

Novel Use of Echo Fusion and Cardiac Computed Tomographic Imaging Guidance for Percutaneous Paravalvular Leak Closure



Lucy M. Safi, DO, FASE, FACC, Vladimir Jelnin, MD, Ruchir Patel, MD, Kevin Oguayo, MD, Tilak K. R. Pasala, MD, and Carlos E. Ruiz, MD, PhD, FACC, FESC, MSCAI, Hackensack, New Jersey

INTRODUCTION

Paravalvular leaks (PVLs) occur in up to 17% of surgical mitral valve replacements, and although most are asymptomatic, 1% to 3% may present with symptoms of heart failure, hemolysis, or both.¹ PVL may occur from friable tissue, infection, or calcification. Although redo operations may be required in some patients, others may be treated percutaneously with good clinical outcomes.^{2,3}

Transesophageal echocardiographic (TEE) imaging is an essential modality used for diagnosis, preprocedural planning, and intraoperative guidance. Echo fusion performed using EchoNavigator software (Philips Healthcare, Best, the Netherlands) is a novel imaging modality that enables real-time overlay of echocardiographic images with fluoroscopy on the same screen.⁴ Computed tomographic (CT) fusion using HeartNavigator software (Philips Healthcare) overlays CT images with fluoroscopy. Fusion imaging is helpful in guiding percutaneous interventions during PVL closure procedures.^{5,6} In patients with complicated anatomy, occasionally transapical access may be required.^{7,8}

CASE PRESENTATION

A 69-year-old woman with a history of coronary artery disease, bileaflet mitral valve leaflet prolapse, and severe mitral regurgitation underwent coronary artery bypass graft surgery and mitral valve replacement in December 2018. At the time of surgery there was hemodynamic instability coming off cardiopulmonary bypass. Intraoperative TEE imaging showed left ventricular outflow tract obstruction, and the replacement mitral valve was downsized to a 25-mm Mosaic porcine valve (Medtronic, Minneapolis, MN). At the end of the procedure, the valve was well seated, with no valvular or paravalvular mitral regurgitation by color Doppler and no evidence of left ventricular outflow tract obstruction. The patient's postoperative stay was complicated by prolonged hospitalization because of gastrointestinal bleeding.

From Hackensack University Medical Center, Hackensack, New Jersey.

Keywords: Echo fusion, Paravalvular leak, Paravalvular leak closure, Bioprosthetic mitral valve, Hemolysis

Dr. Pasala is a member of the speakers' bureau for Philips Healthcare and has received an institutional education grant from Medtronic. A research and educational grant was provided from Philips Healthcare to the institution.

Conflicts of interest: The authors reported no actual or potential conflicts of interest relative to this document.

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2468-6441

<https://doi.org/10.1016/j.case.2020.05.006>

VIDEO HIGHLIGHTS

Video 1: TEE color-compare images showing the severe PVL located at the posterolateral aspect of the prosthesis at a normotensive blood pressure.

Video 2: TEE images (*left*) and echo fusion images (*right*) showing the delivery catheter crossing through the PVL. The endocardium is outlined using EchoNavigator software.

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Approximately 8 months later, the patient began to experience unintentional weight loss, failure to thrive, and progressive dyspnea with exertion. She denied fevers, chills, or sweats. There were no clinical signs of infection, and viral panels were negative. Leukocyte count and tumor markers were all within normal limits. She was found to have hemolytic anemia, with haptoglobin < 8 mg/dL, lactate dehydrogenase of 2,606 IU/L, and a reticulocyte count of 4.8%. On physical examination, a loud systolic murmur was best heard in the axilla.

The patient underwent transthoracic echocardiography, which showed eccentric, moderate to severe mitral regurgitation by color Doppler, mild tricuspid regurgitation, and estimated pulmonary artery pressure of 60 mm Hg (assuming a right atrial pressure of 3 mm Hg). TEE imaging showed a normally functioning bioprosthetic valve with trivial mitral valvular regurgitation and a severe PVL from the posterolateral aspect of the mitral prosthesis ([Figure 1](#), [Video 1](#)).

The etiology of the PVL was thought to be related to suture material dehiscence. There was no evidence of valvular "rocking" or vegetations. The PVL was located from 6 to 8 o'clock in the en face surgical view ([Figure 2](#)), measuring 1.3 × 0.5 cm in size ([Figure 3](#)).

Systolic flow reversal was seen in the pulmonary veins, with an estimated pulmonary artery pressure of 60 mm Hg (assuming a right atrial pressure of 3 mm Hg).

