

# Percutaneous closure of mitral paravalvular leaks: Focus on imaging and technique

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## INTRODUCTION

Paravalvular prosthetic valve leakage is a rare clinical entity. It is observed more commonly in the mitral (up to 15%) than the aortic (up to 10%) position.<sup>(1)</sup> Mostly, these leaks are incidental findings on transthoracic echocardiography and patients are not or hardly symptomatic. Yet, up to 5% of patients will present with haemolytic anaemia, heart failure or both. The cause of the leakage cannot always be identified, certainly if diagnosed late after surgery. Factors that have been identified are tissue fragility and calcification, active-subclinical or healed endocarditis and suturing technique.<sup>(2)</sup> If observed early after surgery, the most likely cause is technical-surgical while "late" leaks are often a consequence of endocarditis. It is therefore of the upmost importance to rule out active endocarditis before even considering percutaneous closure.

Transoesophageal echocardiography (TOE), in particular three-dimensional (3D) TOE, has emerged as an essential tool in the diagnosis and percutaneous management of paravalvular leaks.<sup>(3-5)</sup> If performed properly, it allows direct visualisation of the leak, assessment of its size and shape, judgement of the distance to the valve annulus and position in relation to the leaflets of the valve (in case of a mechanical prosthesis). These elements are key to judging feasibility prior to any percutaneous closure attempt. Even if angiography may still play a role in the assessment of aortic leaks, 3D TOE is the method of choice for mitral leaks.

ECG-gated computed tomographic angiography with 3D reconstruction is an alternative to 3D TOE in the assessment of

## ABSTRACT

**Symptomatic prosthetic paravalvular leakage is a rare clinical condition occurring in up to 5% of patients after valve surgery.**

**Symptoms include haemolytic anaemia, heart failure or both. Leaks tend to be more common in the mitral compared to the aortic position.**

**Three dimensional transoesophageal echocardiography (3D TOE) is essential prior and during percutaneous leak closure. This imaging technique allows to qualify and quantify the leak and to judge feasibility of a percutaneous approach. It also enables the choice of the most appropriated closure device prior to intervention. During the procedure, 3D TOE guides adequate crossing of the leak and device deployment. It also finally allows assessment of the acute procedural result.**

**Percutaneous closure should be considered as the first choice therapy if closure is judged feasible based on 3D TOE assessment. This procedure is currently performed in a limited number of patients by relatively few operators and is characterised by a long learning curve. Currently, literature data are scarce and reported acute procedural success is roughly around 70 to 80%.**

**Intervention is mostly performed with vascular plugs or ventricular septum defect closure devices. Recently, dedicated implants have been made available. Their role has been limited to hybrid procedures from a transapical retrograde approach. SAHeart 2015;12:6-13**

paravalvular leaks.<sup>(6)</sup> This imaging technique will not be discussed in the present article.

During percutaneous closure, in particular again of mitral leaks, 3D TOE is mandatory to guide the intervention. It confirms adequate crossing of the guidewire through the leak, demonstrates correct and stable positioning of the closure device and enables the quantifying of any residual leakage.

In this article, the role of imaging and in particular 3D TOE, will be discussed as well as a few suggested closure techniques for mitral paravalvular leaks. Furthermore, the technique of echo image acquisition will be discussed in detail. An overview of current existing data will be provided.

## THE ROLE OF IMAGING SCREENING BEFORE INTERVENTION

### Two dimensional (2D) TOE

At first, the valve prosthesis is scanned by a step-by-step rotation of the echo probe, looking for the presence of dehiscence and/or paravalvular colour Doppler signals. Occasionally several leaks can be identified. Precise quantification of the leak may be difficult in the 2D mode. Only if dehiscence is present, can the width of the leak be measured. If colour Doppler only unmasks regurgitation, it is advised to measure the smallest portion of the jet at the level of the annulus. Both measurements will be integrated in the final choice of the diameter of the closure device. 2D examination is particularly valuable to judge the distance between the paravalvular channel and the valve, especially for mechanical prosthesis. Closure devices have different characteristics, which will be taken into account in order to anticipate leaflet blockage based on these measurements. As part of the examination, leaflet motion as well as the mean gradient is also recorded.

