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E-Challenges & Clinical Decisions

Atrial Embolization after a Transcatheter Mitral Valve Replacement

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MITRAL REGURGITATION (MR) IS the most prevalent form of valve disease, affecting about 10% of people over the age of 75 years and is associated with increased mortality.[1,2] Management is dependent on the cause, pathophysiology, and predicted treatment efficacy. Although the historic gold standard for disease refractory to medical therapy is valve repair or replacement, over the last decade several transcatheter strategies have emerged, providing less invasive alternative options to elderly and frail patients at high risk for cardiac surgery. Transcatheter mitral valve replacement (TMVR) using a valve-in-native valve approach has become a well-established alternative option for patients with severe primary and secondary MR considered at high or prohibitive surgical risk.[3] Mitral leaflets cannot be assessed by fluoroscopy, so procedural success relies on echocardiographic guidance by transesophageal echocardiogram (TEE).[4] Echocardiographers must be able to provide a comprehensive assessment immediately prior to, during, and after implantation in order to define not only success, but also problematic anatomy and inadequate deployment.

Case

A 78-year-old woman with history of non-rheumatic mitral stenosis and regurgitation, hypertension, pulmonary hypertension, pulmonary embolism, aortic stenosis status post-transcatheter aortic valve replacement with a 23 mm Edwards Sapien valve (Edwards Lifesciences, Irvine, CA), and coronary artery disease presented for elective TMVR. Past surgical history included prophylactic alcohol septal ablation 2 weeks preoperatively to treat septal hypertrophy (2.29 cm), and subsequent permanent pacemaker implantation for complete heart block. On a planning Multidetector Computed Tomography (MDCT) scan, the patient had 270° of circumferential calcium in the mitral annulus (Fig 1). The lateral mitral annulus calcium thickness was measured as 10 mm and medial annular thickness was measured as 11.1 mm, with a calculated mitral annular calcification (MAC) score of 8. Given her comorbidities and severity of her mitral annular calcification, TMVR was chosen rather than open surgical intervention. A transapical approach for TMVR was planned because the patient had anomalous venous return with the absence of a direct inferior vena cava to right atrium blood flow, with blood return via the hemiazygous vein. A 26 mm Sapien 3 Ultra valve was chosen due to her calculated annular area of 4.55 cm^2 by planning CT (Fig 1 and Table 1).

Pre-implantation 2-dimensional and 3-dimensional TEE examinations were performed (Video 1, Figure 1A) and a 26 mm Edwards Sapien 3 Ultra valve was deployed with 15% oversizing (Video 2). Post-implantation TEE images were obtained (Videos 2-4, Figure 2A and B). The patient was extubated and transferred to the intensive care unit in stable condition. Upon arrival in the intensive care unit, the patient

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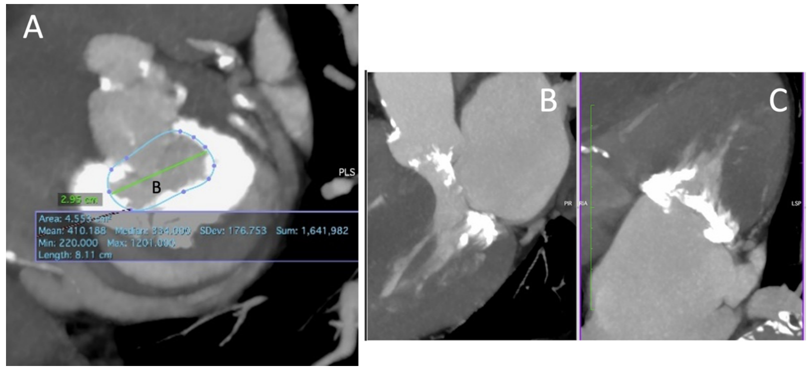

Fig 1. Pre-procedural cardiac computed tomography showing degree of mitral annular calcification.

Table 1
Displays Edwards Sapien Valve Size and Corresponding Native Valve Annulus Area.

