Mitral Regurgitation due to Entrapment of Cut Mitral Chordal Apparatus in a Bileaflet Disk Prosthesis

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INTRODUCTION

Complications of mitral valve replacement (MVR) include injury to the circumflex coronary artery, coronary sinus, and posterior aortic cusp, free wall rupture, and mitral regurgitation (MR).[1] Intraoperative MR is the most common problem and generally paravalvular but rarely can be central.[1-12] We report a case of a patient with severe intraprosthetic central MR with a bileaflet disk prosthesis caused by entrapment of the cut end of distal chordal and papillary muscle (PM) elements. This was recognized by intraoperative transesophageal echocardiography (TEE) and corrected. We discuss a broad differential diagnosis of prosthetic MR and present a comprehensive intraoperative evaluation using TEE.

CASE PRESENTATION

A 38-year-old man was admitted to an outside hospital (OSH) with 2-day history of fever and altered mental status. Three weeks prior to this admission, the patient was treated for pneumonia with oral antibiotics. On admission to the OSH, they were found to have a fever of 104 °F (40 °C), and blood cultures were positive for methicillin-sensitive staphylococcus. Transthoracic echocardiography (TTE) and TEE at the OSH showed a 1.9 × 0.7 cm sized vegetation on the middle scallop (P2) of the posterior mitral leaflet (PML), no evidence of ruptured chord, and mild MR. A computed tomographic (CT) scan of the head showed focal encephalomalacia of the right frontal lobe. A CT scan of the abdomen showed emboli to kidneys and spleen. Intravenous nafcillin for treatment of methicillin-sensitive staphylococcus bacteremia and mitral valve (MV) endocarditis was initiated. Blood cultures became negative 5 days after starting the antibiotic therapy. One week later the patient was transferred to our institution for a higher level of care.

Examination at our hospital showed heart rate of 100 beats per minute, blood pressure 116/74 mm Hg, respiration rate of 20 per minute, and temperature 98.8 °F (37.1 °C). There was a loud pansystolic murmur of MR. Neurologic examination was intact. The hemoglobin was 10 g/dL, white blood cell count 14.4 × 10e9/L, blood urea nitrogen 11 mg/dL, and creatinine 1 mg/dL. The chest radiograph showed early pulmonary edema. A TTE was performed that showed no vegetation, but severe MR was noted due to ruptured chord and flail P2 (Figure 1). The vegetation noted at OSH 1 week earlier was not apparent on our study. A repeat CT scan of the head showed new bilateral frontal and occipital lobe infarcts due to septic emboli. Due to the presence of severe MR and signs of heart failure, MV surgery was recommended. After informed consent the patient was taken to surgery and placed on cardiopulmonary bypass through a median sternotomy with bicaval venous and central aortic cannulation. Intraoperative TEE showed an extremely large, thickened, myxomatous P2 scallop of the PML with 3 ruptured chords and severe MR (Figure 2). The lateral (P1) and medial (P3) scallops of the MV were diminutive, and no vegetations were noted. The heart was arrested, and the left atrium was entered through the Sondergaard groove. Intraoperative examination confirmed the findings of TEE and showed a large P2 with 3 ruptured chords and small P1 and P3. Successful MV repair was not possible due to extensive infective disease of a large P2. During surgery the large P2 was resected, P1 and P3 were preserved, and the MV was replaced with a bileaflet mechanical prosthesis. Testing of the valve at that time showed good prosthetic valve leaflet excursion and function. After separation from cardiopulmonary bypass, however, intraoperative TEE performed by the cardiac anesthesiologist showed severe MR. The mechanism and location of MR (central or paravalvular) were not clear. Intraoperative consultation with the cardiologist led to additional imaging, and the MR origin was localized at the lateral orifice of the prosthetic valve (Figures 3-5, Videos 1-3). Furthermore, based on the TEE, the mechanism of the MR was felt to be due to entrapment of long cut chords and residual anterolateral PM between the lateral disk and the housing of the prosthesis. Therefore, cardiopulmonary bypass was reestablished, the heart was rearrested, and the mitral prosthesis was exposed. Surprisingly, there was no obvious tissue protruding through the valve and the prosthetic disk leaflets moved normally. Without removing the prosthesis, the leaflets were opened, and the residual anterolateral PM and the chords were observed and resected (Figure 6). Repeat TEE showed resolution of the MR (Figures 7 and 8, Videos 4-6). The patient had an uneventful recovery with no residual neurologic deficit and was doing well at last follow-up 3 years later.