### 3D TOE

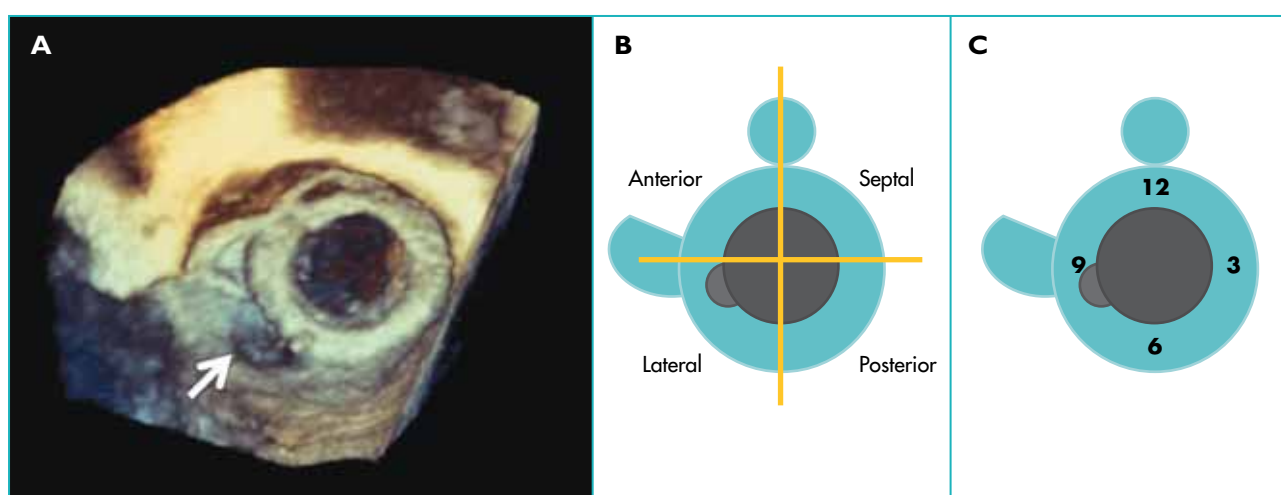
The crucial role of 3D TOE has been mentioned before. Acquisition of the data can be made in a zoom mode to have a first appreciation of the defect size and localisation. Then a full volume acquisition will provide a high frame rate view of the entire valve and annulus. If the defect is visible on the 2D images, it will be nicely delineated in a so-called “surgical view” of the valve (Figure 1a). Localisation is determined using either an anatomical (Figure 1b) or “clock” position (Figure 1c). For the anatomical localisation, the annulus of the valve is divided into 4 quadrants: septal from the posteromedial aspect of the

aortic root to the posterior end of the interatrial septum, posterior from this point to the middle of the lateral wall of the left atrium, lateral from this point to the middle of the left atrial appendage and anterior from this point to the middle of the posterior aortic root. Using a clock positioning, the annulus is divided by an imaginary clock with noon on the aortic root. The defect illustrated in figure 1 is a lateral leak at about 8 o'clock. When the leak is not visible as a defect in the 2D images, the same approach is applied to a 3D colour flow acquisition of the mitral valve. To precisely size the leak, both a grey-scale acquisition and colour flow data set are used (Figure 2). Using dedicated software, a cutting plane parallel to the annulus is positioned at the leak level (Figures 2a and 2b) allowing one to derive maximal and minimal diameter and area. The shape of the leak is also nicely delineated by this approach. Integration of the defects' dimensions, shape and position will determine the interventional strategy. The different implants suggested for closure will be discussed later on. A single or several devices may be needed.

## CLOSURE TECHNIQUE

### General principles

Percutaneous paravalvular leak closure is performed under general anaesthesia, ideally in a biplane X-Ray room, and guided by 3D TOE. Conceptually, the leak is crossed antegrade from a femoral vein-transseptal approach and closed retrograde by pulling back a closure device from the left ventricle towards the leak up to the base of the left atrium. Exceptionally, a loop has to be established by snaring the wire that has crossed the leak antegrade. This more complex procedure is only required if

