# Transcatheter Closure of Paravalvular Defects Using a Purpose-Specific Occluder

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**Objectives** This study sought to describe a method of paravalvular leak closure using a purpose-specific occlusion device.

**Background** Transcatheter closure of paravalvular leaks has been hampered by technical challenges, the limitations of available imaging modalities, and the lack of closure devices specifically designed for this purpose.

**Methods** Patients with severe symptomatic paravalvular regurgitation at high risk for repeat surgery underwent transcatheter leak closure. Both left ventricular puncture and retrograde transfemoral approaches were used with fluoroscopic and 3-dimensional transesophageal guidance. A purpose-specific occluder (Vascular Plug III, AGA Medical Corp., Plymouth, Minnesota) was used.

**Results** Five patients with severe prosthetic mitral and aortic paravalvular leaks underwent attempted closure. Implantation of the device was successfully accomplished in all. In 1 patient, the plug interfered with closure of a mechanical valve leaflet and was removed and replaced with an alternate device. Complications included pericardial bleeding in 2 patients with a transapical approach. There was no procedural mortality. At a median follow-up of 191 days (interquartile range [IQR] 169 to 203 days) all patients were alive. New York Heart Association functional class fell from 4 (IQR 3 to 4) to 2 (IQR 2 to 3), hemoglobin rose from 89 g/l (IQR 87 to 108 g/l) to 115 g/l (IQR 104 to 118 g/l), creatinine fell from 109 $\mu$mol/l (IQR 106 to 132 $\mu$mol/l) to 89 $\mu$mol/l (IQR 89 to 126 $\mu$mol/l). Median echocardiographic follow-up at 58 days (IQR 56 to 70 days) reported residual regurgitation to be reduced from grade 4 to grade 2 (IQR 1.5 to 2.25).

**Conclusions** Closure of mitral and aortic prosthetic paravalvular leaks with the Vascular Plug III using either a transapical (mitral) or a retrograde (aortic) approach appears promising. (J Am Coll Cardiol Intv 2010;3:759–65) © 2010 by the American College of Cardiology Foundation

Paravalvular regurgitation (PVR) after surgical valve replacement may occur when there is an incomplete seal between a prosthetic valve and the surrounding cardiac tissue. Typically this is associated with dehiscence of sewing ring sutures, often precipitated by infection, annular calcification, or technical factors (1–4). Reoperation for PVR is associated with an increased likelihood of a recurrent leak, morbidity, and mortality (5). Transcatheter closure of paravalvular leaks has been hampered by technical challenges, the limitations of available imaging modalities, and the lack of closure devices specifically designed for this purpose (6). We describe our initial experience with paravalvular leak closure using a device specifically designed for this purpose. In patients with mitral PVR, a transapical approach and real-time 3-dimensional (3D) transesophageal echocardiography (TEE) was used, whereas in patients with aortic PVR, a retrograde approach with 3D TEE guidance was used.

## Methods

**Patients.** Four patients underwent transapical mitral paravalvular leak closure with 3D TEE guidance and implantation of a Vascular Plug III occluder (AGA Medical Corp., Plymouth, Minnesota). One patient underwent retrograde transfemoral aortic paravalvular leak closure with 3D TEE guidance and implantation of a Vascular Plug III occluder. Median age was 75 years (interquartile range [IQR] 71 to 81 years); there were 3 women and 2 men. Bileaflet mechanical mitral valves (3 St. Jude Medical Inc. [St. Paul, Minnesota] and 1 Carbomedics Inc. [Austin, Texas]) and 1 aortic bioprosthetic valve (Carpentier-Edwards Perimount, Edwards Lifesciences, Irvine, California) had been implanted a median of 14 years (IQR 14 to 17 years) previously. Two patients had double valve replacement (aortic and mitral) at the time of their surgeries. Median number of thoracotomies was 1 (IQR 1 to 2, with a maximum of 4 thoracotomies in 1 patient). All patients had severe PVR documented by TEE and all were in atrial fibrillation and on long-term anticoagulation. Comorbidities include hypertension in 4 (80%), dyslipidemia in 3 (60%), diabetes in 2 (40%), and renal failure in 4 (80%) patients. The indication for paravalvular leak closure was severe heart failure in 4 and anemia in all 5 patients. All patients had been declined as candidates by at least 2 cardiac surgeons and written, informed consent was obtained.

