

Anti-Anatomical Orientation of Prosthesis with Very High Pressure Gradients Following Mitral Valve Replacement with a Tilting Disc Valve: 25-Year Follow-Up

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Abstract

#27 size mitral Bjork-Shiley tilting disc prosthesis has been reported to have peak gradients of 10 ± 4 mmHg and mean gradients of 5 ± 2 mmHg when functioning normally. We herein describe a patient implanted with #27 Bjork-shiley mitral prosthesis in 1990 who has been followed up for 25 years with persistently high trans-prosthetic gradients with near normal effort tolerance (maximum peak gradients of 45 mmHg and mean gradients of 26 mmHg). Marked pressure gradient was possibly due to anti-anatomical orientation of the prosthesis and probable pressure recovery for which, the patient underwent unnecessary thrombolysis twice for suspected valve thrombosis. Anti-anatomical orientation was shown by major orifice aligned to the outflow tract and antegrade flow jets striking the interventricular septum.

Conclusion: High trans-prosthetic gradients across normally functioning mitral prosthesis in asymptomatic patients can occur not only due to probable pressure recovery but also due to anti-anatomical orientation of the prosthesis. These high gradients may partially dissipate over period of time.

Keywords: Tilting Disc Prosthesis; Pressure Recovery; Anti-Anatomical Orientation

Abbreviations

LV: Left Ventricle; LA: Left Atrium; RA: Right Atrium; AO: Aorta; RV: Right Ventricle

Introduction

The heart valve prostheses after implantation are usually followed up by Doppler hemodynamic evaluation and cine-fluoroscopy. Doppler echocardiography over-estimates trans-prosthetic pressure gradients and under-estimates true effective valve orifice area largely due to a phenomenon of pressure recovery [1]. Pressure recovery denotes an abnormally large kinetic energy (out of total blood energy) required to push blood flow across a prosthesis which then re-converts to pressure energy distal to valve prosthesis. This large pressure drop (pressure energy getting converted to kinetic energy and then back to pressure energy) across the prosthesis usually accounts for 50% of the total trans-prosthetic gradients and has been well-known for mitral prosthesis as well [2]. Differentiating prosthesis obstruction from pressure recovery in patients who have high Doppler velocities across a mitral valve prosthesis is crucial for appropriate management. Mono-leaflet asymmetric mitral prosthesis is usually implanted with anatomical orientation (disc aligned with the anterior mitral leaflet). In this patient, prosthesis orientation was anti-anatomical with antegrade flow jets striking the septum when evaluated by color flow mapping. In anatomical orientation, streamlines pass homogeneously without any spatial differences in flow velocities into the left ventricle and are directed away from the outflow tract. Starting from the anatomical position, blood enters mainly through the major

orifice of the mechanical valve [3]. The single artificial leaflet mimicks the rudder effect of the natural anterior mitral leaflet, preventing blood streaming directly towards the septum. Anti-anatomical orientation of the prosthesis causes a significant increase in turbulence immediately after passing the mitral prosthesis. These phenomena are elegantly shown in this patient by way of very high velocities across the prosthesis and trajectory of diastolic flow jets nearly perpendicular to the inter-ventricular septum.

Case Report

This patient underwent mitral valve replacement using #27 Bjork-Shiley convexo-concave mono-disc mitral metallic prosthesis in 1990 when he was 21 years of age for rheumatic mitral valve disease. He has maintained asymptomatic status, sinus rhythm, normal blood pressure, adequate INR on acenocoumarol and an average build (weight 62 Kg, height 167 cm, BSA 1.6M² in early-2015). He has been regularly followed up by cine-fluoroscopy and trans-thoracic echocardiography. He received thrombolysis with streptokinase twice (in years 2000 and 2003) for suspected acute valve thrombosis in other hospitals wherein he presented with acute dyspnoea. Thrombolysis did not result in reduction in trans-prosthetic gradients and lower respiratory tract infections were the cause of acute dyspnoea. His early-2015 echocardiogram revealed left ventricular end-systolic volume of 44 mL, ejection fraction of 60% and estimated pulmonary systolic pressure of 44 mmHg. His routine biochemical examinations, 12-lead ECG and chest skiagram have been unremarkable. Detailed 2D trans-thoracic examination revealed normal opening of the mitral disc with major orifice directed to the interventricular septum and antegrade flow jets striking the septum in 4-chamber, 5-chamber and parasternal long axis views (Figures 1-3).

