Prosthetic Valves

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Introduction

An echocardiographer who is skilled at assessing prosthetic valves with TEE is in position to significantly impact patient care. TEE is critical in the diagnosis of prosthetic valve dysfunction due to endocarditis, thrombosis, dehiscence, or mechanical failure. Unfortunately, prosthetic valve assessment is challenging for even the best echocardiographers. Not surprisingly, it is frequently the last component of the echo exam to be mastered. It is challenging both because there are so many different valve types and because materials used in valve construction create troubling acoustic shadows and reverberation artifacts. These challenges can be overcome, however, if an echocardiographer can meet three important objectives.

First, the echocardiographer should develop a thorough understanding of the structure and mechanism of each of the commonly used prosthetic valves. Acquiring this understanding requires reading, of course, but more importantly, it requires hands-on examination of prosthetic valve samples. The best way to understand prosthetic valves is to inspect each one carefully. Study the opening and closing mechanism. Having this background knowledge will accelerate the rate at which each valve's echo characteristics are understood.

Second, the echocardiographer needs to develop a systematic examination for each prosthetic valve. The exam must include the appropriate views that will circumvent the acoustic shadows that most prosthetic valves cast. In addition, the exam should include the use of zoom and slow motion replay, both invaluable functions to detect prosthetic valve dysfunction.

Third, to become an expert at assessing prosthetic valve dysfunction, the echocardiographer should always compare the TEE findings with the surgical findings. This is easy for the anesthesiologist and certainly possible for the cardiologist. Looking over the surgeon's shoulder to see the valve as it is extracted is a grand learning opportunity not gleaned by enough echocardiographic initiates.

Table 1

Prosthetic Valve Classification

Mechanical Valves

- Bileaflet valve
  - St. Jude
  - Carbomedics
- Monoleaflet valve
  - Medtronic-Hall
  - Bjork-Shiley
- Ball-Cage valve
  - Starr-Edwards

Stented Tissue Valves

- Porcine aortic valve
  - Carpentier-Edwards
  - Hancock II
  - Mosaic
- Pericardial valve
  - Carpentier-Edwards

Stentless Tissue Valves

- Toronto SPV
- Freestyle

Homograft

- Aortic
- Mitral

Valved Conduit

- St. Jude
- Carbomedics
- Medtronic-Hall

Structure and Mechanism of Prosthetic Valves

The more commonly used prosthetic valves are listed in Table 1, and this section offers pertinent information about each valve. The St. Jude valve consists of an orifice ring, two semicircular leaflets, and a sewing cuff (Fig 1). The two leaflets meet along a line that is outside of the orifice ring. Two "pivot guards" are located on each side of the leaflet closure line and are designed to protect the leaflets. When closed, the leaflets lie at a 30-degree angle to the plane of the orifice. When open, their position is 80 or 85 degrees relative to the orifice. The travel arc is therefore approximately 55 degrees. The open leaflets create one central and two lateral orifices through which centrally directed flow occurs.[1] As the leaflets close, a transient regurgitant *closing jet* occurs. While closed, *washing jets* originate at the orifice ring-leaflet interface and the leaflet-leaflet interface.[2]

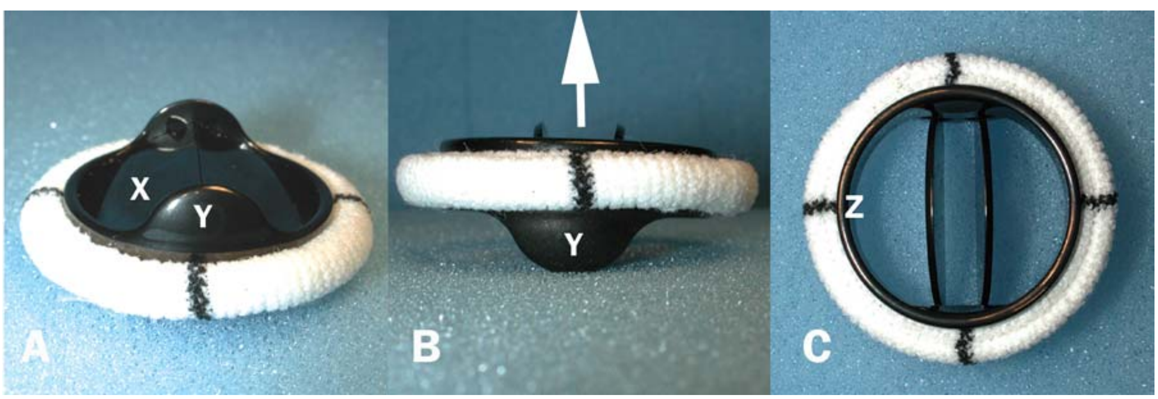

Fig 1: St. Jude mitral valve
Closed leaflets from atrial perspective. X=leaflet, Y=pivot guard. Leaflets coapt above plane of orifice ring at an angle. B. Open leaflets. Arrow defines direction of flow. C. Open leaflets from ventricular perspective. Z=orifice ring surrounded by sewing ring. Note one central and two lateral orifices.

The Carbomedics valve differs slightly from the St. Jude valve (Fig 2). First, the leaflet coaptation line lies within the orifice ring. Thus, pivot guards are absent. Second, the Carbomedics valve has a titanium ring between the orifice ring and the sewing cuff making it more rigid. On the other hand, there are similarities. Both have a high orifice-to-sewing-ring ratio, and both exhibit similar patterns of regurgitant washing jets. The Carbomedics valves and the later models of the St. Jude valve have the advantage of rotatability. That is, after the valve is sewn into the annulus, the leaflets and orifice ring can be rotated for optimal positioning.

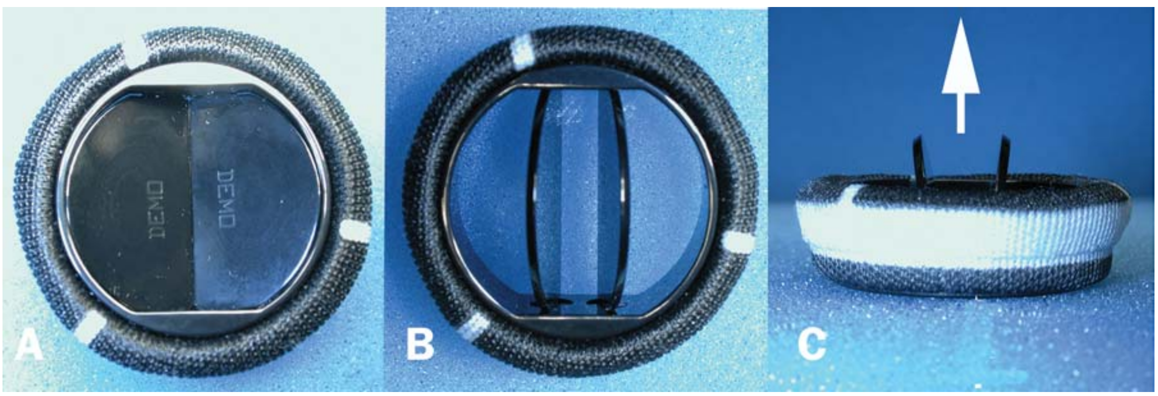

Fig 2: Carbomedics aortic valve
Closed leaflets from aortic perspective. Leaflet coaptation line is within the orifice ring. B. Open leaflets from aortic perspective. C. Arrow defines direction of flow. Note the absence of pivot guards.

Mechanical Valve Regurgitation[2]

All mechanical valves are associated with a small amount of transvalvular regurgitation. When the occluding device of a mechanical valve closes—either the leaflets or the ball—a small amount of blood is forced into the proximal chamber creating the *closing jet*. All mechanical valves have transient closing jets. These closing jets are best appreciated during color Doppler slow motion replay. The bileaflet and single leaflet mechanical valves also have *washing jets*, which are designed to minimize the risk of thrombosis. The jets begin when the valve closes and persist until the valve reopens. Because of its construction, the Starr-Edwards valve does not have washing jets. In Figure 5, light defines where washing jets emanate from a St. Jude and Medtronic-Hall valve. There is no separation between the ball and the orifice ring of a Starr-Edwards valve. Washing jets are easily seen with TEE, and they are useful in determining the valve type and the valve function. Importantly, they always originate within the orifice of the valve.

The Medtronic Hall valve is the most common single tilting disc valve. It consists of an orifice ring, a circular disc with a central aperture, and a sewing cuff (Fig 3). The disc pivots on a central strut and actually elevates slightly as it opens to create a major and minor orifice. The leaflets move from 0 degrees to approximately 75 degrees in the aortic position and 70 degrees in the mitral position during opening. The travel arc is therefore 70 or 75 degrees. The majority of antegrade flow passes eccentrically through the major orifice, the remainder through the minor orifice. Upon closure of the disc, a closing jet is created under the major orifice. While closed, small washing jets originate at the circular disc-ring interface and a larger jet passes through the central aperture. The surgeon has the option of rotating this valve within the sewing ring.

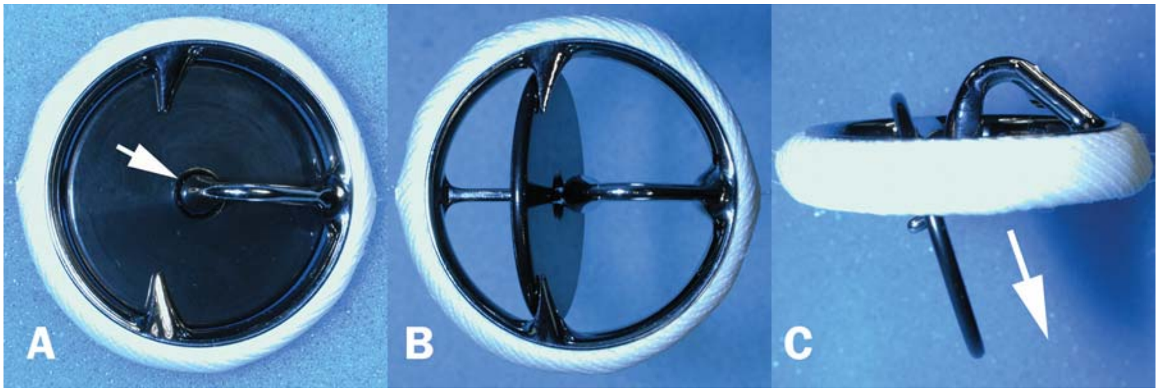

Fig 3: Medtronic-Hall aortic valve
Closed leaflet from ventricular perspective. Arrow defines central aperture with strut. B. Open leaflet. C. Arrow defines direction of flow in the major orifice.

