Doppler and Two-Dimensional Echocardiographic Diagnosis of Björk-Shiley Prosthetic Valve Malfunction: Importance of Interventricular Septal Motion and the Timing of Onset of Valve Flow

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In a 69 year old woman with a “sticking” Björk-Shiley mitral prosthesis, the diagnosis was suggested by both the two-dimensional and the Doppler ultrasound examinations. In particular, the findings of early diastolic paradoxic septal motion, intermittent delayed opening of the prosthetic disc and variable timing of the onset of mitral valve inflow were believed to be diagnostic of a sticking tilting disc prosthesis.

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The noninvasive assessment of prosthetic valves remains a formidable challenge despite the recent advances in imaging provided by M-Mode and two-dimensional echocardiography. The advent of Doppler ultrasound has added a new dimension to the echocardiographic approach to this problem, with cases reported of the use of Doppler echocardiography in the diagnosis of prosthetic valve stenosis (1,2) and paravalvular regurgitation (3) and preliminary reports (4–9) of the use of Doppler ultrasound in evaluating larger series of patients with normal and malfunctioning valvular prostheses. This report discusses a case of an intermittently “sticking” Björk-Shiley prosthesis in which striking Doppler and two-dimensional imaging findings believed to be diagnostic of this disorder were identified. These abnormalities, early diastolic paradoxic motion of the interventricular septum, intermittent delayed opening of the disc and variable timing of the onset of transmitral flow, have not previously been reported as signs of prosthetic valve malfunction.

Case Report

A 69 year old woman with a history of rheumatic mitral stenosis underwent mitral valve replacement (25 mm Björk-Shiley prosthesis) 10 years before admission. She presented to the emergency room with a 5 day history of progressive shortness of breath and paroxysmal nocturnal dyspnea. Physical examination revealed that she had normal sinus rhythm with frequent episodes of atrial fibrillation. The blood pressure was 110/80 mm Hg and the respiratory rate 18/min. There was no jugular venous distension. Examination of the lungs disclosed bibasilar rales and egophony over both lower lung fields. The precordium was normal on palpation. The first heart sound was “mechanical,” the second sound was physiologically split and there was a grade 2/6 systolic ejection murmur best heard along the lower left sternal border.

The chest X-ray film showed an increased cardiac silhouette, interstitial edema and partial right middle lobe atelectasis. The admission electrocardiogram revealed normal sinus rhythm at 90/min, first degree atrioventricular block, left axis deviation and anteroapical T wave abnormalities. During the patient’s subsequent hospital course she was noted to have frequent bursts of atrial fibrillation.

Two-dimensional and Doppler echocardiographic findings. The two-dimensional echocardiogram disclosed intermittent delayed opening of the Björk-Shiley tilting disc, and paradoxic early diastolic motion of the interventricular septum. Illustrative frames from one cycle demonstrating this phenomenon are shown in Figure 1. At the onset of diastole (Fig. 1A), at a time when the tricuspid valve has opened but the dysfunctional prosthetic mitral valve has not, the ventricular septum is shifted toward the left ventricle. As diastole and right ventricular filling continue, the septum continues to shift further toward the left ventricle until the tilting disc finally opens (Fig. 1B). Once the mitral
prosthetic valve has opened, allowing the left ventricle to fill, the septum returns to a more normal midline position. When viewed in real time, this finding was extremely dramatic. The M-mode echocardiographic examination confirmed the irregular opening interval of the tilting disc, but did not reveal a “rounding” of the mitral valve E point, which has been previously reported as a sign of prosthetic dysfunction. (10). Associated findings on the two-dimensional imaging study were left atrial enlargement and systolic notching of the pulmonary valve consistent with pulmonary hypertension.

A pulsed wave Doppler echocardiogram revealed a slightly increased transmitral flow velocity of 1.7 m/s (normal range 0.6 to 1.3), a Doppler half-time of 161 ms (normal range

Figure 1. Two-dimensional echocardiograms showing early diastolic paradoxic septal motion. A, Early diastole (arrow) following tricuspid valve opening; the dysfunctioning tilting disc has remained closed. Note that the interventricular septum is displaced to the left and is convex toward the left ventricle (LV). As diastole continues, the septum continues to shift toward the left ventricle until the mitral valve opens (B). By end-diastole (C), the septum has returned to the midline position and its configuration has normalized. LA = left atrium; RA = right atrium; RV = right ventricle.