The patient was presented at a multidisciplinary meeting, at which both surgical and percutaneous options were discussed. She was deemed to have elevated surgical risk for redo operation because of her frailty and hemolytic anemia, and it was recommended that the patient undergo percutaneous closure of the PVL.

Intraoperative Guidance

In the hybrid operating room, the three-dimensional (3D) TEE probe was placed in the esophagus, and coregistration of the probe using

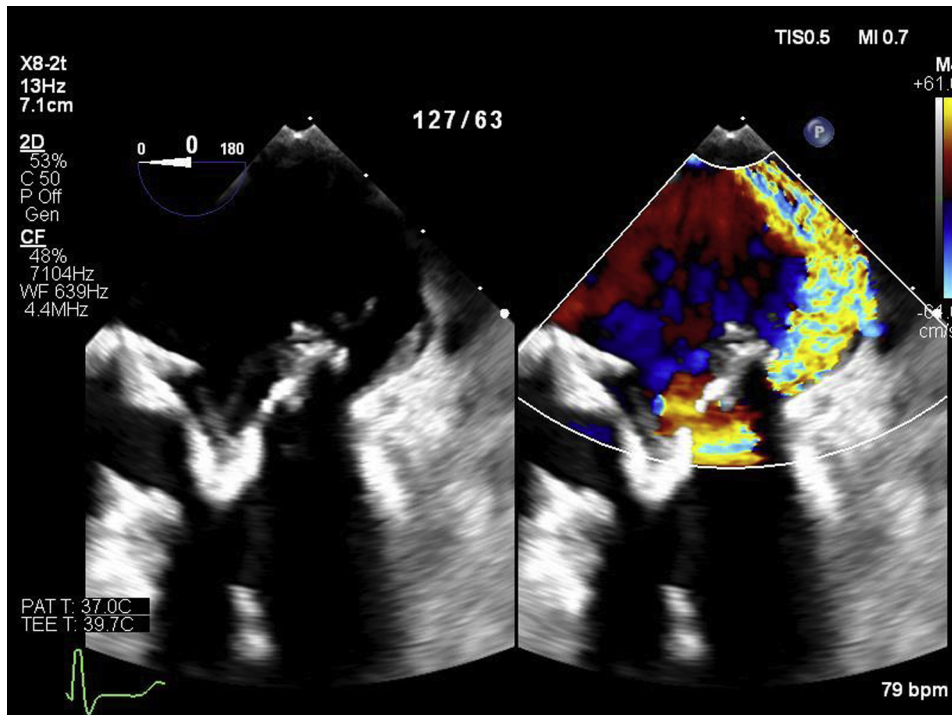


Figure 1 TEE color-compare images showing the severe PVL located at the posterolateral aspect of the prosthesis at a normotensive blood pressure.

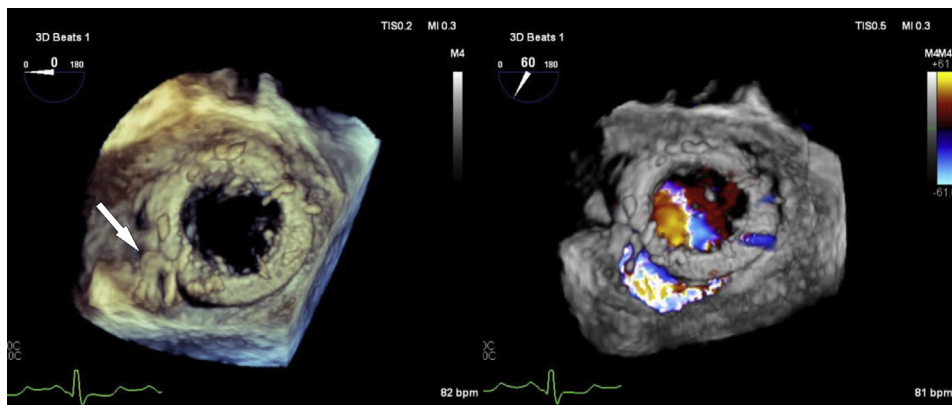


Figure 2 Three-dimensional TEE imaging of the mitral valve prosthesis in surgical view showing disruption of surgical sutures (*left, arrow*) and color Doppler seen through the PVL (*right*) located between 6 and 8 o'clock.

EchoNavigator software was completed. Coregistration allows localization of the TEE probe in fluoroscopic space (Figure 4). After successful coregistration, movement of the C-arm or the TEE probe will update the real-time overlay on fluoroscopy.

