# Cinefluoroscopic Assessment of Mechanical Disc Prostheses: Its Value as a Complementary Method to Echocardiography

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***Background and aim of the study:*** **Many types of mechanical prostheses are used for heart valve replacement, but it is difficult to distinguish between them using transthoracic echocardiography. Hence, cinefluoroscopy complements the echocardiographic evaluation of cardiac prostheses. The aims of the present study were to: (i) describe the contribution of cinefluoroscopy in identifying different prostheses; (ii) compare gradients obtained by Doppler echocardiography with the opening angle of the discs assessed by cinefluoroscopy; and (iii) assess the ability of cinefluoroscopy to distinguish normal from dysfunctional prostheses.**

***Methods:*** **A total of 229 mechanical disc prostheses was prospectively evaluated with cinefluoroscopy. Eight prosthetic valves (six aortic, two mitral) were excluded due to the coexistence of severe left ventricular dysfunction. Thus, the final analysis comprised 221 prosthetic valves (146 aortic, 75 mitral).**

***Results:*** **Based on the characteristics of the ring and the discs, cinefluoroscopy identified 87 single-leaflet and 134 bileaflet prostheses. Disc motion allowed distinction to be made between normal and dysfunctional prostheses (opening angle: 74 ± 13° versus 49 ± 18°). Fluoroscopy could not define disc profile or the ring in 6% of aortic valves and in 26% of mitral prostheses. The technique could be used to identify the TriTechnologies and HP-Biplus valves, but could not provide data on prosthetic function due to radiolucency of the discs. Among the 146 aortic prostheses, Doppler echocardiography helped to identify 109 normal valves and 37 dysfunctional valves. Among 75 mitral prostheses, 54 normal and 21 dysfunctional prosthetic valves were identified. When both methods were correlated, the sensitivity, specificity and positive and negative predictive values of fluoroscopy to distinguish normal from malfunctioning prostheses were 83%, 80%, 89%, and 71%, respectively.**

***Conclusion:*** **Each prosthesis type has radioscopic characteristics that allow its identification. Fluoroscopy permitted rapid and easy evaluation of mechanical prosthetic valve function, and in most cases allowed a distinction to be made between normal and dysfunctional prostheses. The presence of high gradients by Doppler echocardiography, with normal opening angles by fluoroscopy, and without pannus on transesophageal echocardiography, is indicative of patient-prosthesis mismatch. Fluoroscopy was superior to echocardiography in identifying disc motion, whilst Doppler study allowed the measurement of gradients and areas, and semiquantification of regurgitation. Thus, cinefluoroscopy rapidly provides valuable information which is complementary to that obtained by echocardiography.**

The Journal of Heart Valve Disease 2005;14:664-673

Although today both mechanical and biological prostheses are used in cardiac valve replacement, mechanical valves have in the past been used most frequently, and more than 80 have been designed. Over the years, many of these have been discontinued however, and currently the three main valve designs available are ball-in-cage, tilting-disc (single-leaflet), and bileaflet. In Argentina, the 13 types of disc prosthesis assessed most frequently with echocardiography include five tilting-disc valves (Björk-Shiley, Sorin, Omniscience, Medtronic Hall, and Bicer) and eight bileaflet prostheses (St. Jude Medical, CarboMedics, ATS, Sorin Bicarbon, On-X, Jyros, TriTechnologies, and HP-Biplus).

A lack of guidelines for the identification and fluoroscopic evaluation of prostheses makes it difficult for echocardiographers to become familiar with the valves' characteristics. The aims of the present study

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were to: (i) describe the fluoroscopic characteristics that allow the identification of each prosthesis; (ii) evaluate prosthetic function by comparing the gradients measured by Doppler echocardiography to the disc opening angles by cinefluoroscopy; and (iii) assess the ability of cinefluoroscopy to distinguish normal from dysfunctional prostheses.

## Clinical material and methods

### Patient population

The patient population comprised consecutive patients who had been implanted with mechanical disc valve prostheses in either the aortic or mitral position at different medical centers throughout Argentina. All patients subsequently attended the Echocardiography Laboratory of the Argerich Hospital and the Bazterrica Clinic in Buenos Aires. Echocardiographic evaluation was performed between three months and 15 years after the initial valve replacement, and cinefluoroscopy within 20 days of the echocardiogram.

### Definitions

Prosthetic dysfunction was defined by echocardiography as the presence of a peak gradient >42 mmHg for aortic prostheses, an area <1.5 $cm^2$ in mitral prostheses, or the presence of moderate to severe regurgitation (1).

Fluoroscopically, prosthetic dysfunction was defined as the finding of a limitation to disc opening greater than 10% of the normal value reported by the manufacturer.

In order to document malfunction of the prosthetic valves, either transesophageal echocardiography (TEE) or direct observation of the valve in the operating room was utilized.

### Echocardiography

Echocardiographic studies were carried out using Sonos 1000 and 2000 (Hewlett-Packard) and Apogee 200 equipment, fitted with 2.5 MHz transducers for two-dimensional (2-D) echocardiography and Doppler (pulsed, continuous-wave (CW) and color-Doppler), and with a 2 MHz non-imaging transducer for CW Doppler.

2-D echocardiography was performed to visualize the prosthesis from different approaches. In order to measure the mean gradient and area in mitral prostheses, CW Doppler was used from the apical four-chamber view. For the measurement of peak and mean gradients in aortic prostheses, apical five-chamber, right parasternal and subcostal views were used.

The effective mitral area was calculated using the pressure half-time method. The aortic prosthetic area was not calculated because, since patients with systolic left ventricular dysfunction were excluded from the analysis, a low ventricular gradient indicated normal prosthetic function.

Color Doppler was used to assess regurgitations and their type (either valvular or perivalvular) when the source of turbulent flow was found inside or outside the prosthetic ring.

Transesophageal echocardiography was performed in dysfunctional prostheses, with a 5.0 MHz multiplane probe, using standard views, with particular attention being directed at defining prosthetic valve mobility, structure and the presence of any mass on the valve and adjacent cardiac chamber. The ultrasound intensity of the mass was classified visually as either soft or dense. The motion of the valve was classified as normal or abnormal, depending on whether the motion of the disc(s) of the valve was normal or restricted.