The Bjork-Shiley valve is no longer implanted in the United States, but patients will still present with this valve. Slightly different from the Medtronic-Hall valve, this valve has a tilting disc that is held in place by inflow and outflow C-shaped struts. In early models, the disk only opened to 60 degrees. In an attempt to improve the hemodynamic profile of the valve, the Convexo-Concave model was created. Unfortunately, fractures in the C-shaped outflow struts that hold the disk in place have occurred, and some of these fractures have led to disk embolism and death.[3,4] One way to differentiate the Bjork-Shiley valve from the Medtronic-Hall valve is to assess the regurgitant jets. Because the Bjork-Shiley valve does not have a central aperture, only peripheral jets are seen.

The Starr-Edwards valve is rarely implanted today, but because of its durability, many patients continue to present with this ball-and-cage valve. The orifice ring and stellite alloy cage constrain the up and down motion of a silicone ball (Fig 4). The ball (poppet) moves to the top of the cage during ejection of blood; it returns to rest *directly* on the ring in diastole. Antegrade jets move around the circumference of the ball and then converge downstream of the ball. A transient closing jet can be appreciated. Unlike the other mechanical valves, however, the Starr-Edwards valve does not have washing jets. There are no washing jets due to the direct contact of the poppet with the valve ring (Fig 5). It is not surprising that the expected mean gradients associated with this valve are higher than the other mechanical valves. This, the valve's high profile (height), and the high risk of thrombus development have led to a decline in its use.

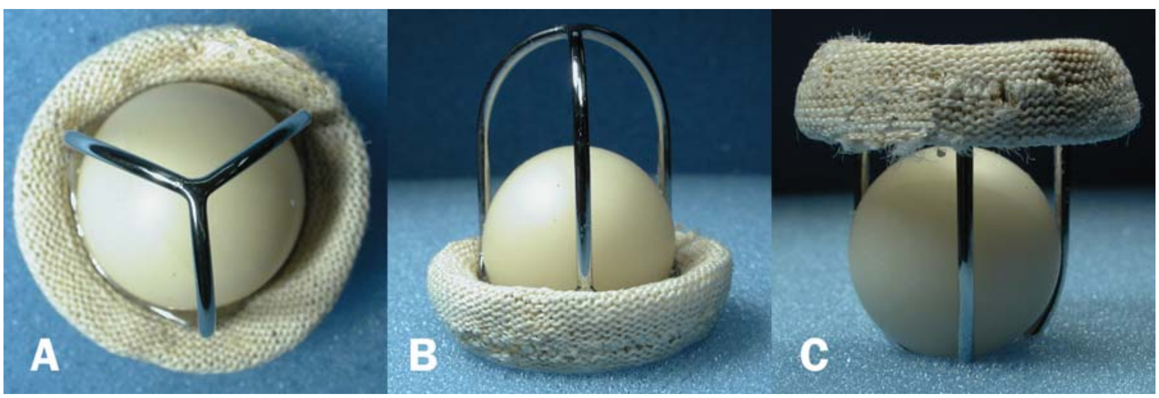

Fig 4: Starr-Edwards valve
Closed valve from above. B. Lateral view of closed valve. C. Open valve.

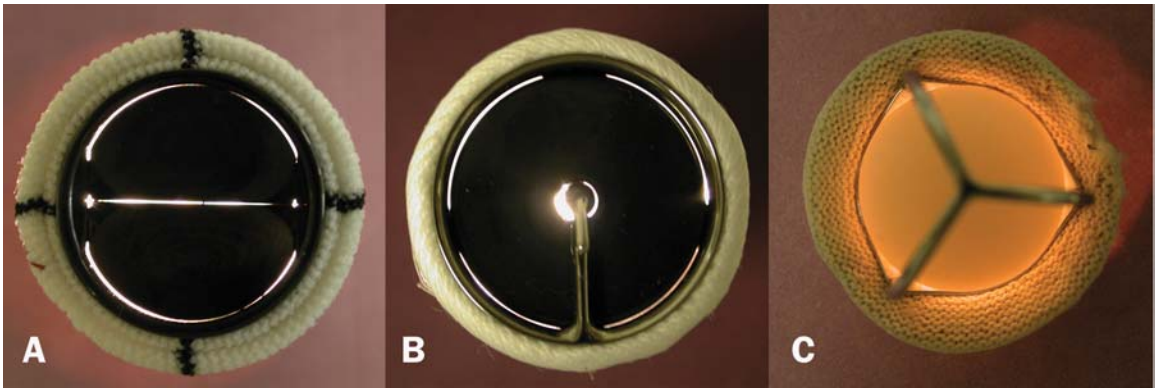

Fig 5: Mechanical valve regurgitant jet origin
A light source was projected through each valve in order to define the sites of washing jets. A. St. Jude valve. B. Medtronic-Hall valve. C. Starr-Edwards valve.

The stented porcine valve, as its name implies, consists of porcine aortic valve leaflets mounted on a stent (Fig 6). The leaflets are treated to decrease antigenicity and the propensity to calcify. They open to a lesser degree than the leaflets in a native valve due to the leaflet treatment and the commissural supports (struts). The flow profile through the valve is similar to that through a native valve. Unfortunately, the sewing ring and struts decrease the effective orifice area. This creates a non-trivial pressure gradient across most of the stented tissue valves. An important concept to remember is that valve

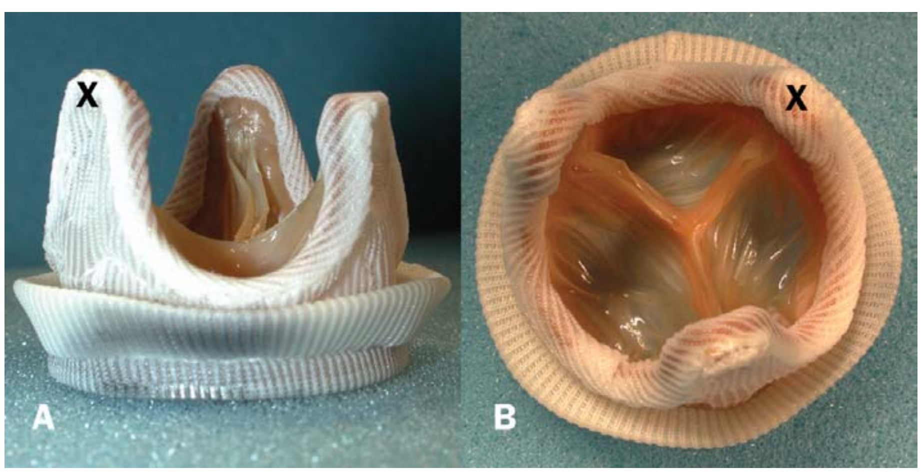

Fig 6: Porcine aortic valve designed for the mitral position (Hancock)
A. Lateral view. X=Commissural support component (strut) of the valve frame. B. View from above. No central gap present.

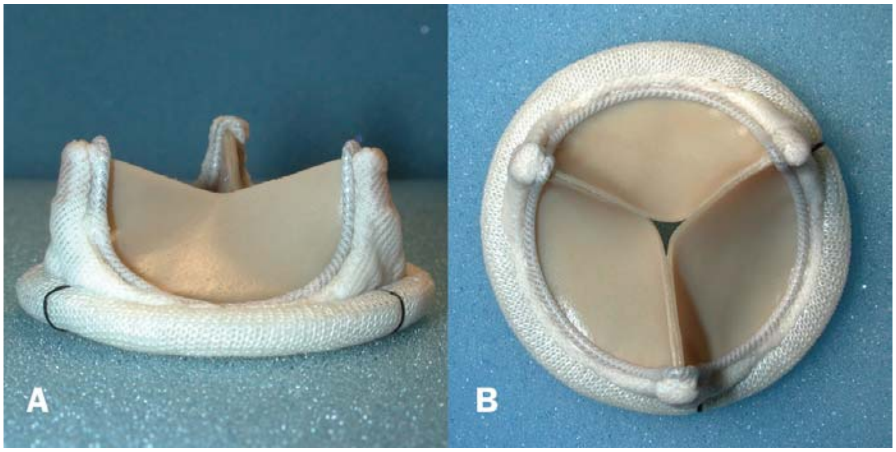

Fig 7: Pericardial valve (Carpentier-Edwards)
A. Lateral view. B. View from above. Note leaflet edges are sharper than porcine valve. Struts are smaller. Central gap is present.

sizes do not describe the internal orifice diameter. They describe the outer diameter of the valve stent. For example a 21-mm Hancock valve has an orifice diameter of 18.5 mm. This small orifice, coupled with the struts and slightly limited leaflet motion, significantly decrease the effective orifice area of any given valve. Stented tissue valves should have minimal regurgitation other than a brief closing jet. However, small-sized and low-velocity regurgitant jets may be seen within the region of the commissures, particularly in the early post-bypass period.

The pericardial valve consists of three leaflets constructed from bovine pericardium and mounted on a stent (Fig 7). The pericardial leaflets have sharper edges than those of the porcine valves, and this can be demonstrated echocardiographically. Gross inspection of the pericardial valve reveals a central gap through which regurgitant flow is frequently seen in the early postoperative period (particularly during partial bypass). In addition, it is not uncommon with this valve to see small regurgitant jets more peripherally along the commissures. It is important to know that the majority of these jets decrease significantly shortly after the bypass period.

