

Left ventricular outflow tract obstruction due to anterior mitral valve leaflet displacement following transcatheter mitral valve replacement: Considerations for future digital planning

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ABSTRACT

Transcatheter mitral valve replacement (TMVR) is a less invasive alternative for patients with mitral valve disease who are at high surgical risk. TMVR demonstrates favorable outcomes, however left ventricular outflow tract obstruction (LVOTO) remains a notorious, potentially life-threatening complication. Three-dimensional computational models (3DCMs) have been developed to simulate the residual neo-LVOT and assess the risk of LVOTO. However, they do not account for the interaction between the anterior mitral valve leaflet (AMVL) and the transcatheter heart valve. We present the case of an 81-year-old female who had reassuring pre-procedural neo-LVOT assessment but experienced acute LVOTO due to AMVL displacement following TMVR. This case emphasizes the strengths and limitations of current 3DCMs in accurately predicting LVOT obstruction. Furthermore, we discuss techniques to prevent and manage LVOT obstruction after TMVR.

1. Introduction

Transcatheter mitral valve replacement (TMVR) is an emerging and less invasive alternative to surgical mitral valve replacement for patients with mitral valve disease at high surgical risk. TMVR has shown favorable safety and feasibility outcomes, with persistent symptom alleviation in selected high-risk patient cohorts [1,2]. Balloon expandable valves have been used for TMVR in valve-in-mitral annulus calcification (ViMAC), valve-in-valve (ViV), and valve-in-ring (ViR) procedures. A notorious risk of TMVR is left ventricular outflow tract obstruction (LVOTO), which has been reported in up to 13% of TMVR procedures

[1,3]. A complex interplay of elements determines the risk of LVOTO. Three-dimensional computational models (3DCMs) were created for the simulation of the residual neo-left ventricular outflow tract (neo-LVOT) after TMVR, providing insight into LVOTO risk [4]. However, 3D CT-guided neo-LVOT risk assessment does not account for the interaction between the anterior mitral valve leaflet (AMVL) and the transcatheter heart valve. We present a case illustrating acute LVOTO caused by AMVL displacement following TMVR, and discuss the management options of LVOTO.

Abbreviations: 3DCM, Three-dimensional computational model; AMVL, Anterior mitral valve leaflet; BATMAN, Balloon-assisted translocation of the mitral anterior leaflet; CT, Computed tomography; EuroSCORE II, European System for Cardiac Operative Risk Evaluation II; LAD, Left anterior descending coronary artery; LAMPOON, Laceration of the anterior mitral valve leaflet to prevent LVOT obstruction; LV, Left ventricle; LVOT, Left ventricular outflow tract; LVOTO, Left ventricular outflow tract obstruction; MAC, Mitral annulus calcification; MSCT, Multi-slice computed tomography; PCI, Percutaneous coronary intervention; SAM, Systolic anterior motion (of the AMVL); SCORPION, Septal bipolar ablation to prevent LVOT obstruction; SESAME, Transcatheter myotomy for septal hypertrophy; TEE, Transesophageal echocardiography; TEER, Transcatheter edge-to-edge repair; THV, Transcatheter heart valve; TMVR, Transcatheter mitral valve replacement; TTE, Transthoracic echocardiography; ViMAC, Valve-in mitral annulus calcification; ViR, Valve-in-ring; ViV, Valve-in-valve.

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2. Case presentation

An 81-year-old female with a history of heartport mitral valve repair (Carpentier-Edwards Physio II Ring 30 mm) performed three years

earlier, presented with heart failure symptoms (New York Heart Association class III) despite maximally tolerated guideline-directed medical therapy. Echocardiography revealed a normal left ventricular ejection fraction with moderate concentric left ventricular hypertrophy