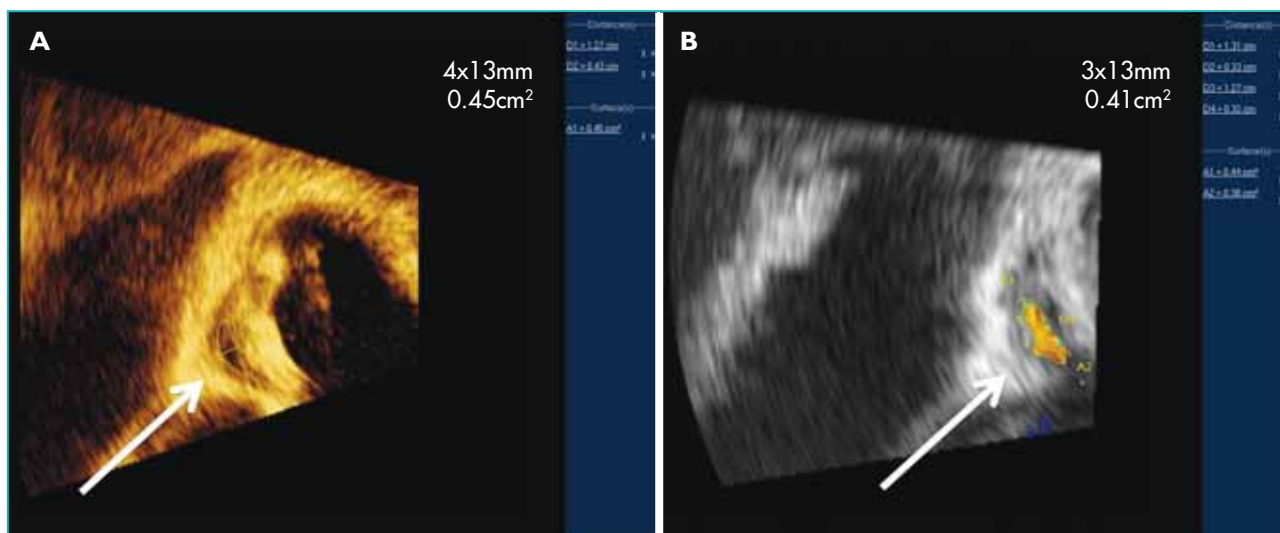


**FIGURE 1: Topography of mitral paravalvular leaks.**

A: 3D echocardiographic view of a large oval-shaped paravalvular leak in a patient with a mitral bioprosthesis.

B: Localisation according to an anatomical 4 quadrants classification.

C: Localisation following a clock classification.



**FIGURE 2: Quantification of a mitral paravalvular leak.**

A: Calculations of the orifice dimensions using a cutting plane at the level of the prosthetic valve annulus in the grey-scale 3D mode.

B: Orifice size calculation derived from a similar cutting plane in a 3D colour data set.

The arrow denotes the position of the leak.

antegrade support is insufficient to cross the leak with the “closure-device” delivery catheter and is ideally performed from a percutaneous transapical approach in order to provide a more co-axial alignment during final closure device deployment. The guidewire is snared from the transapical sheath and externalised to provide the necessary support to cross antegrade with the delivery sheath. Snaring from the left ventricle after gaining retrograde arterial access through the aortic valve is not advised because improper wire-catheter alignment and the risk of laceration of the aortic valve. Furthermore, a substantial number of patients carry prostheses both in mitral and aortic positions, making the latter technique impossible.

It is advised to preventively equip the patient with defibrillation pads to treat potential major ventricular arrhythmias during wire manipulation in the left ventricle. Once transseptal puncture has been performed successfully, unfractionated heparin (70IU/kg) is administered with regular checks of the activated clotting time, which is kept around 300 - 350 seconds.

### Transseptal puncture and leak crossing

Transseptal puncture is performed using standard techniques with a Brockenbrough needle. Puncture can be particularly challenging in patients who have undergone multiple surgical interventions and who present with a stiff, resistant septum. TOE is an elegant tool to guide trans-septal puncture. A short axis view of the aortic valve, between 20 and 50 degrees with focus on the inter-atrial septum is obtained. A multi-plane mode is activated and an orthogonal image, which generally corresponds to the bi-caval view, is additionally displayed. Both

views will allow monitoring of the antero-posterior position of the needle (short axis) and judgement of the height of the puncture (bi-caval).

Once transseptal, a curved Inoue wire (Toray Medical, Urayasu, Japan) can be placed in the left atrium. In general, the left atrium is large secondary to chronic mitral regurgitation. Therefore, the stiff part of the Inoue wire will be positioned at the level of the inter-atrial septum to allow for dilatation with the Inoue dilator (Toray Medical, Urayasu, Japan). Dilatation of the septum is required to enable crossing of the septum with the 8.5F Agilis catheter (St. Jude Medical, St. Paul, MN, U.S.A.). The Agilis catheter is a steerable transseptal catheter that enables exploration of the peri-mitral valve area in search for the leak. Two steerable nobs allow antero-posterior rotation as well as curving of the tip of the catheter up to 180 degrees. Occasionally, dilatation of the inter-atrial septum (at low pressure with a commercially available peripheral balloon) will be required to enable crossing of the septum with the Agilis catheter.