DISCUSSION

Mitral valve replacement with bioprosthetic or mechanical valves is widely performed for the surgical treatment of valve regurgitation and stenosis, particularly when repair is not feasible. Following MVR with a prosthetic valve, the valve should be competent, and the presence of minimal physiological or "washing jets" type of prosthetic MR is normal. The physiologic MR jets are narrow, travel for a short distance, and are noted between the sewing ring and the disks or the

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VIDEO HIGHLIGHTS

Video 1: Two-dimensional TEE, midesophageal 2-chamber view slowed to 30% normal speed, demonstrates entrapment of a portion of the subvalvular apparatus and chordae between the lateral disk and the sewing ring.

Video 2: Two-dimensional TEE, midesophageal 2-chamber view with color-flow Doppler, demonstrates severe MR through the lateral orifice and none through the medial orifice. Mitral regurgitation is dynamic and worse in some beats.

Video 3: Real-time three-dimensional TEE, midesophageal 2-chamber (55°) view slowed to 30% normal speed, demonstrates entrapment of the subvalvular mitral apparatus in lateral orifice.

Video 4: Two-dimensional TEE, midesophageal 2-chamber view after resection of the subvalvular apparatus and chordae, demonstrates normal function of both disks.

Video 5: Two-dimensional TEE, midesophageal 2-chamber view with color-flow Doppler after resection of residual chords and PM, demonstrates resolution of MR.

Video 6: Three-dimensional TEE, midesophageal zoomed view of prosthetic MV after reoperation from left atrial perspective, demonstrates normal opening and closure of both disks.

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space between the 2 disks (Figures 9-11). A frustrating problem with MVR is residual MR, which can be paravalvular or central (Figures 9-11). The distinction between paravalvular and central MR is, of course, critical to guiding the surgical management.[1] Comprehensive TEE examination with the transgastric short-axis view of the MVR, midesophageal scan from 0° to 180°, and select three-dimensional imaging with color Doppler will identify the site, mechanism, and severity of prosthetic MR (Figures 9-11). Understanding the surgical techniques of MVR and pathophysiology of the MR is essential for imaging specialists for precise diagnosis and surgical planning. In 1983, David *et al.*[2] introduced the concept of chordal sparing and significance of annuloventricular continuity in the preservation of left ventricular (LV) function during surgical MVR. Preservation of the anterior MV was noted to be associated with dynamic LV outflow obstruction due to systolic anterior motion.[3] Esper *et al.*[3] recommended excision of the anterior mitral leaflet (AML), preservation of the PML, and subvalvular preservation during surgical MVR. Surgical MVR with subvalvular preservation involves a left atriotomy to expose the MV and then an incision at the base of the AML 2 to 3 mm below the annulus and most of the AML is excised. Most of the chordae tendineae are left attached to both commissural sides of the AML. The PML is preserved and imbricated with the valve sutures in the posterior annulus for reinforcement. The sutures are brought up through the sewing ring of the prosthesis, which is then seated into position and secured. Care is taken to avoid injury to the aortic valve cusps, left circumflex artery, creation of LV outflow tract obstruction, or malfunction of the prosthetic valve cusps or disks due to technical errors.[1]

Most often, MR after MVR is paravalvular,[1] resulting from inadequate apposition between the prosthesis and the mitral annulus due to mitral annulus calcification and infective endocarditis (Figure 9, panel 2, Figure 11). Rarely the MR can be intraprosthetic or central (Figure 9, panel 3A-3E), noted predominantly in mechanical prothesis. In the acute setting, central MR after MVR can be due to multiple etiologies and a wide differential is warranted (Figure 9, panel 3A-3E).[4-12] The height of the valve housing differs among 2 of the more common mechanical mitral prostheses: On-X (Artivion) and St. Jude Medical (Abbott Cardiovascular), with the former having a greater height. This difference has implications for the mechanism of obstructed leaflet as illustrated (Figures 9-11). If the MR develops later, remote from the index operation, thrombus, vegetation, pannus formation, and newly untethered tissue from ruptured chordae are likely culprits.[1,6-12]