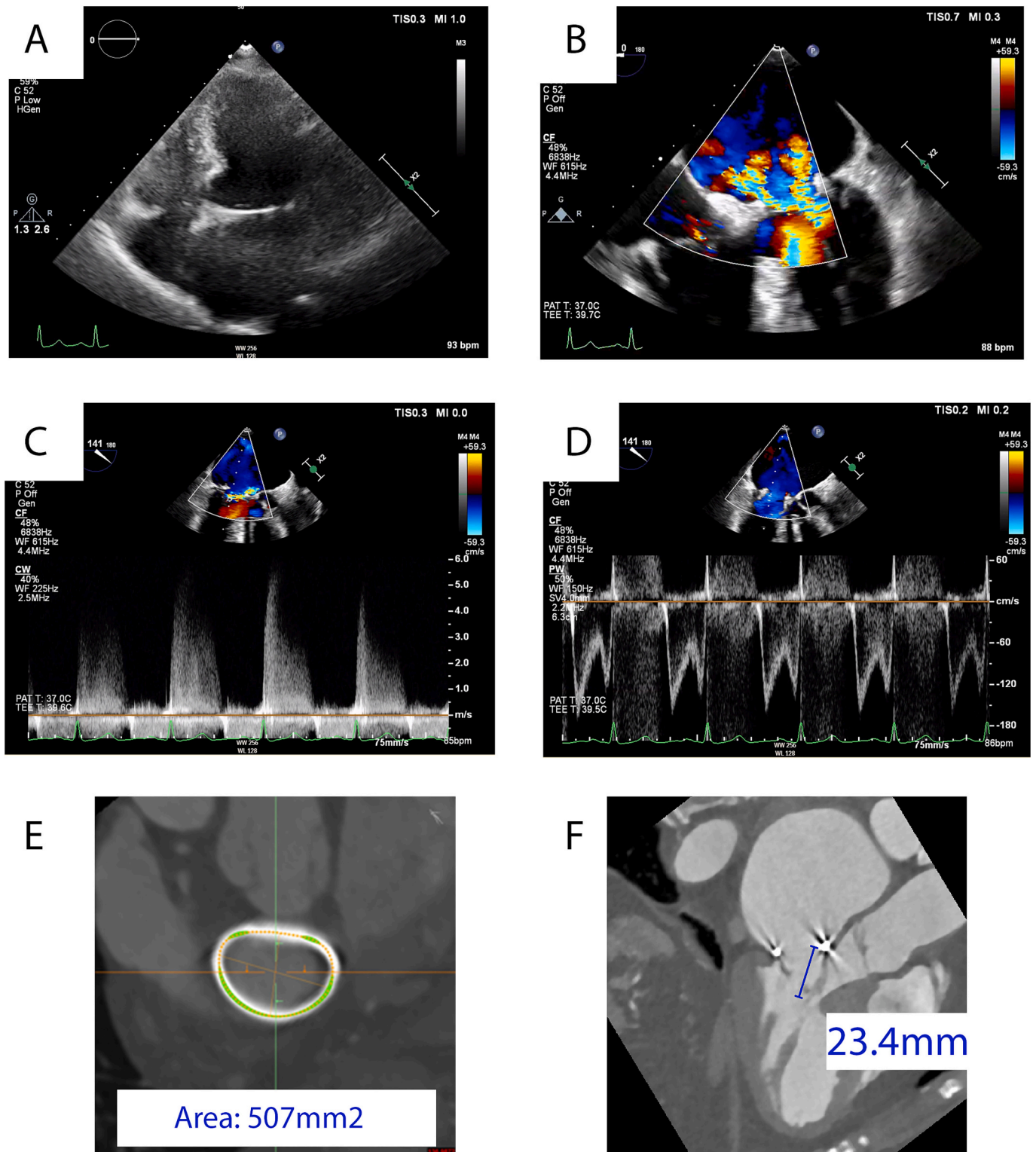


Fig 1. Baseline echocardiographic and computed tomography work-up for TMVR.

(A) Transthoracic echocardiography showing a non-dilated left ventricle. (B) Transesophageal color Doppler echocardiography demonstrating severe mitral regurgitation. (C) Transesophageal continuous-wave Doppler demonstrating severe mitral regurgitation. (D) Continuous-wave Doppler assessment of mitral inflow showing a mean transmittal pressure gradient of 7.5 mmHg. (E) Multi-slice computed tomography showing mitral annular tracing of the annuloplasty ring, with an area measurement of 507 mm². (F) Computed tomography measurement of the anterior mitral valve leaflet (AMVL) length, showing 23.4 mm.

(interventricular septal thickness of 13.5 mm), moderate mitral stenosis (mean gradient 7.5 mmHg) and severe, eccentric mitral regurgitation, attributable to chordal rupture (Fig. 1A–D). Subsequent coronary angiography demonstrated significant stenosis of the left anterior descending artery (LAD).

