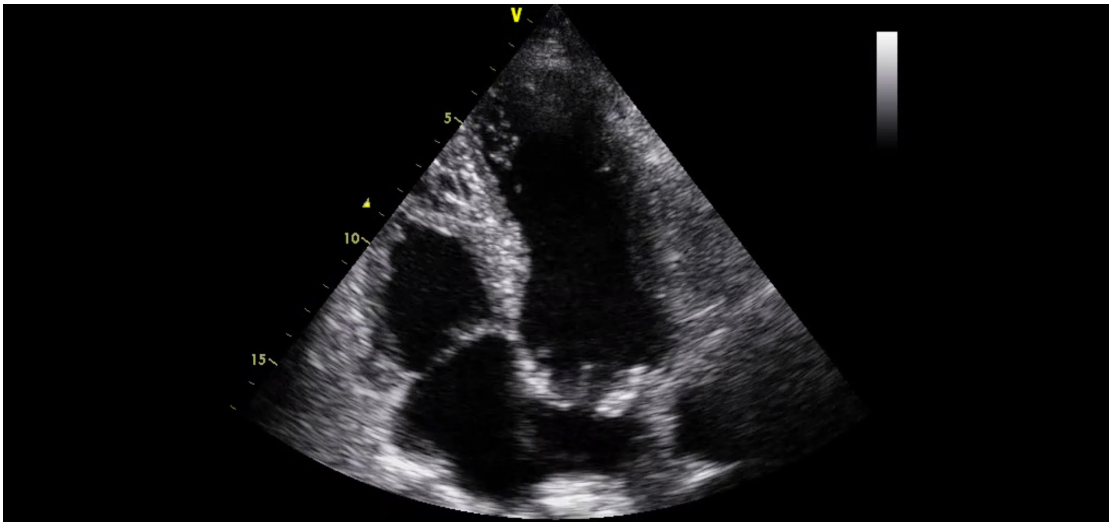
Location

Location and findings in echocardiographic reports typically adhere to a standardized pattern. The topography of the device is often described using a clock reference, mirroring the surgeon's view in the operating room as depicted in the Central Illustration.[10]

In the case of the mitral position, guidance can be based on both clock-face orientation and anatomical relationships. The location is determined relative to the mitral valve annulus and is described as medial, lateral, anterior, or posterior. The clock begins at the 12 o'clock position, toward the aortic valve, which makes the 3 o'clock position at the posteromedial commissure or toward the interatrial septum, and the 6 o'clock position at the midpoint of the posterior ring. This detailed location of the puncture facilitates the optimal selection of the transseptal puncture site.[1,6]

Dimensions

Although the course of the leak may be serpentine-like, assessment of the reflux vena contracta is an important step towards its classification and planning of a possible transcatheter approach, including the selection of devices to be used.[1]



Video 1 – *Transthoracic echocardiography image, an apical 4-chamber window showing rock motion image of the mitral valve prosthesis.*
Link: http://abcimaging.org/supplementary-material/2024/3703/2024-0034_video_01.mp4

Table 1 – Echocardiographic Parameters to Evaluate Mitral Paraprosthetic Leak

	Feature	Minor	Minor to Moderate	Moderate	Moderate to Major	Major
VC, mm	Minimum	<2	2-3	3-5	5-7	≥7
Circumference, %	Minimum	<5	5-10	10-20	20-30	≥30
Reg. Vol., mL	<10	<15	15-30	30-45	45-60	≥60
RF, %	<15	<15	15-30	30-40	40-50	≥50
ERO, mm^2	<5	<5	5-20	20-30	30-40	≥40

VC: Vena Contracta; Reg. Vol.: Regurgitant volume; RF: Regurgitant fraction; ERO: Effective Reflux Orifice.

There is no recommendation to cross the leak with balloon catheters to measure its size due to the risk of iatrogenic injuries in this procedure.[1]

To accurately determine the size of the leak, both grayscale images with acquisition data and color flow are utilized. Using dedicated software, a cutting plane parallel to the ring is positioned at the leak level, enabling derivation of the maximum and minimum diameter and area (see Figure 1).[1,6,10]

A method to enhance the assessment of leak dimensions post-localization is to obtain an image with the smallest possible volume containing the complete path of the leak, achieved through single-beat Gated electrocardiograph (ECG) and a high 3D volume rate (HVR). Subsequently, the Color Doppler mode is acquired. The leak is then opacified by the mapped flow of turbulence seen by Color Doppler in multiplanar analysis. It allows the visualization of the shape of the leak's vena contracta and measurement of its dimensions.[6]

Recently, new 3D image rendering techniques have been introduced to facilitate detailed visualization of the morphology of the leak's path, aiding in the precise guidance of interventional procedures.

