Hybrid approach for transcatheter paravalvular leak closure of mitral prosthesis in high-risk patients through transapical access

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Objectives: To report “hybrid” procedure feasibility and the clinical success of transcatheter paravalvular leak closure through apical access.

Methods: Seven patients (73.6 ± 6.1 years; 4 men) with severe mitral prosthesis paravalvular leak were selected. All patients were at high risk for open surgery because of severe comorbidities and heart failure (New York Heart Association class III-IV).

Results: The defect size was 25 ± 7.8 mm in the long axis and 9.3 ± 2 mm in the short axis. Two defects were detected in 2 patients. The transapical procedure was performed in a “hybrid” surgery room using minithoracotomy and general anesthesia. Three-dimensional transesophageal echocardiography and fluoroscopy were used for imaging. A total of 19 Amplatzer Vascular Plug III devices (St Jude Medical) were implanted in 7 patients, 2.7/patient and 1 to 3/fistula. The procedure time was 150.7 ± 66.8 minutes. In 6 of 7 patients (85.7%), the paravalvular leak was successfully closed, resulting in no or mild residual regurgitation. One patient had moderate regurgitation despite deployment of 3 Amplatzer Vascular Plug III devices. Two patients required blood transfusion related to procedural blood loss. The patients were discharged at 15.3 ± 6.5 days and followed up at 215.7 ± 138.6 days. All but 1 patient reported symptomatic improvement by ≥ 1 New York Heart Association class at follow-up. One patient died 216 days postoperatively.

Conclusions: A “hybrid approach” for transcatheter paravalvular leak closure of mitral prosthesis from the apical route is effective in reducing the regurgitation grade and improving functional capacity in high-risk patients. Complete closure of the defect was maintained at follow-up in most patients. (J Thorac Cardiovasc Surg 2014;148:1965-9)

Paravalvular leak (PVL) occurs in 3% to 10% of patients after primary mitral valve replacement.¹ Clinically relevant PVL can present as deterioration in symptoms of heart failure or hemolytic anemia requiring blood transfusion.

The conventional surgical approach has been open repair of suture dehiscence or prosthesis replacement^{2,3}; however, invasive surgical intervention increases the morbidity and mortality. In addition, the success of surgical PVL repair can be limited by the presence of a severely calcified mitral ring or friable surrounding tissue.⁴

Transcatheter closure of PVL is a less-invasive approach that negates the need for cardiopulmonary bypass and is, therefore, an attractive alternative. Several techniques exist for percutaneous closure of a defect at the mitral prosthesis site.^{5,6} These have commonly involved either antegrade

crossing of the PVL through transseptal puncture or a retrograde approach from the left ventricle.

We sought to evaluate a hybrid approach for the percutaneous closure of mitral PVL using a transapical approach, combining the skills of the cardiac surgeon and interventional cardiologist in the “hybrid room” on the beating heart. The purpose of our study was to report the feasibility and clinical success of a “hybrid” transcatheter PVL closure procedure with the Amplatzer Vascular Plug III (AVP III) device using a transapical route.

METHODS

Study Population

From March 2013 to February 2014, 7 consecutive patients with severe mitral prosthesis PVL were selected for transcatheter closure using the apical approach. All patients were considered by the heart team to be at prohibitive operative risk because of the EuroSCORE II score (mean 11.7 ± 7) and had been denied surgery by the cardiac surgeon.

All patients had severe paravalvular mitral prosthesis leak accompanied by symptoms of heart failure (New York Heart Association [NYHA] class III-IV), and severe pulmonary hypertension (69 ± 15 mm Hg). Three patients had hemolytic anemia, two of whom were transfusion dependent. Two patients had undergone 3 and one 4 previous sternotomies for re-do prosthesis replacement or repair of dehiscence. Three patients had a bioprosthetic valve in the mitral valve position. Four patients had concomitant coronary artery disease and six had chronic kidney impairment. The clinical characteristics are summarized in Table 1.

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Abbreviations and Acronyms

AVP III	= Amplatzer Vascular Plug III
CT	= computed tomography
HF	= heart failure
LV	= left ventricular
MR	= mitral regurgitation
NYHA	= New York Heart Association
PAP	= pulmonary artery pressure (by echocardiography)
PVL	= paravalvular leak
TEE	= transesophageal echocardiography

Preprocedural Imaging

We used 3-dimensional (3D) transesophageal echocardiography (TEE) and electrocardiography-gated computed tomography (CT) angiography to determine the size, location, and anatomy of the PVL. CT was used to evaluate (1) the location of the defect in relation to the surrounding structures, (2) the location of the left ventricular (LV) apex in relation to the chest wall. The location of the defect was reviewed, mimicking the fluoroscopic angles (right anterior oblique 20-30 and left anterior oblique 10-30).

