Paravalvular leak transcutaneous closure, diagnosis, and procedure essential steps.

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Abstract

Paravalvular Leaks (PVLs) are a complication of a surgical or percutaneous valve replacement. They are persistent defects between the native annulus and the sewing ring, which result in a regurgitant prosthesis. They are detected in 2%-18% of patients after a surgical valve replacement. Clinical manifestations of PVLs are seen in 1% to 5% of defects and have a severe prognosis. Surgery redux was the only available treatment to improve these patients' outcomes. But it is usually a high-risk surgery in frail patients with a long history of valve disease. Percutaneous PVL closure emerged as a safer and vital therapeutic option with promising results. Nevertheless, this technique needs a careful pre-procedural assessment and demands high technical expertise. It still has several limitations.

This article focuses on PVLs after a surgical valve replacement and essential steps toward assessment, indication, and achievement of a transcatheter PVL closure (TPVL).

Keywords: Paravalvular leaks, Endocarditis, Transca theater closure.

Abbreviations: IE: Infective Endocarditis, PVL: Paravalvular Leak, TEE: Transesophageal Echocardiography, TPVL: Transcutaneous Closure of Paravalvular Leak, TTE: Transthoracic Echocardiography.

Introduction

Paravalvular Leaks (PVLs) are a complication of a surgical or percutaneous valve replacement. They are persistent defects between the native annulus and the sewing ring, which result in a regurgitant prosthesis. They are more frequent after a surgical replacement of the mitral valve than a surgical replacement of the aortic valve (7% to 17% and 2% to 10% respectively) [1-3] They can be detected early or several decades after the index surgery [4]. Only 1 to 5% of these defects will result in a significant clinical effect [3]; particularly hemolytic anemia or congestive heart failure. In patients with one or both clinical manifestations, an intervention is needed, a percutaneous closure seems an optimal therapeutic solution, less invasive than surgery and having promising results. Nevertheless, this technique has its limitations and complications, hence indications should be carefully weighed.

This article aims to focus on PVLs complicating a surgical valve replacement and essential steps toward indicating and achieving a Transcatheter PVL closure (TPVL).

Table 1 shows the main factors that contribute to a PVL after a surgical valve replacement related to the anatomy of the valve, the surgical technique, the patient's condition, or the surgeon's experience [5]. Infective endocarditis (IE) is the main cause of valve disinsertion and can also be a consequence of a mechanical disinsertion with a secondary bacterial infection. [6,7]

Clinical manifestations of a paravalvular leak

PVLs have three main clinical features. [7] Congestive heart failure, occurs in the case of large or multiple PVLs with a severe valve regurgitation. An anemic syndrome due to hemolysis which occurs on the contrary rather in small PVLs, they are more frequent in mitral valves with preserved left ventricular systolic function [8], which results in a regurgitant jet more turbulent than aortic diastolic insufficiency flow. Hemolysis and anemia may be intermittent, hence their partial improvement during a follow-up should not suggest giving up full exploration.

Infective endocarditis syndrome, in this case, interventional treatment can be only surgical.

It is important to note that the clinical tolerance is not directly correlated to the size of the PVL [7], it is influenced by several factors including the compliance of cardiac chambers, ventricular functions, the existence and degree of anemia, and the rapidity of installation. Symptomatic patients are at the tip of the iceberg. Subclinical PVLs are more frequent and are rather benign; even if they seem to affect somewhat the patient's prognosis [9], they only require a close follow-up and IE prevention. While symptomatic PVLs have a severe prognosis and an intervention when feasible is needed to improve their outcome [10]

Essential steps toward paravalvular leak closure

Figure 1 displays the essential steps from the clinical suspicion to the procedural achieving then evaluation. The first step is a key, and one should have a high index of suspicion of PVL when a patient has a history of valve surgery and presents with one of the above-described nonspecific manifestations. Particularly,

Table 1. *Factors contributing to paravalvular leak occurrence after a surgical valve replacement.*