### Cinefluoroscopy

Cinefluoroscopy was performed using either a Siemens Polydoros 100 or an OEC 9.600-C instrument. The patient was placed in the supine position, and anteroposterior (AP), right anterior oblique and left anterior oblique projections were obtained. It was often necessary to use cranial and caudal angulations until the 'lateral projection' was obtained; this was defined as the projection that provided a simultaneous profile of the ring and discs, and allowed accurate measurement of the discs' opening and closing angles (2).

The AP projection was used to identify the Sorin Bicarbon prosthesis, which is unique because of the convexity of its discs.

Once the appropriate projections had been obtained, cinefluoroscopy was recorded at 30 frames per second during three to ten heart beats, and the data were saved in DICOM format. Frames of interest were magnified and printed for angle measurement.

For patients in sinus rhythm, two consecutive heart beats were averaged to calculate the opening angles, whilst for patients in atrial fibrillation five consecutive heart beats were averaged.

The opening angle was defined as the distance between the ring and the disc in its maximum opening (Fig. 1, left and center). Since in standard St. Jude Medical (SJM) prostheses the ring is radiolucent (Fig. 2E and F), the opening angle (Fig. 1, right) was calculated with the formula: [90 - (D/2)], where D represents the angle between open discs. The recent SJM Masters series has a radiopaque ring; hence, its opening angle was measured as in the remaining prostheses (Fig. 2H and I).

Two operators, both of whom were blinded to the

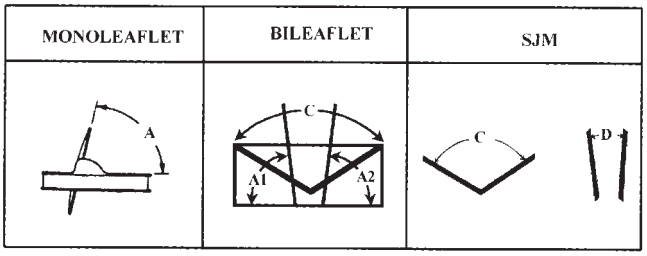


*Figure 1: Measurement of the opening angle in a disc prosthesis. Left: Tilting-disc prosthesis; A: Opening angle. Center: Bileaflet prosthesis with radiopaque ring; C: Closing angle; A1: Left disc opening angle; A2: Right disc opening angle. Opening angle in bileaflet prosthesis = [(A1+A2)/2]. Right: Prosthesis with radiolucent ring (SJM); C: Closing angle; D: Angle between the two open discs. Opening angle of a SJM prosthesis = [90 - (D/2)].*

Doppler echocardiography results, and unaware of the brand of the prosthesis, performed the cinefluoroscopy investigations.

Accurate identification of the type of prosthesis was feasible in all patients.

**Statistical analysis**

Results were expressed as mean ± SD, or as proportions. An analysis of discrete variables was performed using the chi-squared test or Fisher's exact test. Continuous variables were compared using Student's *t*-test for paired data.

Sensitivity, specificity and positive and negative predictive values were calculated to assess the ability of cinefluoroscopy to identify dysfunctional prostheses. To evaluate the correlation between the prosthetic data