Edwards Sapien Valve size	20 mm	23mm	26 mm	29 mm
Native Valve Annulus Area (CT scan)	273-345 mm^2	338-430 mm^2	430-546 mm^2	540-683 mm^2

Abbreviations: CT, computed tomography.

experienced immediate hemodynamic distress, with worsening respiratory failure, flash pulmonary edema, and acute heart failure. The patient was reintubated, and emergent bedside TEE (Figure 2C & 2D, Video 5) revealed an embolized mitral valve into the left atrium, severe mitral regurgitation, and intermittent obstruction of left atrial outflow. After the valve embolization was identified, the patient was emergently returned to the operating room and the mitral valve was replaced with a 29 mm St. Jude Epic valve via a traditional midline sternotomy, bicaval cannulation, and cardiopulmonary bypass (Video 6). The patient had an uncomplicated intraoperative and postoperative course, with follow up TEE showing no paravalvular regurgitation, and a mean gradient of 5 mmHg across the replaced mitral valve. The patient was discharged one week after her surgery.

E-Challenge

Given the clinical context provided, and Videos 1- 4, did this patient demonstrate risk factors for mitral valve embolization?

Discussion

Atrial embolization is a feared, but well described complication of TMVR, with a reported incidence of 0.8% to 6.25% during implantation, and confers a nearly 3-fold increase in 1-

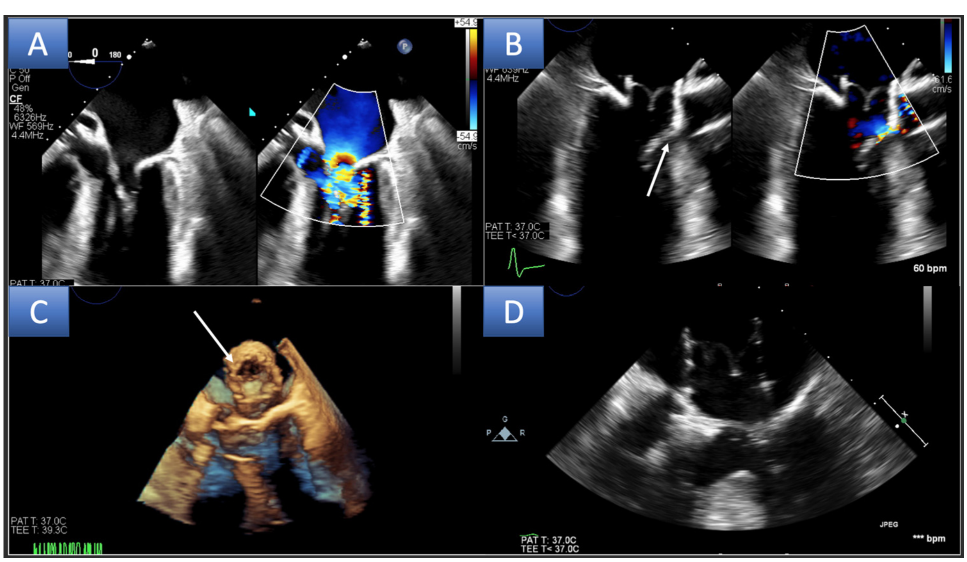

Fig 2. Displays transesophageal echocardiographic images pre- and post-procedure. (A) Midesophageal 4 chamber 2-dimensional (2D) and color compare images pre-procedure. (B) Midesophageal long-axis 2D and color compare, (Note-arrow demonstrates Edwards Sapien prosthetic in contact with the interventricular septum). (C) Three-dimensional echocardiographic image displaying the embolized TMVR valve into the left atrium. (D) Midesophageal long-axis 2D echo image displaying the embolized prosthetic valve into the left atrium.

year mortality.[5-8] Given that valve embolization is a catastrophic event, with significant associated morbidity, it is essential that cardiac anesthesiologists maintain a high index of suspicion perioperatively and carefully consider preoperative risk factors, CT findings, and intraoperative TEE findings.

Previously described risk factors for embolization include: undersized implanted valve, left ventricular outflow tract (LVOT) obstruction, MAC score $\leq$ 7, mitral regurgitation as the primary pathology, and relatively shallow or atrial deployment.[5-8] Factors associated with lower risk of embolization include annular calcium thickness of $\geq$5 mm, calcium distribution of >270° of annular circumference, anterolateral trigone calcification, and anterior mitral leaflet calcification. These factors contribute to TMVR device anchoring, thereby lowering the risk of embolization or migration into the LA.[5] CT-based MAC score was developed by Guerrero et al. and is calculated using (1) average calcium thickness (mm), (2) degrees of annulus circumference involved, (3) calcification at one or both fibrous trigones, and (4) calcification of one or both leaflets.[8] Based on the previously described risk factors, a greater calcium burden should confer a higher success rate for anchoring a replacement valve. The patient in question had near-total circumferential calcium deposition, but despite this, embolization still occurred. Of particular importance, in the same study where Guerrero et al. identified a 6.9% risk of embolization, the authors also determined postoperatively that all cases had received relatively undersized replacement valves.[5,9]