Real time 3D TOE, either in zoom mode or in live 3D, is particularly useful to guide crossing of the leak as it enables instantaneous visualisation of the position and orientation of catheters and wires towards the defect. Perception of the mitral valve anatomy both on echography and fluoroscopy is essential at this stage. Once the Agilis catheter has been positioned in the left atrium, a diagnostic coronary catheter (mostly a 5F Amplatz Right (ARI)) and a straight 0.035inch hydrophilic wire (Terumo Medical, Tokyo, Japan) are advanced to the base of the left atrium. Under 3D TOE guidance, the

Agilis catheter is oriented towards the leak while the ARI catheter is just placed with its distal tip outside the Agilis catheter. The ARI is rotated in the direction of the leak, which is then crossed antegrade with the hydrophilic wire (Figure 3a). With the support of the hydrophilic wire, curved at the apex, the ARI catheter is advanced in the left ventricle. Occasionally (and in particular in “giant” left atria), the ARI catheter cannot be advanced far enough in the left ventricle. In this case, it is advised to place a long soft Teflon 260cm 0.035inch exchange wire through the ARI catheter and to exchange for a long 125cm Multipurpose (MP) catheter. The MP catheter can be curved at the apex and left in situ while preparing the closure device (Figure 3b). Biplane X-Ray is extremely useful while attempting antegrade leak crossing in a lateral and right oblique view.

The hydrophilic wire will tend to cross through the prosthesis rather than through the leak. Adequate fluoroscopic projections will demonstrate if the wire enters the left ventricle outside the surgical annulus rather than through the valve. This will further be confirmed by 3D TOE while the appearance of ventricular ectopic beats also indicates entry into the left ventricle.

Emerging technologies have integrated echocardiography and fluoroscopy into a single fusion imaging technique. At present, this technology has limited penetration and the authors have no experience with it.

### Device preparation, deployment and testing

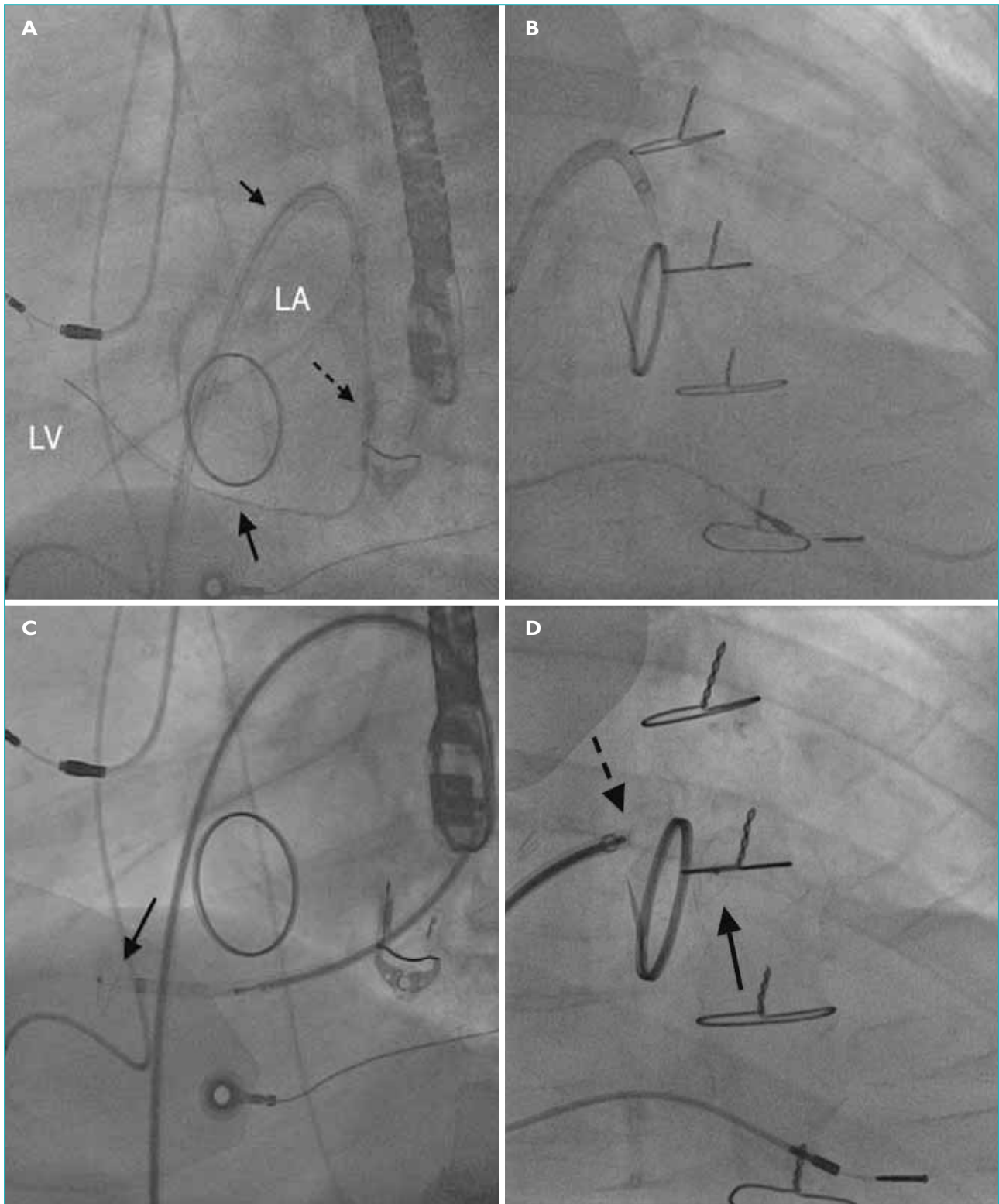
The choice of the device that will be deployed is the result of a consensus between the echocardiographer and the interventional cardiologist. It takes into account the position, size and aspect of the leak. Upfront, the choice diverges between the number of anticipated devices needed and the type of device. Narrow (less than 3mm in diameter) but potentially long crescent leaks are mostly treated with one or more Amplatzer vascular plug III devices (AVP III, St. Jude Medical, St. Paul, MN, U.S.A.) while larger leaks (>3mm) mostly require one or more Amplatzer muscular VSD devices (St. Jude Medical, St. Paul, MN, U.S.A.). Very large leaks may be judged upfront not feasible or requiring multiple muscular VSD devices that may require a second transeptal puncture in order to enable simultaneous release of 2 devices.