The patient was discussed in the heart team, and surgical re-intervention was deemed too high risk (EuroSCORE II: 9.74%). The presence of mitral stenosis precluded the use of transcatheter edge-to-edge repair (TEER). Multi-slice computed tomography (MSCT) was performed to evaluate the feasibility of TMVR. The annulus size of the Physio II Ring was suitable for valve-in-ring TMVR with a 24.5 mm balloon-expandable Myval transcatheter heart valve (THV) system (Fig. 1E). The length of the AMVL was 23.4 mm (Fig. 1F).

3DCM Simulations revealed an aorto-mitral angle of 127 degrees and a reassuring neo-LVOT area of 238 mm² after TMVR with a 24.5 mm Myval THV (Fig. 2A). As the simulated neo-LVOT area was well above the conventional cutoff for neo-LVOT obstruction (189 mm²), the patient was deemed eligible for TMVR [5].

After successful percutaneous coronary intervention (PCI) of the LAD, TMVR was performed using a Myval 24.5 mm prosthetic valve under general anesthesia and transesophageal echocardiography (TEE) guidance (Fig. 3A–B). Directly post-implantation, transesophageal echocardiography identified systolic anterior motion (SAM) of the AMVL and neo-LVOT obstruction occurred (Fig. 3C). An invasive gradient over the LVOT of up to 144 mmHg was measured and the patient was hemodynamically unstable despite vasopressor support and fluid administration (Fig. 3D).

Following careful deliberation, an urgent transaortic resection of the AMVL was performed via median sternotomy and aortotomy. The chordae were transected and the leaflet was resected (Fig. 4). Echocardiographic evaluation post-surgery revealed no signs of LVOT obstruction, with a maximum gradient over the LVOT of 6 mmHg. The patient was successfully weaned from cardiopulmonary bypass and subsequent recovery was uneventful. A CT scan performed after the procedure confirmed appropriate positioning of the Myval THV (Fig. 2B) and a neo-LVOT area of 269 mm², which resembled the simulated LVOT area. The patient reported significant improvement in symptoms and overall quality of life. She underwent regular outpatient follow-up over the subsequent 2 years, with serial echocardiography documentation of stable mitral valve function without LVOT obstruction (Fig. 5A–D).

3. Discussion

LVOTO is a potentially life-threatening complication of TMVR and the risk of LVOTO is influenced by a complex interplay of elements. Factors include anatomical features such as the aorto-mitral angle, extent and distribution of MAC, the type and design of the surgical ring or bioprosthesis in case of ViR and ViV, the angle and depth of transcatheter valve implantation, the dimensions and characteristics of the native mitral valve leaflets, systolic anterior motion (SAM) effect, and the possibility of the AMVL becoming entrapped by the transcatheter heart valve [6].

Using MSCT derived 3DCMs, the residual neo-LVOT area after TMVR can be simulated, which provides insight into the risk of LVOTO and helps determine patient eligibility [4]. An established cut-off value for the neo-LVOT area, which was associated with clinically important neo-LVOT obstruction was set at 189 mm² [5]. Subsequent validation by follow-up CT showed a good correlation of most preprocedural neo-LVOT simulations with post hoc simulations [7].

An important lesson from this case study is that current 3DCM software does not simulate the interaction between the AMVL, THV and LVOT during a TMVR procedure. Since the mitral leaflets cannot be segmented from MSCT images, they are not incorporated into the final 3DCM. This is an important intrinsic limitation of current 3DCMs, in which neo-LVOT calculation is de facto still limited to superposition of the virtual THV within the 3DCM. Since our LVOTO risk assessment relied on automated calculation of the distance from the THV skirt to the LVOT wall as a proxy for the neo-LVOT dimensions, the risk of LVOTO by AMVL displacement was not appreciated. AMVL lengths of ≥ 25 mm are considered high risk for dynamic LVOT obstruction due to SAM. Based on the length of 23 mm in this case we considered the risk low [8]. However, AMVL laxity, likely due to the prior rupture of the chordae tendineae, may have been a main contributing factor for the AMVL displacement and severe LVOT obstruction after TMVR.

