Percutaneous Closure of Mitral Prosthetic Paravalvular Leak

A discussion of the disease etiology, treatment techniques, and outcomes of percutaneous PVL repair, as well as an illustrative case report.

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Paravalvular leaks (PVLs) are a well-recognized complication of mechanical or bioprosthetic surgical valve replacement. It is estimated that more than 60,000 patients per year undergo surgical heart valve replacement in the United States, with a reported incidence of 5% to 15% for some form of PVL.[1] Most PVLs are small and clinically benign; however, larger PVLs can manifest in heart failure or hemolysis, necessitating either surgical or percutaneous repair.[2] Although surgical repair has historically been the standard treatment for severe PVLs, "re-do" surgery confers increased morbidity and mortality; therefore, development of less-invasive percutaneous PVL closure techniques has gained momentum within the field of structural interventional cardiology.

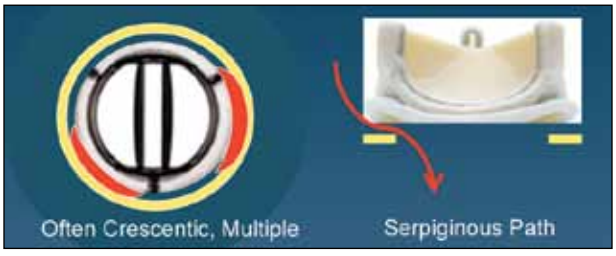

Figure 1. PVLs are often crescentic in shape, and there may be more than one defect. The shape can make complete closure with a single round device challenging, and often, more than one device is required to achieve closure. The path of the regurgitant orifice can also be serpiginous, which makes wire and catheter crossing potentially difficult.

ETIOLOGY

In the majority of patients, PVLs occur within the first 6 months after surgical valve replacement. Infective endocarditis is the most common cause of PVL and is more prevalent in patients undergoing valve replacement for active native valve endocarditis, with a risk ranging from 0.06% to 5.4%.[2] Anatomically speaking, one factor leading to PVL is thinning of the mitral valve annulus due to myxomatous degeneration, resulting in an increased risk of stitch dehiscence. Furthermore, annular calcification may cause suture breakage or prevention of appropriate apposition of the prosthetic ring to the tissue annulus, leading to dehiscence and PVL. Prosthesis and annular size mismatch, especially in a markedly dilated left ventricle, can cause retraction of the valve annulus ring away from the prosthesis, contributing to PVL formation.

Surgically related PVL due to inadequate suturing technique and knot slippage occurs immediately after valve replacement and can, in some cases, be prevented by the use of mattress sutures bolstered with pledgets to sandwich valvular-annular tissue between the pledgeted sutures. Diagnosing PVLs is often difficult because the associated murmur is often soft, and transthoracic images and color flow Doppler may be hindered by the prosthesis and the presence of significant valvular calcification. Transesophageal echocardiography (TEE) provides greater sensitivity and specificity in detecting PVLs and differentiation from transvalvular regurgitation and is essential for any symptomatic patient in whom a PVL is suspected.[3]

CLINICAL MANIFESTATIONS

Patients with PVLs generally present with symptoms attributable to hemolytic anemia and/or congestive heart failure. The mechanism of hemolysis associated with PVLs is due to turbulent flow and high-velocity shearing forces through the often crescent-shaped and

TABLE 1. OUTCOMES OF SURGICAL CORRECTION OF PROSTHETIC PVLs IN SELECT SERIES

Publication	Mitral	Aortic	No. Pts	Severe Hemolysis	NYHA III/IV	Mechanical Valve	Periprocedural Mortality	7–10 y Mortality
Akins,[4] 2005	92	44	136	38%	58%	77%	7%	70%
Genoni,[5] 2000	50	0	50	NR	52%	97%	6%	NR
Kirali,[6] 2001	14	0	14	7%	86%	93%	7%	26%

Abbreviations: NR, not reported.

serpiginous paravalvular tracts (Figure 1). The degree of hemolysis is inversely proportional to the size of the tract and can range from mildly compensated hemolytic anemia to severe hemolysis requiring repeated transfusions. Large or multiple PVLs can cause hemodynamically significant regurgitation, gradually leading to diminished cardiac function or acute exacerbation of underlying congestive heart failure.