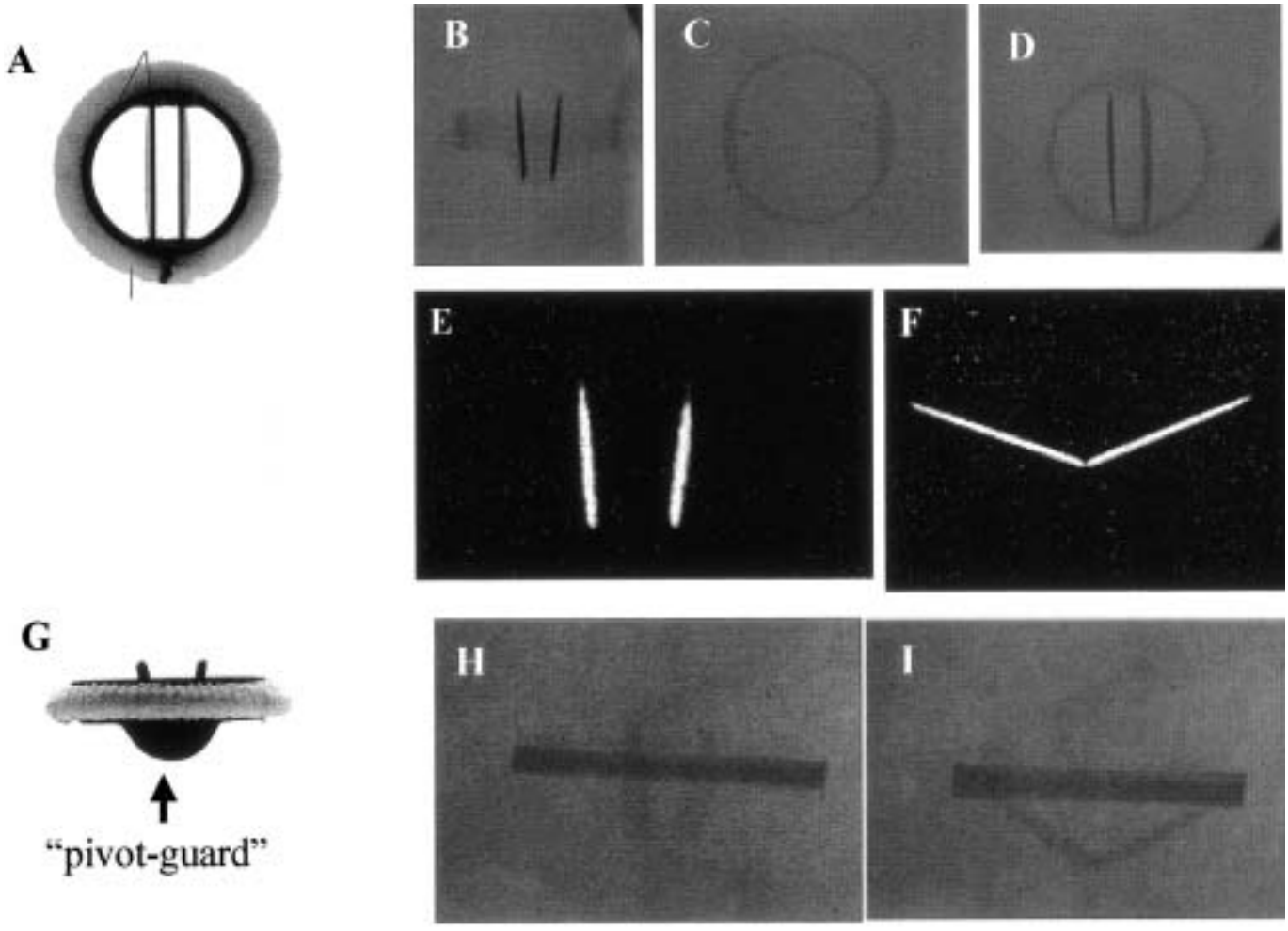


*Figure 2: The St. Jude Medical (SJM) prosthesis. A) Anteroposterior view, standard SJM valve. B-D) Fluoroscopy of an explanted standard SJM valve. The lateral view shows the ring and open radiopaque discs (B). Anteroposterior view with closed (C) and open discs (D). Fluoroscopic evaluation of the explanted prosthesis shows slight radiopacity of the ring with its classic 'pivot guard'. Post-implantation, the ring is not visualized (it is radiolucent). Note that the discs are more radiopaque than the ring, which also allows them to be radiopaque once the valve has been implanted. E) Lateral fluoroscopic view of a patient with a SJM valve implanted in the aortic position with a radiolucent ring and the open (E) and closed (F) radiopaque discs. G: Lateral view, SJM, Masters Series. H,I) Lateral fluoroscopic view of a patient with a SJM valve, Masters Series, implanted in the aortic position. The radiopaque ring, and the open (H) and closed (I) discs are visualized.*

by Doppler echocardiography (gradient or the valve area), and the disc-opening angle by fluoroscopy, correlation and simple regression tests were used. A p-value <0.05 was considered to be statistically significant.

## Results

A total of 229 mechanical disc prostheses was studied; of these, eight were excluded (six aortic, two mitral) due to the coexistence of severe systolic left ventricular dysfunction. Hence, the final analysis comprised 221 prosthetic valves (146 aortic, 75 mitral), in 207 patients (121 men, 86 women; mean age 59 ± 14 years). Among these patients, 143 were in sinus rhythm and 64 in atrial fibrillation.

The average prosthesis size was 22 mm for aortic valves, and 28 mm for mitral. The single-leaflet prostheses included 48 Omniscience, 11 Sorin, 13 Björk-Shiley, 12 Medtronic Hall and three Bicer. The bileaflet prostheses included 46 SJM, 22 CarboMedics, 18 Sorin Bicarbon, 24 TriTechnologies, eight HP-Biplus, 10 ATS, four On-X and two Jyros.

### Echocardiography

***Detection of the type of prosthesis***

Since the discs in bileaflet prostheses protrude 3-5 mm from the ring, they can be seen as being parallel in diastole in mitral prostheses, or in systole in aortic prostheses.

In the 75 mitral prostheses, the leaflets were frequently (85%) identified in diastole separated by an echo-free space. This was easier when the surgeon performed the implant in an anatomical position (an anterior and a posterior disc), whereas in non-anatomical implants or in those in intermediate positions their recognition became more difficult.

Among the 146 aortic prostheses, the opening motion allowed identification of the separate leaflets in only one-fourth of the cases.

The prosthesis model could not be distinguished by 2-D echocardiography in any of the patients.

### Prosthesis function

Among the 146 aortic prostheses, 109 were normal and 37 dysfunctional. In the valves with normal prosthetic function (Table I), the peak and mean gradients were 23.7 ± 9.9 mmHg and 13.5 ± 6.3 mmHg, respectively.

Aortic prosthetic regurgitation was mild in 35 cases (24%), moderate in one case (0.7%), and severe in five cases (3.4%). Peri-prosthetic regurgitation, when detected, was mild in three patients (2%) and severe in two (1.4%).

Among the 75 mitral prostheses, 54 were normal and 21 dysfunctional. In those valves with normal prosthetic function (Table II), the mean gradient and effective prosthetic area were 5.2 ± 2.2 mmHg and 2.2 ± 0.5 $cm^2$, respectively. Prosthetic mitral regurgitation was mild in four cases (5.3%) and moderate in two (2.7%). Mild peri-prosthetic regurgitation was identified in three patients (4%), and moderate in one patient (1.3%).

When correlated to the Doppler echocardiography findings, sensitivity, specificity, positive predictive value and negative predictive value of fluoroscopy to distinguish normal from dysfunctional prostheses were 83%, 80%, 89%, and 76%, respectively.

*Table I: Normal aortic prostheses (n = 109).*

| Prosthesis | Peak gradient (mmHg) | Mean gradient (mmHg) | Opening angle (º) |
|---|---|---|---|
| Tilting-disc prostheses | | | |
| Björk-Shiley (n = 5) | 21.6 ± 8.5 | 12.2 ± 7.7 | 66.5 ± 6.0 |
| Sorin single tilting disc (n = 5) | 32.0 ± 9.6 | 19.0 ± 5.0 | 48.7 ± 15.4 |
| Omniscience (n = 7) | 35.8 ± 6.4 | 20.3 ± 4.1 | 40.2 ± 6.2 |
| Medtronic Hall (n = 5) | 22.3 ± 2.7 | 12.7 ± 1.5 | 72.0 ± 8.7 |
| Bicer (n = 2) | 13.5 ± 6.0 | 9.0 ± 8.5 | 65.5 ± 3.5 |
| Bileaflet prostheses | | | |
| SJM (n = 26) | 23.2 ± 9.7 | 12.5 ± 5.8 | 80.2 ± 6.2 |
| CarboMedics (n = 16) | 25.4 ± 9.1 | 15.2 ± 5.7 | 80.0 ± 5.7 |
| Sorin Bicarbon (n = 8) | 16.2 ± 5.6 | 9.7 ± 3.9 | 80.0 ± 1.4 |
| ATS (n = 8) | 23.3 ± 11.4 | 12.1 ± 6.7 | 74.9 ± 6.4 |
| TriTechnologies (n = 14) | 22.6 ± 12.3 | 11.8 ± 6.9 | Radiolucent discs |
| HP-Biplus (n = 4) | 31.5 ± 9.5 | 23.2 ± 11.0 | Radiolucent discs |
| On-X (n = 3) | 13 ± 1 | 7.3 ± 0.6 | 80.8 ± 1.4 |
| Jyros (n = 1) | 23.5 ± 12.1 | 11.9 ± 6.7 | Poor radiopacity |
| Mean ± SD | 23.7 ± 9.9 | 13.5 ± 6.3 | 73.5 ± 12.7 |