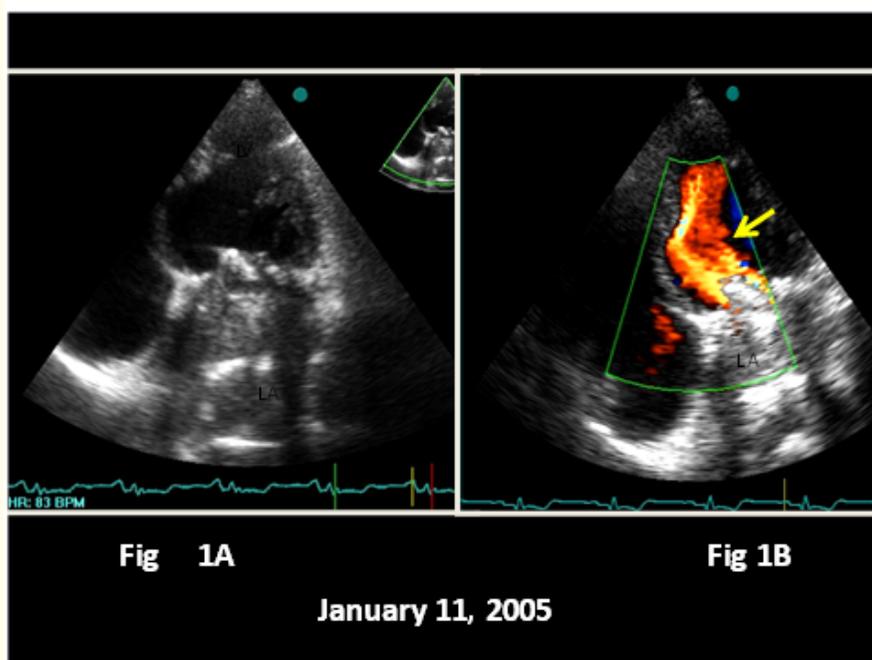


Figure 1: Trans-thoracic echocardiographic 4-chamber view showing open tilting disc (Figure 1A) with major orifice aligned to the septum. Note L-shaped antegrade diastolic flow jets impinging upon the septum (yellow arrow, Figure 1B).