TREATMENT

Medical treatment is primarily intended to provide symptomatic relief with afterload reducing agents and diuretics. Appropriate antibiotic therapy in cases of PVL associated with infective endocarditis is paramount, and active endocarditis is a contraindication to device closure. Iron supplementation may be effective in the majority of patients with hemolytic anemia, although transfusions may be required and, occasionally, the administration of recombinant erythropoietin can eliminate the need for repeated transfusion.[7]

Despite medical therapies, however, many patients will continue to experience worsening NYHA functional class and intractable hemolytic anemia, necessitating reoperation. Unfortunately, repeat surgery is often unsuccessful, with a high incidence of recurrence as the original anatomical problems persist, resulting in reformation of PVLs.[8] Furthermore, these patients are generally sicker than at the time of the index surgical procedure, and therefore, reoperation carries markedly higher morbidity and mortality rates (Table 1). In a case series by Akins et al, a total of 136 patients underwent surgical correction of a PVL (32% aortic and 68% mitral, 48% primary repair and 52% replacement of prosthesis), and the operative mortality and preoperative stroke rates were 6.6% and 5.1%, respectively.[4] Ten-year mortality in that series was 70%, with similar perioperative and long-term mortality rates reported by other investigators.[5,6]

PERCUTANEOUS PVL CLOSURE TECHNIQUES

The first successful transcatheter closure of PVLs was reported by Hourihan and colleagues in 1992 with the use of the Rashkind double-umbrella closure technique.[9] No specific device has since been developed or approved by the US Food and Drug Administration for percutaneous PVL repair. Therefore, the choice of percutaneous therapeutic options is limited to the off-label use of closure devices designed for repair of other cardiac defects. The Amplatzer family of closure devices (St. Jude Medical, Inc., St. Paul, MN), including the septal occluder, VSD muscular occluder, duct occluder, and vascular plugs, has gained favor and are the devices most commonly used off-label for transcatheter PVL repair.[10] In the United States, the Amplatzer Vascular Plugs (AVP) II and IV (St. Jude Medical, Inc.) are commonly used. The AVP IV has the advantage of being delivered through a 0.038-inch diagnostic catheter lumen and can be placed in very serpiginous and long-tunnel PVLs, such as those that occur after transcatheter aortic valve replacement. The AVP III device (St. Jude Medical, Inc.) has a thin rectangular shape that is designed to conform to a crescent-shaped PVL defect and has been used with success, although it is not currently available in the United States. Device selection and sizing requires careful examination of the PVL anatomy, specifically the diameter and length of the defect, and its relationship to the surrounding cardiac structures.

Closure device delivery to the mitral PVL can be achieved via a retrograde or antegrade approach (Figure 2), with each strategy limited by several factors. Specifically, antegrade access through the PVL may not be possible due to significant regurgitation through the paravalvular defect, and the presence of a mechanical aortic valve prevents retrograde crossing of a PVL. Nevertheless, the ultimate objective of percutaneous

TABLE 2. OUTCOMES OF PERCUTANEOUS PVL CLOSURE IN RECEN

Publication	Mitral	Aortic	No. Pts	Severe Hemolysis	NYHA III/IV	Mechanical Valve	Postclosure	
							Regurgitation (MR ≤ Mild)	Transfusion-Free
Sorajja,[11] 2011	99	27	126	37 (29%)	93%	61%	78%	52%
Ruiz,[12] 2011	38	11	43	8 (14%)	86%	40%	NR	95%
Cortes,[13] 2008	27	0	27	18 (67%)	74%	100%	59%	NR

Abbreviations: MACE, major adverse cardiac events; MR, mitral regurgitation; NR, not reported.

closure is to deliver a wire through the paravalvular defect, over which a catheter or guide can be placed through the defect, and through which a closure device can be deployed.