Most cases of malfunction due to entrapment of the preserved native valve tissue or chordae have been reported several days after surgery (Figure 9, panel 3B, 3C).[7-9] Agostini *et al.*[9] reported a case of MR due to entrapment of ruptured chords (Figure 9, panel 3C) 4 years after the MVR. Fijalkowski *et al.*[10] reported MR due to

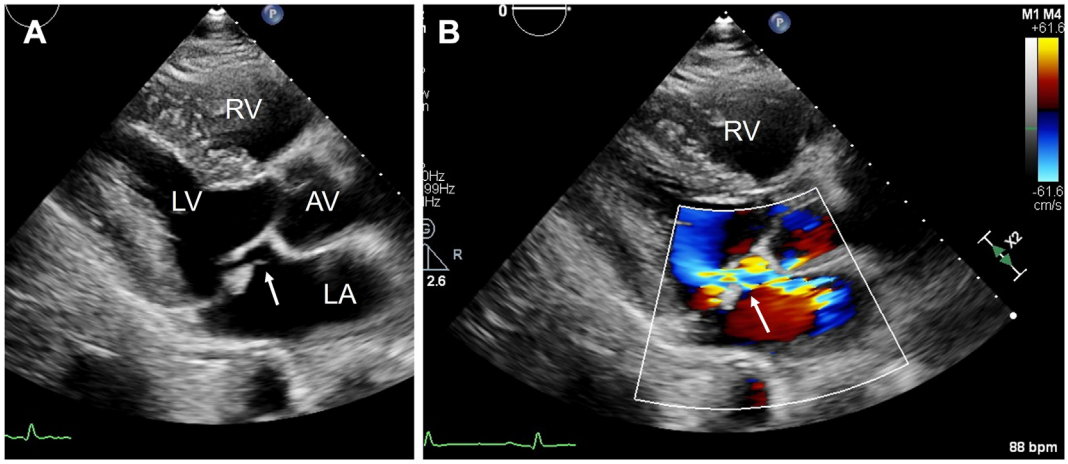

Figure 1 Two-dimensional TTE, parasternal long-axis view without **(A)** and with **(B)** color-flow Doppler, demonstrates the thickened edge of the middle scallop of MV (P2) with ruptured chord and flail leaflet (*arrow*) with associated eccentric anteriorly directed severe MR (*arrow*). *AV*, Aortic valve; *LA*, left atrium; *LV*, left ventricle; *RV*, right ventricle.

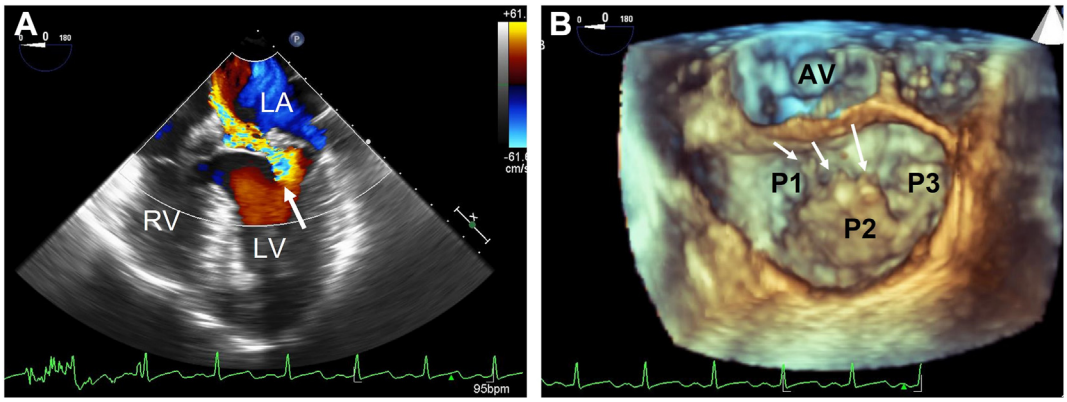

Figure 2 **(A)** Two-dimensional TEE, mid-esophageal 4-chamber view (0°) with color-flow Doppler, demonstrates an eccentric jet of severe MR (*arrow*). **(B)** Real-time three-dimensional TEE, volume-rendered short-axis systolic image of MV from the left atrial perspective, demonstrates the large, thickened flail P2 scallop with 3 ruptured chords (*arrows*) and the relatively smaller lateral (P1) and medial scallops (P3). *AV*, Aortic valve; *LA*, left atrium; *LV*, left ventricle; *RV*, right ventricle.