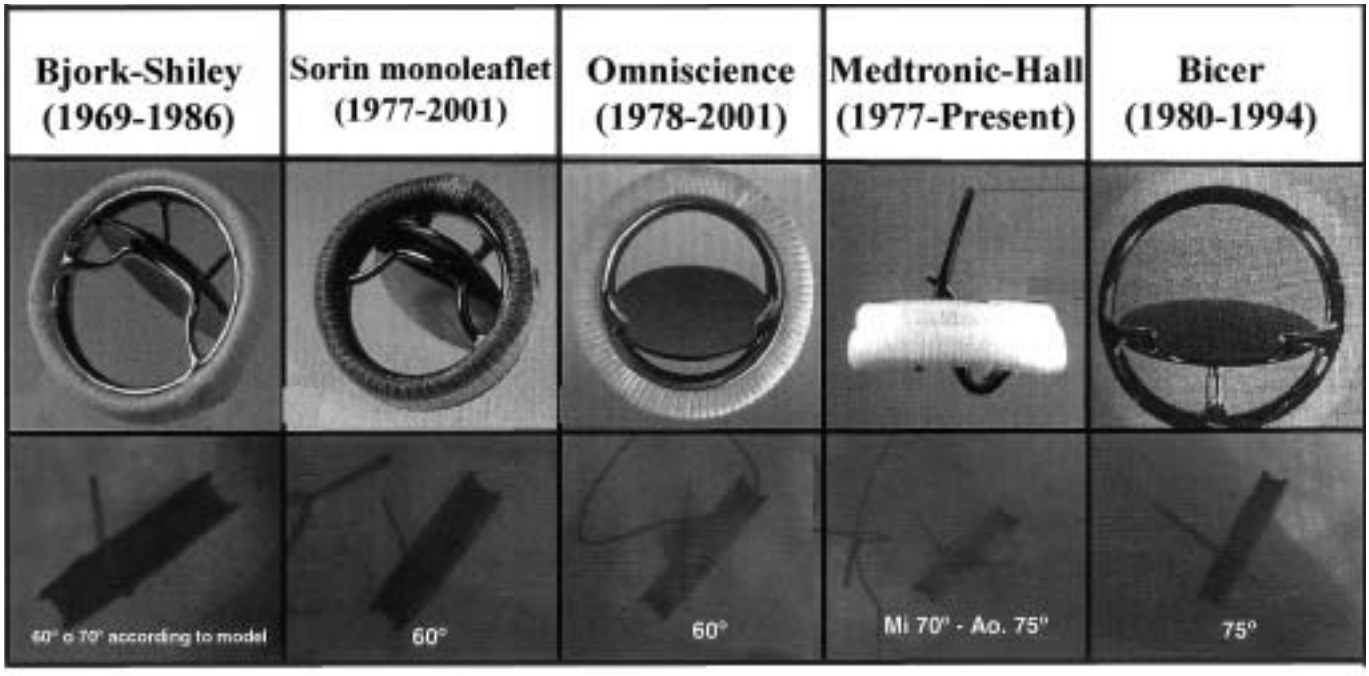


*Figure 3: A quick guide to fluoroscopic identification of tilting-disc prostheses. Upper (in parentheses): The year of the first implant and when manufacturing was discontinued. Lower: Normal opening angle as informed by the manufacturer. The Medtronic Hall is the only tilting-disc prosthesis still marketed in Argentina.*

**Cinefluoroscopy**

Due to the variable orientation in which the surgeon implanted the prostheses, lateral projection (which allows for functional assessment) was not feasible in 20 of 75 mitral prostheses (26.7 %), nor in 10 of 146 aortic prostheses (6.9%).

**Tilting-disc prostheses**

***Björk-Shiley***

Björk-Shiley prostheses manufactured up until 1975 had radiolucent discs, but these were later replaced with radiopaque discs. The radiopaque ring has two struts welded to it, one of which protrudes slightly over the edge of the ring and is useful for achieving a

*Table II: Normal mitral prostheses (n = 54).*

| Prosthesis | Mean gradient (mmHg) | Area ($cm^2$) | Opening angle (º) |
|---|---|---|---|
| Tilting-disc prostheses | | | |
| Björk-Shiley (n = 5) | 4.2 ± 2.0 | 2.3 ± 0.7 | 64.5 ± 15.0 |
| Sorin single tilting disc (n = 3) | 4.3± 0.6 | 1.9 ± 0.3 | 70.0 ± 14.1 |
| Omniscience (n = 7) | 7.7 ± 2.0 | 2.1 ± 0.2 | 44.0 ±13.2 |
| Medtronic Hall (n = 4) | 4.9 ± 1.6 | 1.82 ± 0.3 | 71.0 ± 8.9 |
| Bicer (n = 1) | 3 | 1.7 | 82 |
| Bileaflet prostheses | | | |
| SJM (n = 10) | 5.0 ± 2.1 | 2.2 ± 0.6 | 82.8 ± 2.8 |
| CarboMedics (n = 4) | 5.7 ± 3.8 | 2.5 ± 0.8 | 82.0 ± 0.7 |
| Sorin Bicarbon (n = 7) | 4.7 ± 1.4 | 2.2 ± 0.3 | 77.9 ± 1.4 |
| ATS (n = 1) | 4 | 1.83 | 66 |
| TriTechnologies (n = 7) | 5.4 ± 1.0 | 3.0 ± 1.4 | Radiolucent discs |
| HP-Biplus (n = 2) | 7 | 1.5 | Radiolucent discs |
| On-X (n = 1) | 6 | 3.3 | - |
| Mean ± SD | 5.2 ± 2.2 | 2.2 ± 0.5 | 71.6 ± 13.2 |