Local anatomy	Surgery technique	Patient's status	Surgeon's experience
Infection	Supra-annular aortic valve replacement	Advanced age	Lack of experience
Friability	Continuous mitral valve sutures	Endocarditis	NA
Calcifications	Annular reconstruction	Low body mass index	NA
Noncircular annulus	Difficult annular access	Denutrition	NA
NA	NA	Number of previous valvular surgeries	NA

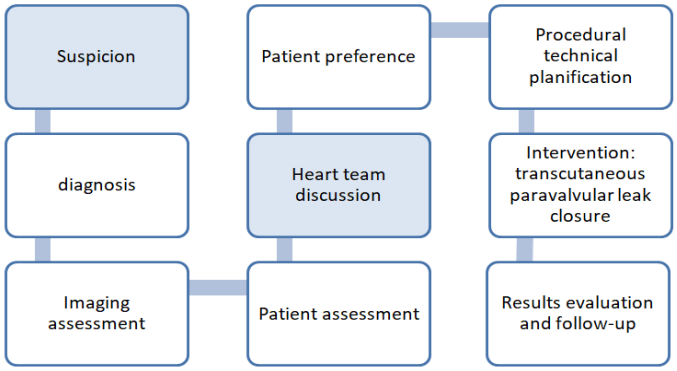

Figure 1. *Essential steps for the decision and planification of a paravalvular leak closure.*

negative Transthoracic Echocardiography (TTE) these patients should lead Transesophageal Echocardiography (TEE) or even a multimodal imaging investigation. After a full patient's status and PVL's investigation, the indication of a procedure relies on many factors: among which patient's clinical status, morphological and anatomical data, technical considerations, and interventional and surgical teams experience…etc. A weighted and careful decision is holding by a medical team including the cardiologist, the surgeon, the anesthetist… and confronted with the patient's preferences after full procured explanations.

Current indications of transcatheter paravalvular leak closure and contraindications

In the current American guidelines, the percutaneous repair is a preferable indication in patients with intractable hemolysis of NYHA 3-4 heart failure who are at high risk for surgery and suitable anatomy for a percutaneous intervention when performed in centers with expertise [11]. Nevertheless, with growing experience and technical improvements, TPVL is indicated by many teams in the first line in symptomatic patients with variable surgery risk levels and based on studies and meta-analysis that compared TPVL to surgery redux with favorable results [12-13]. Transcatheter intervention is formally contraindicated in IE, which is crucial to eliminate hemocultures and imaging before considering this therapeutic option. TPVL is also not possible in case of extensive disinsertion and rocking prosthetic valves

Cardiac imaging for paravalvular leak assessment and procedural guidance

Assessment of PVLs relays in most cases totally on ultrasounds. Imaging modalities are complementary and multimodality imaging is usual.

Imaging modalities and their role*:*

1. Transthoracic Doppler echocardiography**:** is performed as a first-line noninvasive test. It is essential for imaging detection or suspicion of PVLs. It helps to determine their number, location, size, and quantification. In Aortic PVLs, TTE can be sufficient particularly in anterior aortic PVLs, however their sensitivity and precision are weak in mitral PVLs that can be missed by TTE due to acoustic shadows. TTE is fundamental for the assessment of prosthetic valve flows, ventricles size and functions, atrial size and functions, pulmonary pressures, and other valves' status [7,14-16]. TTE is useful for periodic follow-up.
2. Two (2D) and Three (3D) dimensional transesophageal Doppler echocardiography**:** is the reference test for PVL assessment, it is performed in patients with suspected PVL after a comprehensive TTE, either this latter was contributive or not. TEE is essential in the investigation of mitral PVL, multiple PVLs, and complex ones [14-16]. TEE permits to assess accurately the localization of the leak by exploring the whole circumference of the sewing ring by 2D, 3D, and color Doppler modes. When using 3D imaging a careful gain setting and joint color Doppler imaging are important to eliminate artifactual images and gain dropouts [15]. A double opposite clock face is used to indicate the mitral and aortic PVLs sites. The mitral clock face is divided into septal, posterior, lateral, and anterior dials (Figure 2). The shape, number, length, and height of PVLs are determined by 3D TEE [7,14], which also indicates the defect distance from the ring and the PVL spatial position concerning the mechanism of the prosthesis. Precise sizing using 3D multiplanar reconstruction is a key to choose an adequate device when a TPVL is indicated. Besides previous elements, calcifications are important to predict procedural difficulties (Table 2) [16,17].
3. The quantification of the regurgitation is better evaluated by non-orifice related parameters like vena contracta and proximal is velocity methods that are distorted by the