The closure devices are chosen 2mm to 3mm larger than the diameter of the defect. They are flushed and prepared with a French compatible TorqVue (St. Jude Medical, St. Paul, MN, U.S.A.) transeptal delivery catheter. Of note, the longest TorqVue I catheter is only 80cm long and may be too short to cross the leak, in particular in tall patients or giant left atria. A 120cm TorqVue II catheter can then be used. The TorqVue II is not used upfront as it implies opening an additional package

and requires particular manipulation of the implant loader, which is shorter than the TorqVue II catheter.

If crossing of the leak with a TorqVue I is judged feasible and the closure device has been loaded within the delivery sheath, a 260cm 0.035inch long Amplatzer super stiff wire (Boston Scientific, Natick, MA, U.S.A.), manually widely curved at its tip, is advanced across the diagnostic coronary catheter. This wire is engaged in a stable position at the apex of the left ventricle. It is advised to perform this only at this stage, as this wire will tend to retract towards the left atrium over time.

The Agilis and diagnostic coronary catheter are withdrawn while leaving the super stiff wire in place. The TorqVue I catheter is then advanced over the stiff wire through the interatrial septum and the leak into the left ventricle. Subsequently, the dilator and wire are withdrawn and the loader with the closure device is screwed on the TorqVue I catheter, as for any typical defect closure procedure using Amplatzer technology. The closure device is pushed up to the tip of the TorqVue catheter. Further advancement allows opening up of the distal part of the closure device, often accompanied by gently pulling back the TorqVue catheter to avoid entrapment of the device into trabeculae or the mitral subvalvular apparatus. The TorqVue closure device is then pulled back under fluoroscopic echo guidance leaving the proximal-central part of the closure device partially deployed (Figure 3c). At the level of the annulus, this part of the device may be further deployed while holding firm traction on the device. Once well apposed on the ventricular side, the prosthesis is inspected by echocardiography for potential interference with the valve leaflets. Subsequently, the proximal-atrial part of the implant will be released by withdrawal of the TorqVue sheath while keeping the implant in a stable position (Figure 3d). Correct placement can be judged by biplane X-Ray and 3D TOE. Echocardiography will further confirm this and enable quantification of any residual leak. Deployment is quite similar whether a plug III or muscular VSD device is used. As mentioned before, the latter will be implanted in large leaks. If multiple muscular VSD implants are considered, a second transeptal puncture and device placement to allow simultaneous release may be required in order to anticipate device embolisation. Incomplete closure of large leaks by muscular VSD devices carries a risk of massive post procedural hemolysis, which will compromise final procedural success. Therefore, the objective should be complete or near complete closure by the techniques described above. Figures 3 and 4 demonstrate the different steps from leak crossing to deployment of a muscular VSD device in a patient with a large paravalvular leak, respectively from a fluoroscopic and 3D TOE perspective. Figures 5 and 6 demonstrate full closure of this leak by 3 consecutive muscular VSD devices, again by fluoroscopy and echocardiography.



**FIGURE 3: Steps in paravalvular leak closure, fluoroscopic perspective.**

A: Crossing of a large postero-lateral leak by means of a hydrophilic wire (thick arrow at the level of the leak) and an Amplatz Right coronary catheter (dotted arrow) through an Agilis catheter (thin arrow), LA denotes left atrium, LV is left ventricle.

B: Positioning of a 125cm long 6F multipurpose catheter across the leak at the apex of the left ventricle.