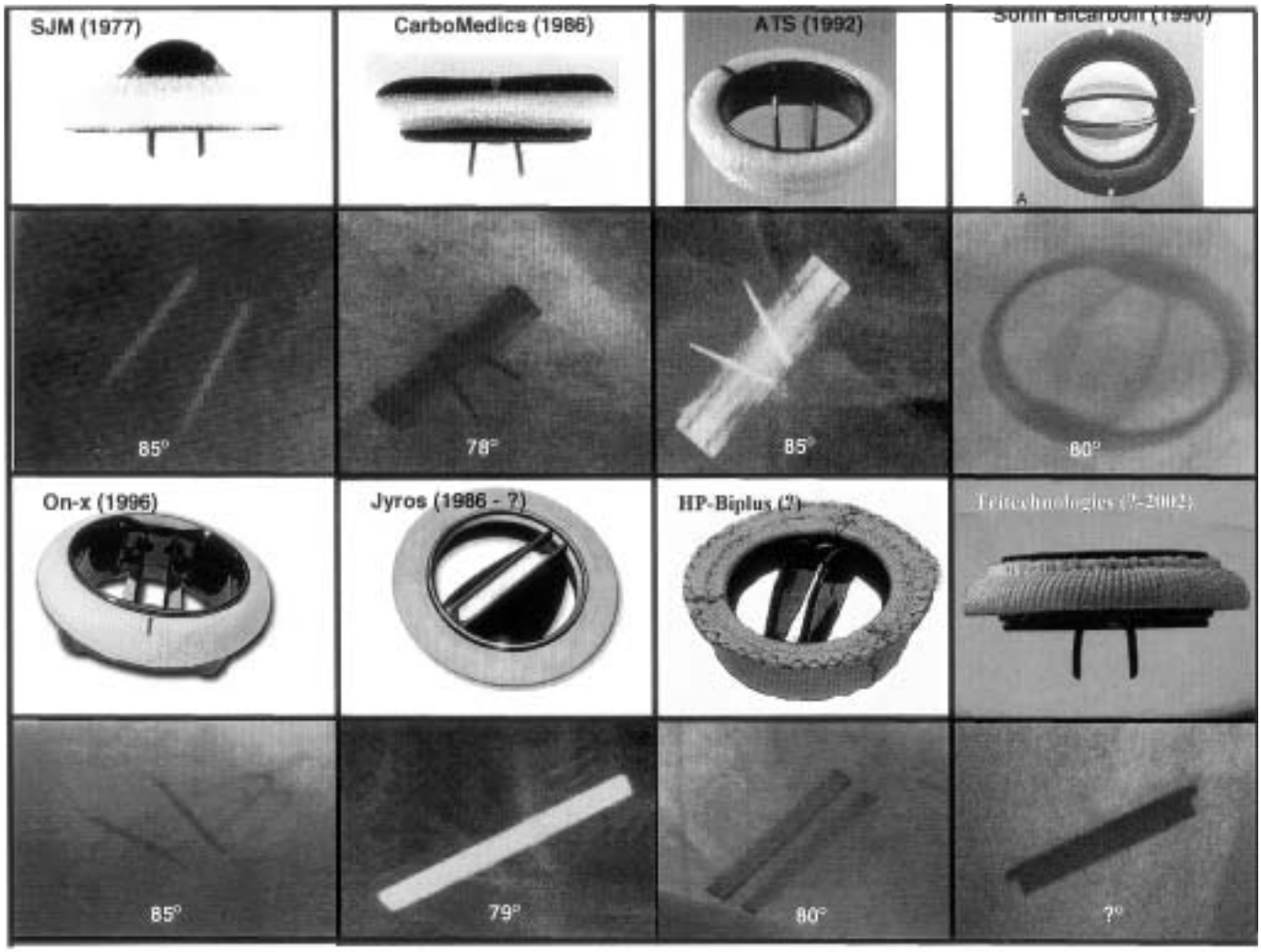


*Figure 4: A quick guide to fluoroscopic identification of bileaflet prostheses. Upper: Above each prosthesis (and in parentheses) is indicated the year of the first implant and, in discontinued models, the year when manufacturing was discontinued. Lower: Normal opening angle as informed by the manufacturer. Note that the discs of the HP-Biplus and Tri-technologies are radiolucent on the lateral view.*

fluoroscopic profile, in which the two struts should overlap. The disc has a characteristic radiopaque rim which, in the lateral view, is seen as one line. Prostheses manufactured up until 1981 had a normal opening angle of 60°, whereas those manufactured after this time had a 70° angle.

A total of 13 Björk-Shiley prostheses was studied (six aortic, seven mitral). Of the six aortic prostheses, five were normal (Table I), while the mean opening angle was 66.5 ± 6.0º. One patient had an asymptomatic prosthetic dysfunction due to moderate stenosis.

Of the seven mitral prostheses, five were normal (Table II). One normal valve could not be correctly aligned for measurement, but in the other four the mean opening angle was 64.5 ± 15º. Two patients had symptomatic severe mitral prosthetic stenosis, and one of these is currently awaiting surgery. The other patient was in NYHA functional class III-IV; fluoroscopy showed an opening angle of 10º, and the Doppler study revealed a mean gradient of 24 mmHg and an area of 0.4 $cm^2$. After thrombolytic therapy with streptokinase (2,500,000 IU bolus plus 100,000 IU/h during 10 h), the patient increased her diuresis and blood pressure without inotropic support, and the prosthetic closing click reappeared on auscultation. Later, fluoroscopy showed an opening angle of 40º, whilst Doppler showed a reduction of the mean gradient to 2 mmHg. This improved hemodynamic status permitted the patient to undergo surgery.

***Sorin Single Tilting Disc***

In the Sorin valve, the ring and disc are both radiopaque, with a fluoroscopic design that is similar to that of the Björk-Shiley valve, and with an opening angle of 60º (Fig. 3).