A marker was placed at the ideal transseptal puncture site using EchoNavigator software. Biplane imaging was used to follow the transseptal needle to the appropriate location on the atrial septum for puncture (Figure 5).

After transseptal access was obtained, a soft Glidewire (Terumo Medical, Somerset, NJ) and angled catheter were used to cross the PVL. Three-dimensional TEE imaging was used to help guide the

wire through the PVL and not through the mitral valve prosthesis (Figure 6).

The wire was passed through the PVL, looped in the left ventricle, and out the aorta to create a "rail" for stability (Figure 7).

The catheter was advanced into the PVL (Figure 8), but despite the "rail" created previously, the serpiginous track of the PVL lead to instability of the delivery catheter inside the PVL, and the procedure was converted to transapical access for better stability of the catheter system.

Gated cardiac CT imaging was performed before the procedure. Coregistration of the CT images with fluoroscopy was completed

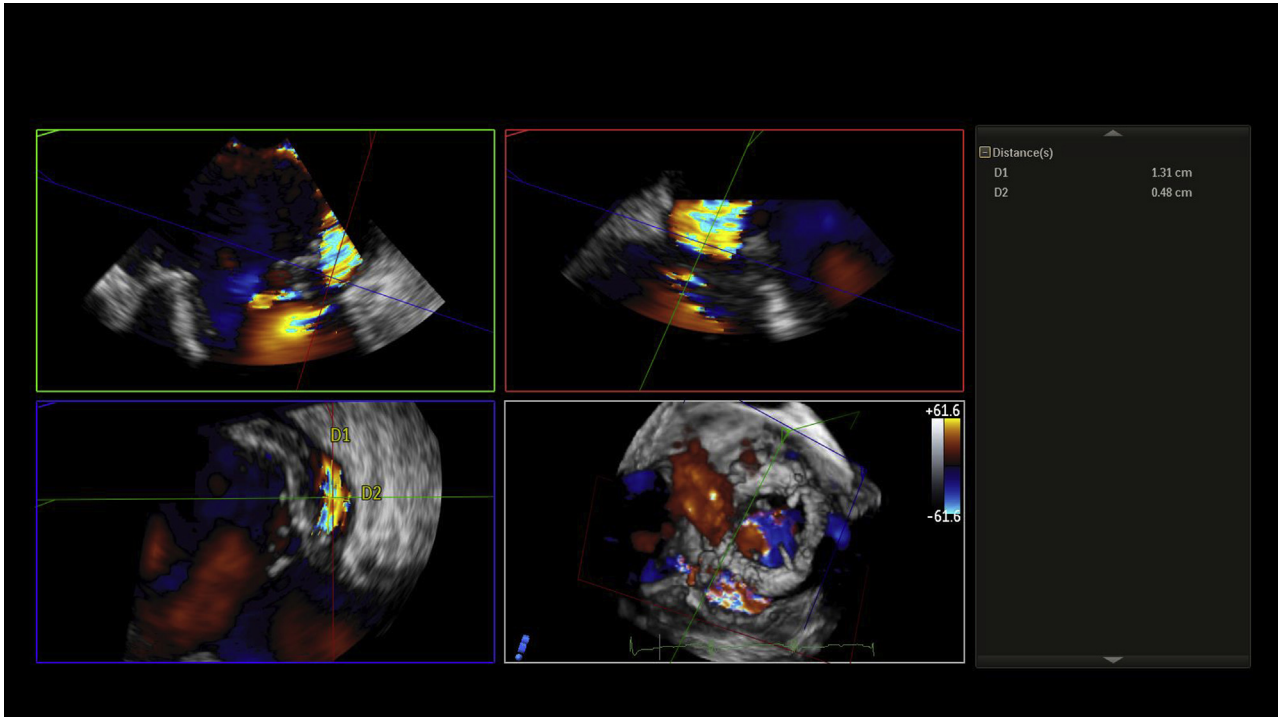


Figure 3 Measurement of the PVL using multiplanar reconstruction.