Figure 2. Abnormal timing of the onset of mitral valve inflow illustrated by the pattern of mitral inflow and prosthetic valve opening and closing recorded during Doppler interrogation of the mitral valve. The patient has normal sinus rhythm. The numbers depicted above the arrows refer to the time in milliseconds from prosthetic valve closing to valve opening (that is, the opening interval). The opening interval of the prosthetic valve is very irregular. The onset of mitral inflow on the third beat is markedly delayed (818 ms), with mitral inflow beginning only after atrial systole.
60 to 130 for a tilting disc prosthesis) (1), mitral regurgitation and intermittent abnormal timing of the onset of mitral inflow. The most dramatic examples of the latter phenomenon are illustrated in Figure 2; as shown, the interval from valve closure to valve opening is irregular. Particularly striking is the third beat in which the onset of mitral inflow is near the end of diastole (peak of the electrocardiographic R wave), that is, after atrial systole.

**Catheterization findings.** On the basis of the echocardiographic findings, considered diagnostic of prosthetic valve malfunction, the patient underwent cardiac catheterization before mitral valve replacement. This study revealed the following pressures: (mm Hg): right atrium (mean) = 2, right ventricle = 38/3, pulmonary artery = 38/19 with a mean of 30, left atrium = 20 and left ventricle = 125/8. Initially the mean gradient across the mitral prosthesis was 13 mm Hg with a cardiac output of 4.1 liters/min. Intermittently, however, there was elevation of this gradient to 23 mm Hg, with a concomitant reduction in the left ventricular systolic pressure to 75 mm Hg and cardiac output to 2.7 liters/min. Cinefluoroscopy of the Björk-Shiley tilting disc did not suggest abnormal motion of the suture ring or a restricted range of opening of the tilting disc. Because the fluoroscopic images do not include a simultaneous electrocardiogram the “sticking” was difficult to differentiate from the variability in cycle length that resulted from the patient’s underlying rhythm (atrial fibrillation). The left ventriculogram was uninterpretable because of contrast-induced ventricular tachycardia; however, a left atrial contrast angiogram performed with a transseptal catheter demonstrated delayed filling of the left ventricle.

**Surgical findings.** The patient subsequently underwent replacement of the malfunctioning Björk-Shiley prosthesis, at which time the surgeon reported that “disc motion was impeded by scar which had grown into the orifice of the valve.” The pathology report indicated that the valve was endothelialized with growth of fibrous tissue on the inflow aspect of the lip of the valve that “appeared to interfere with disc motion.”

**Discussion**

The present case is an example of prosthetic valve malfunction in which fibrous tissue ingrowth onto the inflow portion of the valve resulted in intermittent sticking of the tilting disc. This diagnosis was suggested by both the two-dimensional and the Doppler ultrasound examinations; in particular, the findings of early diastolic paradoxic septal motion and an intermittent delay in both the opening of the prosthesis and the onset of mitral inflow were believed to be diagnostic.

Although M-mode and two-dimensional echocardiography have largely supplanted cinefluoroscopy and phonocardiography in the routine noninvasive assessment of prosthetic valves, these imaging tests still lack sensitivity and specificity for prosthetic valve dysfunction. This is particularly true for the Björk-Shiley prosthesis, because the two-dimensional echocardiographic assessment of valve function is complicated by multiple reverberating echoes arising from the suture ring and metallic disc. One reported (10) M-mode echocardiographic sign of a malfunctioning Björk-Shiley prosthesis is a rounding of the E point on the M-mode echocardiogram, which is thought to be due to impaired disc opening. As mentioned previously, this sign was not observed in our case. However, clear-cut variability in the timing of disc opening was noted, and beats in which opening was most delayed were associated with dramatic diastolic paradoxic septal motion.

