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Annular Rupture During Transcatheter Aortic Valve Replacement without a Surgical Option–The Double-edged Sword of Mechanical Circulatory Support

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Cover Page Footnote

Special thank you to Annette Gourlay (Structural heart program coordinator), Farhana Khanam (Structural heart program administrative support), and the Cardiac Catheterization Lab team at Foothills Medical Centre. An additional thank you to our patient who provided consent and support for this case to be submitted for publication hoping that her experience would help other medical practitioners provide emergent care to their critically ill patients.

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Case Report

Annular Rupture During Transcatheter Aortic Valve Replacement without a Surgical Option–The Double-edged Sword of Mechanical Circulatory Support

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Abstract

Transcatheter aortic valve replacement (TAVR) has become a well-established treatment option for patients with severe aortic stenosis. With advances in the field and positive outcomes in clinical trials, TAVR use has expanded from being limited to older patients with prohibitive surgical risk to younger patients with intermediate and low surgical risk. As operators' experiences have grown and technology has evolved, there are fewer TAVR complications. However, when complications do occur, they remain associated with significant morbidity and mortality. Aortic annulus rupture is a catastrophic complication of TAVR. Risk factors for annulus rupture include valve oversizing, female gender, a large calcification burden in the subannular area and left ventricular outflow tract, a small annulus, a calcified bicuspid aortic valve, and a narrow aortic root. When a rupture occurs, emergent cardiac surgery is a common intervention; however, not all patients are candidates for emergent surgery. We present a case of a 79-year-old female patient who developed an annular rupture during TAVR with a balloon-expandable valve. The patient was successfully treated; we reversed anticoagulation and controlled her blood pressure. We also performed a pericardiocentesis and provided temporary support by using extracorporeal membrane oxygenation.

Keywords: TAVR, ECMO, mechanical circulatory support, aortic stenosis, complications

Background

Over the past twenty years, the use of TAVR in managing aortic stenosis has expanded to include younger patients at low surgical risk.[1] Despite continuous improvement in the field and a reduction in associated complications, when complications occur, they can be associated with significant morbidity and mortality.[2] Annular rupture is one of the most feared complications of TAVR, with an incidence ranging between 0.4% and 2.3%.[3,4,5,6,7] This complication carries a high morbidity and mortality rate, with the risk of death reported between 49-67% at 30 days.[7] While emergent cardiac surgery is a common intervention for annular rupture,[3,7] some patients are not candidates for this procedure or have declined this intervention in discussions with the multidisciplinary heart team in advance of their TAVR. We present a patient who experienced an annular rupture at the time of TAVR and was treated without emergent surgical intervention.

Case Report

Patient History and Presentation

A 79-year-old female patient was referred to our facility for consideration of TAVR after being admitted with heart failure and critical aortic stenosis. Her past medical history included hypothyroidism, hypertension, moderate mitral regurgitation, cor triatriatum sinister, and paroxysmal atrial fibrillation. She is an ex-smoker and reported no other substance use. She lives at home with her husband and was functionally independent at the time of admission. Her cardiovascular examination showed a grade 3 systolic murmur at the right upper sternal border radiating to the carotids. Her echocardiogram showed concentric left ventricular hypertrophy (LVH) with a preserved left ventricular ejection fraction of 57%, moderate mitral regurgitation, and critical aortic stenosis with a Vmax of 5.4 m/s, mean gradient of 68 mm Hg, and aortic valve area of 0.49 cm^2. The electrocardiogram showed sinus rhythm with LVH and left axis deviation. A computed tomography scan protocoled for TAVR showed mild annular and subannular calcification along the aortomitral continuity (Figure 1). Annulus measurements can be found in Table 1.

Diagnosis and Intervention

After a multidisciplinary heart team discussion, the patient was deemed to be an appropriate candidate for TAVR. The team selected an Edwards Sapien Ultra 23 mm valve (Edwards Lifesciences, Irvine, CA) and planned an undersized initial deployment volume of 15 cc (nominal -2 cc). The patient agreed to a TAVR procedure, but she did not want a sternotomy or surgical intervention, even in the event of a catastrophic complication. She did approve the use of temporary resuscitation including cardiopulmonary resuscitation (CPR), intubation, and temporary percutaneous mechanical circulatory support.