Planning and Intraoperative Steps

The first step is to define the access route to approach the leak. Venous or arterial access alternatives are possible in any condition but must be selected according to certain anatomical variations. Femoral venous access requires a transseptal puncture to access the left side, and this procedure is important in planning how to manage catheters inside the left atrium.[1,6]

A short-axis view of the aortic valve is acquired, positioned between 20 and 50 degrees, with a focus on the interatrial septum. This is followed by activating the multiplanar mode to display an orthogonal image corresponding to the bicaval view.[11]

For mitral leaks, selecting the transseptal puncture site should consider its location to enhance the procedure's success rate. Typically, a central puncture is preferred, allowing sufficient height above the mitral annulus to accommodate the curvature of the steerable sheath (usually around 2.5 cm, depending on the model and sheath size).[1,6,9,10]

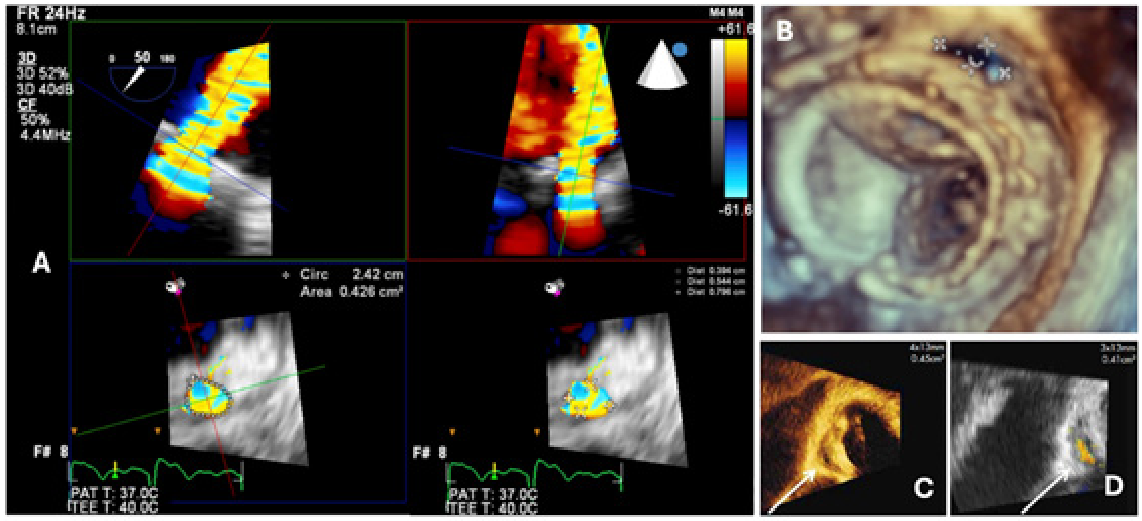


Figure 1 – *Assessment of size and appearance of the mitral paraprosthetic leak. A) Steps for calculating the area of the vena contracta and its dimensions. B) Use of the 3D method to measure the dimensions of the paraprosthetic leak. C and D) Assessment on different color scales and with Color Doppler. Adapted from Gafoor et al.[1] and Pysz et al.[6]*

The anterograde crossing of the leak opening is conceptually carried out using a transseptal approach, with closure performed retrogradely by pulling the device from the left ventricle toward the left atrium.[11]

For mitral leaks in the anterior region, a more superior puncture may be better as it generally improves coaxiality during traversal. The posteriorly located mitral leak remains the most challenging to access. A low posterior puncture is generally necessary to obtain the best coaxiality, allowing crossover. However, this can be constrained by individual anatomical variations, such as the size of the fossa ovalis and the angle at which the inferior vena cava enters the right atrium.[1,6,9,10]

In cases where the anatomy of the mitral access is challenging, retrograde transfemoral arterial access can be considered due to its anatomical feasibility in approaching the leak.[6] The transapical thoracotomy approach may also be used to aid in anatomical positioning, but this is typically an exceptional measure.[6,10]