**Procedure.** The procedure was conducted under general anesthesia in a hybrid operating room with fluoroscopic and TEE guidance. Antibiotic prophylaxis was administered. In 2 mitral patients, percutaneous puncture of the left ventricular apex was performed under TEE and fluoroscopic

**Abbreviations and Acronyms**

**3D** = 3-dimensional

**IQR** = interquartile range

**PVR** = paravalvular regurgitation

**TEE** = transesophageal echocardiography

guidance using a pigtail catheter in the apex as a landmark (Fig. 1), whereas in the other 2 patients with mitral PVR, the apex was punctured under direct vision through a small intercostal incision. After puncture of the left ventricular apex, a standard J-wire was advanced into the left ventricle and the needle was exchanged for a 5-F sheath. Heparin was administered to maintain an activated clotting time above 250 s. An angled catheter (Glidecath, Terumo Medical Corp., Somerset, New Jersey) was advanced through the sheath and directed at the regurgitant lesion allowing an angled hydrophilic guidewire (Glidewire, Terumo Medical Corp.) to be steered through the defect into the left atrium. An appropriately sized occluder device (Vascular Plug III) was introduced either through the standard short 12-cm length 6- or 7-F arterial sheath (St. Jude Medical) or a through a longer hydrophilic sheath (Shuttle, Cook Inc., Bloomington, Indiana).

In the patient with aortic PVR, femoral arterial access was used. The defect was wired using a 6-F multipurpose guide catheter and an angled hydrophilic guidewire (Glidewire). The Vascular Plug III device was deployed through the guide catheter.

If the device interfered with mobility of the surgically implanted valve, it was removed. If regurgitation was not reduced to a moderate range, a second device was implanted. At the completion of the procedure, heparin was reversed with protamine, and the left ventricular sheath was removed. In case of a percutaneous apical puncture, the puncture site was manually compressed until hemostasis was achieved. Heparin was started 4 h after hemostasis was achieved followed by resumption of oral anticoagulation.
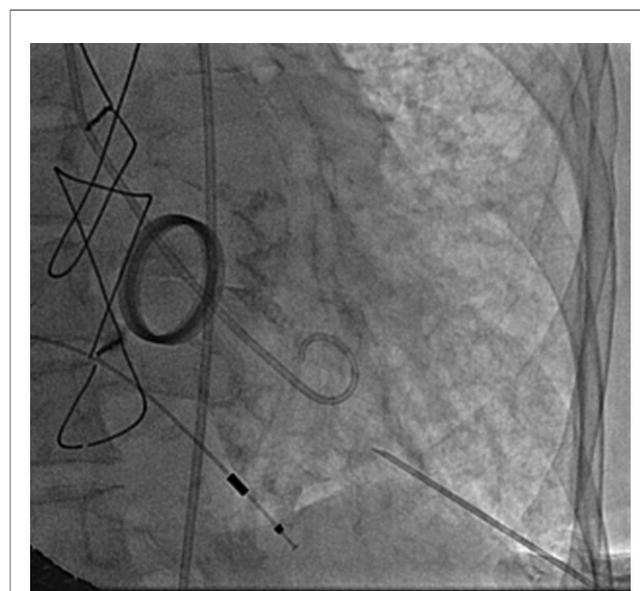