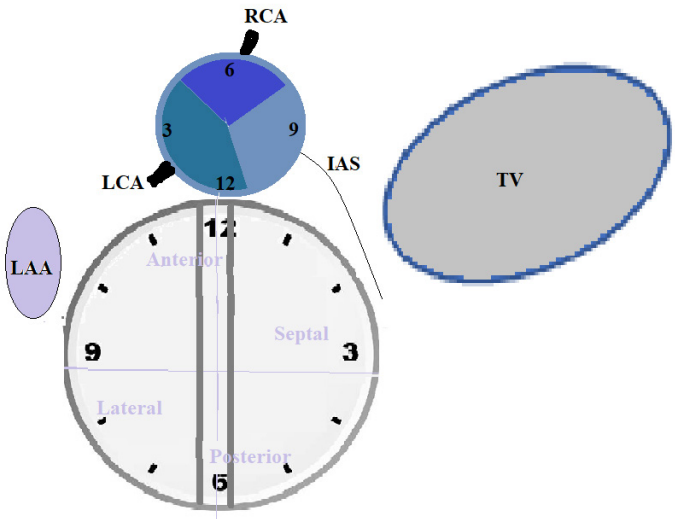

Figure 2. *Schematization of en face view by three-dimensional echocardiography.*

irregular shape and location of the defect. Regurgitant volume by continuity equation, reversal diastolic aortic or pulmonary venous flow, cavities consequences, and pulmonary pressures are more useful to consider in parallel with clinical status.

4. 2D and 3D TEE, is the backbone for procedural guidance, especially in mitral PVLs while TTE and fluoroscopy can be sufficient to guide an aortic PVL closure. Septal puncture is guided by biplane (45° and 130°) imaging when an anterograde approach is chosen for a mitral PVL reduction, real-time 3D and zoom help the crossing of the PVL, the position of the occluder device is then verified by 2D and 3D echo when deploying the occluder device, it is important to check the mobility the prosthetic valve and its flow (Figure 3). Per-procedural echo detects intervention complications (tamponade, embolization of the occluder, impinging, and blocking of the valve.) and residual leaks (Figure 3) [16].
5. TEE is important to consider during follow-up if a complication is suspected (i.e. endocarditis, relapse, or extension of PVLs)

Table 3 summarizes the role of echocardiography imaging for the pre, per, and post-procedure assessments

1. Fluoroscopy is useful to detect rocking prosthetic valves in the initial evaluation and to guide the TPVL [16].
2. Fusion imaging which, combines echocardiography and fluoroscopy, is precious to guide the TPVL, it saves intervention time and increases success rate [18-20].
3. Intracardiac echocardiography is also an innovative means to guide TPVL without general anesthesia. It was reported in a series of 21 interventions in 18 patients as "feasible, safe, and associated with acceptable procedural success rates" [21].
4. magnetic resonance imaging, cardiac tomography imaging, and cardiac tomography-fluoroscopy fusion imaging. Experienced teams reported higher success and better short and long terms outcomes by using these powerful imaging modalities for the planification and guidance of TPVLs. Extension of indications and treatment with the confidence of complex, multiple PVLs (especially aortic PVLs) are also allowed [22].