The stentless valves have been designed to decrease the pressure gradient inherent in the stented valves.   The Toronto Stentless Porcine Valve (SPV) is an excised porcine aortic valve that contains only enough aortic tissue to support the commissures and leaflets (Fig 8 a). In other words, most of the sinus tissue is removed.   A polyester (echoreflective) fabric around the base of the valve facilitates suturing, promotes tissue ingrowth, and separates the xenograft from the patient's aortic wall. The valve is inserted with a subcoronary technique so there is no need for coronary reimplantation. Importantly, the patient's sinotubular junction must be small enough relative to the valve size to maintain leaflet coaptation.

The Freestyle valve is an entire porcine aortic root (Fig 8 b). It also has an echoreflective polyester covering at the base of the valve.   It provides the surgeon with

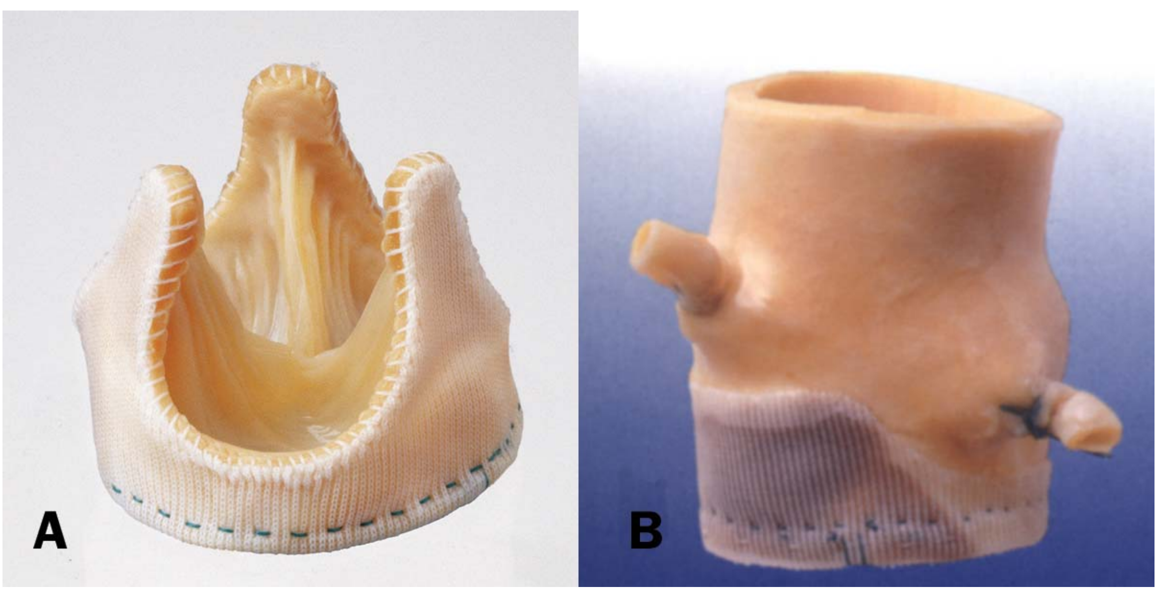

Fig 8: Stentless valves
A. Toronto SPV stentless valve (St Jude Medical). B. Freestyle Valve (Medtronic)

more implantation flexibility (full-root technique, root-inclusion technique, complete subcoronary technique, and modified subcoronary technique) than the Toronto SPV.[5] Depending on the technique used, coronary re-implantation may be necessary.

Echo Appearance of Prosthetic Valves

When the appropriate view of a bileaflet valve is obtained, two leaflets can be seen opening and closing. Where this view is obtained depends on where the surgeon implants the valve (e.g., mitral or aortic position) and how the surgeon orients the valve within the annulus. When the ultrasound beam is perpendicular to the leaflet commissure or leaflet coaptation line (Fig 9 a), two leaflets are seen opening and closing. When parallel, only one leaflet is seen and its motion in the TEE image is limited. Figure 10 shows a St. Jude mitral valve that was inserted in the anti-anatomic position with 2-D and color Doppler. When two leaflets are seen, several jets originate centrally and diverge laterally; in addition, small jets originate laterally and are directed perpendicular to the

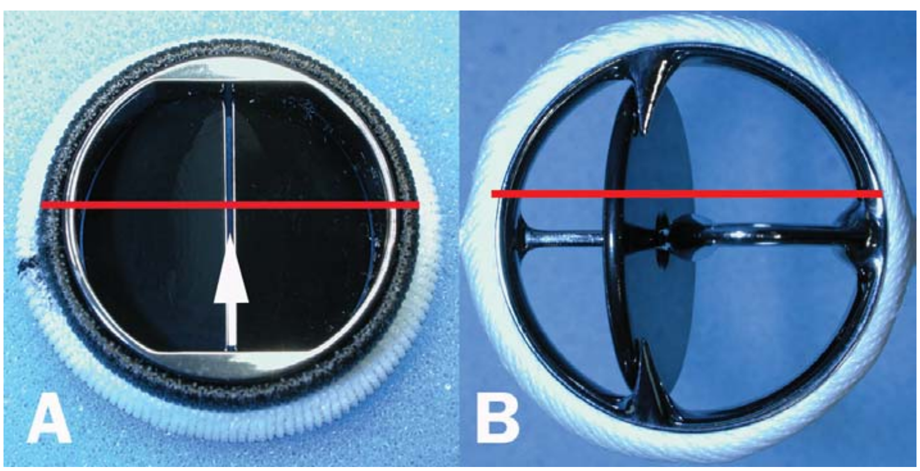

Fig 9: TEE planes

A. St. Jude valve. When the TEE plane is parallel to the red line, two leaflets that form an inverted "V" will be seen. When the plane is perpendicular to the red line or parallel to the closure line (arrow), only one leaflet will be seen. B. Medtronic-Hall valve. When the TEE plane is parallel to the red line and the strut, the full leaflet excursion will be appreciated.

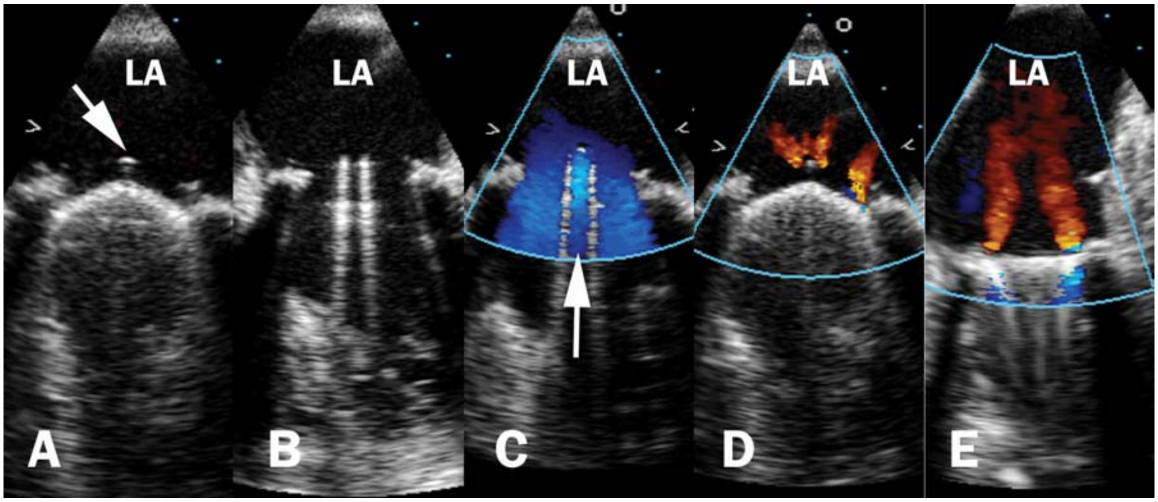

Fig 10. St. Jude mitral valve transesophageal views

A. Two-leaflet view, closed. Arrow defines the pivot guard. B. Two-leaflet view, open. C. Two-leaflet view, open with color Doppler. Arrow points to central orifice. D. Two-leaflet view, closed. Regurgitant jets: three central jets that seem to diverge slightly, one peripheral jet that is perpendicular with the closed leaflet. Often there would be a second color jet originating on the other side of the valve as well. E. Color Doppler of a St. Jude valve with the TEE plane parallel to the closure line. There are two laterally-originating and centrally-directed regurgitant jets.

closed leaflet. When one leaflet is seen, two regurgitant jets originate laterally at the leaflet margins and converge toward the center of the valve.