In the retrograde approach, a Terumo floppy Glidewire (Terumo Interventional Systems, Somerset, NJ) is used to cross the paravalvular defect through a diagnostic catheter that is first positioned in the left ventricle and then advanced over the wire into the left atrium. A Terumo stiff-angled Glidewire can be used for added support, or an arteriovenous wire loop can be established after transseptal puncture in the usual fashion with a BRK needle and a Mullins (or other transseptal) sheath through which the wire is subsequently snared and externalized. The Mullins sheath is then exchanged for the closure device delivery sheath that is advanced through the venous system through the paravalvular defect into the left ventricle. The closure device is then subsequently deployed within the defect.

The antegrade approach is performed via a transseptal puncture in the usual fashion with a BRK needle (St. Jude Medical, Inc.) and a Mullins sheath (Medtronic, Inc., Minneapolis, MN) through which a diagnostic catheter is then advanced into the left atrium. A Terumo floppy Glidewire is used to cross the paravalvular defect, and the diagnostic catheter is advanced over the wire into the left ventricle. The floppy Glidewire can then be exchanged for a more supportive wire. The Mullins sheath is then exchanged for the device delivery sheath, which is used to deploy the closure device within the defect. An arteriovenous loop can be used if additional support is required by directing the Terumo floppy Glidewire from the left ventricle out to the level of the descending aorta and subsequently snaring and externalizing the wire through the femoral arterial sheath.

There are also cases in which a left ventricular transapical approach may be necessary if the operator is unable to cross the leak antegrade and there is a mechanical aortic valve present. This technique can be performed percutaneously or in a hybrid OR with a minithoracotomy for direct visualization of the left ventricular apex. A 5- or 6-F sheath is generally used, but can be varied depending on the size of the occluder required. The sheath can usually be safely removed with passive hemostasis, as these patients have all had at least one prior open heart surgery with consequent pericardial scarring. In some cases, direct surgical closure of the apical puncture may be required.

COMPLICATIONS AND CLINICAL OUTCOMES OF PERCUTANEOUS PVL CLOSURE

Besides the usual complications related to percutaneous interventions, including thromboembolic events, iatrogenic cardiac injury, and vascular complications, several complications are inherent to transcatheter closure of PVLs. Impingement of the prosthetic valve leaflet during systole can prevent proper valve closure, leading to a sudden increase in the regurgitant volume. A more feared complication is obstruction of a mechanical tilting-disk valve, which may be pulled shut after device deployment or tilting of the closure device after deployment, blocking prosthetic valve leaflets.[14] Other complications include device embolization, bioprosthetic leaflet erosion, or complete

NT SERIES				
	Complications			
	Periprocedure	30 d		90 d–3 y
	MACE	Death	Stroke	Death
	NR	2%	2%	36%
	NR	5%	NR	14%
	7%	NR	7%	NR

heart block due to deployment of a closure device at the level of the junction of the interventricular and interatrial septum that houses the atrioventricular node.

Several studies have demonstrated impressive short- and long-term outcomes further supporting the feasibility of percutaneous closure of PVLs as an alternate to surgical reoperation (Table 2).[11,15] In the largest published series by Sorajja et al,[9] percutaneous repair of 154 PVLs was attempted in 126 patients with heart failure (93%), hemolytic anemia (29%), or both and who were at high risk of open surgery (mean estimated Society of Thoracic Surgeons mortality, 6.7%). Procedural success defined as ≤ 1+ residual regurgitation was achieved in 77% of the patients, with no periprocedural deaths. The 30-day mortality rate was 2.3%, with a 1.6% rate of stroke. Of note, a significant learning curve was demonstrated, with mean procedure time decreasing from a peak of > 160 minutes to < 130 minutes. At long-term follow-up (mean, 17 ± 17 months), survival was 64%, and 72% of patients who had presented with heart failure were free of severe symptoms. Of note, however, hemolysis persisted in 14 of the 29 survivors despite a reduction in the degree of mitral regurgitation, and the presence of hemolysis portended a worse outcome.