Of the 11 prostheses studied, eight were aortic and

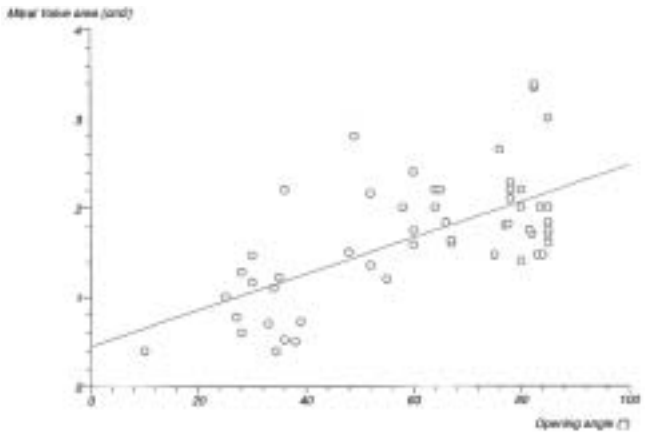

*Figure 5: Mitral prostheses. Correlation between the opening angle (fluoroscopy) and the effective prosthetic area (Doppler echocardiography). r = 0.64 (95% CI 0.45-0.77); p <0.0001.*

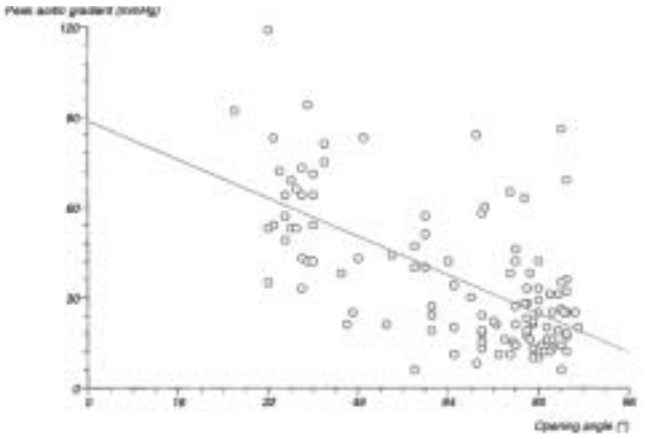

*Figure 6: Aortic prostheses. Correlation between the opening angle (fluoroscopy) and the peak gradient (Doppler echocardiography). r = 0.63 (95% CI 0.51-0.73); p <0.0001.*

three were mitral (Table II). The opening angle of the mitral valve was 56.6 ± 6.1º. One mitral valve could not be correctly aligned for measurement, but in the other two valves the opening angle was 70.0 ± 14.1º.

Among the aortic prostheses, three were dysfunctional with high gradients, although the patients remained asymptomatic.

***Omniscience***

The Omniscience ring is made from titanium and has a pivot-guard on both sides, which is used to overlap them in the lateral view and hence allow their identification with fluoroscopy (Fig. 3).

A total of 48 Omniscience valves was studied (31 aortic, 17 mitral). A 60º opening (as reported by the manufacturer) was an extremely unusual finding. Most of these valves (78%) were dysfunctional, due to either moderate or severe stenosis, and half of the patients were symptomatic; five are currently awaiting surgery, seven required reoperation, and one patient died.

Surgical and pathological results showed the underlying cause of malfunction to be thrombus in three cases, pannus formation in three, and combined thrombus/pannus in one case. In all of these patients the surgeon replaced the valve with another type of prosthesis.

Among the aortic prostheses with normal gradients (Table I), most had a restricted disc opening (40.2 ± 6.2º). The seven normal mitral valves (Table II) had an opening angle of 44.0 ± 13.2º. Only two mitral prostheses had an opening angle greater than 54º.

Two mitral prostheses could not be correctly aligned for opening angle measurement.

***Medtronic Hall***

In this valve the ring is radiopaque and the strut is 'S'-shaped, which allows its fluoroscopic identification (see Fig. 3). The disc is also radiopaque, and the opening angle reported by the manufacturer is 70º for mitral prostheses and 75º for aortic prostheses.

A total of 12 Medtronic Hall valves was studied (six aortic, six mitral). Of the six aortic valves, five were normal (Table I), with an opening angle of 72.0 ± 8.7º. The remaining prosthesis was severely stenosed, but the patient was not symptomatic.

Among the six mitral prostheses, two were dysfunctional due to moderate to severe restriction to opening; these patients were asymptomatic, and are currently under close follow up. The remaining four prostheses were normal (Table II), with a mean opening angle of 71.0 ± 8.9º.

***Bicer***

In the Bicer valve the ring is radiopaque, and there are two small protrusions and an arm, which retains the disc. The disc is also radiopaque, and opens at 75º. In the anteroposterior view, this valve can be distinguished from the Björk-Shiley due to its single strut. Other differences from the Björk-Shiley valve are that, in the lateral view, the strut of the Bicer valve does not exceed the ring; likewise, its disc exceeds both edges of the prosthetic ring (see Fig. 3).

A total of three Bicer valves was studied (two aortic, one mitral). All valves had normal function (Table I), and the disc could be aligned appropriately with a mean opening angle of 65.5 ± 3.5º.

**Bileaflet prostheses**

***St. Jude Medical***

This valve can be distinguished because its ring is not radiopaque, and only the discs are seen, moving like 'butterfly wings' (Fig. 4): in the lateral view, they

are seen as a 'V' when the valve is closed, and as two lines that are almost parallel when it is open. The disc opens at 85º with respect to the ring's plane. Seen from the anterior view, the discs appear as two lines (see Fig. 2D), which are almost parallel, and these disappear when closed (see Fig. 2C).

The Masters series from SJM has a radiopaque ring, and the discs remain suspended, further away from the ring's plane (see Fig. 2H and I) because, in contrast to other bileaflet valves, it has a higher pivotal point.

A total of 46 SJM valves was studied (31 aortic, 15 mitral). The aortic prostheses with normal function (Table I) had an opening angle of 80.2 ± 6.2º.

Normal mitral prostheses (Table II) had an opening angle of 82.8 ± 2.8º. Three mitral and two aortic prostheses could not be aligned for the fluoroscopic analysis.

There were five aortic and four mitral valves with moderate or severe stenosis. Two patients with aortic SJM Master #21 prostheses developed asymptomatic 'mismatch' with high peak and mean gradients of 74 ± 16 and 41 ± 13 mmHg, respectively. On fluoroscopy, the opening angle measured was normal (80 ± 4º), and TEE allowed pannus formation to be ruled out in both patients. One aortic prosthetic valve was not analyzed due to severe regurgitation.