Surgical Implantation of Mechanical Valves in the Mitral Position

When implanting a bileaflet valve in the mitral position, the surgeon can orient the valve such that the prosthetic leaflet commissure is parallel or perpendicular to the native valve's commissure. When parallel the valve is said to be anatomic, when perpendicular, anti-anatomic. Because diastolic blood flow through the native mitral valve is directed posteriorly, surgeons tend to insert bileaflet mitral valves in the anti-anatomic position in order to increase the likelihood that both leaflets will open symmetrically—the flow impacts both leaflets equally. In the anatomic position, the anterior leaflet may not open as readily as the posterior leaflet. How the surgeon inserts the valve directly affects the omniplane angle at which you will see one and two leaflets. A similar situation occurs with the Medtronic Hall valve. In general, the surgeon will orient a Medtronic Hall valve in the mitral position such that the major orifice is directed posteriorly.[6]

The one leaflet of the Medtronic-Hall valve can be seen best when the ultrasound plane is parallel to the strut (Fig 9 b). In this plane the full excursion of the leaflet will be appreciated. A deep transgastric view and a transesophageal long axis view of a Medtronic-Hall valve in the aortic position is demonstrated in figures 11 and 12, respectively. In both situations, the surgeon aligned the valve such that the major orifice is directed toward the noncoronary sinus. This alignment provides a flow profile that is as close to physiologic as possible for this prosthetic valve.[7] The regurgitant jets associated with the Medtronic-Hall valve allow distinction from the other commonly used valves. The predominant and distinguishing jet originates in the central aperture and is directed centrally. Two smaller lateral jets may be seen depending on how the echo

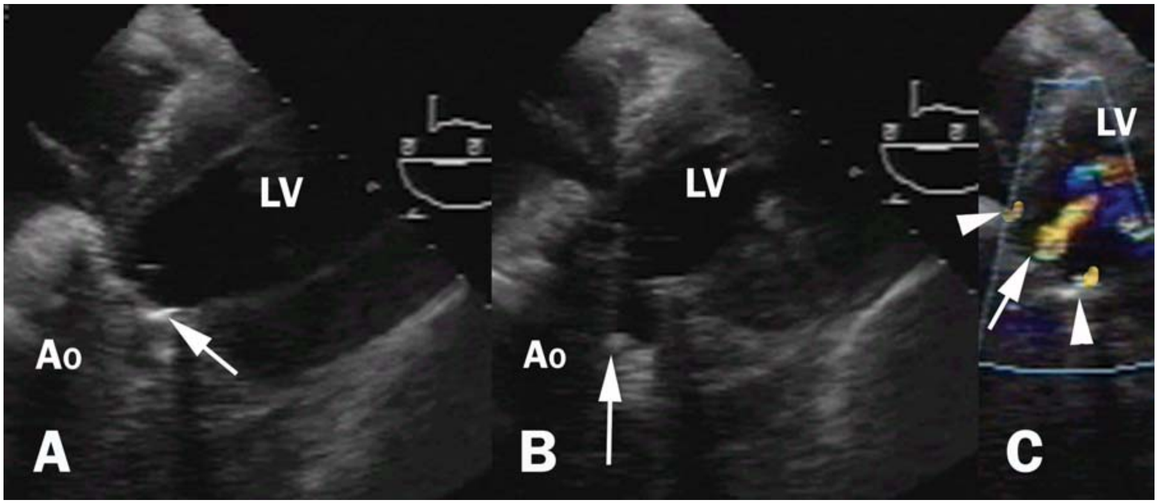

Fig 11: Medtronic-Hall aortic valve deep transgastric view

A. Closed valve. Arrow points closed leaflet near the noncoronary cusp. B. Open valve. Arrow points to the open leaflet. Major orifice flow directed toward the the non-coronary sinus. C. Color Doppler reveals the predominant central jet (arrow) and a small peripheral jet (arrowhead).

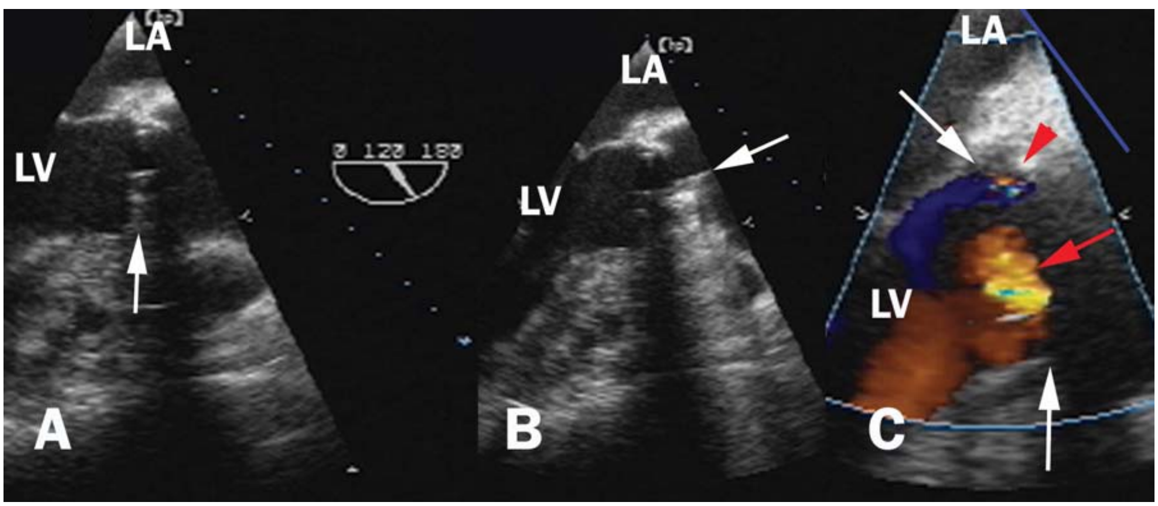

Fig 12: Medtronic-Hall aortic valve transesophageal long-axis view

A. Closed valve. Arrow points the leaflet at the level of the sewing ring. B. Open valve. Arrow points the distal edge of open disc. Major orifice flow is directed toward the noncoronary sinus. Minor orifice is obscured by artifact. C. Color Doppler reveals a predominant central jet (red arrow) and a small peripheral jet (red arrow head). White arrows define the sewing ring. Second peripheral jet is not seen at bottom of picture because of acoustic shadowing by strut. If TEE plane transects the valve off center, then two peripheral jets are seen without the central jet.

beam transects the valve. In the transesophageal view, only one jet will be seen if the ultrasound beam transects the central aperture since the strut will create an acoustic shadow (Fig 12 c). Both jets are more likely to be seen when using one of the transgastric views (Fig 11 c).

A Starr-Edwards valve is echocardiographically distinct. Figure 13 demonstrates a Starr-Edwards valve in the mitral position.   A significant acoustic shadow created by the poppet and the sewing ring. The regurgitant color jet associated with the Starr-Edwards valve is a short-lived closing jet. There is no washing jet. The antegrade flow pattern consists of blood streaming around the poppet and then converging downstream.

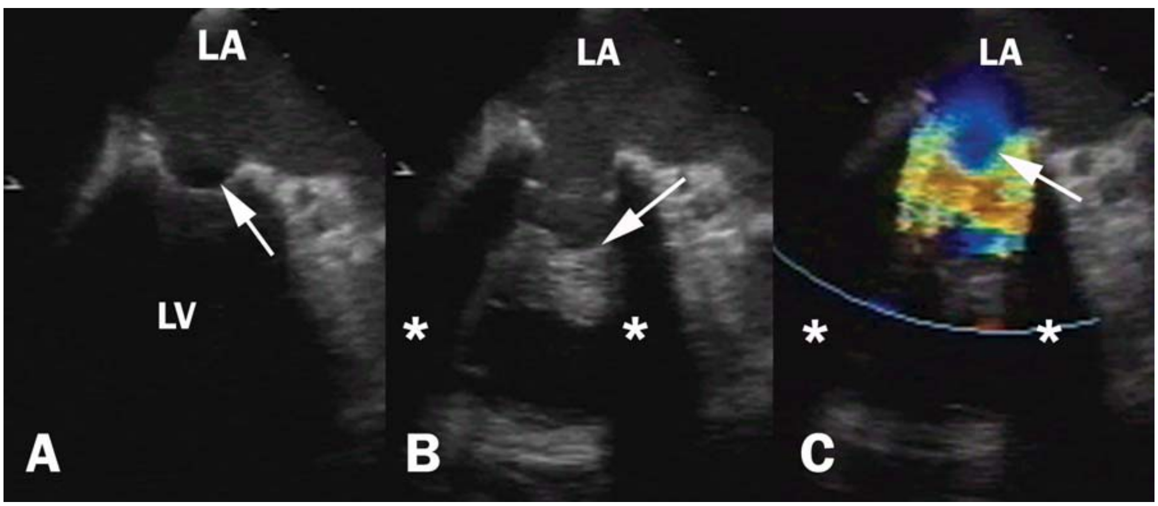

Fig 13: Starr-Edwards mitral valve with transesophageal four-chamber view
A. Closed valve. Arrow points to poppet border. B. Open valve. Asterisks define acoustic shadows. C. Color Doppler reveals flow acceleration around the poppet.

The TEE appearances of stented porcine and pericardial valves are similar. The leaflet motion in both valves approximates that of the native valve except for the slightly limited excursion. Figure 14 demonstrates a porcine valve (Hancock II) and a pericardial valve

(Carpentier-Edwards) in the aortic position. In the short-axis view, the pericardial leaflets are more evident than those of the porcine valve. Struts can be recognized in the short-axis view of the valve, making it easy to differentiate a stented from a stentless valve. Color Doppler application may reveal occasional trivial regurgitant jets at the commissures, either centrally or peripherally.

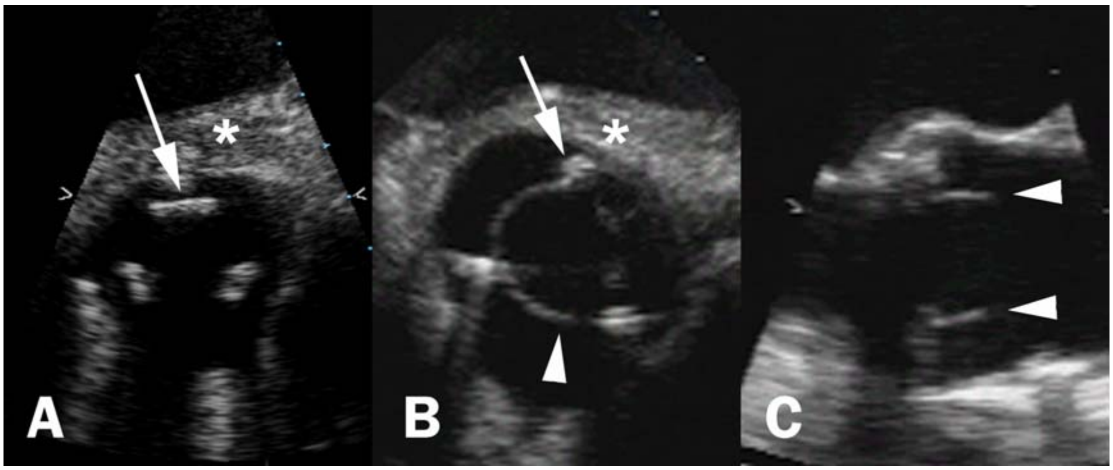

Fig 14: Stented tissue valves in the aortic position.
A. Porcine valve (Hancock II), short-axis view. Struts (arrow) are easy to see, but leaflets are not. B. Pericardial valve, short-axis view. Struts (arrow) and leaflets (arrowhead) are easy to see. C. Pericardial valve, long-axis view. In this view only leaflets (arrowheads) are seen. Asterisks define postoperative edema.