C: Deployment of the distal part of a muscular Ventricular Septum Closure device (VSD) in the left ventricle. The arrow demonstrates clearly that the central part of the implant is only partially deployed.

D: Anchoring of the VSD device within the leak. The full-line arrow indicates the distal (ventricular) part of the implant, while the dotted arrow indicates the proximal (atrial) side.



The vascular plug III is particularly suited for slit-like leaks. Antegrade crossing of these leaks will be more time consuming whether it be with the hydrophilic wire or delivery catheter. A TorqVue II catheter will be more convenient in this case. The Agilis catheter can be left in place and provides additional back up to cross the leak while this delivery catheter can host the largest plug available. If indicated, a second serial plug can be implanted safely without the need for a second transseptal puncture, as device embolisation is very unlikely. Small residual leaks will be more forgiving in terms of haemolytic risk. It is speculated that this is due to the softer consistency of the device.

Devices are released upon gently clockwise counter rotation and after gentle wiggling manoeuvres to check for device stability. In general, the transseptal catheter and delivery cable are not co-axial to the plug, which will often slightly rotate to its final position upon release.

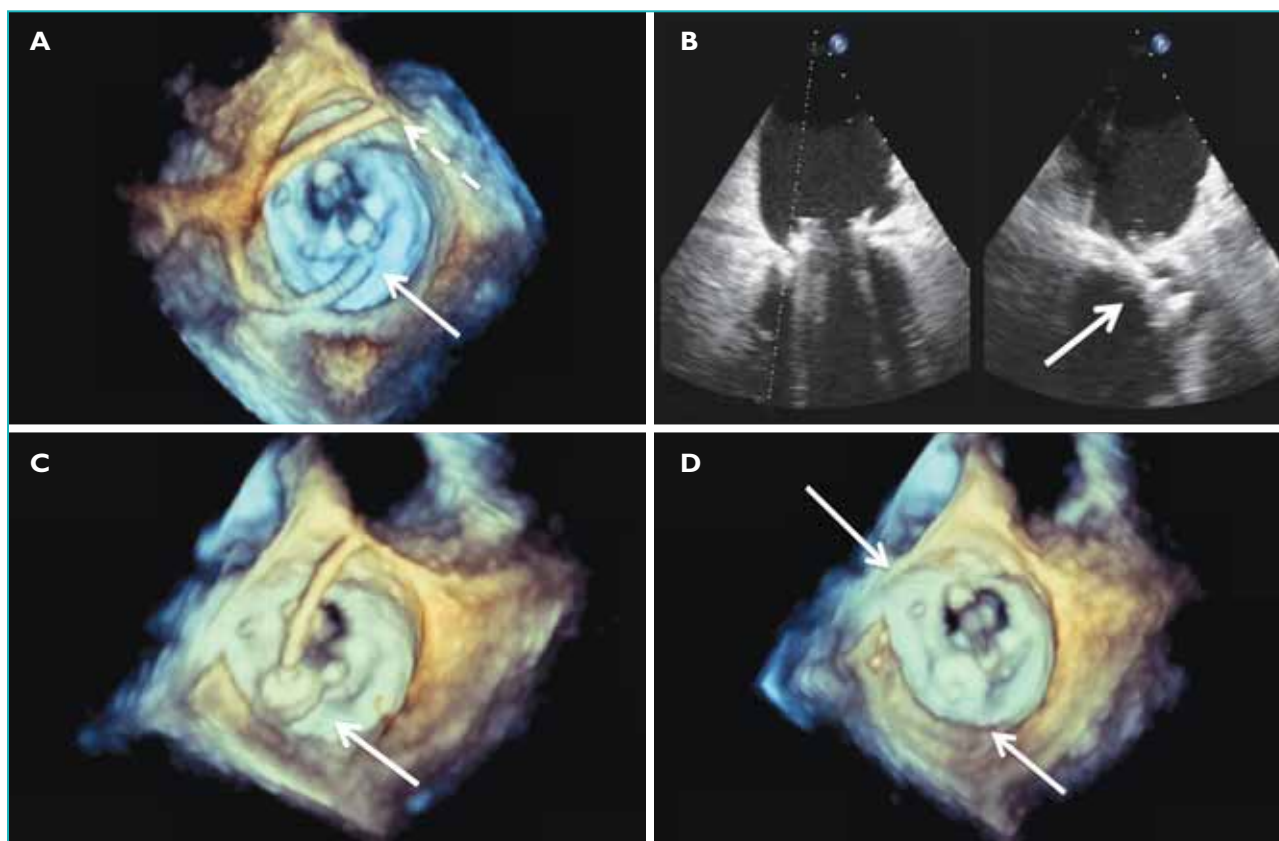
At the end of the procedure, it is important to screen for potential complications. The presence of pericardial effusion,

the integrity of the inter-atrial septum, potential displacement of the closing device and adequate functioning of the valve prosthesis are verified.