**Figure 1. Puncture of the Left Ventricular Apex**

Fluoroscopic guidance using a pigtail in the left ventricle as a landmark.
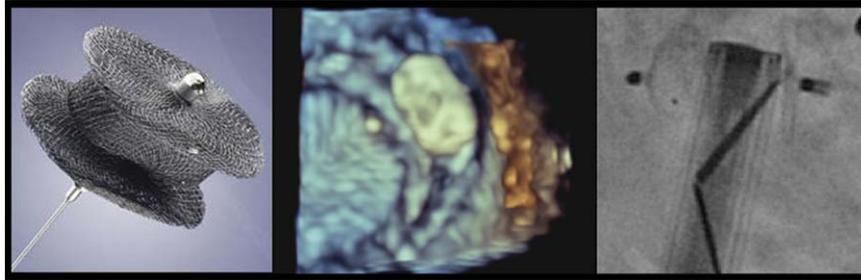
**Figure 2. The New Purpose-Specific Device for Paravalvular Leak Closure**

The Amplatzer Vascular Plug III with the extended proximal and distal rims for optimal fixation in an area with high flow. **(Left)** Ex vivo, **(middle)** 3-dimensional transesophageal echocardiography image, and **(right)** fluoroscopic image.

**Vascular Plug III.** The Vascular Plug III is an oval-shaped dense nitinol mesh (Fig. 2). The height of the device is 6.5 mm. Various core sizes are available with dimensions ranging from 4 to 14 mm in the long axis and 2 to 5 mm in the short axis. The core is extended on the inflow and outflow aspects by 2-mm rims in order to ensure a stable position. The 2 smallest devices (4 × 2 mm and 6 × 3 mm) can be deployed through a 4-F sheath (internal diameter: 0.065 inches), followed by the 8 × 4-mm and 10 × 3-mm devices that require a 5-F sheath (internal diameter: 0.072 inches). Larger occluders require a 6-F (for the 10 × 5-mm device, internal diameter: 0.072 inches) or a 7-F sheath (for the 12 × 3-mm, 12 × 5-mm, 14 × 3-mm, and 14 × 5-mm devices, respectively; internal diameter: 0.098 inches). If a guide catheter is used for deployment, the size corresponding to the required internal diameter has to be chosen. As with other Amplatzer occluders (AGA Medical Corp.), the device is deployed by pulling back the delivery system, thereby releasing first the distal rim and finally the proximal rim. The device can be retracted as long as the delivery cable is not unscrewed from the device.

**Echocardiography.** Imaging was performed using an iE33 ultrasound system (Philips Medical Systems, Andover, Massachusetts) with a fully sampled 3D matrix array TEE transducer.

In comparison to 2-dimensional TEE imaging, real-time 3D TEE gives clear en face views of the mitral valve and paravalvular structures (7,8). This imaging modality enables visualization of the size, shape, and number of paravalvular defects on both real-time 3D volume images and full volume 3D color Doppler (Fig. 3). Real-time 3D and full volume 3D color Doppler images also assist in positioning and deployment of the device chosen during the procedure. The 3D imaging provides good spatial resolution for guiding the position of the guidewire and catheter within the defect (Fig. 4) and for the positioning and deployment of the Vascular Plug III (Figs. 5A and 5B). The full volume

3D color Doppler helps define the extent of the regurgitant jet pre- and post-device insertion (Figs. 6A and 6B).