The stentless valve appearance varies with the implantation technique. In general, it is difficult to differentiate a stentless valve from a native valve. Increased echodensity present at the suture lines and the acoustic shadow created by the sewing cloth will, however, allow distinction. Figure 15 demonstrates a Freestyle (Medtronic) valve that was inserted in a patient who presented with an infected aortic porcine valve prosthesis. A stentless valve can be differentiated from a homograft because the homograft does not create an acoustic shadow. No significant regurgitation is expected in the stentless valves.

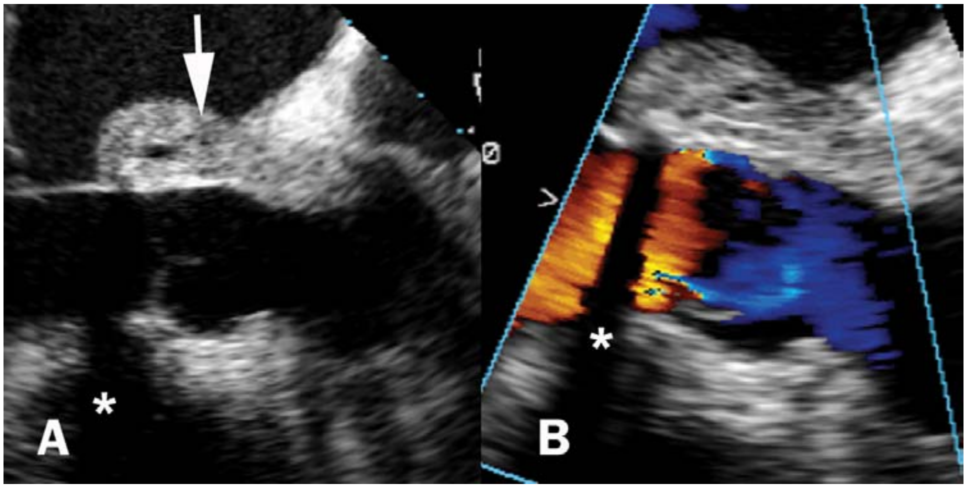

Fig 15: Freestyle (Medtronic) aortic valve transesophageal long-axis view.
A. Arrow defines periaortic thickening consistent with post-operative edema. Asterisk defines acoustic shadow. B. Color Doppler accentuates the acoustic shadow.

Systematic Valve Examination—General Concepts

Whether assessing a prosthetic valve in the immediate postoperative period or in the setting of suspected prosthetic valve dysfunction, performance of a systematic exam is important. Six questions that should be answered are listed in Table 2.

Table 2

Six questions to answer during an examination of prosthetic valves

1. Is the valve well-seated?
2. Is the occluding mechanism opening and closing normally?
3. Is there any unexpected valvular or paravalvular regurgitation?
4. Is there evidence of prosthetic valve stenosis?
5. Is there any unexpected mass on the sewing ring or leaflets?
6. Is there any involvement of other cardiac structures?

The exam typically begins with a 2-D echo assessment. The sewing ring is inspected to confirm that it is well-seated. A well-seated valve does not rock relative to the rest of the heart, nor does it have areas of hypoechodensity surrounding it. Then the occluding mechanism is studied. The leaflets or discs or poppet should move quickly from the closed to open positions. Irregular or restricted motion of one leaflet or one disc at any time other than during the bypass period is abnormal (low flow states, e.g., partial separation from bypass, may be associated with asymmetric leaflet opening). While studying the sewing ring and leaflets, abnormal echodensities may be noticed; these could represent sutures, fibrin strands, pannus, thrombus, or vegetation from endocarditis.[8-12]

Color Doppler is used to confirm the presence of normal antegrade flow and to demonstrate the expected washing jets.[2, 13] It is also used to rule out the presence of pathologic valvular or paravalvular jets. When looking for pathologic regurgitation, the entire circumference of the valve's sewing ring must be assessed; perfunctory exams can miss important pathology.

Doppler ultrasound is used to assess the prosthetic valve gradients, and if necessary, the prosthetic valve area. As with native valves, color-guided continuous wave Doppler can be used to determine the mean and peak gradients across prosthetic valves. In general, the mean gradient determined by TEE across any of the valve positions correlates well with the mean gradient determined by direct pressure measurement.[14] However, the peak prosthetic valve gradient determined by TEE may be higher than that determined by direct pressure measurement, particularly in the aortic position (see Pressure Recovery).[15]

In general, if the patient has a good cardiac output, if the 2-D and color exam is normal, and if the gradients are within normal limits, then the effective orifice area will be acceptable. If any of these three conditions are not met, the effective orifice area should be calculated, typically with the continuity equation. Most prosthetic valves have an effective orifice area (EOA) that is less than a native valve, particularly when the valve size is small.[16] The expected prosthetic valve EOA varies considerably with valve type, valve size, and valve position.

Whenever a prosthetic valve has been inserted or whenever a prosthetic valve is dysfunctional, a search for involvement of other cardiac structures is necessary, particularly those contiguous with the valve in question. Insertion of a mitral valve can inadvertently cause aortic valve dysfunction. An abscess affecting a prosthetic aortic valve may extend into the anterior mitral leaflet.[17] Endocarditis of a prosthetic mitral valve can seed the aortic valve. All of these findings may be critical to the patient's outcome.

Pressure Recovery[15]

The peak instantaneous gradient determined by TEE can differ from a direct pressure measurement. When blood travels through the orifices of a St. Jude valve, for example, there is significant conversion of pressure energy to kinetic energy. This localized increase in blood velocity translates into a higher local pressure gradient. Downstream in the aorta some of this kinetic energy is converted back to pressure energy. Practically speaking, if a surgeon directly measures the LV pressure and the aortic pressure in the distal ascending aorta (through the cardioplegia catheter), that peak-to-peak gradient may be significantly less than a TEE-determined peak instantaneous gradient, particularly for the St Jude valve. Both numbers are accurate. The difference is due in part to pressure recovery.

Systematic Examination—Specific Valve

Prosthetic Mitral Valve

The same views used to assess native mitral valves should be used to assess prosthetic valves.[18] Mitral valve assessment should commence by obtaining a four-chamber view and centering the mitral valve in the screen. The ultrasound beam is moved slowly and methodically from 0 to 180 degrees to scan the valve with 2-D echo in order to assess the integrity of the suture line and the motion of the discs or leaflets. A search for abnormal masses on the leaflets or the sewing ring occurs concomitantly. Zoom and slow motion replay should be used. Return from 180 degrees to 0 degrees while applying color Doppler to search for evidence of pathologic regurgitation. The color sector needs to be wide enough to see paravalvular jets but small enough to maintain a high frame rate. If a paravalvular leak is noted, attempt to map its location. Figure 16 depicts a prosthetic mitral valve mapping technique that helps describe to the surgeon the location of the paravalvular leak.[19] The technique requires that the exam begin with the prosthetic valve centered in the midesophageal four-chamber view and that the echocardiographer move in ten degree increments looking for presence of the jet. If a jet is seen, look at the omniplane degree. If the jet is on the left side of the valve as it appears on the screen, the jet should be mapped between 0 and 180 degrees. If the jet appears on the right side of the screen, the jet is mapped between 180 and 360 degrees (omniplane angle plus 180 degrees). After mapping the findings in the reference view (Fig 16 a), the view is transposed into the standard surgical view (Fig 16 b).

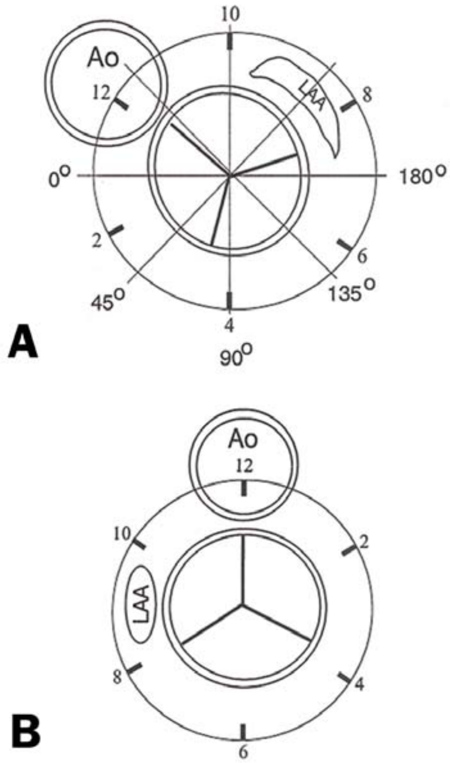

Fig 16: Prosthetic mitral valve mapping diagrams
A. Echo perspective of the mitral valve (looking at valve from apex of LV). B. Surgeon's view of the mitral valve. See text for details. (Foster GP, Isselbacher EI. Accurate localization of mitral regurgitatant defects using multiplane TEE. Ann Thorac Surg 1998;65: 1025.)