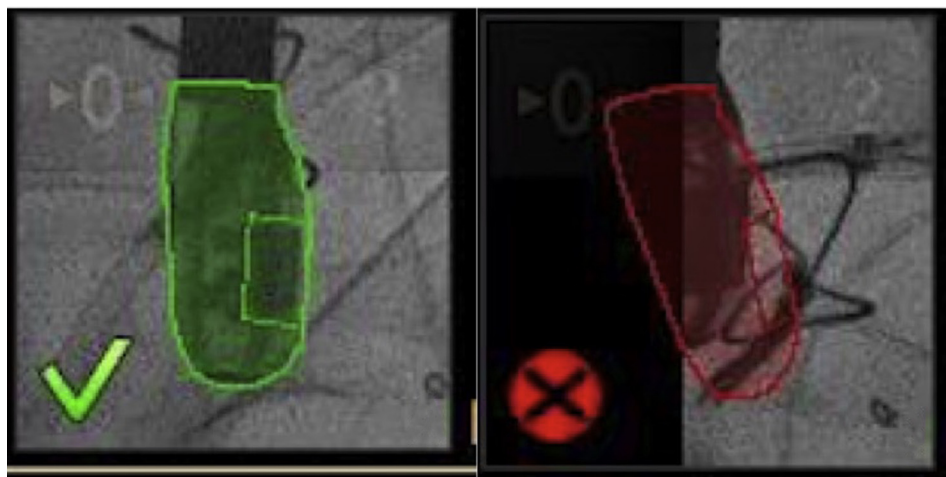


Figure 4 EchoNavigator image showing that the probe is coregistered with fluoroscopy (*left*) and not coregistered (*right*).

using HeartNavigator software allowing localization of the CT images in fluoroscopic space. Both echo fusion (Figure 9) and CT fusion (Figure 10) images were displayed simultaneously on separate screens to help guide the interventionalist during the transapical access.

The mitral valve annulus was labeled for orientation using EchoNavigator software (Figure 11).

The correct rib space and angle of approach were identified, and a micropuncture needle was advanced into the left ventricle (Figure 12).

Using EchoNavigator software, a virtual marker was placed at the location of the PVL. A Neff wire (Cook Medical, Bloomington, IN) was passed through the micropuncture needle and guided through the PVL using TEE guidance (Figures 13 and 14).

A micropuncture catheter was then advanced over the wire into the left atrium. The wire was exchanged for a 260-cm Glidewire, which was snared through the transeptal sheath and exteriorized out into the femoral vein, creating an atrioventricular rail. Then a TorqVue delivery catheter (St. Jude Medical, St. Paul, MN) was advanced from the femoral vein across the PVL, and two Amplatzer Vascular Plug II (8 and 10 mm) devices and an Amplatzer Vascular Plug IV (8 mm) were advanced and deployed across the PVL (Video 2). Residual PVL was evaluated and determined to be trace to mild (Figure 15).

Transapical access was closed using an Amplatzer Vascular Plug IV and Surgiflo Hemostatic Matrix Kit (Johnson & Johnson, New Brunswick, NJ; Figure 16).

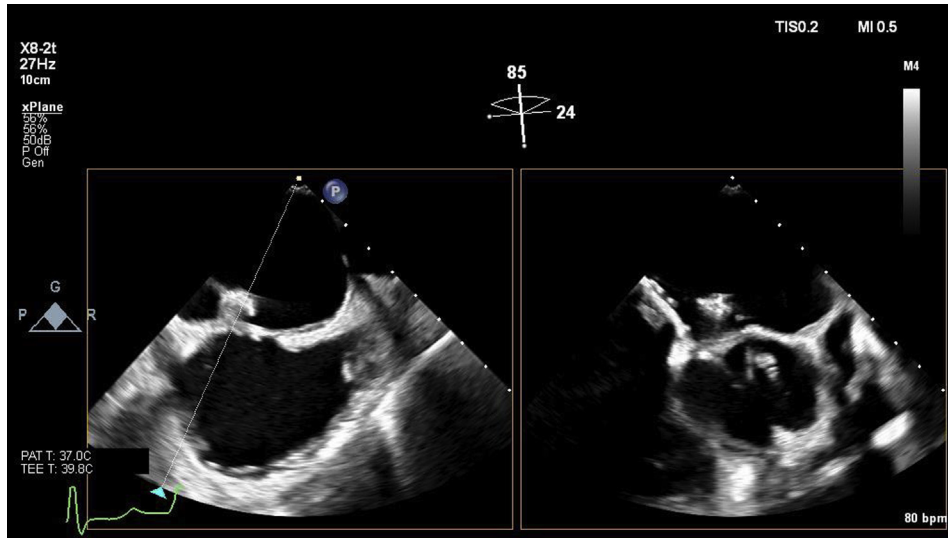


Figure 5 Biplane imaging showing transseptal puncture in the inferior aspect of the atrial septum.

