Percutaneous Closure of Iatrogenic Ventricular Septal Defect Following Surgical Aortic Valve Replacement Using Two Different Approaches

Takashi Matsumoto, MD, Wen-Loong Yeow, MD, Saibal Kar, MD

Abstract: Iatrogenic ventricular septal defect (VSD) is a rare complication following surgical aortic valve replacement (SAVR). In this report, we describe two cases of iatrogenic VSD following SAVR (both mechanical and bioprosthetic aortic valve), which were successfully closed with two different percutaneous techniques (retro-aortic and transseptal approach). The report discusses the differences in the techniques and the literature supporting the procedure.

Key words: ventricular septal defect, aortic valve replacement complication

Ventricular septal defect (VSD) is a recognized but rare complication of surgical aortic valve replacement (SAVR) and percutaneous closure has become the intervention of choice. Successful percutaneous closure depends on the anatomical location of the defect, the type of prosthetic valve, and the corrective technique employed. In this report, we discuss two cases of successful closure with different percutaneous techniques (retro-aortic and transseptal approach).

Case reports

Patient 1. A 72-year-old man developed severe shortness of breath, New York Heart Association (NYHA) class III following redo-SAVR with an On-X mechanical aortic valve (On-X Life Technologies). Postoperatively, he developed complete heart block (CHB) requiring a permanent pacemaker (PPM) implantation. He remained very symptomatic and further evaluation revealed a 9 mm subaortic VSD (Figure 1A). In view of the fact that the patient had undergone two open-heart surgical procedures, he was considered to be very high risk for a third open-heart surgery. He was therefore referred for consideration of percutaneous closure of the iatrogenic VSD. The procedure was performed under general anesthesia with transesophageal echocardiographic (TEE) guidance. A retro-aortic approach was planned and access was obtained with a 6 Fr sheath in the right femoral artery (RFA) and an 8 Fr sheath in the right femoral vein (RFV). The calculated shunt fraction (Qp/Qs) was 4:1. An attempt was made to cross the VSD using the standard retro-aortic technique. A multipurpose catheter with a wire was advanced very easily across the mechanical aortic valve, through the VSD without any difficulty. However, immediately after crossing the defect, the patient developed severe aortic insufficiency (AI) and hypotension, requiring removal of the catheter and wire.

A transseptal (TS) approach was then employed. TS puncture was performed in the mid fossa of the atrial septum under fluoroscopy and TEE guidance. A Mullins sheath was then advanced into the left ventricle (LV) and a left ventriculogram (LV gram) confirmed a moderate-sized subaortic VSD (Figure 2A). A 7 Fr end-hole balloon floatation catheter was advanced through the Mullins sheath and easily floated across the VSD into the right ventricle (RV) (Figure 2B). A 300-cm long 0.035” Noodle wire (AGA Medical) was advanced through the balloon floatation catheter into the pulmonary artery (PA). The wire was then snared using a 25 mm GooseNeck Snare (ev3) and exteriorized from the RFV, thus forming a venous-arterial-venous loop. An 8 Fr 45° Amplatzer Torque Vue Sheath (AGA Medical Corporation) was advanced through the right femoral vein over the wire into the LV. A 14 mm Amplatzer Muscular VSD Occluder was then deployed successfully under fluoroscopic (Figure 2C) and TEE guidance. Of note, the superior edge of the left side disc hinged on the inferior aspect of the aortic valve prosthesis, without...
causing dysfunction of the mechanical prosthetic valve as confirmed by echocardiography and angiography. Postprocedural calculated Qp/Qs ratio was reduced to 1.2:1. On the following day, transthoracic echocardiogram (TTE) revealed no significant residual shunt and the patient was discharged home without any complications (Figure 1B). At 3-year follow-up, the patient remains asymptomatic with no residual shunt or valve dysfunction.