Table 1. Aortic annulus measurements as noted on computed tomography.

Aorta and Annulus Area	Measurement
Annulus area	351 mm^2
Annular perimeter	68.0 mm
Minimal and maximal diameter	25.0 x 18.3 mm
Calcification	mild, flat along aortomitral continuity without significant protrusion
Subannular area	315 mm^2
Coronary heights	left coronary artery (14.9 mm) right coronary artery (16.5 mm)

Figure 1. Computed tomography scan of the aortic annulus.

The procedure was completed in the cardiac catheterization lab with a multidisciplinary heart team, including two interventional cardiologists, a cardiac surgeon, a cardiac anesthesiologist, and allied health practitioners. Bilateral femoral artery cannulation was completed under dynamic ultrasound and fluoroscopic guidance. We used a micropuncture access technique with angiography to confirm the appropriate puncture sites. A balloon-tipped temporary pacemaker wire (5-French, Pacel wire [Abbott Laboratories, Chicago, IL]) was inserted into the right ventricle via a left femoral venous sheath. A 14-French e-sheath (Edwards Life Sciences) was inserted via the right femoral approach with preclosure completed with 2 Proglide devices (Abbott Laboratories) in anticipation of post-procedure repair. A suitable deployment angle was identified, highlighting the 3-cusp view of the aortic valve (Figure 2).

Figure 2. Aortic root angiogram highlighting the deployment angle and aortic valve 3-cusp view.

A Sapien Ultra 23 mm valve was then advanced into position across the aortic valve, and its position was confirmed with aortic root angiography. The valve was deployed under rapid pacing protocol. Aortic root angiography demonstrated a constrained valve with a significant paravalvular leak; the valve was postdilated to a maximal volume of 16 cc (nominal -1 cc). At this point, a repeat aortic root angiogram demonstrated a small amount of contrast dye extravasating from the annulus underneath the left coronary ostium; the patient began to experience worsening hypotension (Figure 3).

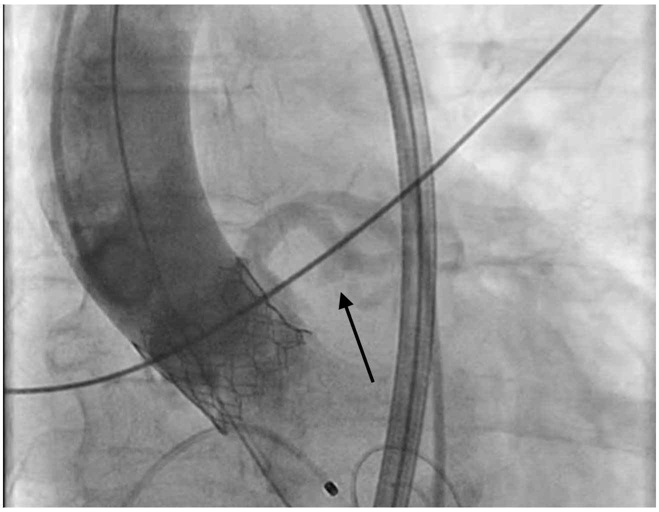

Figure 3. Repeat aortic root angiogram after valve deployment with contrast extravasating due to the annulus rupture (see the arrow).

These findings were suggestive of an annular rupture with pericardial tamponade. Results from transthoracic echocardiography confirmed an expanding pericardial effusion. The patient was immediately sedated, intubated, and given intravenous protamine to reverse anticoagulation; repeat activated clotting time testing showed normal levels. The subcostal window appeared to be the most accessible; thus, we attempted a pericardiocentesis from this approach. We removed a small amount of blood, which briefly improved the patient's hemodynamics, but we were unable to successfully advance a wire into the space. Her hemodynamics subsequently worsened, and after a brief heart team discussion in the catheterization lab, we elected to place the patient on veno-arterial extracorporeal membrane oxygenation (V-A ECMO). We exchanged the 14 French femoral arterial sheath and the femoral venous sheath used for TAVR with a 17 French arterial cannula and a 23 French venous cannula.