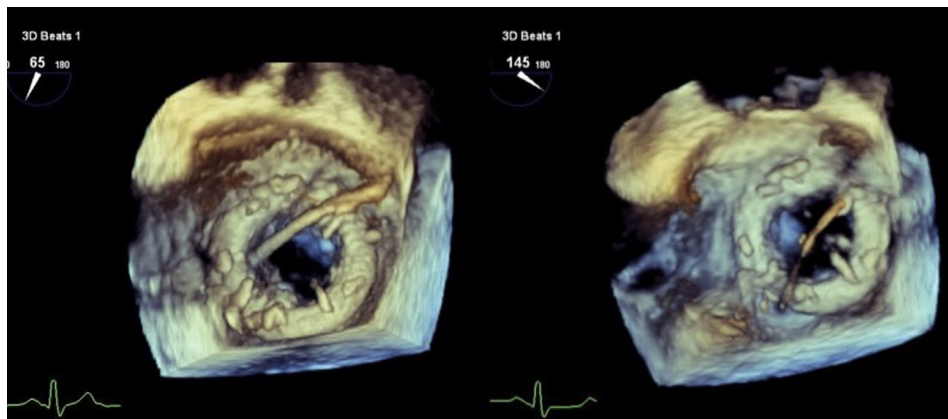


Figure 6 Intraprocedural 3D TEE imaging showing a wire across the mitral valve prosthesis (left) and a wire across the PVL (right).



Figure 7 TEE image (left) and echo fusion image (right) showing wire across the PVL looping in the left ventricle and exiting into the aorta, creating a “rail.”

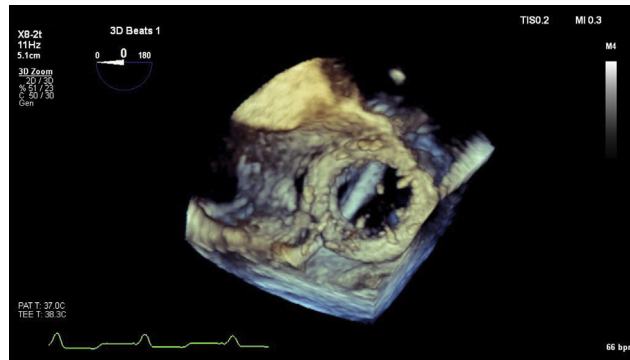


Figure 8 Intraprocedural 3D TEE imaging showing the catheter across the PVL from the surgical view.

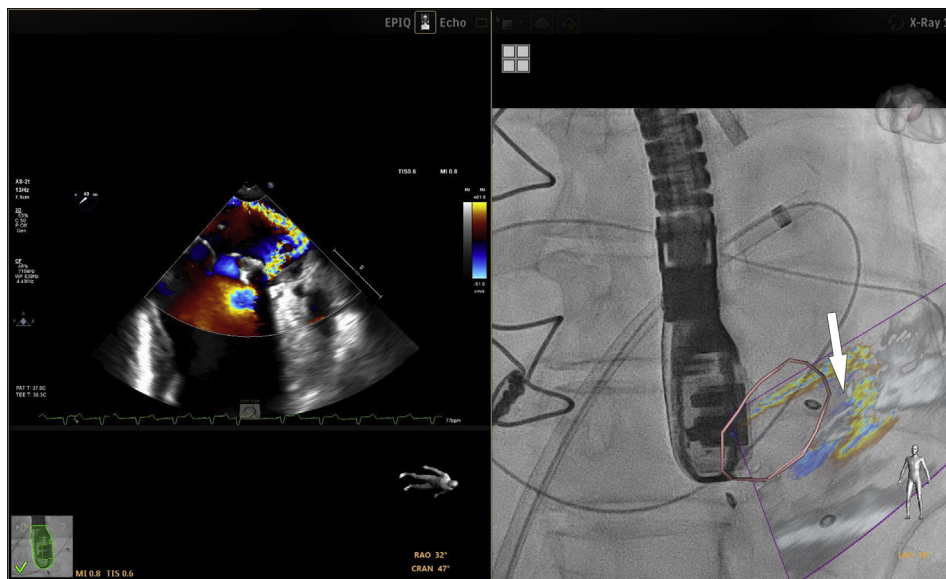


Figure 9 TEE imaging (*left*) showing severe PVL by color Doppler. Echo fusion images (*right*) showing the sheath across the atrial septum and origin of the PVL (*arrow*).