A total of 9 defects producing PVLs were identified in 7 patients. The median defect size was 25 ± 7.8 mm (range, 6.6-33) in the long axis and 9.3 ± 2 mm (range, 6-12) in the short axis. Two patients had 2 defects.

The location of the leak was described by analyzing the mitral annulus in a clock-like format from the surgeon's view⁷: 3 defects were in the septal position, 3 in the posterolateral, 1 in the posterior, and 2 in the anterior aspect of the mitral prosthesis.

All patients provided written informed consent.

AVP III Device

In all patients, we used the AVP III device (St Jude Medical, Plymouth, Minn), which closely resembles the shape of the PVL. A more detailed description of the device has been previously reported.⁸

Transcatheter Closure of PVL

All procedures were jointly performed by a cardiac surgeon and interventional cardiologist in a "hybrid room." At our institution, the hybrid suite is a catheterization facility with a sophisticated fluoroscopy arm and the capability of the more complex surgical procedures possible in a standard catheterization suite. With the patient under general anesthesia, a left lateral thoracotomy in the fifth intercostal space (4-5-cm incision) was used to expose the apex of the heart. Two standard purse string sutures were placed, and an echocardiographically guided puncture was performed. Using fluoroscopy, a straight-tip, 0.035-in. Terumo guidewire (Terumo Europe, Heverlee, Belgium) was advanced into the left ventricle and across the defect into the left atrium. A 7F introducer sheath was advanced across the defect into the left atrium. Two 0.035-in. wires were then inserted to facilitate the introduction of a second 7F sheath if simultaneous delivery of 2 AVP III devices was required. A third percutaneous coronary intervention wire, delivered across the defect, was used as a safety wire in case a third plug would become necessary. 3D TEE and fluoroscopy were used to navigate the delivery catheter through the leak, to orientate the device in the defect, and to assess the interaction of the device within the mitral valve prosthesis ring. Two-dimensional and 3D color Doppler were used to evaluate the residual regurgitation through the leak after device implantation. A final decision to release the AVP III device was made only after final confirmation of a complete seal.

Study Endpoints

The study endpoints were the severity of the residual PVL, death from any cause, heart failure NYHA class, and the necessity for blood transfusions. These parameters were collected after the procedure and at 215.7 ± 138.6 days (range, 30-364) of follow-up.

Definitions

Transcatheter closure of the PVL around a mitral prosthesis was considered successful when a complete seal was achieved after implantation of an AVP III device with no, or mild, residual regurgitation.

Death from any cause was defined as any death in-hospital or at 215 ± 138.6 days.

The NYHA functional classification was used to assess the severity of symptoms in relation to physical activity.

Statistical Analysis

Continuous results are reported as the mean $\pm$ standard deviation. The categorical data are presented as counts and percentages. Calculations were performed using the SPSS, version 16.0 (IBM Corp, Armonk, NY).

RESULTS

The transcatheter mitral prosthesis PVL closure time was 150.7 ± 66.8 minutes (range, 70-265). In 6 of 7 patients (85.7%), the PVL was successfully closed, resulting in no, or mild, residual regurgitation. In 1 patient, residual moderate leak was present after complete release of 3 AVP III devices (12×5 , 14×5 , and 12×5 mm). The procedure was complicated by embolization of 2 AVP III plugs to the left atrium; however, these were successfully recaptured and reimplanted using the same access site.

A total of 19 AVP III devices (2.7/patient, range, 1-5; 1-3/fistula) were implanted in 7 patients. Five devices were implanted in 1 of the patients with 2 defects (Figure 1). The number of devices implanted in each case is listed in Table 2. Two patients required blood transfusion related to procedural blood loss.

The patients were discharged at 15.3 ± 6.5 days (range, 7-24) after defect closure.

Follow-up

One patient was readmitted with severe gastrointestinal bleeding requiring blood transfusion and subsequently died of advanced heart failure and severe anemia at 216 days after the procedure.

An improvement from NYHA class III-IV to class II was maintained in 3 patients (42.9%); and 3 patients remained in NYHA class III (Table 2).

In 2 patients with blood transfusion-dependent hemolytic anemia, the frequency of blood transfusions decreased postoperatively. In 1 of them, incomplete defect sealing resulted in moderate residual regurgitation.