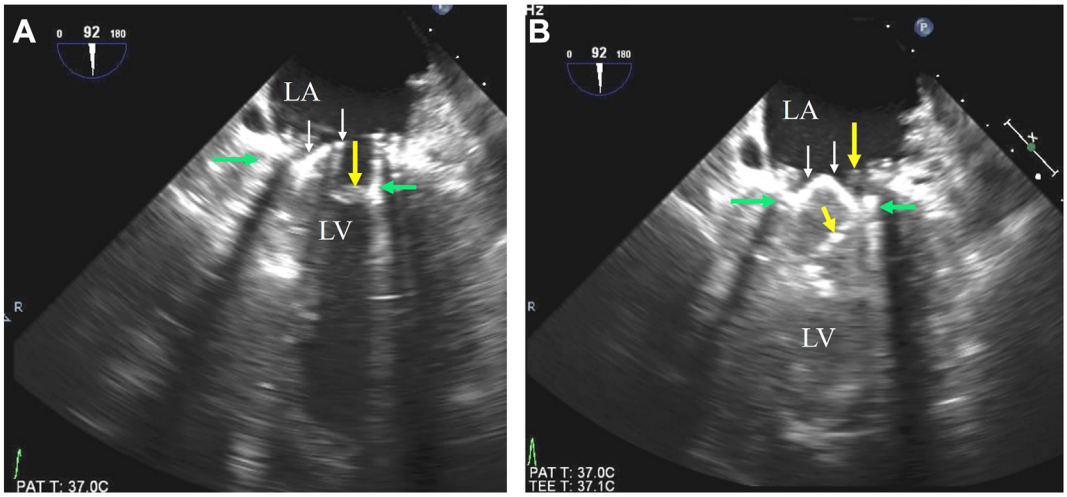

Figure 3 Two-dimensional TEE, midesophageal 2-chamber (92°) view in end diastole **(A)** and early systole **(B)**, demonstrates the entrapment of a portion of the subvalvular apparatus and chordae (*yellow arrows*) between the lateral disk (*both disks, white arrows*) and the housing of the prosthetic valve (*green arrows*). Medial disk (*white arrow*) shows normal closure. *LA*, Left atrium; *LV*, left ventricle.

entrapment of the ruptured proximal head of the PM in a patient with ischemic heart disease (Figure 9, panel 3D) 2 weeks after MVR. Delayed rupture of chords and rupture of a PM in these cases likely occurred due to increased stress on the chordae during the PML-sparing replacement procedure.

In the case presented in this report, the P2 segment was extremely large and flail, with chordal rupture close to the margin of P2 (Figure 2B). The entire P2 was resected during MVR, and residual elongated chords and PM became entrapped in the lateral orifice between the disk and the housing, causing dynamic MR (Figures 3-5, Videos 1-3). In a case where leaflet resection is required and chords are elongated, there is a greater potential of valve dysfunction due to entrapment of residual subvalvular tissue (Figure 9, panel 3E). In such a case, resection of the chordae to the involved valve segment and transection of the relevant PM at its base would reduce the risk of valve dysfunction. Leaflet movement is assessed at the time of surgical implantation with intraoperative TEE to allow resection of abnormal tissue or simple rotation of the occluding device. However, prosthetic valve malfunction can be dynamic and therefore occult during the period of cardiac arrest. In the presented case, on initial implant the leaflets moved normally, and again on reinspection of the valve after reestablishing cardiopulmonary bypass cut chords were not stuck between the disk and the housing. The incontrovertible TEE findings, however, led to resection of extralong chordae tendineae and residual anterolateral PM with resolution of the problem (Figures 7 and 8, Videos 4-6).