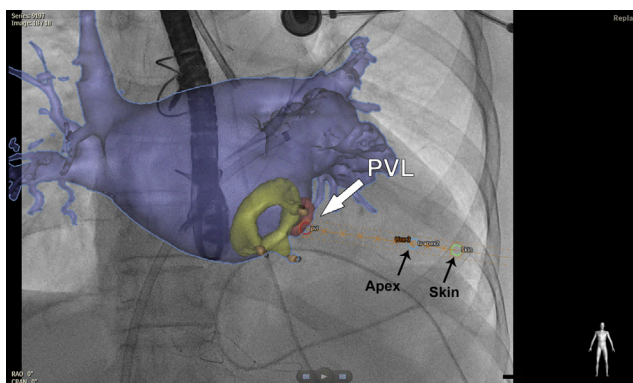


Figure 10 Gated cardiac CT image using HeartNavigator software showing recommended rib space and angle of approach for transapical access.

Improvement of estimated pulmonary artery systolic pressure (using peak tricuspid regurgitation velocity by Doppler) was seen, suggestive of improved hemodynamics (Figure 17).

Concordantly there was also a notable drop in left atrial pressure seen when measured invasively. Postprocedurally, there was improvement in the patient's hemolytic blood parameters, and she was discharged home the next day with close follow-up.

DISCUSSION

TEE imaging is a vital part of a PVL closure procedure, with frequent communication between the interventionalist and echocardiographer. Three-dimensional TEE images can be used to determine the size and location of a PVL. On the basis of these characteristics, the best closure device is then selected. Image quality may vary

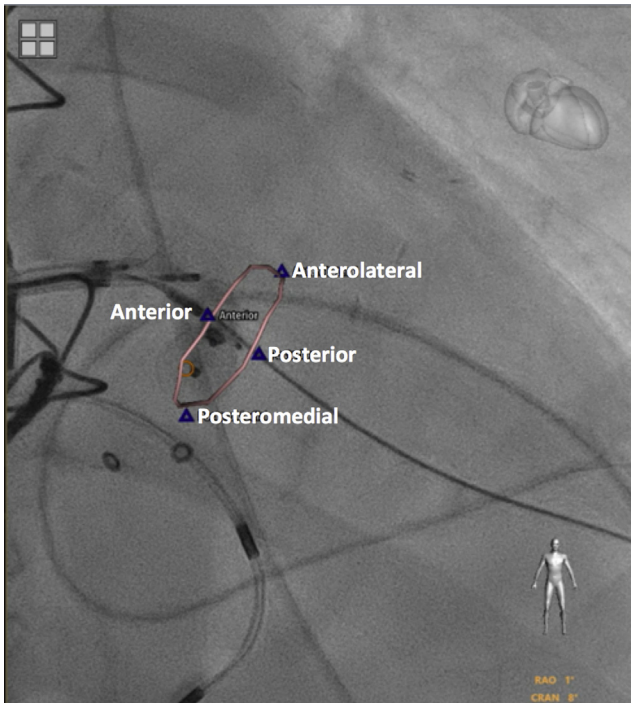


Figure 11 Portions of the mitral valve annulus labeled using EchoNavigator software.

from patient to patient, and prosthetic material, catheters, and wires may lead to echocardiographic artifacts.

Echo fusion technology provides a unique overlay of echocardiographic two-dimensional, 3D, and color Doppler images with fluoroscopy in real time. These images shift with motion of the C-arm,

allowing continuous feedback to the operator. Placement of annotation markers at specific locations such as the preferred atrial septal puncture site or the origin of the PVL, can guide the proceduralist toward the correct fluoroscopic location.

Similarly, CT fusion allows prior CT images to be overlaid with real-time fluoroscopy. Often CT images are obtained before intervention (on separate days) to limit intravenous contrast exposure to the patient. Filling conditions may vary between the time of acquisition and the time of intervention, leading to some anatomic variability. Another limitation of CT fusion is that anatomic correlation with true anatomy may become inconsistent after the chest is invaded with catheters and wires.

The information obtained from both imaging modalities is synergistic during advanced structural heart interventions in which immediate feedback and accuracy is essential. A transeptal approach to mitral valve PVL closure is classically the preferred method for closure; however, in patients in whom that approach is unsuccessful or unfavorable, transapical access may be required.⁹ Combined echocardiographic and CT fusion imaging provides an assessment of the 3D anatomy that can be used to determine the best access approach and provide intraprocedural guidance.

CONCLUSION

We present the case of a patient with a large mitral valve PVL leading to symptomatic hemolytic anemia. Percutaneous PVL closure interventions can be challenging, and multiple access sites may be needed for successful closure. Both echo fusion and CT fusion imaging technology provide synergistic information to better understand 3D anatomy and to safely and successfully facilitate alternative access sites for percutaneous PVL interventions.