### Anticipation of complications

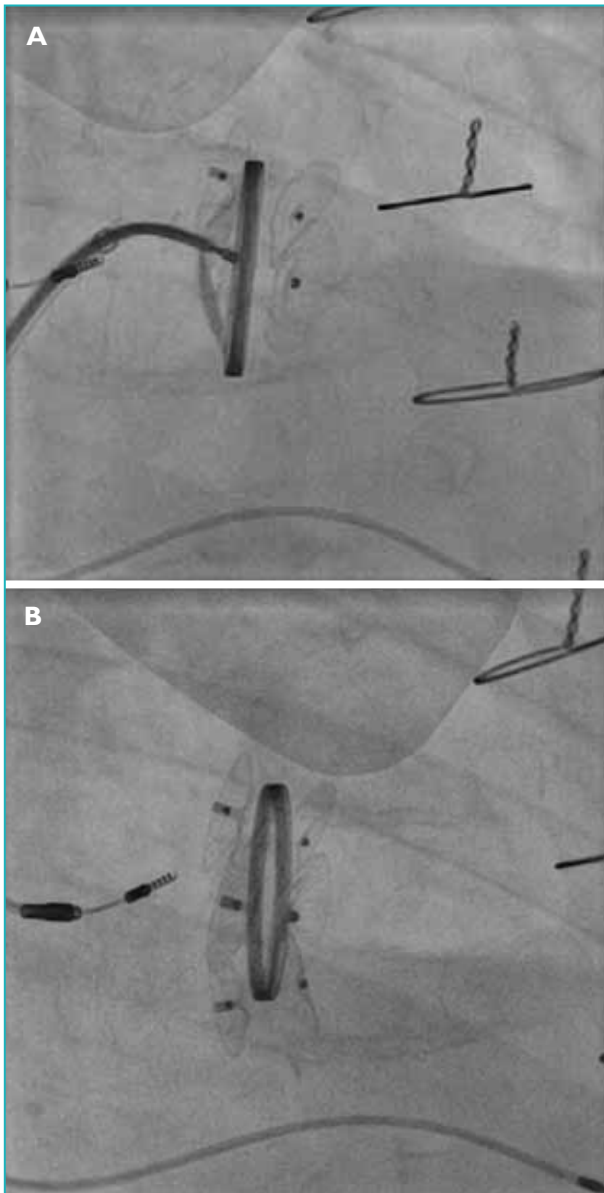
The most feared complication of paravalvular leak closure is device embolisation. The risk for this complication can be kept minimal by adequate sizing of the leak by 3D TOE and defining the interventional strategy upfront.

Another more frequent complication is total or partial leaflet blockage of mechanical prostheses. This may be corrected by gently pulling back the implant into the channel of the leak, device recapture and repositioning or downsizing of the implant. This complication occurs more often with the muscular VSD device because of its inherent properties and alternatively an Amplatzer PDA may be considered in specific cases. Even if device repositioning is technically feasible, it is advised to assure a stable position before release, as the implant may slide back to its original position once released, thereby blocking a leaflet.