Table 2. *Main factors that predict the difficulty of a transcutaneous paravalvular leak closure procedure.*

Factors predicting difficulty of transcutaneous paravalvular leak closure
Septal and posterior position
Large defects (a third of the circumference)
Multiple defects
Irregular non-linear defects (U or S shapes versus I and C shapes)
Important Calcification
Flux angulation superior to 50°
Defects next to the valve mechanism

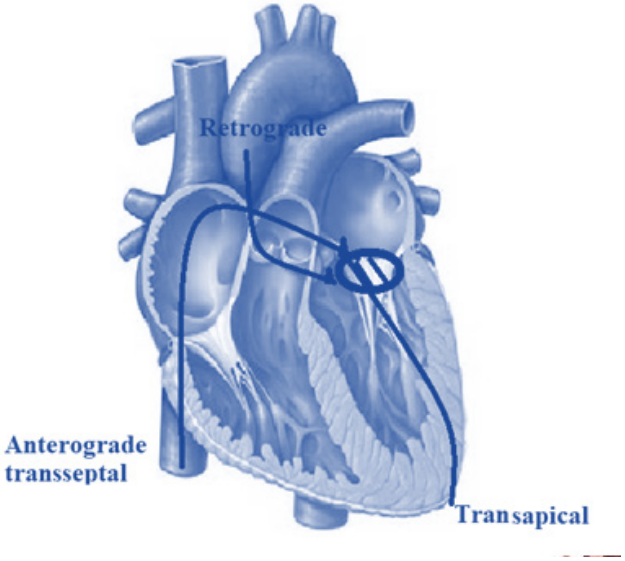

Figure 3. *approaches for transcutaneous paravalvular leak closure.*

Table 3*. Role of echocardiography imaging for the pre, pre, and post-procedure assessments.*

Pre-procedure	Procedure	Post-procedure
General cardiac assessment.	Septal puncture	Position (migration)
Assessment of morphological and functional characteristics of the PVL	Spatial catheters and guides orientation	The function of prosthetic valve
Selection of suitable anatomy for TPVL	Occluder positioning	Residual leak/ relapse of regurgitation
Elimination of infective endocarditis and extensive dehiscence	The normal function of prosthetic valve	Complications (infective endocarditis)
Planification of procedures; choice of the approach, devices, and occluders	Immediate results	General cardiac assessment
NA	Complications (tamponade)	NA

Transcatheter paravalvular leak closure

After a full assessment, TPVL is currently indicated in a large number of patients as a reasonable alternative to surgical repair. Planification of the intervention implies the choice of adequate approaches and devices. The procedure is usually performed in a catheter laboratory under general anesthesia and joint TEE and fluoroscopy guidance.

Approaches: For the mitral valve, the anterograde transeptal approach is the most used, however, an anterograde transaortic approach is more suitable for septal and posterior PVLs. The combination of both approaches forming an arteriovenous loop and transapical access are alternatives particularly for large or multiple PVLs necessitating the use of multiple devices [23]. The retrograde approach is not feasible in the case of a mechanical aortic valve. As far as the aortic valve is concerned, the retrograde approach is the most used, and the transapical approach is useful for multiple and complex PVLs [24].

Occluder devices: Rare dedicated devices were designed by manufacturers; Amplatzer Vascular Plug III (Abbott Vascular) and the Paravalvular Leak Device (Occlutech), they are theoretically more suitable, and have more adapted shapes than non-dedicated devices; Amplatzer Vascular Plug II and IV (Abbott Vascular), Amplatzer duct occluder devices (Saint Jude Medical), Atrial septal defect and ventricular septal defect devices. All devices are used off-label and do not have FDA approval [25]. Figure 4 illustrates the main steps of a TEE guided mitral TPVL