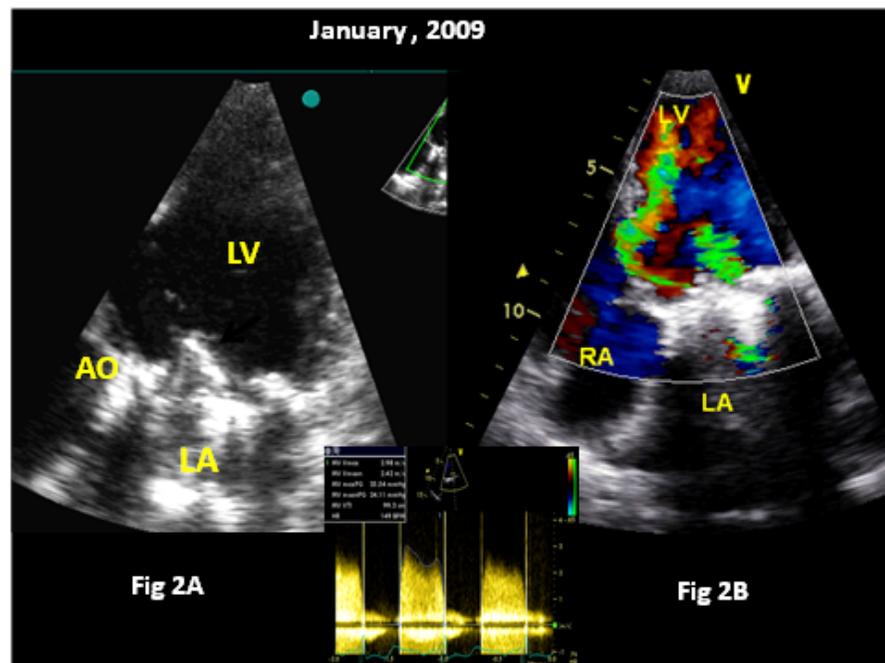


Figure 2: Modified apical 4-chamber view showing tilting disc in open position (Figure 2A). Diastolic flow jet through major orifice tracking along the ventricular septum (Figure 2B). Inset picture shows trans-prosthetic mean diastolic pressure gradient of 24 mmHg. Recordings in January, 2009.

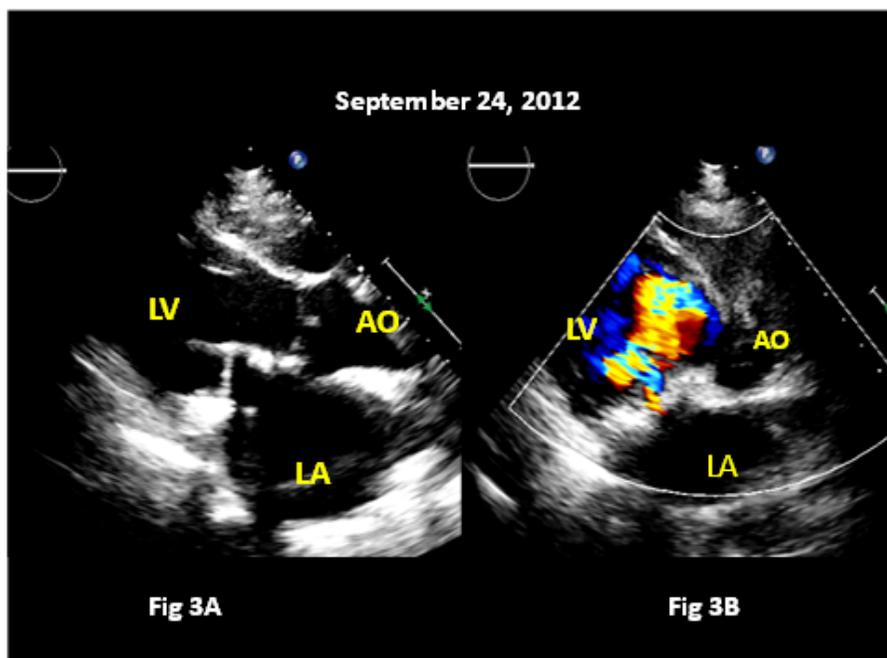


Figure 3: (Year 2012) Parasternal long axis view showing tilting disc in mitral position during diastole (Figure 3A). Slight tilt of the long axis view shows trans-prosthetic flow jets directed vertically perpendicular the septum (Figure 3B).

Although, at various echocardiographic examinations, different trans-prosthetic pressure gradients were recorded, maximum peak and mean gradients of 45 mmHg and 26 mmHg have been estimated with a peak trans-mitral velocity of 3.34 m/sec (Figure 4). Cine-fluoroscopy revealed normal motion of the disc with opening angle close to 45° and 3D trans-esophageal examination showed normal disc motion with no evidence of pannus (Figure 5).