The patient required less than two minutes of continuous high-quality CPR while the ECMO cannulas were being deployed. Immediately after ECMO deployment, her hemodynamics improved briefly; however, her blood pressure dropped further (Figure 4A). A repeat aortic root angiography showed a brisker extravasation of contrast from the annular rupture site. A repeat transthoracic echocardiogram showed expansion of the pericardial effusion, with a large collection around the apex. Under dynamic echocardiography guidance with an attached in-plane needle, we successfully inserted a pericardial drain from the left apical approach; 300 mL of blood was drained and returned immediately to the patient.

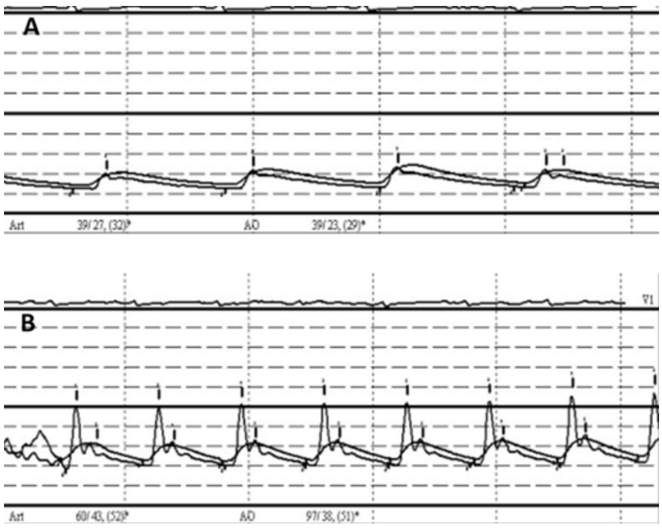

Figure 4. Arterial waveform measured in the femoral artery showing severe hypotension immediately after extracorporeal membrane oxygenation deployment (Panel A) and improvement after drainage of pericardial effusion (Panel B).

Her hemodynamics immediately improved, and her blood pressure stabilized without ongoing inotrope or vasopressor support (Figure 4B). We suspected that the retrograde arterial V-A ECMO flow worsened the blood extravasation through the annular rupture site, so we reduced the ECMO flow briefly to less than 1 L/min. A repeat aortic root angiogram at this low ECMO flow showed no further contrast extravasation from the aortic annulus. After a multidisciplinary discussion, we decided to remove the ECMO cannulas, and the access site was repaired with the previously deployed Proglide devices. A repeat femoral angiography showed appropriate hemostasis.

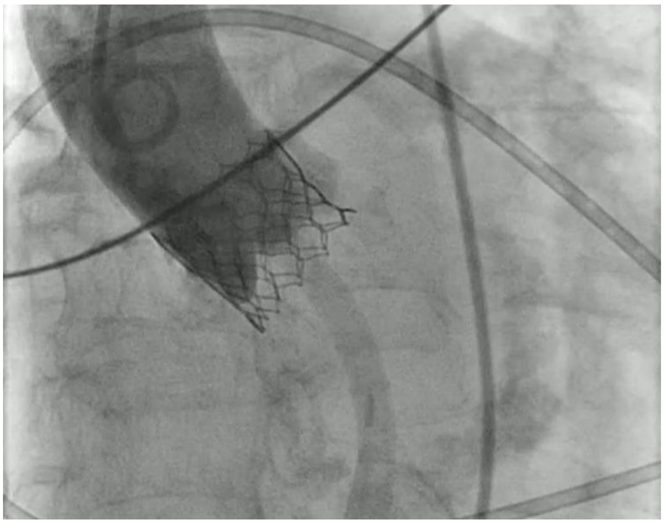

Figure 5. An aortic root angiography showed resolution of the annular rupture site bleeding with the absence of contrast extravasation after removing the extracorporeal membrane oxygenation cannulas and lowering the mean arterial pressure.