## Results

**Procedural outcome.** Device implantation was successful in all patients with a procedural time of 106 min (IQR 93 to 140 min). Fluoroscopy time was relatively short at 15 min (IQR 13 to 20 min) and contrast use relatively low at 25 ml (IQR 20 to 50 ml). Two patients underwent implantation of 2 occluders. The Vascular Plug III device sizes implanted in mitral position were 8 × 4 mm (implanted in 1 patient; implanted, removed, and replaced by a Duct Occluder [AGA Medical Corp.] in another patient), 10 × 3 mm (in 1 patient), 10 × 5 mm (in 2 patients), and 12 × 5 mm (in
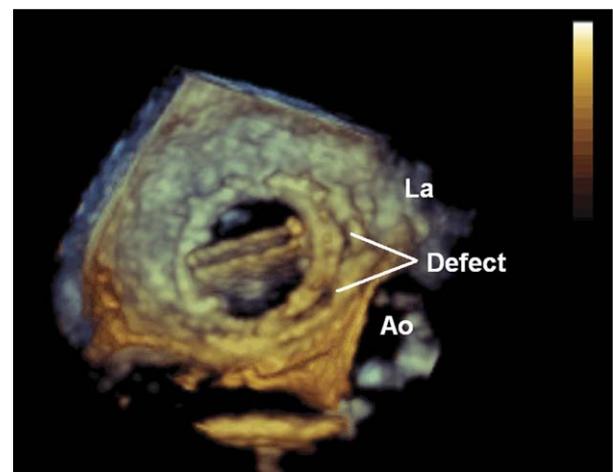


**Figure 3. Localization of the Paravalvular Leaks With 3D TEE**

Real-time live 3-dimensional (3D) transesophageal echocardiography (TEE) image of the mitral annulus and mechanical prosthesis en face from the left atrium in diastole. The paravalvular defect is located along the antero-lateral border of the prosthesis ring. Ao = aorta; La = left atrial appendage.
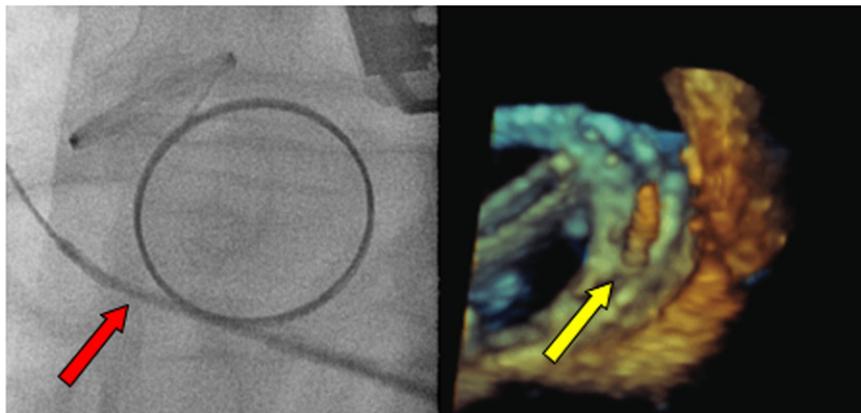
**Figure 4. Procedural Guidance Using Fluoroscopy and 3D TEE**

**(Left)** Fluoroscopic image of a posterior leak wired **(red arrow)**. **(Right)** Real-time live 3D TEE image of the mitral annulus and mechanical prosthesis en face from the left atrium in diastole. The catheter **(yellow arrow)** can be seen through the paravalvular defect located along the border of the mitral prosthesis ring. Abbreviations as in Figure 3.

1 patient). The Vascular Plug III size used in aortic position was $10 \times 5$ mm. In 1 mitral patient, the initial device was placed from the apex and a second device was implanted at the same sitting using a retrograde approach after a failed attempt using the apical approach. In another patient, the left ventricular retention disk of an $8 \times 4$-mm Vascular Plug III interfered with a prosthetic leaflet and was removed (Fig. 7). Subsequently a $6 \times 4$-mm Duct Occluder was implanted with its single retention disk within the left atrium thereby avoiding interference. Bleeding complications occurred in 2 mitral patients. In 1 patient, a localized pericardial hematoma was treated conservatively. In the second patient, a hemothorax prompted a left-sided thoracotomy to oversew the apical bleeding site. Both bleeding

complications were diagnosed on routine post-procedural echocardiograms that were performed 2 and 48 h after the procedure. No complication occurred in the patient with an aortic paravalvular leak closure. Discharge home was at a median of 14 days (IQR 8 to 20 days). Prolonged hospital stays were mainly due to mobilization problems in a frail population and to the patient that needed surgical repair of the access site. Residual regurgitation as assessed by TEE was reduced to mild in 3 patients and trivial in 2 patients (Fig. 8).