The case highlights the critical role of intraoperative TEE for the diagnosis and management of prosthetic MR. Current guidelines recommend intraoperative TEE before total weaning of cardiopulmonary bypass as well as baseline postoperative echocardiography before discharge from hospital or 2 to 4 weeks later.[13]

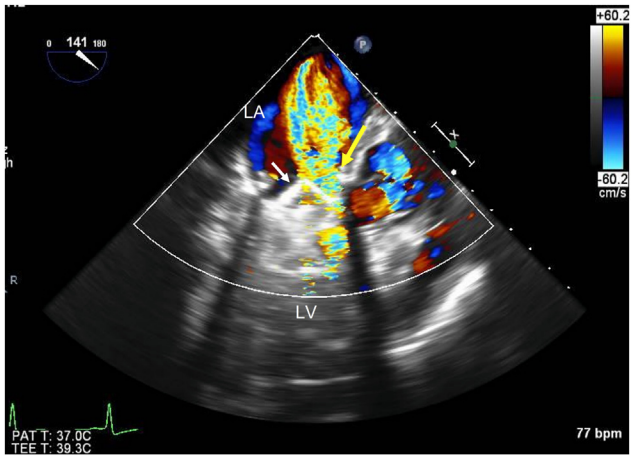

Figure 4 Two-dimensional TEE, mid-esophageal long-axis (141°) view with color-flow Doppler in midsystole, demonstrates severe MR (*yellow arrow*) through the lateral orifice and normal function of medial disk (*white arrow*). *LA*, Left atrium; *LV*, left ventricle.

Figure 5 Real-time three-dimensional TEE, midesophageal 2-chamber (55°) view, volume-rendered display in end diastole, demonstrates normal opening of disks (*white arrows*) and entrapment of the subvalvular mitral apparatus (*yellow arrow*). Housing of the bileaflet disk prosthetic valve is between the *green arrows*. *LA*, Left atrium; *LV*, left ventricle.

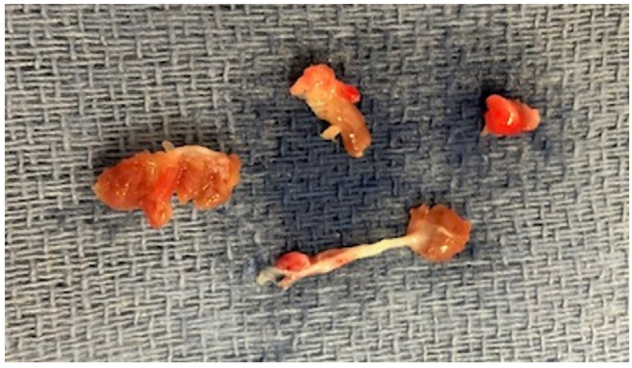

Figure 6 Intraoperative surgical photograph of the resected surgical specimens of residual lateral PM and chordae, which were entrapped.

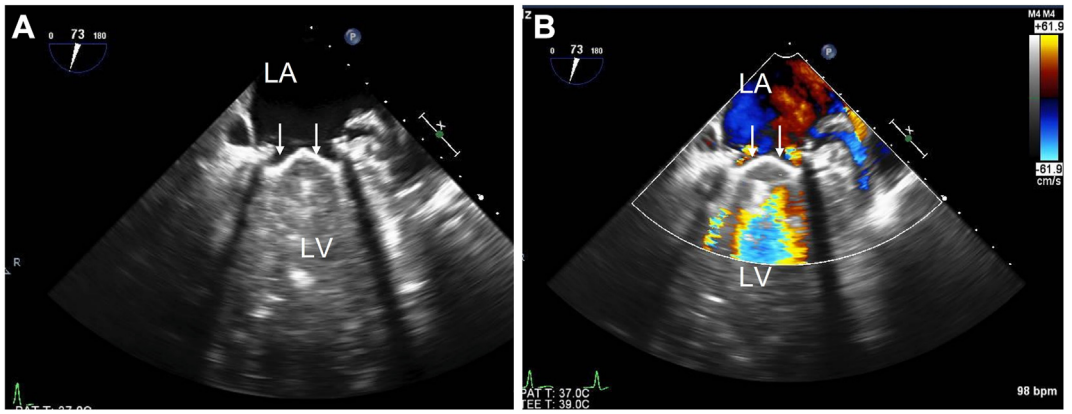

Figure 7 Two-dimensional TEE, midesophageal 2-chamber (73°) view in systole without **(A)** and with **(B)** color-flow Doppler after re-operation, demonstrates normal closure of both disks (*arrows*) and normal prosthetic MR. *LA*, Left atrium; *LV*, left ventricle.