A hydrophilic wire is generally used to cross the leak, followed by the insertion of a diagnostic catheter. Subsequently, the wire is exchanged for a stiffer one, guided by fluoroscopy and intraoperative transesophageal echocardiography.[1]

Intraoperative echocardiography plays a crucial role in the procedure, supporting tasks ranging from transseptal puncture to crossing the leak with wires and catheters, as well as in the precise positioning of occlusion devices. It is also essential for the early detection of serious complications such as tamponade or the risk of wire entanglement within the cardiac chambers.[1,6,9,10]

In instances where the orifice is narrow or anatomically distorted, positioning and crossing can be particularly challenging. In these situations, after the catheter tip is positioned near the leak orifice, as confirmed by transesophageal 3D echocardiography, it may be beneficial to revert to biplanar color Doppler imaging. This approach enables precise guidance of catheter and/or wire movements toward the orifice, allowing simultaneous visualization in two directions with superior temporal and spatial resolution compared to 3D imaging.[6]

In selected cases, to mitigate the risks associated with transesophageal echocardiography and anesthesia, intracardiac echocardiography may serve as an alternative, despite its technical limitations compared to transesophageal echocardiography devices, particularly in terms of spatial definition, and its limited availability in most national services.[6,10,12,13]

When choosing closing devices, it is recommended to select those 2 to 3 mm larger than the measured diameter. After positioning and fully opening the devices inside the orifice but while still attached to the introducers, echocardiography should be used to evaluate the immediate results. This should include an assessment of the mobility of the prosthesis located there, residual regurgitation jet with assessment of vena contracta and effective regurgitation area (ROS), as well as hemodynamic parameters evaluated by Doppler, such as transprosthetic gradients and flow in pulmonary veins, among others.[6,10]

Due to the limited availability of devices designed for occluding paraprosthetic leaks, adaptations are often necessary during the planning of this intervention. Consequently, finding a perfect device is uncommon. Still, it is crucial to consider potential interference with prosthetic leaflets or other mobile elements, as well as adjacent anatomical structures like the left ventricular outflow tract.[1]

Operators should also note any changes in hemodynamic conditions during intra-procedural evaluations and compare them with pre-procedure conditions, especially considering the effects of anesthesia or deep sedation.[6]

While mild residual regurgitation may not have significant hemodynamic repercussions, any residual injury should not be tolerated due to the risk of developing clinically significant hemolysis post-procedure, which would not benefit the patient. In cases of moderate or severe injuries, repositioning of occluding devices, addition of more devices, or selection of devices with different shapes may be necessary.[6,14]

Echocardiographic and laboratory monitoring to evaluate residual regurgitation or hemolysis should be performed at least every six months or in cases of changes in the patient's symptoms. Although rare, device displacements can occur, leading to some degree of regurgitation or hemolysis over the years.[1]

New Imaging Methods and Special Situations

In some cases, new techniques and tools may be used to improve visualization and spatial definition. Transillumination (Philips®), a new 3D rendering tool that uses a moving light source to improve depth perception, can be used to localize the paraprosthetic leak better.[15] Another promising tool is the fusion image between echocardiography and fluoroscopy. In cases of acoustic shadows secondary to prostheses that pose a significant limitation to transesophageal echocardiography, the use of EchoNavigator software, already employed in transcatheter procedures for other valve pathologies, can be a useful tool to guide the interventional team.[16]

The production of 3D printed models for adequate intervention planning and also for training centers has emerged as an interesting technique. The first step is to acquire high-quality image data in a DICOM (Digital Imaging and Communication in Medicine) format, whether by echocardiography, tomography, or another method. This data is processed and exported into stereolithography file formats, which are then used by the 3D printer.[17]

Final Considerations

The use of imaging techniques is crucial in both the screening and intra-procedural stages of percutaneous closure of paravalvular mitral leaks. It has a significant impact on prognosis. A thorough discussions within a Heart Team setting is a decisive step, and the echocardiographers play a pivotal role in this process.

Author Contributions

Conception and design of the research, acquisition of data, analysis and interpretation of the data, statistical analysis, obtaining financing, writing of the manuscript and critical revision of the manuscript for intellectual content: Bignoto T.

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Study Association

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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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