Next, the hemodynamic function of the valve is assessed. Measure the peak and mean gradients across the valve using color guided pulse or continuous wave Doppler. Scan the valve with probe movement and omniplane rotation to find the highest gradient. With the same Doppler image, you may determine the pressure half time and use it as an *index* of valve function. It should not be used to determine the valve area since the pressure half-time method does not accurately estimate prosthetic valve area.[20] Alternatively, the continuity equation may be used to calculate the prosthetic mitral valve area, albeit with some restrictions[21-23]:

$$\textbf{Prosthetic Valve Area} = \frac{\mathbf{0.785\ D^2_{LVOT} \times TVI_{LVOT}}}{\mathbf{TVI_{PV}}}$$

Using the left ventricular outflow tract (LVOT) as the site for forward stroke volume measurement requires that there is no significant aortic insufficiency and no significant mitral insufficiency. The presence of the first would lead to an overestimation of the prosthetic valve area; significant mitral insufficiency would lead to an underestimation.

Occasionally, transgastric views of the mitral valve may be necessary in patients with a suspected prosthetic valve mass or thrombosis. Via the deep transgastric view, the left ventricular side of the mitral prosthesis can be inspected.

Prosthetic Aortic Valve

Inspection of the aortic valve requires two transesophageal views and at least one transgastric view. The short axis view of the aortic valve should be evaluated first. Bioprosthetic leaflet anatomy and excursion will be well defined in this view. All three leaflets should move symmetrically. An abscess cavity can be detected. Color Doppler reveals valvular or paravalvular regurgitation. A long-axis view of the aortic valve is evaluated next. Rotation of the probe from left to right will provide a scan of the entire circumference of the valve's sewing ring. Even though the proximal portion of a regurgitant jet will be masked due to acoustic shadowing (unless looking at a homograft), a jet of pathologic significance will be appreciated in the LVOT. To best assess disc motion and regurgitant jet anatomy of a prosthetic aortic valve, use one or more of the transgastric views: long axis view, deep transgastric view, and basal transgastric view. Zoom and slow motion replay is particularly helpful. These same views will be required to determine the prosthetic valve gradients and area.

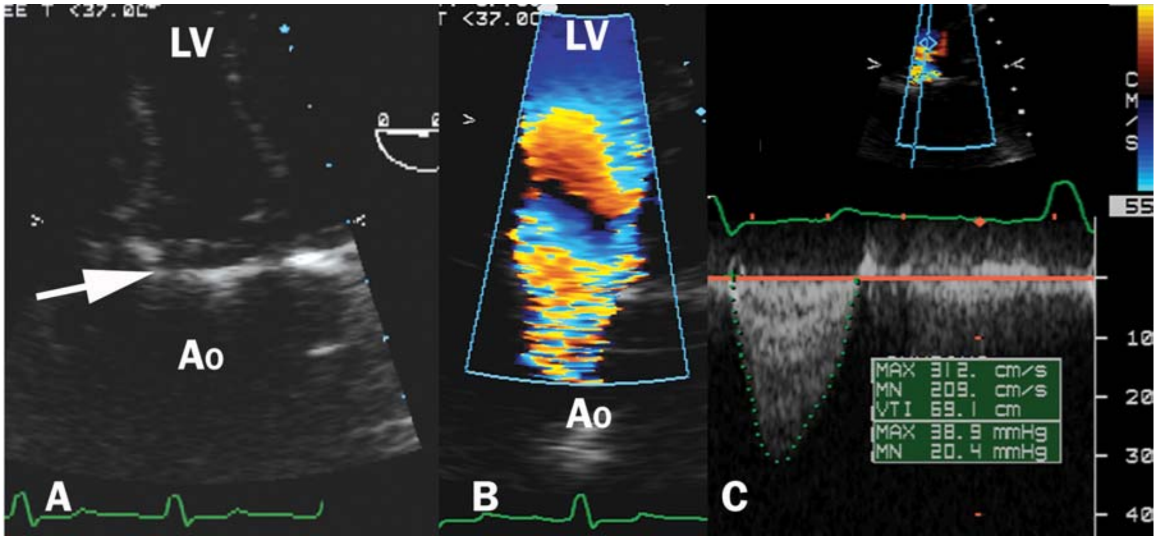

Fig 17: Prosthetic valve gradient

A. Deep transgastric view of Starr-Edwards valve. Arrow points to annulus. B. Color Doppler used to align CWD cursor. Color flow must be visualized distal to the annulus. C. Peak gradient=38 mmHg, mean gradient=20 mmHg.

The peak and mean gradients should be determined in all patients (Fig 17). Acceptable gradients depend on the valve size and the cardiac output. If the gradient is elevated (in general, a mean greater than 20 mmHg), or if the cardiac output is low, some measure of the valve area is necessary[18]. The continuity equation is valid in this setting[24, 25]:

$$\textbf{Prosthetic Valve Area} = \frac{\mathbf{0.785\ D^2_{LVOT} \times V_{LVOT}}}{\mathbf{V_{PV}}}$$

The peak velocity may be used in place of the time velocity integral since the flow rate and the prosthetic valve velocity are being measured in close proximity. Typically the LVOT diameter is measured in early systole, and the peak velocities are measured individually. The LVOT peak velocity is determined with pulse wave Doppler and the prosthetic valve peak velocity with continuous wave Doppler. Figure 18 demonstrates the images required to determine the area of a bioprosthetic valve. If the LVOT is

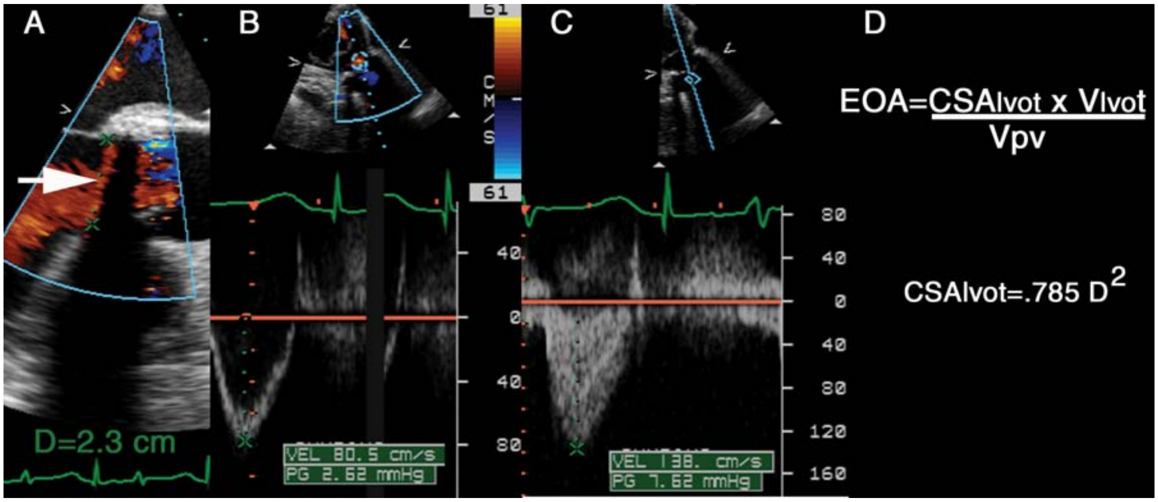

Fig 18. Continuity equation for prosthetic aortic valve
A. Transesophageal long-axis view for LVOT diameter in early systole. B. LVOT peak velocity with PWD. C. Valve peak velocity with CWD. D. Continuity equation for prosthetic aortic valve.

difficult to visualize, use of the valve size as the LVOT diameter has been shown to correlate reasonably well with the actual orifice size.[24]

An alternative to determining the peak velocities individually is to use the double envelope technique.[26] With this technique, the peak LVOT and the peak prosthetic valve velocities are obtained in one continuous wave Doppler envelope. Finally, an even shorter, but clinically useful method of assessing prosthetic valve area is the Doppler Velocity Index (DVI).[24, 26] It is the ratio of the LVOT peak velocity and the prosthetic valve peak velocity. Use of the DVI obviates the need to determine the LVOT diameter, which is the measurement associated with greatest error in the continuity equation. In general, if the DVI is less than 0.25, the valve has clinically significant stenosis.[26]

Tricuspid and Pulmonic Valves

The assessment of the tricuspid valve is similar to that of the mitral valve in that the transesophageal views usually provide enough information for a full assessment unless there is concern of a possible mass on the right ventricular side of the valve. The pulmonic valve is rarely replaced but may be assessed in a similar manner to the aortic valve. In addition, a gradient across the pulmonic valve can usually be obtained in the high transesophageal position (pulmonic valve and pulmonary artery bifurcation view).

Prosthetic Valve Complications

In general, valve malfunction can be associated with one of three problems: excessive regurgitation, reduced effective orifice area, or a mass on the valve (e.g., thrombus or vegetation).[27] Excessive regurgitation can lead to hemolysis or when severe, heart failure. A reduced effective orifice area typically presents as dyspnea on exertion. A mass on the valve may present as bacteremia (endocarditis) or stroke (thrombus or endocarditis

Table 3 summarizes many of the causes of valve dysfunction. Many of these complications will be noted in the immediate postoperative TEE exam. Others will not occur until late in the life of the valve.

Table 3

Prosthetic Valve Complications

1. Regurgitation
    a. Valvular
        i. Valve structural defect
        ii. Surgical complication
        iii. Bioprosthetic leaflet failure
        iv. Mechanical leaflet malfunction
        v. Endocarditis

    b. Paravalvular (paraprosthetic)
        i. Severely calcified annulus
        ii. Surgical complication
        iii. Disrupted suture
        iv. Endocarditis and abscess

2. Stenosis (decreased effective orifice area)
    a. Mechanical
        i. Inadequate leaflet opening
            1. retained chordae
            2. structural defect
            3. thrombus
        ii. Pannus formation

    b. Bioprosthetic
        i. Calcification
        ii. Thrombus
        iii. Pannus formation

3. Mass on the valve
    a. Endocarditis
    b. Thrombus
    c. Pannus

1. Aortic St. Jude valve thrombosis

A 46 year-old patient received a St. Jude aortic valve prosthesis in 1987 for severe aortic insufficiency of a congenitally bicuspid valve. She presented 13 years later with cardiopulmonary distress. She had recently stopped taking coumadin. By TEE, one leaflet appeared frozen in a semi-open position. The second leaflet did not demonstrate full opening movement, but closed appropriately (Fig 19 a-b). This resulted in both aortic insufficiency and stenosis (Fig 19 c). TEE revealed a peak gradient of 145 mmHg across the valve. The surgeon found thrombus encasing the anterior leaflet and restricting the posterior leaflet. The valve was replaced with another St. Jude valve and the dilated ascending aorta was replaced with a tube graft.