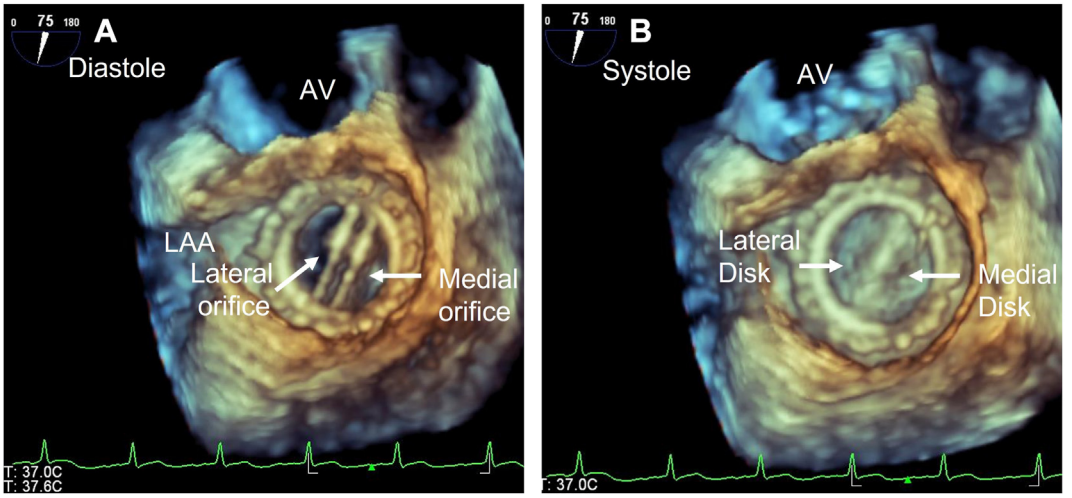

Figure 8 Real-time three-dimensional TEE, midesophageal zoomed en face view, volume-rendered display of prosthetic MV after re-operation from left atrial perspective in diastole **(A)** and systole **(B)**, demonstrates normal opening and closure of both disks (*arrows*). *AV*, Aortic valve; *LAA*, left atrial appendage.

CONCLUSION

In summary, severe central MR of the prosthetic MV caused by entrapment of the cut chordae tendineae and PM is a rare complication of MVR. Despite appropriate leaflet excursion on testing immediately after implantation, dynamic central MR should be considered due to entrapment of residual tissue of the subvalvular apparatus, particularly when the PML has been resected and not spared. In surgical MVR, when resection of the PML is necessary, care should be taken to resect chordae and PM to the involved segment to reduce the potential of subsequent dynamic entrapment. This case illustrates the critical role of TEE in the diagnosis of chordal entrapment after MVR.

ETHICS STATEMENT

The authors declare that the work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

CONSENT STATEMENT

The authors declare that since this was a non-interventional, retrospective, observational study utilizing de-identified data, informed consent was not required from the patient under IRB exemption status.

FUNDING STATEMENT

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DISCLOSURE STATEMENT

The authors report no conflict of interest.

SUPPLEMENTARY DATA

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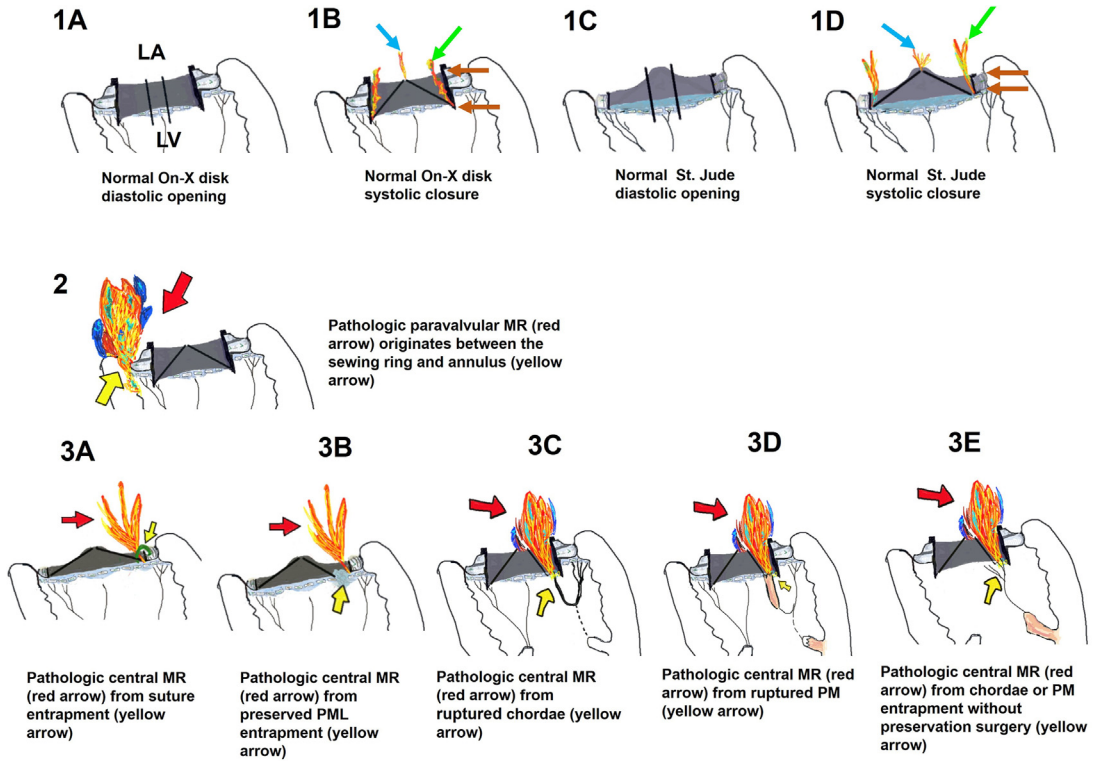