In a separate series by Ruiz et al,[12] 57 percutaneous PVL closures were performed in 43 patients, of which, 84% had congestive heart failure and predominantly involved the mitral prosthesis (n = 38). Procedural success was achieved in 86% of the patients, with 28 of 35 patients improved by at least 1 NYHA functional class. No periprocedural death was reported, and the survival rates for patients at 6, 12, and 18 months after PVL closures were 91.9%, 89.2%, and 86.5%, respectively.

CASE REPORT

At our institution, percutaneous repair of PVL is generally a first-line approach to these patients if it is believed to be technically feasible. A 61-year-old man was referred to our institution with NYHA class II to III with a dilated left atrium, atrial fibrillation, and systolic dysfunction (left ventricular ejection fraction, 40%). The patient was initially well until 2007, when he presented with severe shortness of breath and was found to have acute heart failure from a ruptured chord. He underwent emergent repair but had recurrent mitral regurgitation in 2009, necessitating mitral valve replacement with a Carbomedics valve (Sorin Group, Milan, Italy). Echocardiography demonstrated a significant 3+ PVL located lateral and anterior to the valve. Laboratory findings demonstrated anemia consistent with mild hemolysis (hemoglobin, 12.6 g/dL; lactate dehydrogenase, 322 U/L; haptoglobin, 1 mg/dL). Given the patient's two previous sternotomies and higher risk for reoperation, he was referred for percutaneous repair of the PVL after informed consent was obtained.

Coronary angiography was initially performed and demonstrated no significant angiographic evidence of occlusive coronary artery disease. Under ultrasound guidance, right femoral venous access was achieved, and two Perclose closure devices (Abbott Vascular, Santa Clara, CA) were deployed for preclosure. The femoral vein was cannulated with a 14-F Sidearm sheath (Cook Medical, Bloomington, IN). Under direct TEE guidance, a BRK needle was advanced through a Mullins sheath across the interatrial septum, and left atrial pressures were confirmed. An Amplatzer extra-stiff wire and an Agilis catheter (St. Jude Medical, Inc.) were advanced into the left atrium, and a 6-F JR4 guide was advanced inside the Agilis catheter.

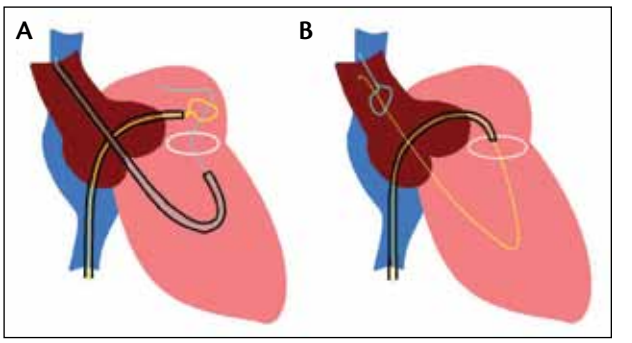

Figure 2. Mitral PVLs can be approached retrograde (A) from the left ventricle or antegrade (B) from the left atrium. Retrograde approaches can include transapical access in patients with a mechanical aortic valve. In general, a wire is passed through the defect followed by a catheter through which the closure device is delivered. In some cases, the wire can be snared and externalized to form a continuous arteriovenous loop for robust wire support.