**Patient 2.** An 86-year-old female presented with ongoing fatigue and shortness of breath on exertion (NYHA class III) 5 months after a bioprosthetic SAVR, and was found to have developed a 4 mm subaortic VSD (Figure 3A). In the absence of other causes, it was felt that this iatrogenic VSD was the cause of her symptoms. The baseline echocardiography confirmed that there was sufficient rim below the aortic valve for consideration for percutaneous closure. Following discussion with the cardiac surgeons, it was felt that the percutaneous approach would be preferable to redo sternotomy. The procedure was performed under general anesthesia with fluoroscopic and TEE guidance. Two 6 Fr sheaths were placed in the RFA and RFV, respectively. The baseline Qp/Qs ratio was 1.5:1. Intraprocedural TEE and LV gram confirmed a 4 mm subaortic VSD (Figure 4A). A retro-aortic approach was planned, and the VSD was crossed retrograde using a 6 Fr internal mammary catheter and 0.035° angled Terumo Glidewire (Terumo). Unlike the previous case, there was no hemodynamic compromise or significant aortic insufficiency with the catheter across the valve. The wire and catheter were advanced across the VSD into the PA. The Terumo wire was exchanged with a 300-cm long 0.035° Noodle wire. The tip of the wire was snared in the PA and exteriorized from the RFV, completing an arterial-venous loop (Figure 4B). The 7 Fr 45° Amplatzer Torq Vue sheath was then advanced from the RFV over the wire across the VSD into the LV. In a similar fashion as the previous case, a 6 mm Amplatzer Muscular VSD Occluder was successfully placed across the VSD. Echocardiography and angiography confirmed the successful closure of the defect without aortic valve dysfunction (Figure 4C). Postprocedural calculated Qp/Qs ratio was 1:1. The patient was discharged home the following day with no significant residual shunt confirmed by TTE (Figure 3B). Two weeks after the procedure, the patient developed asymptomatic CHB, detected on routine follow-up ECG, requiring PPM implantation. At 3-year follow-up, the patient remained asymptomatic with no significant residual shunt or aortic valve dysfunction.

**Discussion** Disruption of the left ventricular outflow tract during SAVR can rarely result in a VSD. Mechanical complications such as a paravalvular leak or VSD should be considered in the differential diagnosis in patients who continue to have symptoms of left heart failure following SAVR. Asymptomatic VSD without evidence of LV volume overload and/or a calculated left to right shunt greater than 1.5, does not require closure. In both cases here, following a thorough evaluation, the iatrogenic VSD was considered to cause persistent heart failure following surgery. Due to inherent risk of redo-sternotomy, a transcatheter rather than redo surgical closure should be considered as the first option. In both these instances, the defect size and the presence of a small rim below the aortic valve allowed percutaneous closure. Due to the angulated right cardiac anatomy and trabeculated RV, VSDs are crossed from the LV side with either a retro-aortic or TS approach. The presence of a mechanical valve in the aortic position offers challenges in crossing of the valve with a wire and catheter. Successful closure of an iatrogenic VSD by crossing the defect via a retro-aortic approach through a bileaflet mechanical valve has been described in the literature. On the other hand crossing a mono-disc mechanical aortic valve can be dangerous and potentially fatal. The fear of catheter entrapment across mechanical aortic valve led to the TS approach, first described by Klein et al. In this approach, access is gained to the LV by performing a TS puncture and advancing a Mullins sheath from the femoral vein to the LA and then LV. The VSD is then crossed using a balloon flotation catheter through the Mullins sheath. The flow across the VSD helps the flotation catheter to float across the defect. As discussed by the authors, the important aspects of this technique are a catheter and wire loop in the left ventricular outflow tract to direct and support...
passage into and across the VSD, and the “chase the dragon technique” utilizing wire support in the delivery sheath to prevent kinking of the sheath during device advancement. Inadvertent anterograde catheter and wire entrapment across the mechanical aortic valve could still occur while probing the VSD and if there is excessive laxity in the venous-arterial-venous loop. Also, if there is excessive tension in the venous-arterial-venous loop, the intra-atrial septum and mitral apparatus could be serrated. As yet, the TS approach in a patient with mechanical mitral valve replacement has not been described.