Figure 9 Schematic representation of On-X (1A, 1B) and St. Jude (1C, 1D) bileaflet prosthetic MVs demonstrates normal physiologic MR. Normal prosthetic MR originates from between the disks (*blue arrows*) and between the disks and housing (*green arrows*). The height of the housing is higher with the On-X compared to the St. Jude MVR (*brown arrows*). Paravalvular MR (panel 2) and various mechanisms of central MR (panels 3A-3E) are also demonstrated.

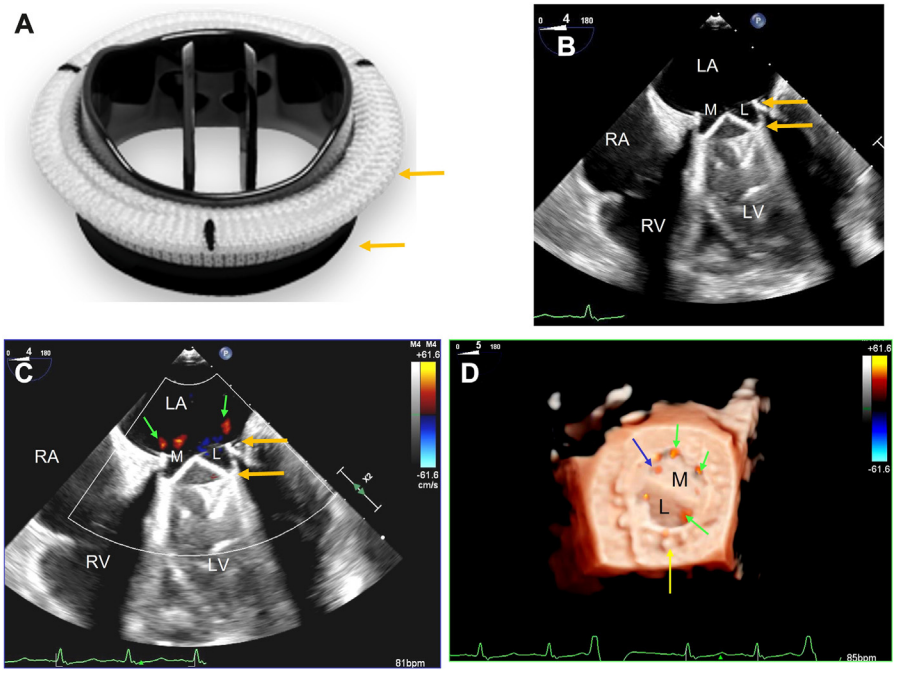

Figure 10 Photograph of On-X bileaflet disk MV prosthesis **(A)** demonstrates the height of housing (*between orange arrows*; 14 mm). Two-dimensional TEE, midesophageal 4-chamber (4°) view without **(B)** and with **(C)** color-flow Doppler, demonstrates the height of housing (*between orange arrows*) and coaptation of the medial (M) and lateral (L) disks as well as the physiologic (or "washing") MR jets between the housing and the disks (*green arrows*). Real-time three-dimensional TEE zoomed en face volume-rendered view of prosthetic MV from left atrial perspective in systole with color-flow Doppler **(D)** demonstrates the entire sewing ring with stitches (*yellow arrow*) and physiologic MR that originates between the housing and the disks (*green arrows*) and between the disks (*blue arrow*). *AV*, Aortic valve; *LA*, left atrium; *LV*, left ventricle; *RV*, right ventricle.