**FIGURE 4: Steps in paravalvular leak closure, echographic perspective.**

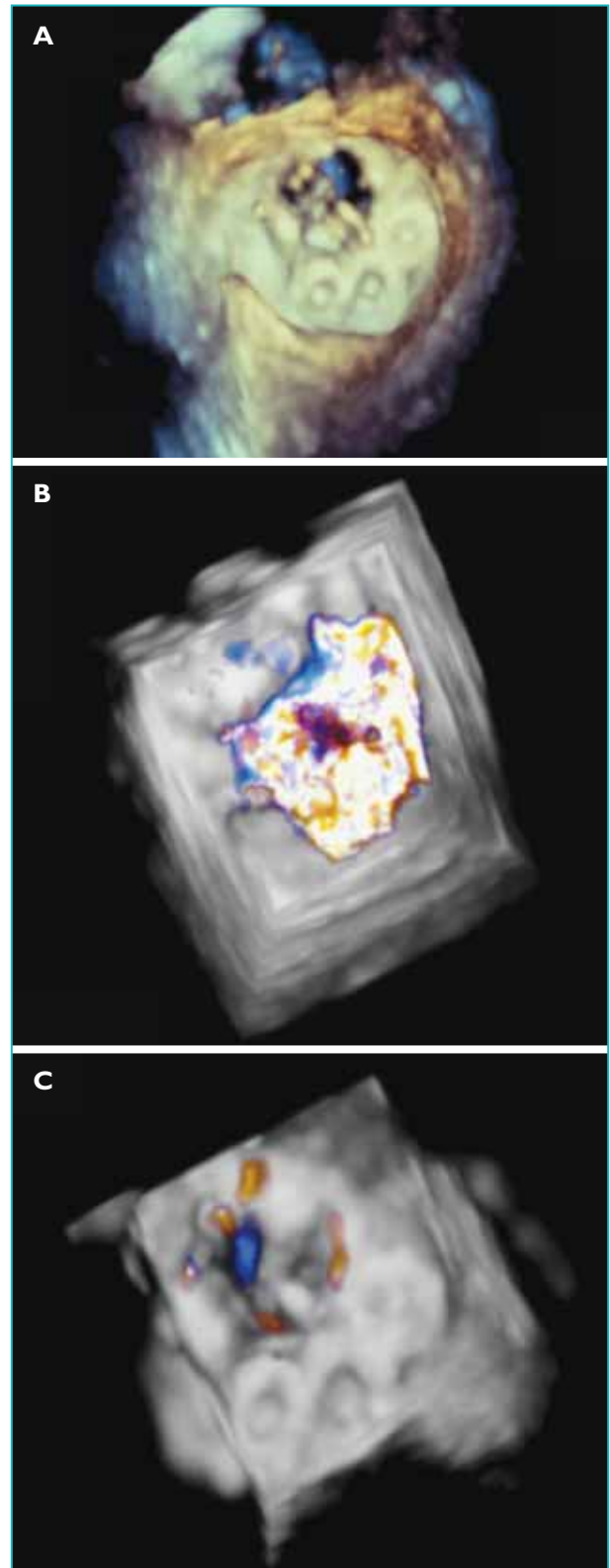
- A: 3D echo visualisation of an Agilis catheter across the inter-atrial septum (dotted arrow) and positing of a diagnostic coronary catheter (full-line arrow) through the leak.
- B: 2D orthogonal multi-plane views demonstrating the deployment of the distal (ventricular) part (arrow) of a VSD device.
- C: Assessment of a deployed VSD (arrow) implant device prior to release.
- D: Assessment after implantation of 2 VSD devices.



**FIGURE 5: Steps in paravalvular leak closure, deployment of additional devices, fluoroscopic views.**  
 A: Positioning of a second VSD device just prior to release.  
 B: Final image after implantation of a third device.

A stable position can be assessed by gentle wiggle manoeuvres and morphological analysis of the atrial side of the device by 3D TOE. Pre-operative 3D TOE imaging will demonstrate the distance of the leak to the surgical annulus, the leaflet structures and position of the leak towards the plane of the valve. Integration of this information into the interventional strategy should minimise the risk of leaflet blockage.

Worsening or appearance of haemolytic anemia is another feared complication after paravalvular leak closure. It may be encountered after implantation of the more rigid muscular VSD device in large leaks



**FIGURE 6: Steps in paravalvular leak closure, deployment of additional devices, echographic views.**  
 A: Final image after implantation of a third device.  
 B: 3D colour flow analysis of the paravalvular reflow jet before intervention.  
 C: Final colour flow assessment after implantation of 3 VSD devices.

From a theoretical perspective, closure of paravalvular leaks in bioprostheses is easier as the risk of interference with the leaflets is much lower than with mechanical valves. There is theoretical risk of eroding the bioprosthesis by a too large implant but this complication has, at present, not been described.

### Literature overview

A limited number of papers have been published on paravalvular leak closure. In total less than 200 patients have been reported, in a few series of papers, with the largest experiences being from the Mayo Clinic and Lennox Hill Heart Institute in the U.S. Reported acute procedural success ranged between 70 and 80%. The above-mentioned complications have all been reported, all in single digit numbers. Recently, a dedicated device has been developed by Occlutech (Helsenborn, Sweden) and has received the CE mark. It has been implanted in a small number of patients by hybrid surgical-percutaneous transapical approach (personal communication, unpublished data). This device has a square or rectangular design and is available in different sizes. At present, there is no data available on antegrade closure with this new implant.

### CONCLUSIONS

Percutaneous closure is emerging as the technique of choice for paravalvular leakage. 3D TOE provides insight in the mechanisms, morphology and feasibility of percutaneous closure. If judged technically feasible, the procedure should be guided by 3D TOE using available, non-dedicated closure implants. This intervention has the potential to palliate patients excluded from any other therapeutic alternative.

**Conflict of interest: Eric Eeckhout has a proctoring activity for St. Jude Medical and Occlutech companies. Alain Delabays has a proctoring activity for St. Jude Medical company.**

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