For patients with a bioprosthetic aortic valve, the retro-aortic approach is the best method, and for patients with a bileaflet mechanical aortic valve, a retro-aortic approach could be attempted first as long as the hemodynamics are closely monitored, and then switched to a TS approach if unsuccessful.

Once the VSD is crossed, any soft exchange-length (240 cm or 300 cm) J-tipped wire can be used to create the arterial-venous or venous-arterial-venous loop. In our case, a soft 300-cm long Noodle wire was used. This wire has been specially designed for this purpose. However, any soft exchange-length wire can be used.

The size and type of VSD occluder device is important. The Amplatzer Muscular VSD Occluder is the only device available for transcather closure of a VSD in the United States. Each device comprises two nitinol discs connected by a waist. The sizes of the device range from 4 to 18 mm (waist diameter). Each of the discs is 5 to 8 mm larger than the waist. The size of the defect is measured at end diastole by TEE and/or left ventricular angiography. A device that is 2 mm larger than the maximum measured diameter should be selected. An important contraindication for percutaneous closure of VSD is absence of any subaortic rim. In the first case, there was no rim below the aortic valve; however, we could anchor this device against the lower half of the rim of the mechanical valve without interfering with the leaflets. In the second case, there was a small 4 mm rim just below the prosthetic valve, which allowed the adequate anchoring of the device.

Post-SAVR heart block can occur either from disruption of tissue during the surgery or following transcatheter closure of the defect. This is the most common complication and can occur in up to 9% of cases with 4%-6% requiring PPM implantation.67

In the first case, the patient required a pacemaker following the SAVR and in the second case, a PPM was implanted 2 weeks after closure of the VSD due to symptomatic CHB. The mechanism leading to CHB remains uncertain; direct compression or inflammation of the atroventricular conduction bundle is plausible. Indeed, anti-inflammatory therapy or surgical device removal is effective in some cases.5,7

Percutaneous closure is a safe and effective treatment of an iatrogenic VSD following SAVR. Different approaches may be employed depending on the type of prosthetic aortic valve.

References

From the Heart Institute, Cedars-Sinai Medical Center, Los Angeles, California.
Disclosure: The authors have completed and returned the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Kar is a grant recipient and consultant for St Jude Medical, Boston Scientific, Abbott Vascular, and Gore Medical. The remaining authors report no financial relationships or conflicts of interest regarding the content herein.
Address for correspondence: Saibal Kar, MD, FACC, FAHA, FSCAI, Heart Institute, Cedars-Sinai Medical Center, 8631 W. Third Street. Room 415E, Los Angeles, CA 90048. Email: saibal.kar2@cshs.org

**Figure 1.** Transesophageal echocardiogram of case 1 (A) with the 9 mm ventricular septal defect (white arrow). Postprocedural transthoracic echocardiogram (B) with a 14 mm Amplatzer Muscular VSD Occluder (white arrow). RA = right atrium; RV = right ventricle; LA = left atrium; LV = left ventricle.
Figure 2. Angiographic images in case 1. (A) Left ventriculogram revealing ventricular septal defect (white arrow) and an On-X mechanical aortic valve (black arrow). (B) 7 Fr Berman wedge catheter (white arrow) crossing ventricular septal defect. (C) The GooseNeck snare (white arrow) capturing the Noodle wire, completing a venous-arterial-venous loop. (D) Final left ventriculogram with minimal flow across the occluder.

Figure 3. Transesophageal echocardiogram of case 2 (A) with the 4 mm ventricular septal defect (white arrow). Postprocedural transthoracic echocardiogram with (B) 6 mm Amplatzer Muscular VSD Occluder (white arrow). RA = right atrium; RV = right ventricle; LA = left atrium; LV = left ventricle.
Figure 4. Angiographic images in case 2. (A) Left ventriculogram revealing ventricular septal defect (white arrow) and bioprosthetic valve (black arrow). (B) An arterial-venous loop through the ventricular septal defect (white arrow). (C) Final left ventriculogram with minimal flow across the occluder.