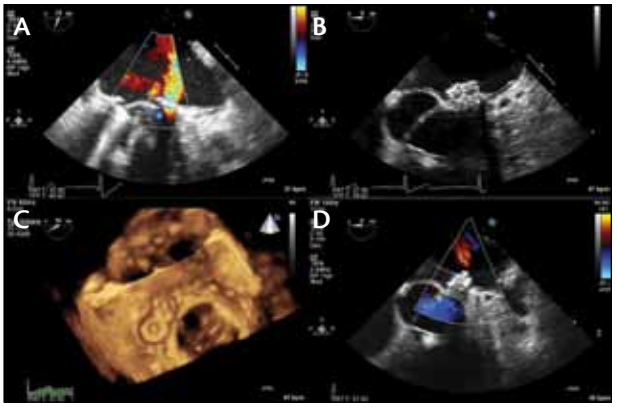

Figure 3. TEE imaging of PVL closure. Baseline lateral PVL jet located near the left atrial appendage orifice (A). Two-dimensional appearance of closure devices (B). Three-dimensional image of closure devices side by side in crescentic defect (C). Color Doppler showing no significant residual regurgitation after device closure (D).

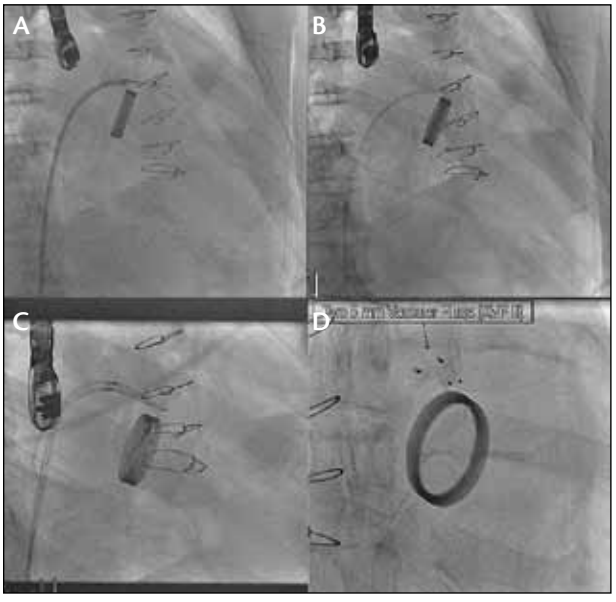

Figure 4. Fluoroscopic imaging of PVL closure. Two Glidewires across defect in the right anterior oblique projection (A). Two 6-F coronary guide catheters across the defect (B). Both distal discs of the closure devices deployed simultaneously prior to full deployment (C). Fluoroscopic assessment to ensure normal mechanical prosthetic leaflet motion is critical. Final fluoroscopic appearance of both closure devices with normal leaflet motion (D).

A Glidewire was then advanced through the guide across the PVL into the left ventricle. The guide and the Agilis catheter were removed, and a 7-F JR4 guide was advanced through the leak into the left ventricle. Two Amplatzer superstiff wires were then advanced through the JR4 into the left ventricle. Two 6-F Q3.5 guide catheters (Boston Scientific Corporation, Natick, MA) were loaded onto each wire, respectively, and the guides were advanced into the left ventricle. Two 8-mm AVP II devices were then loaded and deployed simultaneously in the PVL. TEE confirmed reduction of the mitral regurgitation from 3+ to 1+ (Figures 3 and 4). The patient's recovery was uneventful, and he continued to do well at follow-up with no recurrent heart failure or hemolysis.

CONCLUSION

PVLs can occur after surgical valve replacement, and transcatheter repair of PLVs can be technically challenging but feasible. Reported outcomes with percutaneous closure of PVLs are promising and comparable, if not superior to, standard surgical reoperation, which carries significant mortality and morbidity risk. Despite the availability of numerous closure devices for percutaneous repair of other cardiac defects, devices designed specifically for PVLs remain to be developed. With the future advent of closure devices specific for PVLs, percutaneous repair may ultimately prove to become the gold standard treatment in this setting. ■

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