In two patients with mitral prosthetic valves and inadequate anticoagulation, TEE showed prosthetic thrombosis. One patient required surgery, and the other was treated with fibrinolytic drugs. One patient had severe prosthetic dysfunction for which the cause at surgery was found to be a pannus. The second patient had high gradients due to anemia, but after blood transfusion these were normalized.

***CarboMedics***

This valve has a ring which is reinforced with another titanium ring that confers its radiopacity, characterized by seven concentric circles. The discs open at 78°.

A total of 22 CarboMedics valves was studied (17 aortic, five mitral). The normal aortic prostheses (Table I) had an opening angle of 80.0 ± 5.7º, while the normal mitral prostheses (Table II) had an opening angle of 82.0 ± 0.7º.

One aortic valve was dysfunctional due to moderate stenosis, but the patient was asymptomatic. In one aortic and one mitral valve, the discs could not be aligned during fluoroscopy.

***Sorin Bicarbon***

In this valve, the ring, struts and discs are radiopaque. In frontal view, its distinctive characteristic is a curved profile, which separates the valve orifice in similar sections (Fig. 4). In lateral view, the opening angle measures 80º.

A total of 18 Sorin Bicarbon valves was studied (nine aortic, nine mitral). Normal aortic prostheses (Table I) had an opening angle of 80.0 ± 1.4º, while normal mitral valves (Table II) had an opening angle of 77.9 ± 1.4º. Two mitral prostheses could not be adequately aligned for angle measurement. One patient with a #21 aortic valve developed an asymptomatic 'mismatch', with peak and mean gradients of 100 and 65 mmHg, respectively. On fluoroscopic examination, an opening angle of 78º was found, and TEE eliminated the presence of pannus formation.

Two mitral prostheses were dysfunctional due to asymptomatic moderate stenosis.

***ATS***

The appearance of this valve is similar to that of the CarboMedics (see Fig. 4). It has a titanium ring with greater radiopacity, whilst in its center there is a horizontal slot through which passes the wire that allows its rotation. The discs open at 85º.

A total of 10 ATS valves was studied (nine aortic, one mitral). Among the aortic prostheses, only eight were analyzed as the ninth valve had severe perivalvular regurgitation.

In the normal aortic prostheses (Table I) the opening angle was 74.9 ± 6.4º, whereas in the sole mitral prosthesis (Table II) the opening angle was 66.0º.

***TriTechnologies***

This valve can be distinguished with fluoroscopy by the presence of two adjacent radiopaque rings, one being longer than the other (see Fig. 4). In the smaller ring there is a small, vertical slot.

Fluoroscopy does not provide functional information because the discs are radiolucent. The only way of visualizing the discs was by fluoroscopic analysis of a previously explanted valve.

A total of 24 TriTechnologies valves was studied (16 aortic, eight mitral). Two of the aortic valves were dysfunctional, one due to severe stenosis and the other due to severe regurgitation. One patient with a mitral prosthesis had severe stenosis (area 0.9 $cm^2$) and moderate regurgitation, and is currently awaiting surgery.

Three patients in whom an attempt was made to implant this prosthesis were excluded from the statistical analysis, because during surgery the valve had to be replaced with another prosthesis. In these three patients one disc became detached - in two cases before implantation, and in the third case during post-implant rotation.

***HP-Biplus***

In the lateral fluoroscopic view, two thick, symmetric and parallel rings are seen, separated by a radiolucent ring (Fig. 4). The gradients of normal aortic prostheses

are listed in Table I.

One mitral prosthetic valve was dysfunctional due to severe stenosis, while the other had a mean gradient and area of 7.0 mmHg and 1.5 $cm^2$, respectively.

In the lateral view, fluoroscopy does not provide functional information because the discs are radiolucent. However, the frontal view shows the discs as two parallel lines that are slightly radiopaque.

A total of eight HP-Biplus valves was studied (six aortic, two mitral). Two of the aortic prostheses were dysfunctional due to severe stenosis, but the patients were asymptomatic.

***On-X***

This valve is identified on fluoroscopy because in the lateral view the ring is seen as two thin parallel rings (see Fig. 4). The discs are radiopaque and open at 85°.

On 'in-vitro' fluoroscopy, in the aortic prosthesis two fine lines form the ring and the discs exceed both edges of the ring. In the mitral prosthesis, the ring is seen as two thick lines and the discs exceed only one edge of the ring.

A total of three On-X aortic valves was studied (Table I); on fluoroscopy, the opening angle was 80.8 ± 1.4º.

In addition, one mitral valve was studied which had a gradient of 6.0 mmHg and an area of 3.3 $cm^2$. The opening angle could not be measured because it was impossible to profile the discs appropriately.

***Jyros***

This valve can be distinguished because its radiopaque ring is thinner than that of the ATS and CarboMedics valves. The discs open at 79°, but their slight radiopacity makes fluoroscopy difficult (see Fig. 4).

Two aortic Jyros valves were studied; one valve was normal, while the other valve had moderate stenosis (gradients of 63 and 42 mmHg). The discs could not be adequately profiled due to their poor radiopacity.

**Correlation between Doppler echocardiography and fluoroscopy**

In the mitral prostheses, the mean opening angle was 61.4 ± 22.7º, the effective prosthetic area was 1.7 ± 0.7 $cm^2$, and the correlation between them was r = 0.64 (95% CI 0.45-0.77), p <0.0001 (Fig. 5).

In the aortic prostheses, the mean opening angle was 65.8 ± 18.4º, the peak gradient was 35.9 ± 23.2 mmHg, and the correlation between them was r = 0.63 (95% CI 0.51-0.73), p <0.0001 (Fig. 6).

## Discussion

The assessment of prosthetic function is essential in order to interpret the clinical status of patients after valve implantation. Before the introduction of echocardiography into clinical practice, cinefluoroscopy was used for many years to evaluate prosthetic valves.

Although, today, echocardiography is used routinely for the functional evaluation of prostheses, it has certain limitations that may be complemented with information provided by fluoroscopy (3). For example, echocardiography is unable to identify the type of disc prosthesis implanted, and very often the reverberations produced by the valve's metallic components do not allow differentiation to be made between a single disc and a double leaflet valve. In Argentina, most patients are unaware of the type of prosthesis that they have received.