In TMVR for failing surgical bioprosthesis or ring, the sizing of a prosthetic valve primarily relies on the manufacturer reported true internal diameter of the surgical device,[10] whereas in the native mitral annulus, the sizing relies on a MDCT annulus measurement. This measurement is often complicated by the mitral annulus' nonplanar saddle shape. In native mitral annuli, factors such as leaflet calcification, noncircumferential calcification, and extension of annular calcification plays a role in determining the degree of implanted valve oversizing (usually 10%-25%), with a general rule that a greater degree of oversizing is required for a less calcified annulus.[10] In the authors' patient, the replacement valve was chosen based on the consensus of 2 structural heart experts after consideration of CT annulus sizing.

Signs of Unstable Prosthetic Valve

During the procedure, moderate eccentric paravalvular regurgitation was noted (Video 3), and the interventricular septum appeared to be intermittently in contact with the prosthetic mitral valve during end-systole, with associated mild rocking motion of the implanted MV along its interface with the anterior mitral valve leaflet (Video 4). Though there was no hemodynamic evidence of LVOT obstruction, Video 4 demonstrates a likely mechanical etiology for valve embolization and is consistent with previously described LVOT obstruction as a risk factor. Despite this patients' prior septal ablation, the interventricular septum was seen in contact with the inferior portion of the implanted valve during systole, pushing the valve upward toward the left atrium.

Based on published risk factors, preoperatively this patient should have carried an intermediate risk for valve embolization. Her high native valve calcium burden, (MAC score 8) would be generally protective, though the annulus had only 270° of calcification and her anterior mitral valve leaflet did not demonstrate heavy calcification. Furthermore, given the MDCT annular measurement, the chosen valve should have been appropriately sized. Embolization may have been primarily related to imprecise deployment of the valve, or due to cardiac motion during deployment resulting in inadequate fixation of the valve in the mitral annulus.[5] Another possible explanation for the timing of this embolization may center around periextubation changes in intrathoracic pressures and ventricular loading conditions. In the setting of an imperfect valve deployment, increased left ventricular pressure and acute changes in preload associated with extubation and coughing may have precipitated a progressive unwitnessed increase in paravalvular regurgitation, possibly to the point of complete detachment of the implanted valve from the annulus. Given the finding of intermittent septal contact, an acute decrease in left ventricular preload could have acutely increased the degree of valve-septal contact and led to detachment. In the procedure suite, the subtle rocking motion of the implanted valve coupled with significant paravalvular MR was likely a harbinger for subsequent valve embolization (Videos 3 and 4). It is possible that further balloon dilation or oversizing would have prevented this event, but due to the area of poor contact being the interface with the less calcified section of anterior mitral leaflet, it is not certain that this would have led to significantly improved fixation. Additionally, balloon dilation and excess oversizing carries significant risks, including potential impact on the existing transcatheter aortic valve replacement, entrapment and blockage of the prosthesis, and rupture of the mitral annulus.[11]

To decrease the risk of embolization, some operators advocate deploying the valve in conical shape and flare in the LV.[12] Though a few cases of catheter-based interventions to treat valve embolization have been published, unfortunately, this situation most often requires emergent surgical intervention.[5,9] Considering the risks of embolization using TMVR, further refinement of patient selection and pre-procedural evaluation is required. In this case, TEE provided a valuable, rapid method of detection of embolization of the replacement mitral valve, as well as demonstrated intraoperative findings which were likely predictive of future embolization.

Conclusion

MR has a high prevalence in older patient populations. For patients with significant comorbidities and associated high surgical risk, TMVR is an emerging treatment option. Given the complexity of mitral valve anatomy and its pathology, thoughtful patient selection is essential to minimize complications. It is, therefore, crucial to understand the role of multimodal imaging tools, particularly TEE, for procedural guidance and post-procedural minimization of complications. It is essential that interventional echocardiographers be able to identify patients at particular risk of valve embolization by identifying concerning intraoperative TEE findings.

Conflicts of Interest

None.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1053/j.jvca.2022.03.021.

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