DISCUSSION

The principle findings of the present clinical study were that complete closure of the paravalvular mitral prosthesis defect, resulting in no or mild residual leak, was achieved

TABLE 1. Baseline characteristics

Characteristic	Pt. no.						
	1	2	3	4	5	6	7
Age (y)	85	77	72	72	75	63	73
Gender	Male	Male	Female	Female	Female	Male	Male
Previous revascularization	Yes	Yes	No	No	Yes	Yes	Yes
Previous pacemaker	Yes	No	Yes	No	Yes	Yes	Yes
Previous IE	No	No	Yes	No	No	No	No
Previous surgery for PVL	No	No	Yes	Yes	No	No	Yes
Sternotomies (n)	1	1	3	3	1	1	4
Interval since valve surgery (mo)	11	12	3	110	70	7	102
Atrial fibrillation	No	Yes	Yes	Yes	Yes	No	Yes
Renal insufficiency	Yes	Yes	Yes	Yes	No	Yes	Yes
Blood transfusion dependent	No	No	No	Yes	No	No	Yes
NYHA class	III	IV	III	IV	IV	III	III
Log EuroSCORE II	9.5	7.6	21	9.3	22.2	3.5	9.1
LVEF (%)	35	55	55	50	20	60	50
PAP (mm Hg)	66	90	77	No	55	50	76

Pt. no., Patient number; IE, infective endocarditis; PVL, paravalvular leak; NYHA, New York Heart Association; EuroSCORE, European System for Cardiac Operative Risk Evaluation; LVEF, left ventricular ejection fraction; PAP, systolic pulmonary artery pressure.

in 6 of 7 patients. The procedure success rate was 85.7% immediately after the procedure, and 71.4% at 215.7 ± 138.6 days. Also, closure of the defect resulted in substantial improvement in heart failure symptoms by ≥1 functional class in 5 of the 7 patients (71.4%) at 215.7 ± 138 days, suggesting the durability of the procedure.

Other investigators have reported their experience with percutaneous closure of mitral prosthesis PVLs using a variety of approaches and techniques. Complete closure of the defect has been achieved in most patients, with success rates ranging from 59% to 82%.⁹⁻¹¹

A mitral PVL defect can be sealed using an antegrade approach through an atrial transseptal puncture or a retrograde approach from the left ventricle. The effectiveness

of the antegrade approach could potentially be limited by the anatomic location of the defect. High success rates (83%) have been reported with posteriorly located defects⁹; however, the outcomes have been less favorable when the defect is in the septal or anterior position.

Consistent with other investigators,^{12,13} we found the transapical approach to be both practical and feasible, with complete closure achieved in >85% of patients. Unlike the antegrade transseptal approach, which will be constrained by the anatomic location of the defect and the left atrial size, the transapical approach allows access to defects in all anatomic locations and successful device delivery. Thourani and colleagues¹³ reported successful transapical closure of the PVL in 3 patients using the Amplatzer ventricular septal defect occluder and Amplatzer

FIGURE 1. Complete sealing of 2 paravalvular mitral prosthesis defects was achieved after implantation of 5 Amplatzer Vascular Plug III devices.

TABLE 2. Treatment and follow-up data per patient

Pt. no.	Age (y)	Baseline					Procedure		Follow-up			
		Previous sternotomy	NYHA class	Defects (n)	Defect location, size (mm)	PVL grade	AVP III devices (n); size (mm)	PVL grade	Duration (d)	PVL	NYHA class	MACE
1	83	1	III	1	Septal, 16 × 7	Severe	2 devices; 8 × 4, 14 × 5	Mild	320	Mild	II	—
2	77	1	IV	1	Septal, 21 × 12	Severe	2 devices; 12 × 5, 8 × 4	None	329	Mild	III	—
3	72	3	III	2	Posterolateral, 32 × 9	Severe	3 devices; 12 × 5, 12 × 5, 8 × 4	Mild	364	Moderate	III	Re-do planned
4	72	3	IV	2	Anterior, size unknown; posterior, size unknown	Severe	5 devices; 14 × 5, 10 × 5, 10 × 5, 12 × 5, 10 × 5	None	201	None	III	Death
5	75	1	IV	1	Posterolateral, 33 × 9	Severe	3 devices; 12 × 5, 10 × 5, 14 × 5	None	41	Mild	III	—
6	63	2	III	1	Anterior, 6.5 × 6	Severe	12 × 5	None	170	None	II	—
7	73	4	III	1	Septal, 20 × 10	Severe	3 devices; 12 × 5, 12 × 5, 14 × 5	Moderate	29	Moderate	II	—

Pt. no., Patient number; NYHA, New York Heart Association; PVL, paravalvular leak; AVP, Amplatzer Vascular Plug; MACE, major adverse cardiac event.

patent ductus arteriosus occluder device. Smolka and colleagues¹² achieved an excellent seal with AVP III devices in 6 of 7 patients in whom an initial transvascular approach had failed or seemed unfeasible.