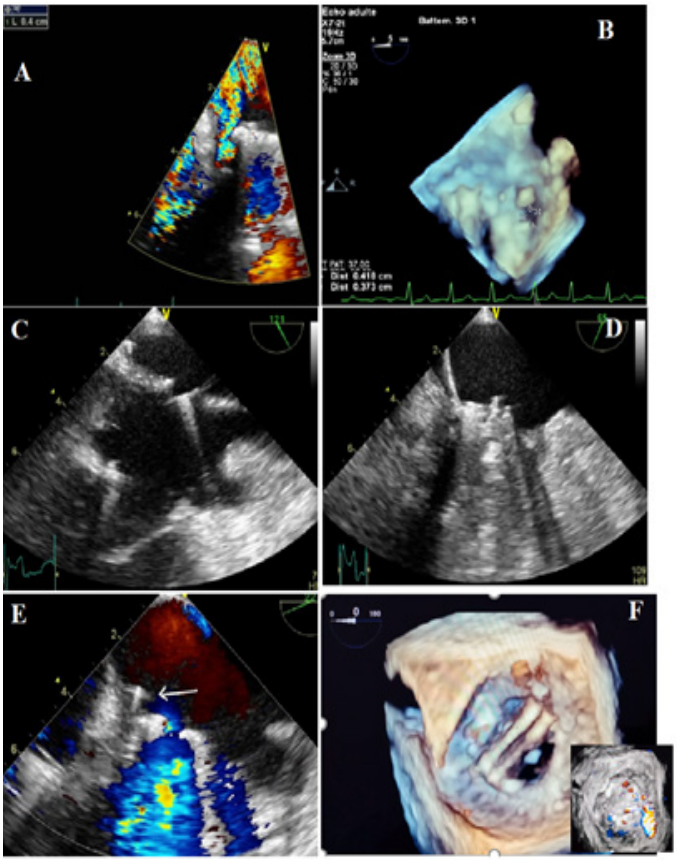

Figure 4. *Illustration of steps of a mitral septal paravalvular leak transcutaneous closure. 4a) paravalvular leak in color Doppler tranesophageal echocardiography; 4b) Assessment of the defect by three-dimensional transesophageal echocardiography;4c) the interatrial septal crossing by the wire;4d) Crossing of paravalvular leak by the delivery catheter; 4e) The occluder device deploying and verification of the prosthetic valve flow; 4f) final result assessment by three-dimensional and color echography.*

Transcutaneous para valvular leak closure results

Compared to surgery TPVL has lower technical success (about 90% *vs* 70% to 86%) but fewer short-term adverse events and lower 30 days mortality (about 4% *vs* 11%) [25-28]. Mitral TPVL has higher adverse events and mortality rates than aortic TPVL [25]. Three years prognosis and survival are improved when the TPVL is successful without or with an only mild residual leak [29]. After a first TPVL, repeated transcutaneous or surgical interventions can be needed during follow-up. Main adverse problems are worsening or new hemolysis in mitral PVLs, significant residual PVL, encroachment of the prosthetic valve, vascular injury, tamponade, hemothorax (transapical approach), device embolization, stroke, relapsing and new PVL, infective endocarditis, and death [3,25].

Limitations

In this review patients' assessment by a comprehensive investigation and surgical risk, scores calculation was not reported while it is a very important piece toward indicating and achieving TPVL. Follow-up was not detailed.

Conclusion

Since its first description in 1992 by Hourihan, et al. [30], TPVL has undergone an important evolution and became a confirmed technique. It is currently considered as a first-line and vital solution for PVLs reduction by many teams, even if surgery remains the reference technique in guidelines. It is important to note that it demands high expertise and is feasible only in reference centers with a multidisciplinary team contribution. It remains limited by dedicated devices availability and lack of financial support.

Take-Home Messages

Patients having a PVL with clinical impact have a severe prognosis and a successful PVL reduction improves their outcome

We should have a high index of suspicion of PVL in patients with a prosthetic heart valve and unexplained persistent heart failure, anemia, or sepsis. TEE should always be performed after a full TTE investigation in these patients.

TPVL indication should be a weighed and careful decision hold by a multidisciplinary medical team along with the patient's preferences

TPVL is performed after a comprehensive patient's status evaluation and a multimodal imaging cardiac investigation

TPVL has undergone an important evolution, it is considered as a first-line solution for PVLs reduction by many teams even if surgery remains the reference technique in guidelines.

TPVL demands high expertise and is feasible only in reference centers

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