**Paradoxic septal motion.** It is widely recognized that paradoxic septal motion occurs after cardiothoracic surgery (11). However, this phenomenon is primarily a systolic event, and it is easily distinguishable from the abrupt early diastolic paradoxic motion noted in this study. The abnormality in our case is most analogous to the early paradoxic diastolic septal motion previously reported by Weyman et al. (12) in the presence of moderate to severe native mitral valve stenosis. They suggested that, in patients with significant mitral stenosis, the interventricular septum moves toward the left ventricle at the onset of diastole in response to unimpeded filling of the right ventricle and delayed left ventricular inflow. They hypothesized that, when the left ventricle has eventually filled, the pressure difference between the two ventricles normalizes and the septum shifts back to a more midline position, so that by end-diastole the location and configuration of the septum are normal. We assume that the intermittent early distolic paradoxic septal motion seen in the present case also reflects filling of the right ventricle before the left. Because this sequence is the reverse of that which occurs during normal physiologic filling of the ventricles (13), this finding is clearly abnormal and may be considered to be diagnostic of prosthetic valve stenosis. The intermittent nature of the abnormality is in keeping with the intermittency of the delay in disc opening and onset of mitral flow.

**Doppler assessment of prosthetic valve function.** There are several case reports (1–3) of the Doppler diagnosis of prosthetic valve malfunction. Ferrara et al. (3) reported a case of regurgitant flow across a mitral Björk-Shiley prosthesis using the pulsed wave Doppler technique, and Gross and Wann (2) reported a case of mitral porcine bioprosthetic valve stenosis in which continuous wave Doppler technique demonstrated accelerated flow (3 m/s) across the prosthetic valve. Since these early observations, large numbers of prosthetic valves have been studied with Doppler echocardiography, and several preliminary reports (4–9) have attested to the utility of this technique in assessing normal and mal-
functioning prostheses. In addition, recent experience with the color Doppler assessment of prosthetic valves suggests that color flow mapping may provide spatial orientation information not available with the current pulsed wave technique (14-18).

The major new finding in our case with respect to Doppler ultrasound features of prosthetic valve dysfunction was the variably delayed onset of mitral inflow. Under normal conditions, mitral inflow begins at the end of isovolumetric relaxation, which occurs after the electrocardiographic T wave (13). The opening interval of the mitral prosthesis in our case was highly irregular, and in some beats inflow was initiated at end-diastole (Fig. 2). This finding was readily apparent when the patient had normal sinus rhythm. However, during atrial fibrillation, it was less noticeable on initial inspection because of the expectation that the mitral opening intervals will be irregular whenever the underlying cardiac rhythm is irregular. This underscores the importance of timing all prosthetic valve flow profiles by reference to the simultaneously recorded electrocardiogram. Although, in this patient, the variability in the timing of valve opening was also apparent on the two-dimensional and M-mode echocardiographic studies, it is not always possible to adequately image prosthetic discs. In such situations, careful scrutiny of the Doppler spectral recordings is particularly important.

**Differential diagnosis.** It is our belief that the constellation of imaging and Doppler echocardiographic findings presented in this report is pathognomonic for the “sticking” prosthetic disc. Conceivably, a large mobile left atrial mass could also have produced intermittent delayed onset of mitral valve inflow; however, if such a mass did compromise the atrioventricular canal, one might expect that there would be diminished mitral inflow throughout diastole, rather than abnormal timing of the onset of mitral inflow. Moreover, such a mass should have been detectable on the two-dimensional echocardiographic imaging study.

Only one additional patient with an intermittently sticking prosthesis has been studied in our laboratory. That patient’s valve was partially occluded by thrombus so that flow, even when the disc opened at the appropriate time, was restrictive. In addition to the findings described in this report, the Doppler study in that case demonstrated a pattern typical of mitral stenosis with high velocity flow with prolonged pressure half-time.

**Summary.** This report presents, for the first time, the imaging and Doppler echocardiographic features of a “sticking” Björk-Shiley prosthesis—intermittent early diastolic paradoxic motion of the interventricular septum, delayed opening of the disc and variability in the timing of onset of mitral inflow.

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**References**