Future iterations of 3DCM software should include segmentation of the mitral leaflets, enabling an estimation of the extent of AMVL displacement relative to the LVOT. Ideally, simulations should also account for changing hemodynamic states.

Medical management of LVOT obstruction post-TMVR includes betablockers, inotropes, and ensuring optimal volume status. However, instances of hemodynamic instability may necessitate urgent surgical intervention, as exemplified by our patient's scenario. Alternative percutaneous interventions have been described to either prevent or address LVOTO acutely. Septal modification strategies include alcohol

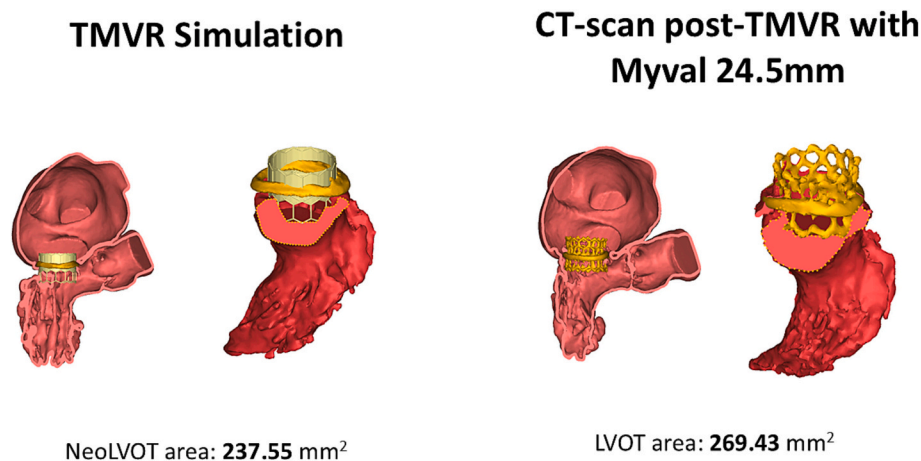


Fig. 2. Preprocedural TMVR simulation versus post-TMVR CT evaluation.

(A) TMVR simulation using three-dimensional computational modeling (3DCM) estimates a neo-LVOT area of 237.55 mm², which is above the established LVOT obstruction risk threshold. (B) Post-TMVR CT confirming proper valve positioning with an end-systolic LVOT area of 269.43 mm², closely correlating with the preprocedural simulation.

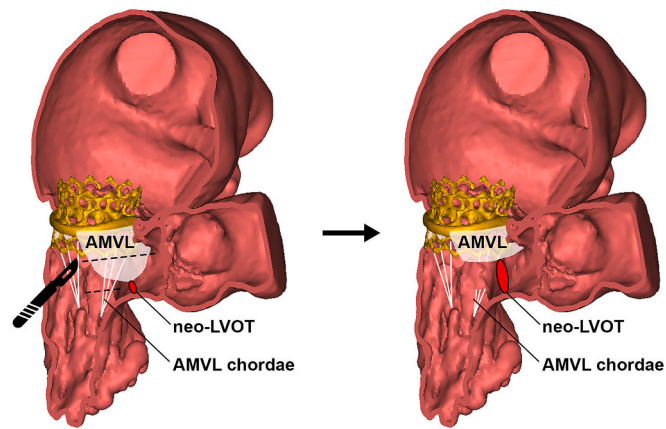


Fig. 4. Illustration of the anterior mitral valve leaflet (AMVL) resection to relieve left ventricular outflow tract (LVOT) obstruction.

The left panel shows AMVL displacement into the neo-LVOT, contributing to obstruction. The right panel illustrates the post-resection state, with the AMVL excised, increasing neo-LVOT area and restoring flow.