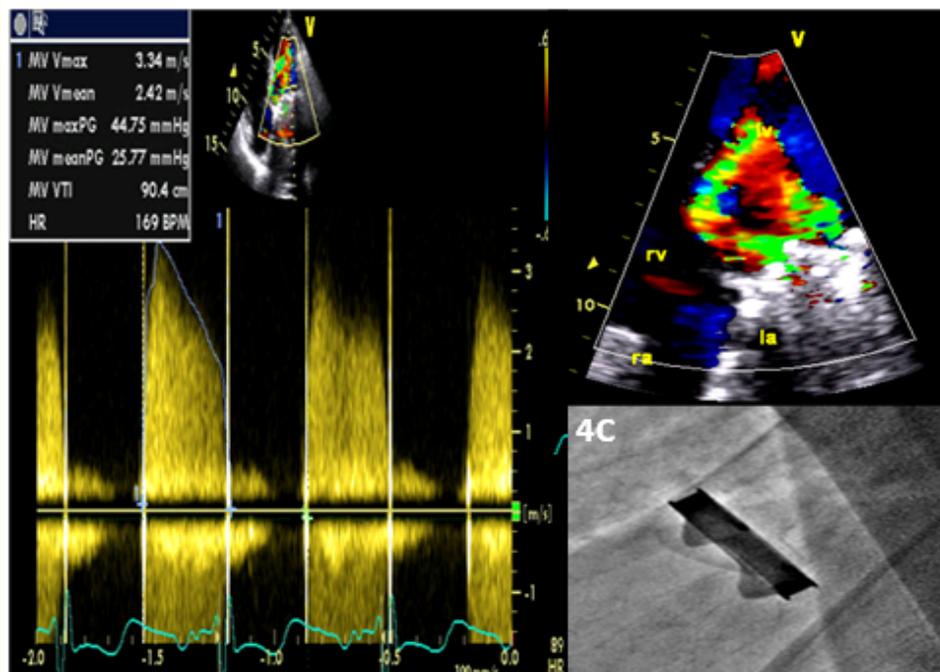


Figure 4: Continuous-wave Doppler interrogation of the mitral prosthesis showing peak and mean pressure gradients of 45 mmHg and 26 mmHg respectively at a heart rate of 89/minute. Peak trans-prosthetic velocity is 3.34 meter/sec (Figure 4A). Figure 4B shows still more curved antegrade jets with L-shape. Figure 4C shows cine-fluoroscopic normal opening of the tilting disc in LAO* view.

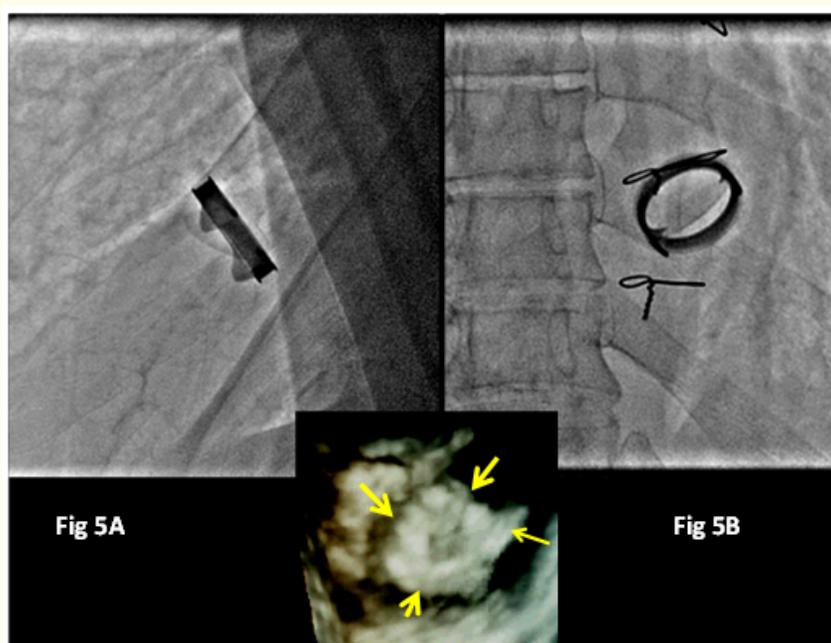


Figure 5: Normal eccentric opening of the tilting disc of the mitral prosthesis (Figure 5A and 5B). Inset shows normal sewing ring and disc in 3D trans-esophageal view from the left atrium (arrows).