Figure 12 Echo fusion images in which the left ventricular endocardium (arrow) is outlined using EchoNavigator to help guide transapical puncture.

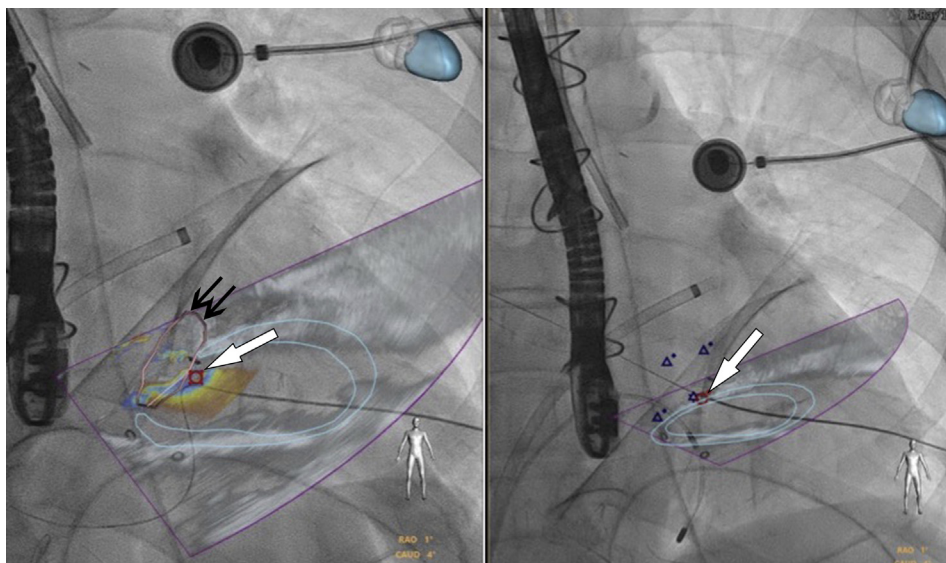


Figure 13 Echo fusion images showing (left) the outlined left ventricular endocardium and color Doppler to locate the PVL. A red marker (open circle) was placed at location of the defect using EchoNavigator software. (Right) A wire is seen passing at the location of the marker and into the PVL. Arrow indicates origin of PVL; double arrow indicates mitral valve annulus.

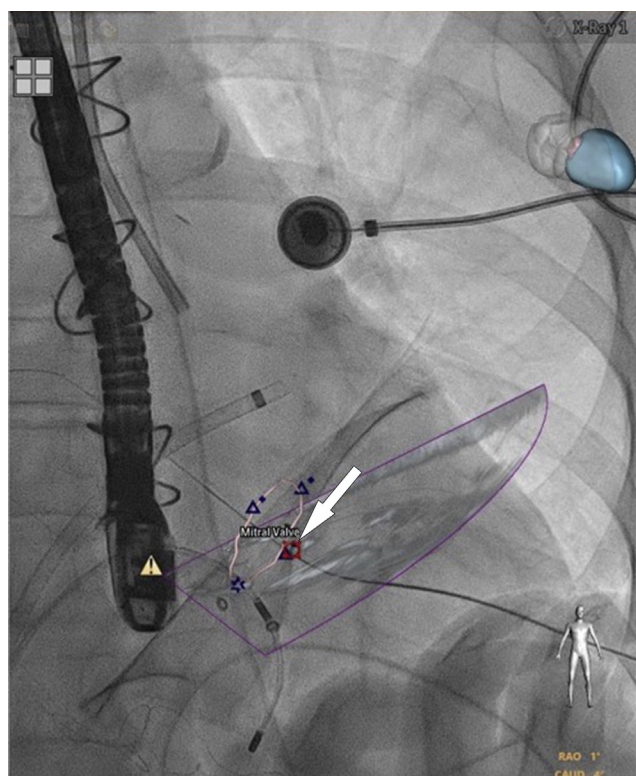


Figure 14 Echo fusion images in which the mitral valve annulus is marked (triangle) and a red marker (open circle) was placed at the origin of the PVL (arrow) using EchoNavigator software.