During this portion of the procedure, we noted that the patient's blood pressure had steadily increased. We repeated an aortic root angiography, which showed recurrent contrast extravasation from the annular rupture site. We used a nitroglycerin infusion to lower the patient's blood pressure, targeting a mean arterial pressure (MAP) of 60 mm Hg. No further dye was noted to be extravasating from the rupture site (Figure 5). A repeat aortic root angiography showed a well-functioning bio-prosthetic valve with no significant paravalvular leak and patent coronary vessels. Transesophageal echocardiography showed no significant paravalvular leak and no evidence of reaccumulation of the pericardial effusion. The patient was transferred to the cardiac intensive care unit (CICU) with the pericardial drain in place. She remained intubated but was otherwise hemodynamically stable.

In the CICU, she was initiated on antiplatelet medication but did not receive anticoagulation medication despite the indication of her known atrial fibrillation. A computed tomography with contrast of the chest did not show evidence of a pseudoaneurysm or ongoing contrast extravasation. There was minimal output from the pericardial drain and it was removed on postoperative day two. The patient was extubated on postoperative day four, and her blood pressure was maintained at normal target ranges. Serial echocardiograms did not show reaccumulation of pericardial fluid. She was neurologically intact. Later in her admission, she developed a complete heart block and required the insertion of a permanent pacemaker. She continued to improve clinically and was discharged home after 12 days in the hospital.

Discussion

Annular rupture describes injuries to the aortic root and left ventricular outflow tract (LVOT) as a result of a procedural complication related to TAVR.[3] The anatomical location of the injury determines the type of annular rupture. Four main types of annular rupture are described in the literature: supra-annular, intra-annular, subannular, and combined rupture.[3] Supra-annular ruptures involve the sinus of Valsalva, the Sino-tubular junction, or the coronary ostium.[3] An aortic dissection or a hematoma in the aortic wall suggests this type of rupture. Intra-annular ruptures occur at the site of the native annulus and can be seen as dye extravasation at the valve site after TAVR. Subannular ruptures include injuries to the free myocardial wall, anterior mitral leaflet, or the interventricular septum. Injuries to the free myocardial wall usually occur at the LVOT just below the left coronary sinus and can present as massive bleeding secondary to free wall rupture or as a pseudoaneurysm below the left coronary sinus. Injuries to the interventricular septum can present as conduction abnormalities, fistula, or ventricular septal defect formation, causing left to right shunting. Injuries to the area between the non-coronary sinus and the anterior mitral leaflet can cause severe mitral regurgitation, resulting in sudden severe shunting of blood into the left atrium.

Annular rupture is a rare and life-threatening complication of TAVR.[3,4,5,6,7] This type of injury usually occurs after one of the following: balloon valvuloplasty of a native valve, TAVR, or deployment valve dilatation when a paravalvular leak is identified.[3,8] This complication has been described more often with balloon-expandable valves, most likely because of the higher radial force and the need to sometimes oversize the valve to prevent paravalvular leak.[3,6,7,9] Risk factors for annular rupture during TAVR include valve oversizing (> 20%); female gender, most likely attributed to a smaller annular size; a large calcification burden of the subannular area and LVOT, especially if extending to the non-coronary cusp; small annuli (< 20 mm); calcified bicuspid aortic valve; and narrow aortic root.[3,4,7,8] Not all cases of annular rupture are diagnosed. Interestingly, some of them are thought to be sealed by the valve and can go unrecognized.[3,10]

Clinical presentations of annular rupture vary based on the location and severity of the complication and can range from no symptoms to sudden hemodynamic collapse.[3,10,11] Sudden hemodynamic compromise is the most common clinical presentation because of blood in the pericardial space causing cardiac tamponade.[7,12] Annular rupture should be suspected after valve implantation or after deployment dilatation if the patient develops hypotension, tachycardia, or other signs of hemodynamic collapse.[7] Urgent contrast angiography and echocardiography are the two imaging modalities of choice when annular rupture is suspected. If there is evidence of bleeding into the pericardial space, annular rupture should be suspected.[7,11] Our patient developed a sudden hemodynamic compromise. Aortic root angiography showed dye extravasation and echocardiography revealed pericardial effusion, leading to an annular rupture diagnosis. According to the anatomical location classification, our patient had an intra-annular rupture, which is thought to be caused by tears in the native aortic annulus occurring at the time of valve deployment. Interestingly, despite the fact that we purposely undersized the valve (nominal -1 cc) and there was only mild annular calcification (Figure 1), the patient still developed this complication. The main risk factor was female gender.