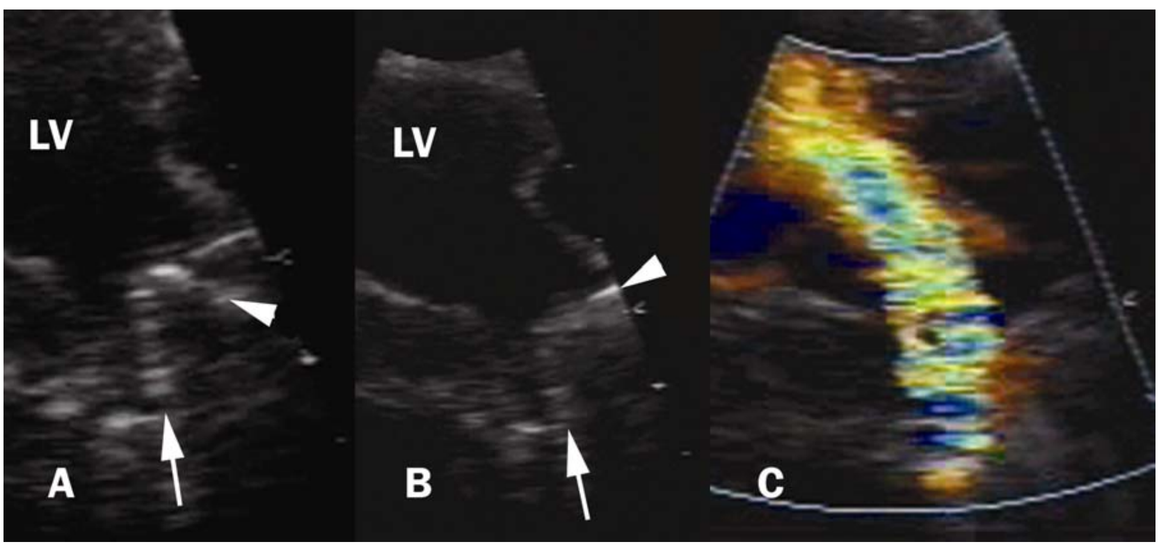

Fig 19. Case 1
A-B. St. Jude valve in aortic position, transgastric long-axis view. One leaflet is fixed (arrow) and one has restricted motion (arrowhead). C. Severe aortic insufficiency.

Comment: The patient's history was pivotal in the early diagnosis of this life-threatening situation. There are several reasons why patients might stop taking their prescribed anticoagulant therapy. When such a patient has a mechanical valve, TEE can confirm the diagnosis of thrombosis and expedite emergent surgery. A high transvalvular gradient can be caused by prosthetic valve stenosis or severe regurgitation. In this situation, both were occurring. Zoom and slow motion replay allowed the echocardiographer to identify the inhibited motion of one of the leaflets compared to the other.

2. Mitral bioprosthetic stenosis

A 74 year-old patient underwent MVR in 1988 using a porcine aortic valve. She presented with congestive heart failure. The TEE examination revealed thickened and calcified leaflets (Fig 20). Leaflet motion was severely restricted. Doppler assessment revealed moderate prosthetic mitral stenosis with a mean gradient of 7 mmHg. The mitral valve area was not determined. There was mild mitral insufficiency, but no paravalvular leak. There was also mild-to-moderate aortic insufficiency and a widely patent foramen ovale (PFO). Due to the symptoms, the echo appearance of the valve, and the gradient of 7 mmHg, the patient went to the OR for a replacement of her mitral prosthesis.

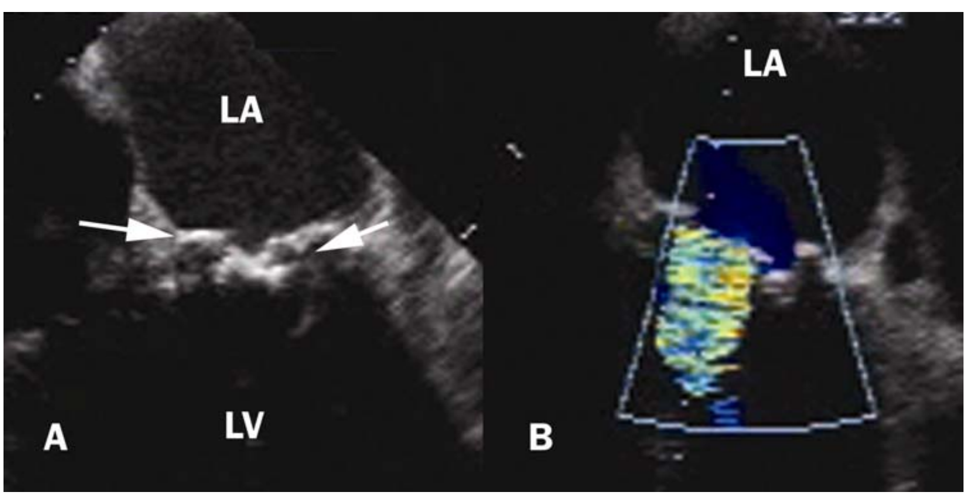

Fig 20. Case 2
A. Porcine valve in the mitral position, transesophageal view. Severe calcification of the leaflets. Arrows approximate the sewing ring. B. Turbulent diastolic flow through narrowed orifice.

Comment: In a symptomatic patient with a mitral valve bioprosthesis, the degree of leaflet immobility and calcification on 2-D echo is probably enough to warrant surgical intervention. Determination of the gradients is also helpful. Using the pressure half-time method to estimate the mitral valve area in this situation poses two problems. First the pressure half-time method overestimates the true valve area of prosthetic valves (mechanical more than bioprosthetic). Second, the presence of a PFO will also lead to an overestimation of the true valve area since the PFO will allow faster decay in the LA-LV diastolic pressure gradient. Calculation of the mitral valve are using the continuity equation is this situation would be susceptible to error as well. The presence of AI and MR would lead to an error in the calculation of the area if the LVOT were used as the site of forward flow determination.

3. Mitral St. Jude valve paravalvular leak

An 81 year-old patient with a St. Jude valve in the mitral position presented with a new murmur and anemia. TEE evaluation revealed a large paravalvular leak that spanned approximately twenty percent of the valve circumference (Fig 21 a-c). The paravavlular leak was mapped to 9 through 11 o'clock using the mitral prosthetic mapping technique (Fig 22 a-b).[19]

Comment: In this case, the color jet appeared when the omniplane reached 54 degrees. The jet is on the right side of the valve as the echocardiographer looks at the monitor (Fig 21 a). Any jet that is on the left side of the monitor is mapped between 0 and 180

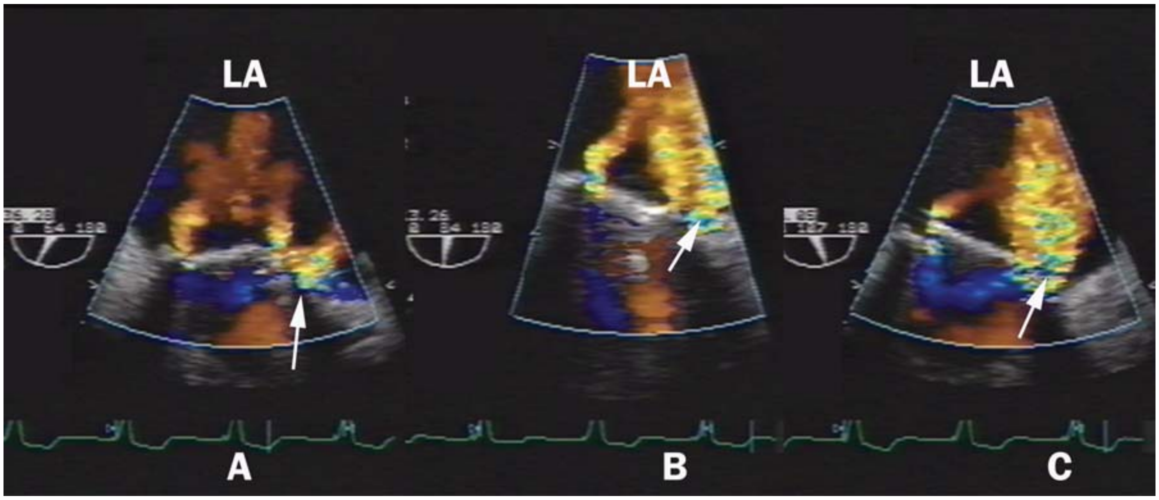

Fig 21. Case 3
St. Jude mitral valve, transesophageal view. Arrow defines paravalvular leak. The two washing jets appear normal. B-C. Arrow defines more significant paravalvular leak.