**Follow-up.** At a median follow-up of 191 days (IQR 169 to 203 days) all patients remained alive. New York Heart Association functional class improved from a median of 4 (IQR 3 to 4) at baseline to class 2 (IQR 2 to 3). At last
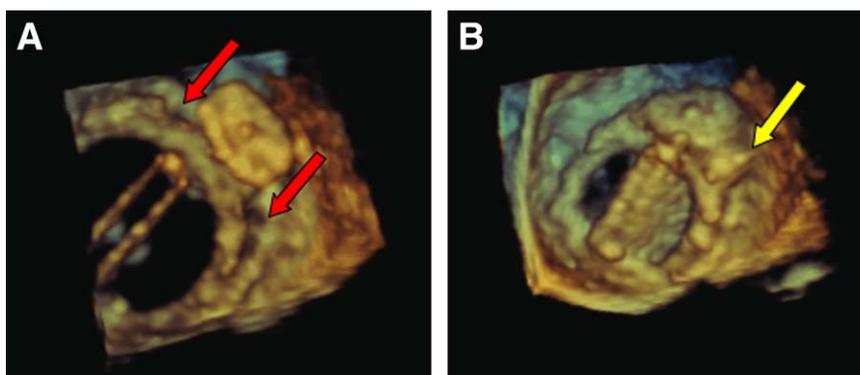


**Figure 5. Positioning and Deployment of the Vascular Plug Using 3D TEE Guidance**

**(A)** Real-time live 3D TEE image of the mitral annulus and mechanical prosthesis en face from the left atrium after introduction of an Amplatzer occluder device through the defect. There are remaining defects anterior and posterior to the occluder **(red arrows)**. **(B)** Real-time live 3D TEE image of the mitral annulus and mechanical prosthesis en face after introduction and release of a second Amplatzer occluder device across the paravalvular defect **(yellow arrow)**. Abbreviations as in Figure 3.
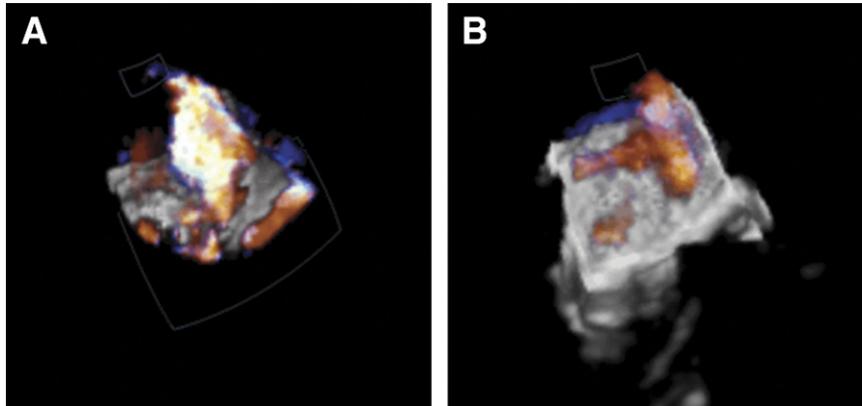
**Figure 6.** Quantification of the Severity of Paravalvular Leaks With 3D TEE

**(A)** Full volume color 3D image showing severe paravalvular regurgitation through the defect seen in Figure 1 during systole. **(B)** Full volume color 3D image showing significant reduction in the paravalvular leak after the insertion of 2 Amplatzer devices. Abbreviations as in Figure 3.