The patient continues to be largely asymptomatic and on conservative treatment with oral anti-coagulants and aspirin.

Discussion

This 47-year old gentleman received 27# Bjork-Shiley convexo-concave single-disc mitral prosthesis for rheumatic mitral valve disease in 1990 when he was 21 years of age. He has remained largely asymptomatic except for recurrent lower respiratory tract infections, two of these episodes resulting in inappropriate thrombolysis for suspected valve thrombosis (high trans-prosthetic gradients on trans-thoracic echocardiography mistaken for acute valve thrombosis in other hospitals). However, he has maintained good effort tolerance, is in sinus rhythm, with an estimated pulmonary artery systolic pressure of 40 - 45 mmHg over these twenty-five years despite having very high trans-prosthetic gradients, normal disc motion on cine-fluoroscopy and on 3D trans-esophageal echocardiography without any obstruction.

The use of simplified Bernoulli equation to estimate trans-valvular pressure gradients is based on an assumption: that all potential energy converted into kinetic energy at the level of the stenosis is completely lost downstream in turbulent friction, vortex formation, and heat. Although this may be true for native valves, it is mostly not found in prosthetic heart valves. Re-conversion of kinetic energy into pressure energy downstream is responsible for pressure recovery which is the major source of disproportionately large trans-prosthetic pressure gradients. The classic model of pressure recovery is that localized high velocities occur close to the prosthetic valve, with subsequent flow deceleration and recovery of pressure distal to the valve orifice. Variable pressure recovery in prosthesis may be dependent upon the valve design, orifice characteristics, flow rates and jet orientation [4]. We cannot accurately quantify pressure recovery in our patient; however based upon normal values available in literature [5], it appears substantial. The pressure profile through the major orifice shows possibly deep-pressure well both at disc level and beyond with gradual increase in pressure further downstream. In the mitral configuration, virtually no further pressure recovery occurs beyond the level of the valve in bileaflet prosthesis [1] but this may not be true of tilting disc with anti-anatomical orientation. However, we have not measured trans-prosthetic pressures invasively and cannot be sure that these high pressure gradients are due to pressure recovery.

The transvalvular flow characteristics of monoleaflet mitral prosthetic valves are well known [6]. However, orientation of the mitral valve prosthesis has not received much clinical attention.. Potential hemodynamic disadvantages of sub- optimum orientation of monoleaflet asymmetric mitral prostheses need more careful scrutiny, even though Bjorky-Shiley prosthesis is no longer in use. A more physiological orientation with the large orifice opening in a posterior fashion mimics the rudder effect of the natural anterior mitral leaflet and preserves the natural vortices of the left ventricle during diastole, preventing blood from streaming directly to the septum. The asymmetrically constructed valve shows a tendency towards better performance if the larger orifice face is oriented towards the posterior leaflet, thereby mimicking the function of the native anterior leaflet. The anti-anatomical position in our patient, where the large orifice was oriented perpendicular to the opening axis of the native valve leaflets offered the worst hemodynamics and the freedom of the blood to enter the ventricular cavity was limited. Maintenance of physiological blood flow paths in the heart is important to obtain a good outcome following mitral valve replacement because it may have an energy-saving effect by facilitating the separation of the outflow and inflow paths, so avoiding any mixing of the blood.

Conclusion

High trans-prosthetic gradients across normally functioning mitral prosthesis in asymptomatic patients can occur not only due to probable pressure recovery but also due to anti-anatomical orientation of the prosthesis. These high gradients may partially dissipate over period of time.

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