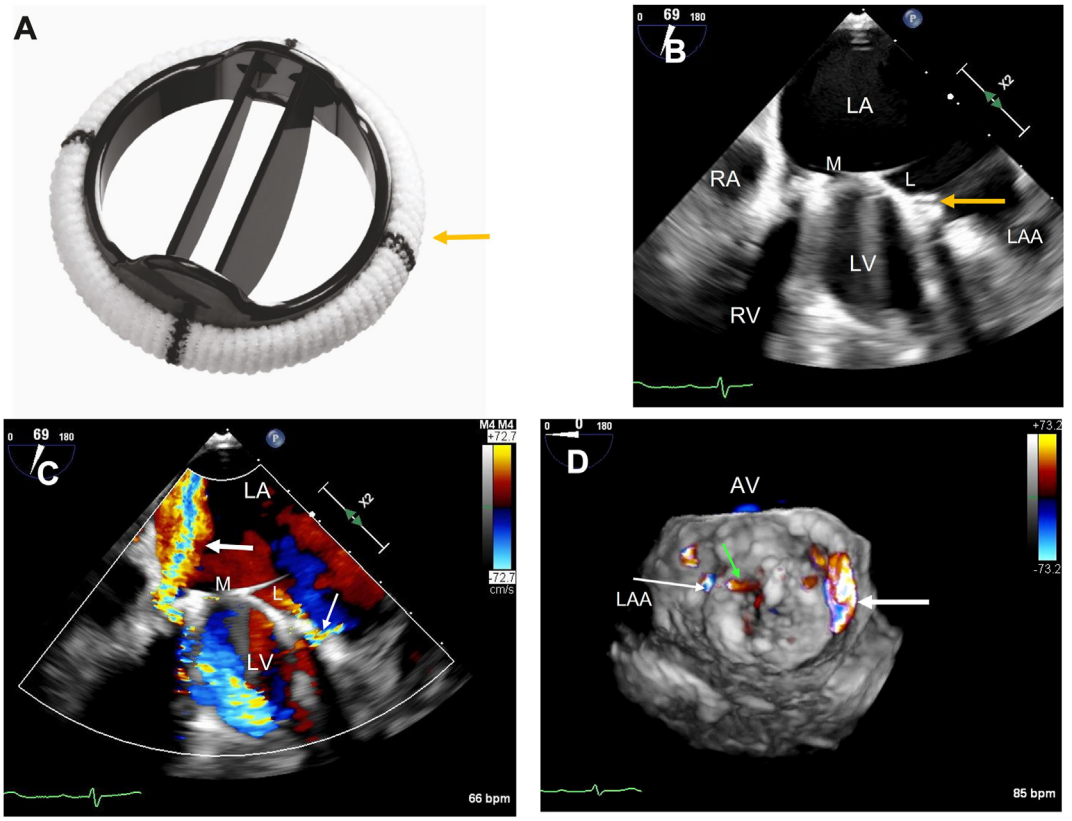

Figure 11 Photograph of St Jude bileaflet disk MV prosthesis **(A)** demonstrates the height of the housing (*orange arrow*; 6 mm distance). Two-dimensional TEE, midesophageal long-axis view (69°) without **(B)** and with **(C)** color-flow Doppler, demonstrates the medial (M) and lateral (L) disks occlude at the bottom of the sewing ring (*orange arrow*), as well as paravalvular medial (*thick white arrow*) and lateral (*thin white arrow*) MR. Real-time three-dimensional TEE, zoomed en face volume-rendered view of prosthetic MV from left atrial perspective in systole with color-flow Doppler **(D)**, also demonstrates physiologic MR (*green arrow*) between the housing and the lateral disk, larger medial (thick white arrow) and smaller lateral (thin white arrow) paravalvular MR. *AV*, Aortic valve; *LAA*, left atrial appendage; *LA*, left atrium; *LV*, left ventricle; *RV*, right ventricle.

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