Managing patients with annular rupture can vary depending on the clinical presentation. Regardless of the type of rupture, hemodynamic support and the management of anticoagulation and pericardial tamponade are required. Surgical interventions vary depending on the location of the rupture. These interventions include lesion repair, aortic valve replacement, pericardial patch, aortic root graft, and/or mitral valve repair.[3] In patients with severe hemodynamic compromise and cardiogenic shock related to pericardial tamponade, immediate pericardiocentesis and reversal of anticoagulation should be performed.[7] Additional management steps include the use of recombinant factor VIIa and autotransfusion of the drained pericardial blood.[7,13] If patients remain unstable, hemodynamic support, such as ECMO, can be an ideal bridge to additional interventions or surgery.[7] If the bleeding remains uncontrolled and the patient's condition does not stabilize with these measures, surgical management with emergent sternotomy and annulus repair should be considered.[7]

Yafen Liang et al. conducted a retrospective cohort study examining patients who developed catastrophic complications during or immediately after TAVR.[14] Seven (13.7%) of the patients who developed catastrophic TAVR-related complications had acute aortic root disruption. Five out of seven required ECMO support, and two required surgical intervention. Three out of seven patients did not survive, two of whom had undergone emergent surgical intervention.[14] In hemodynamically stable patients, particularly in cases with contained annulus rupture, a more conservative approach with reversing anticoagulation and pericardial drainage, if required, can sometimes be adequate.[2,3,7] Fortunately, our patient responded well to conservative measures as she was not a candidate for emergent sternotomy per her own directive.

An interesting factor in our case was the hemodynamic effect of V-A ECMO on the patient's bleeding from the annulus rupture site. While V-A ECMO is not routinely used in managing annular ruptures, it served as a bridge to provide hemodynamic support and ongoing perfusion to her vital organs until we were able to perform the necessary interventions. The high blood flow from the arterial ECMO cannula sent in a retrograde fashion towards the ascending aorta appeared to worsen the bleeding from the rupture site and increase the size of the pericardial effusion. Cardiac tamponade also resulted in poor ECMO flow, most likely because of its adverse effect on the ECMO circuit by preventing the venous cannula from adequately draining blood from the right atrium.[15] However, the expansion of the pericardial effusion facilitated the successful insertion of a pericardial drain from a different approach, and the successful evacuation of the pericardial effusion immediately resulted in improved ECMO flow and stabilization of cardiac hemodynamics, with the ability to quickly wean the patient off the mechanical support.

The patient's blood pressure and the amount of anticoagulation required during TAVR also contributed to the extensive bleeding from the rupture site. However, aggressive blood pressure control with targeted hypotension and anticoagulation reversal with protamine improved bleeding and facilitated additional hemostasis at the rupture site. An important consideration is the potential reintroduction of anticoagulation medication, given the patient's atrial fibrillation and the indication of this therapy to reduce stroke risk. We will repeat a computed tomography scan of the chest to assess the annular rupture site before considering the reintroduction of anticoagulants.

This case demonstrates an important method of managing patients with contained annular rupture secondary to TAVR when emergent surgery is not an option. It also highlights the relationship among cardiac tamponade, percutaneous mechanical circulatory support with V-A ECMO, and an elevated mean arterial pressure and their effects on an actively bleeding rupture site at the aortic annulus. Thankfully, this patient responded to a conservative management strategy, as she was not a surgical candidate. She remains fully functional and independent.

Consent

Our case report adheres strictly to traditional patient confidentiality and privacy standards. All patient data has been de-identified and presented in a manner that precludes the possibility of patient identification. Patient consent was attained.

Disclosures

None.

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