transthoracic echocardiographic follow-up, at a median of 58 days (IQR 56 to 70 days), residual regurgitation (mitral regurgitation in 4 patients, aortic regurgitation in 1 patient) was reportedly reduced from grade 4 at baseline to grade 2 (IQR 1.5 to 2.25). Left ventricular ejection fraction was unchanged (median: 65% [IQR 60% to 70%]). Estimated systolic pulmonary arterial pressure by echocardiography was unchanged (baseline: 48 mm Hg [IQR 43.5 to 58.25 mm Hg], follow-up: 42 mm Hg [IQR 33 to 47 mm Hg]). After 191 days (IQR 169 to 203 days), creatinine fell from 109 $\mu$mol/l (IQR 106 to 132 $\mu$mol/l) to 89 $\mu$mol/l (IQR 89 to 126 $\mu$mol/l), glomerular filtration rate rose from 45 ml/min (IQR 42 to 46 ml/min) to 54 ml/min (IQR 45 to 71.5 ml/min) and hemoglobin improved from 89 g/l (IQR 87 to 108 g/l) to 115 g/l (IQR 104 to 118 g/l). In the 1 patient for whom hemolysis

was the main indication for perivalvular leakage closure, no more schistocytes were found in the blood and initially elevated plasma bilirubin and urine urobilinogen levels normalized.

## Discussion

The major findings of our work are the promising results of paravalvular leak closure using the purpose-specific Amplatzer Vascular Plug III, the simplification of mitral paravalvular leak closure by a transapical approach, and the advantage of using 3D TEE guidance.

Management of severe paravalvular leaks in candidates with prohibitive surgical risk is challenging, and current American and European guidelines do not address this issue (9,10).
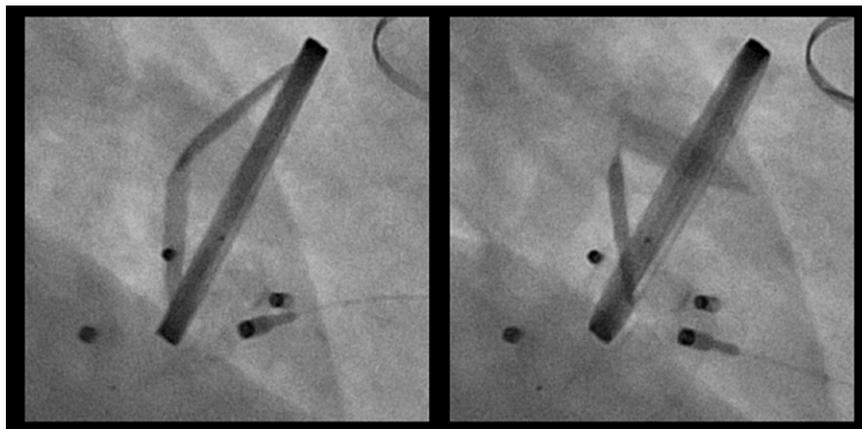