CRedit authorship contribution statement

Lucas Uchoa de Assis: Writing – review & editing, Writing – original draft, Visualization, Software, Project administration, Investigation, Formal analysis. **Mark M.P. van den Dorpel:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Conceptualization. **Ben J.L. Van den Branden:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Investigation, Conceptualization. **Nicolas M. Van Mieghem:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

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Declaration of competing interest

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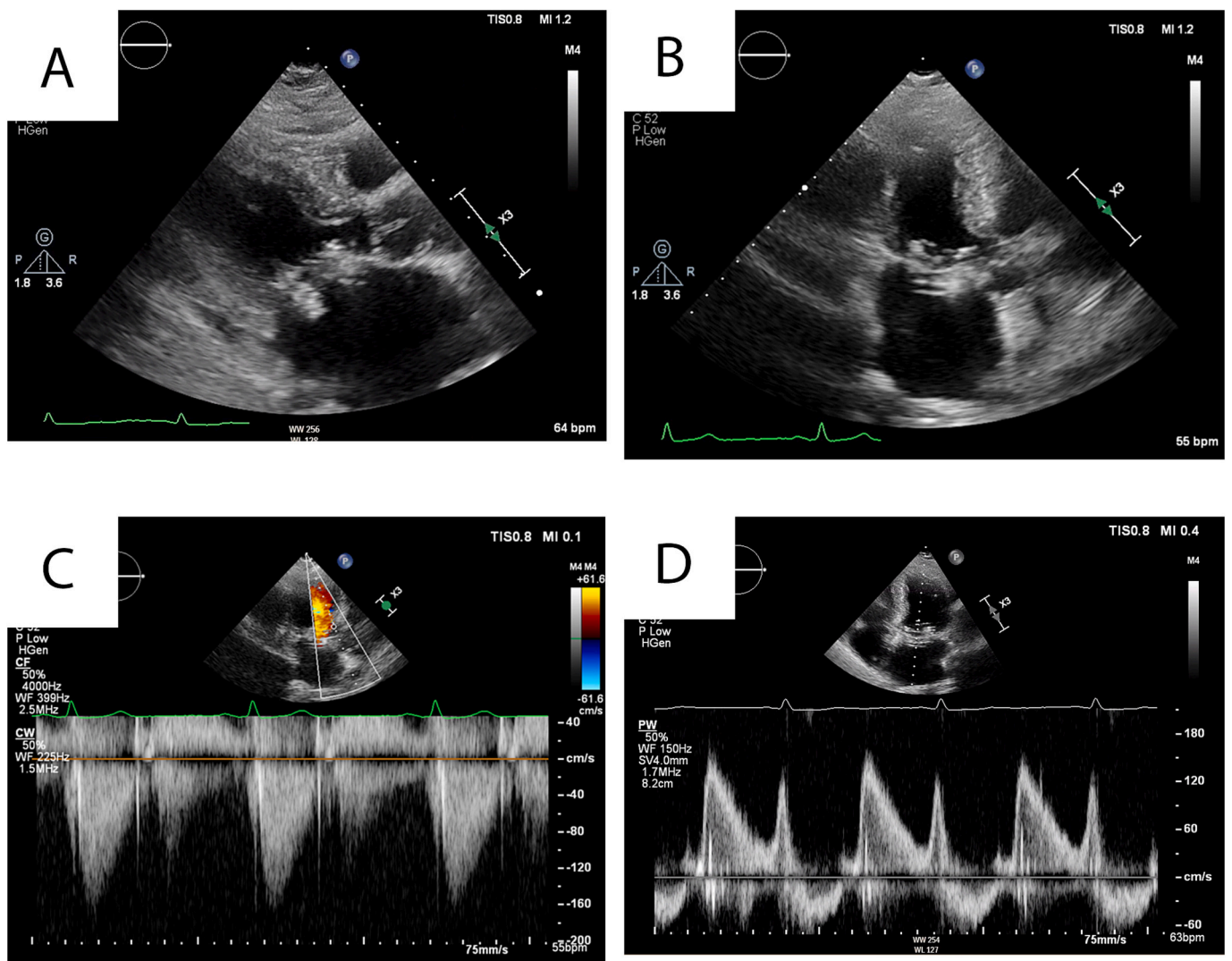


Fig. 5. Postoperative echocardiographic assessment after anterior mitral valve leaflet resection. (A, B) Transthoracic echocardiography showing absence of left ventricular outflow tract (LVOT) obstruction after anterior mitral valve leaflet resection. (C, D) Doppler echocardiographic assessment demonstrating resolution of LVOT obstruction and a reduced transmitral gradient, indicating preserved mitral valve function.

Abbot Vascular, Boston Scientific, Medtronic, Anteris, JenaValve, Daiichi Sankyo, Amgen, Siemens, Teleflex, PulseCath BV, and Abimed.

Data availability

No data was used for the research described in the article.

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