Just as with Smolka and colleagues,¹² we used >1 AVP III plug to seal the defect channel; however, our patient selection criteria were slightly different. In our series, a hybrid approach was used from the outset. We believe this resulted in a shorter procedure, which, in patients with multiple comorbidities, might translate into quicker recovery and improved long-term outcomes. Also, preprocedural CT imaging was performed in all our patients, providing useful additional information to 3D-TEE. The procedure was guided by 3D-TEE and fluoroscopy; however, preprocedural CT imaging offered a number of additional advantages, including determining the precise anatomic location of the defect and whether it was easily visible; determining the anatomic location of the LV apex relative to the chest wall, which proved essential for access planning; and determining the optimal access and deployment angles to be used angiographically. Additional clinical studies should reveal whether new imaging technologies combining real-time 3D-TEE synchronized with angiographic views would facilitate the procedure even more.

In all cases, we were able to cross the defect channel, including the patient with a serpiginous tunnel, and deploy the devices across the leak. We found that proximity to the defect (10–15 cm from the apex) gave better control during device delivery, positioning, and deployment. Apical access also facilitated the manipulation of 2 to 3 devices simultaneously, which could potentially facilitate the closure of larger defects and the delivery of several devices, if required (Figure 1). Also, access site bleeding (LV apex) can be easily controlled. No late complications from ventricular puncture were observed.

We believe that a hybrid approach to PVL closure should be considered for high-risk patients, in particular, those in whom conventional surgery has failed to repair the

dehiscence. Also, this approach can be used for defects in all anatomic locations relative to the mitral prosthesis. The only contraindications to the procedure would be the presence of LV thrombus, a calcified LV apex, or an unstable prosthesis due to significant dehiscence.

At present, no device with indications for PVL closure has been approved. Experience with the AVP III device has been limited to case reports and small case series.¹⁴ However, the ellipsoidal shape, design, and available dimensions of the AVP III seem to closely match the defects associated with mitral prostheses. Therefore, interference with the function of the mitral prosthesis can be avoided by rotating the device under direct vision using real-time 3D-TEE. In our series, no interference with the prosthesis was noted after device deployment. Our results are consistent with those from other investigators, supporting this device application for sealing a periprosthetic defect and contribute to up-to-date available clinical experience.^{14–17}

In the last patient (Table 2), we were not able to achieve complete success because of the presence of a large, oval-shaped defect, measuring 20 × 10 mm on CT. It might be that an alternative device with a more oval shape would have worked better in this patient.

Complete sealing was well maintained at follow-up in most of our patients (71.4%) and was associated with an improvement in NYHA functional class. Improved functional status to NYHA class II was maintained at the last follow-up visit in 3 patients (42.9%). The remaining 3 patients (Table 2) had limited functional capacity (NYHA class III) owing to the recurrence of a moderate leak between 2 contiguous implanted devices (patient 3), the presence of poor left ventricular systolic function with an ejection fraction of 25% (patient 5), and mild improvement from NYHA class IV to class III associated with defect closure (patient 2). The recurrence of PVL in patient 3 might have resulted from late displacement of the AVP III devices and/or additional progression of the prosthesis dehiscence.

At present, the application of transcatheter PVL closure is limited to those patients at high surgical risk. Almost one half of the patients (43%) in our series had previously undergone surgery for dehiscence correction. Moreover, in 3 patients who had previously undergone 3 to 4 sternotomies, this was the only treatment option remaining. In 2 patients with blood transfusion-dependent anemia, a reduction occurred in the frequency of the blood transfusions.

Study Limitations

The AVP III device has not been approved by the Food and Drug Administration and is not available for use in the United States. The small sample size our study was another limitation, and additional studies, ideally with a randomized controlled design, are needed to assess the advantage of this technique compared with percutaneous transvascular repair.

CONCLUSIONS

Our results have shown that a hybrid approach for transcatheter mitral prosthesis PVL closure using the transapical approach is practical, feasible, and effective in reducing the degree of mitral regurgitation and improving the functional capacity of high-risk patients. Effective defect sealing was maintained at follow-up in most of our patients.

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