**Figure 7.** Device Interference With Prosthesis Leaflets

Interference of the Amplatzer Vascular Plug III with 1 leaflet of the mechanical valve: **(left)** both leaflets closed; **(right)** posterior leaflet does not open properly.
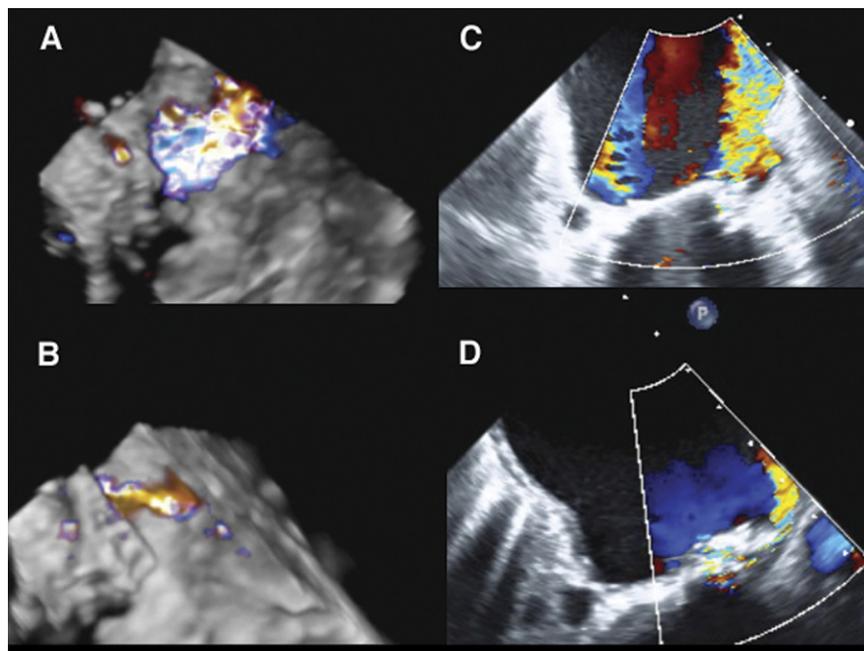
**Figure 8. Significant Reduction of Mitral Regurgitation**

Improvement of mitral regurgitation from severe **(A, C)** to trivial degree **(B, D)** on 3D TEE **(A, B)** and 2-dimensional transesophageal echocardiography **(C, D)**.

Percutaneous paravalvular leak closure is a technically difficult procedure with varying success rates around 60% to 80% (11–13). Procedural success is mainly dependent on the ability to wire the defect and the completeness of defect occlusion, without interference with the valve leaflets by the device chosen. Most leaks are either oval- or crescent-shaped; however, the location and extent of the leaks vary individually and multiple imaging modalities may play a role (6,14–17). Three-dimensional echocardiography appears particularly useful in this setting.

The oval shape and dimensions of the Amplatzer Vascular Plug III appear well-suited for paravalvular leak closures. The relatively small retention rims may be less likely to interfere with mechanical valve leaflets than other currently available occluders (18–23). Although, the Amplatzer Duct occluder lacks a retention rim on 1 side, this may compromise stability.

The transapical approach to the mitral valve avoids the need for a catheter passage across the interatrial septum or a prosthetic aortic valve. Importantly, apical access allows relatively direct access to the mitral valve over a short, straight course. In 1 patient, the apical approach for placement of a second device failed, demonstrating that a variety of approaches may, on occasion, be necessary. The study population is small and does not allow us to draw general conclusions. Larger studies are therefore needed.

Initial experience with transapical puncture was obtained during diagnostic hemodynamic studies in patients with aortic valve pathology, although this is currently rarely used other than in patients with double mechanical valves (24). Reportedly, the risks of hemothorax or hemopericardium were approximately 5% (25). More recently, transapical puncture has found favor as access for transcatheter valve implantation (26,27) Transapical access can either be via a percutaneous puncture or a small intercostal cut-down. Although more invasive and complex, a cut-down facilitates controlled closure of the puncture site, possibly reducing bleeding complications. The bleeding complications that occurred in our series did not affect the overall success rate of the procedure, except for a prolonged hospital stay in the patient in need for surgical repair.

Three-dimensional TEE was particularly helpful to obtain clear relationships between the defect, the guidewire, and the catheter. These relationships cannot be obtained as easily with 2-dimensional TEE or any other imaging techniques. The full volume 3D color Doppler helps define the extent of the regurgitant jet pre- and post-device insertion, guiding device size and placement.

## Conclusions

The Amplatzer Vascular Plug III is a promising device adding to the interventionalists' armamentarium of paravalvular leak closure devices. Three-dimensional TEE guidance of the procedure gave a clear en-face view of the valve and paravalvular structures. This imaging modality was

invaluable for guiding wire position, device delivery and deployment, assessing residual paravalvular leaks, and prosthetic valve function. For mitral paravalvular leaks, a transapical procedure is a promising alterative to a retrograde or transseptal approach.

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