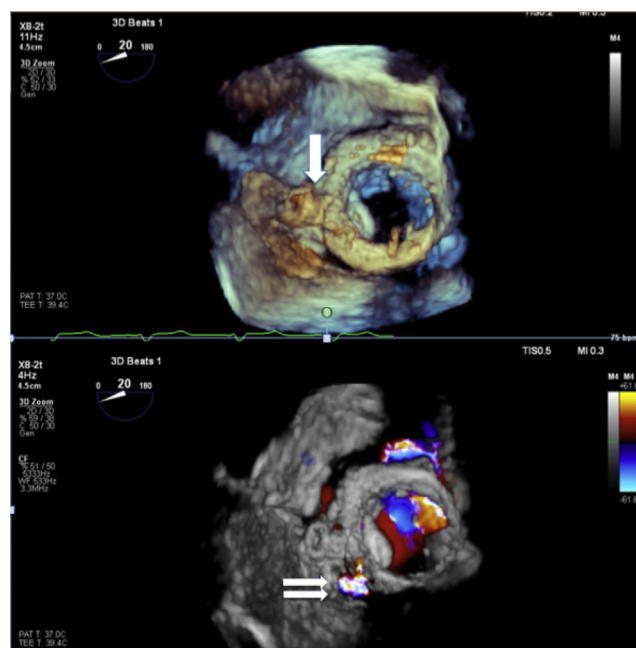


Figure 15 Three-dimensional TEE image of the PVL after placement of two Amplatzer Vascular Plug (AVP) II devices and one AVP IV (top, arrow) and trace residual PVL noted on color Doppler (bottom, double arrow).

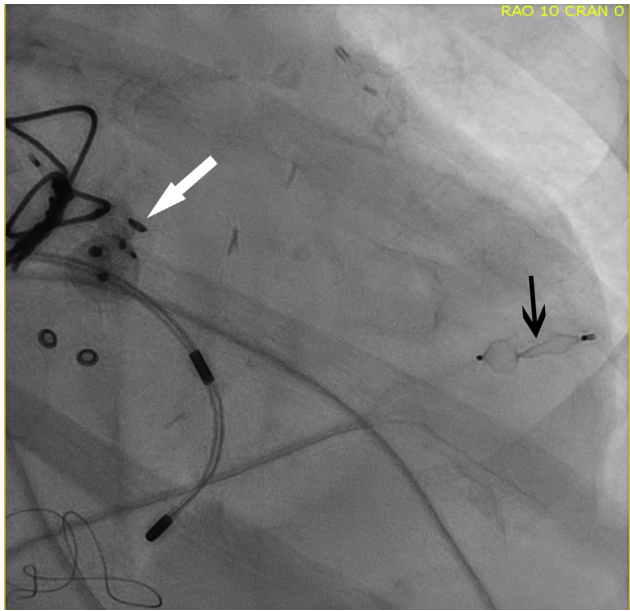


Figure 16 Fluoroscopic image showing closure of the left ventricular (LV) access site with an Amplatzer Vascular Plug (AVP) IV in the left ventricular apex. *Black arrow* indicates AVP IV closing LV apex access. *White arrow* indicates AVP II and AVP IV at the location of the PVL.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.case.2020.05.006>.

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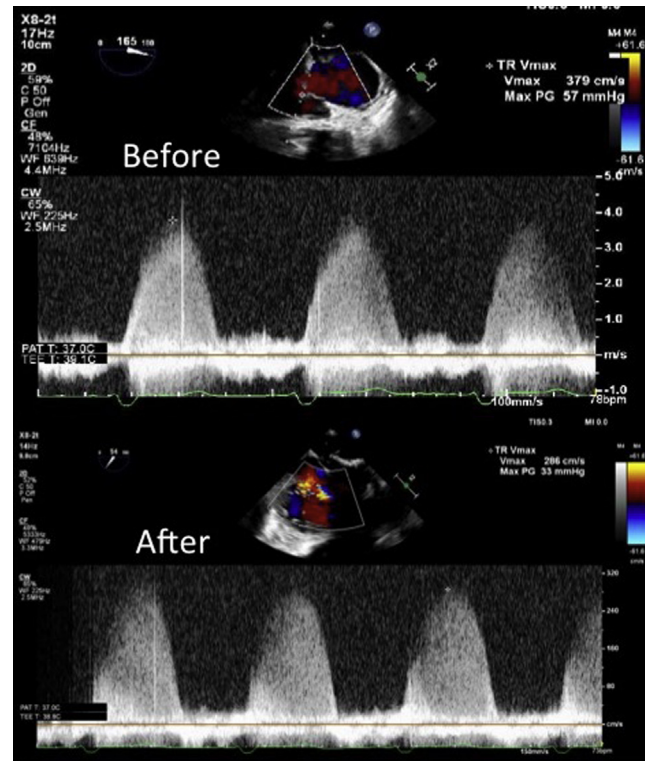


Figure 17 Reduction of estimated pulmonary artery systolic pressure was seen at the end of the procedure.

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