The best demonstration of this complementary value of echocardiography and fluoroscopy is the diagnosis of 'mismatch' (4). In patients who have undergone aortic valve replacement, in whom high gradients have been identified by Doppler, and in whom TEE has ruled out the presence of pannus, fluoroscopy with a normal opening angle allows a diagnosis to be made of prosthesis-patient mismatch. In the present study, mismatch was seen in only three of 146 aortic prostheses (2.4%), and all were size #21 mm.

Fluoroscopy is a rapid and simple method for identifying and evaluating the function of different types of disc prosthesis. It can also be used to detect prosthetic dysfunction at an early stage, even in the absence of echocardiographic abnormalities (5). Up to 24% of patients with prosthetic thrombosis have been reported to have a non-diagnostic ('silent') Doppler that may in fact be identified using fluoroscopy (1). This occurred more frequently in patients with bileaflet valves (33%) than in those with single tilting-disc valves (10%), and may reflect the patients' better tolerance to prosthesis obstruction. Since Doppler echocardiography is used as the 'gold standard' for normal valve function, this phenomenon might explain why the sensitivity and specificity of fluoroscopy are not higher. These results may be different, however, if TEE had been used as the 'gold standard' for normal prostheses.

Although several reports were made some years ago about the radioscopic appearance of certain prostheses (3,6-8), until now there have been no reports of any fluoroscopic images of prostheses implanted in Argentina (9). Moreover, when the manufacturers' web pages are searched for images, the information is generally not available.

The present report, together with a guide for quick fluoroscopic identification of mechanical disc prostheses (see Figs. 3 and 4) should provide a useful tool for echocardiographers (9). Taking into account the normal opening values of the discs, lower values would suggest prosthetic dysfunction due to thrombosis or pannus.

Although pannus less frequently limits the opening of prosthetic discs (10), in those patients with an aortic prosthetic valve and high gradients, if TEE eliminates the existence of pannus, then normal fluoroscopy will identify prosthesis-patient mismatch.

Fluoroscopy allows the functional evaluation of mechanical prostheses, provided that the lateral projection obtained is technically adequate. Following an initial learning stage, this can be achieved with the majority of prostheses. In the present study, those bileaflet prostheses which, in spite of an inadequate profile, had parallel discs in the anteroposterior view were considered normal. Hence, the evaluation failed in only 6.9% and 26.7% of the aortic and mitral prostheses, respectively, and these values were of similar magnitude to those reported by others (8).

In the present report, each prosthesis was shown to have distinctive fluoroscopic characteristics that permit its rapid identification. In addition, fluoroscopy is very useful in the functional evaluation of prostheses with radiopaque discs, although it cannot provide functional information in prostheses with radiolucent discs (Tri-technologies and HP-Biplus) or in those that are barely radiopaque (Jyros).

Doppler echocardiography allows the measurement of gradients and prosthetic area, and also provides a semiquantification of regurgitation. During the postoperative follow up of prostheses, fluoroscopic evaluation provides complementary information to that obtained with echocardiography.

**Study limitations**

A lack of cases for three prostheses (Bicer, Jyros and On-X), because they are infrequently used in Argentina, was a major limitation, as was the poor disc radiopacity in the Jyros, HP-Biplus and TriTechnologies valves, as this hindered their functional evaluation. A further problem was that TEE was not used as the 'gold standard' to monitor normal prosthetic function. In addition, whilst the surgeon decided upon prosthetic orientation in order to optimize the anatomic outcome, this hindered fluoroscopic evaluation, although in general it was possible to measure the opening angle in most valves.

*In conclusion*, the design of each prosthesis model incorporates radioscopic characteristics that allow for its precise identification. In this respect, fluoroscopy provides a rapid and easy assessment of the function of mechanical prostheses and, in most patients, allows a distinction to be made between normal and dysfunctional valves. In patients with prosthetic aortic valves, after eliminating the presence of pannus with TEE, the presence of high gradients by Doppler echocardiography and a normal opening angle by fluoroscopy is indicative of prosthesis-patient mismatch. Fluoroscopy is superior to echocardiography in identifying disc motion, whilst Doppler provides measurement of gradients and areas, and semi-quantification of regurgitation. Thus, fluoroscopy provides rapid and valuable information that is complementary to that provided by echocardiography.

**References**

1. Montorsi P, De Bernardi F, Muratori M, et al. Role of cine-fluoroscopy, transthoracic and transesophageal echocardiography in patients with suspected prosthetic heart valve thrombosis. Am J Cardiol 2000;85:58-64
2. Björk VO, Henze A, Hindmarsh T. Radiopaque marker in the tilting disc of the Björk-Shiley heart valve. Evaluation of in vivo prosthetic valve function by cineradiography. J Thorac Cardiovasc Surg 1977;73:563-569
3. Butany J, Ahluwalia MS, Munroe C, et al. Mechanical heart valve prostheses. Identification and evaluation. Cardiovasc Pathol 2003;12:1-22
4. Pibarot P, Dumesnil JG. Hemodynamic and clinical impact of prosthesis-patient mismatch in the aortic valve position, and its prevention. J Am Coll Cardiol 2000;36:1131-1141
5. Gueret P, Vignon P, Fournier P, et al. Transesophageal echocardiography for the diagnosis and management of nonobstructive thrombosis of mechanical valve prosthesis. Circulation 1995;91:103-110
6. Morse D, Steiner RM, Fernandez J. Cardiac valve identification atlas and guide. In: Dryden Morse RM, Sa JF (ed.). Guide to prosthetic cardiac valves. Springer-Verlag, New York, 1985:257-346
7. Aoyagi S, Kawara T, Fukunaga S, et al. Cineradiographic evaluation of ATS open pivot bileaflet valves. J Heart Valve Dis 1997;6:258-263
8. Montorsi P, Cavoretto D, Repossini A, et al. Valve design characteristics and cine-fluoroscopic appearance of five currently available bileaflet prosthetic heart valves. Am J Card Imaging 1996;10:29-41
9. Cianciulli TF, Lax JA, Cerruti FE, et al. Cinefluoroscopic characteristics of the twelve different types of mechanical valve prostheses implanted in Argentina. Echocardiography 2004;21:211
10. Nakatani S, Andoh M, Okita Y, et al. Prosthetic valve obstruction with normal disc motion: Usefulness of transesophageal echocardiography to define cause. J Am Soc Echocardiogr 1999;12:537-539