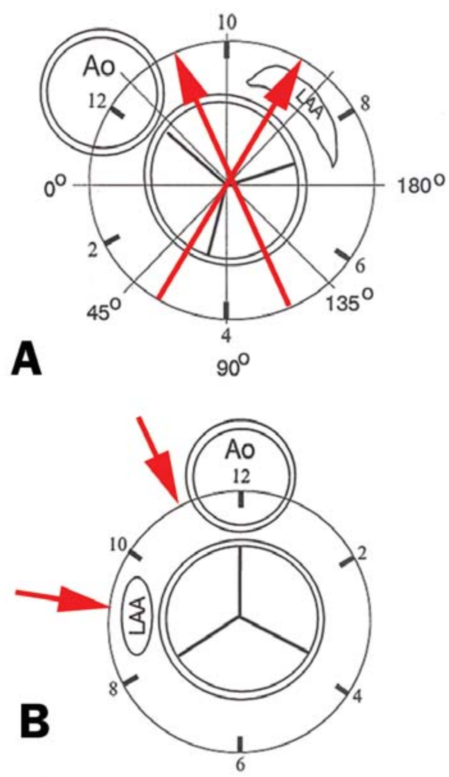

Fig 22. Case 3 cont.
Mitral prosthetic valve mapping technique. A. Echo perspective of the mitral valve (looking at valve from apex of LV). B. Surgeon's view of the mitral valve. See text for details.

degrees, any on the right side of the screen is mapped between 180 and 360 degrees. Thus, a jet seen at 54 degrees on the right side of the monitor begins at a location that is mapped directly across from the 54-degree site, which is 234 degrees, or 9 o'clock. At 107 degrees the jet is still present and is on the right side of the screen so the jet is localized to 287 degrees, or 11 o'clock (Fig 21 c). The area of regurgitation can then be translated into an image that represents the surgeon's view from the right side of the patient (Fig 22 b)

4. Mitral Starr-Edwards valve dehiscence

A 42 year-old patient with mitral valve prolapse suffered a bout of endocarditis and underwent a porcine MVR. The valve deteriorated by 1987, at which time he had a Starr Edwards MVR. Thirteen years later he presented with left shoulder pain, fever, and shortness of breath. Blood cultures were positive for group B streptococcus. TEE revealed echogenic masses attached to the sewing ring (Fig 23 b). The echodensity of the masses was similar to that of the surrounding cardiac tissue. In addition, a paravalvular leak involving approximately one-third of the annulus was demonstrated (Fig 23 D). Severe rocking of the prosthetic valve consistent with partial dehiscence was noted. Surgical inspection revealed large vegetations present on the sewing ring and around the valve annulus.

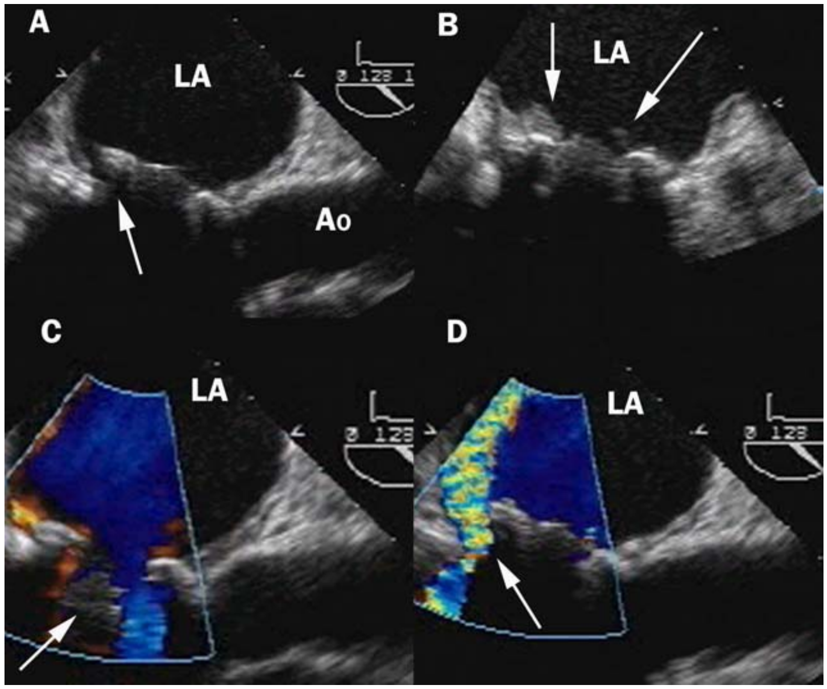

Fig 23. Case 4
Starr-Edwards valve endocarditis. A. Arrow defines hypoechogenic area consistent with partial dehiscence. B. Arrows point to vegetations. C. Diastolic flow around poppet (arrow). D. Posterior paravalvular regurgitation (approximately 5 o'clock).

Comment: Since the intensity of the masses was similar to that of surrounding cardiac tissue, thrombus or acute vegetation were more likely than chronic vegetation or pannus.[11,12] Pannus and particularly chronic or "healed" vegetations typically have greater echodensity. The clinical setting and presence of paravalvular leak certainly supported the diagnosis of vegetations. This case also provides a good example of a significant area of hypoechodensity indicative of partial valve dehiscence (Fig 23 a).

5. Porcine aortic valve destruction

A 63 year-old patient underwent a porcine AVR in 1991. Nine years later she presented with heart failure. Her preoperative TEE revealed severe prosthetic valve insufficiency due to apparent leaflet perforations (Fig 24 a-b). The surgeon found two torn leaflets (Fig 24 c) without evidence of sewing ring dehiscence or commissural separation from a strut.

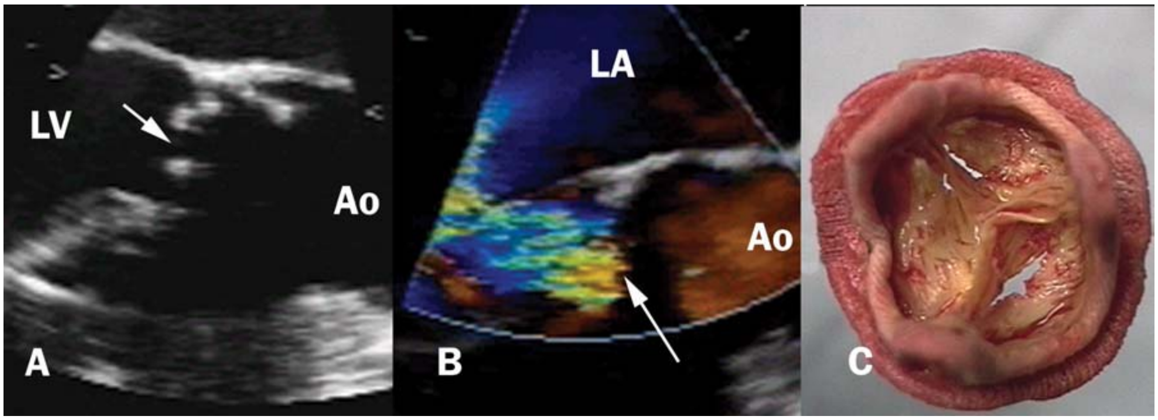

Fig 24. Case 5
Porcine valve degeneration. Transesophageal long-axis view. A. Arrow points to apparent hole in one of leaflets. B. Regurgitation fills approximately 60% of LVOT. C. Gross specimen with leaflet perforation.

Comment: A common cause of tissue valve failure is leaflet destruction either by excessive calcification or perforation. Occasionally, one of the commissures will separate from the commissural support (strut), which creates flail of one or two leaflets. The color jet associated with perforation will usually be more central than the jet associated with a flail leaflet.

6. Aortic tissue valve with abscess

A 73 year-old patient underwent an AVR in the late 1980s with a 23 mm porcine bioprosthesis. Twelve years later he presented with a febrile illness. A TTE revealed evidence of valvular and paravalvular regurgitation. Intraoperative TEE revealed a rocking bioprosthetic valve with an abscess cavity in the intervalvular fibrosa (Fig 25).

The surgeon found a fluid-filled cavity in the posterior aortic root. The cavity extended into the base of the anterior mitral leaflet. He elected to implant an aortic homograft and used the anterior mitral leaflet component of the homograft to reinforce the area surrounding the abscess cavity.

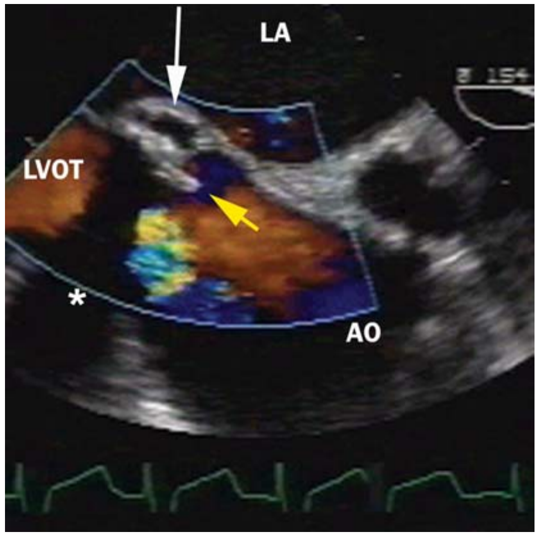

Fig 25. Case 6
Porcine valve endocarditis with abscess. Transesophageal long-axis view. A. Yellow arrow depicts a strut. White arrow points to an abscess cavity in the intervalvular fibrosa.

Comment: This is an example of collateral damage. The abscess in the aortic root extended into the region of the mitral valve via the intervalvular fibrosa. The region of the mitral-aortic continuity, known as the intervalvular fibrosa, is the weakest segment of the aortic ring and contains mostly fibrous and relatively avascular tissue.[27] Abscess can form there easily. Not detecting this can lead to residual infection and devastating consequences for the patient.

7. Aortic homograft fungal endocarditis

A 55 year-old patient with a homograft in the aortic position presented with vague symptoms. He was diagnosed with *Staph. aureus* endocarditis. Antibiotics were started promptly, but his symptoms rapidly progressed. He developed myocardial ischemia in the right coronary artery distribution and suffered an embolic stroke. He was emergently taken to the OR. Intraoperative TEE revealed a large perihomograft space anteriorly (Fig 26 a-c). The surgeon therefore decided to cannulate the patient's femoral vessels prior to performing the sternotomy. The surgeon found a large nonhealing space between the noncoronary sinus and the homograft that was impinging on the right coronary artery. The repair included another homograft and coronary bypass grafts.

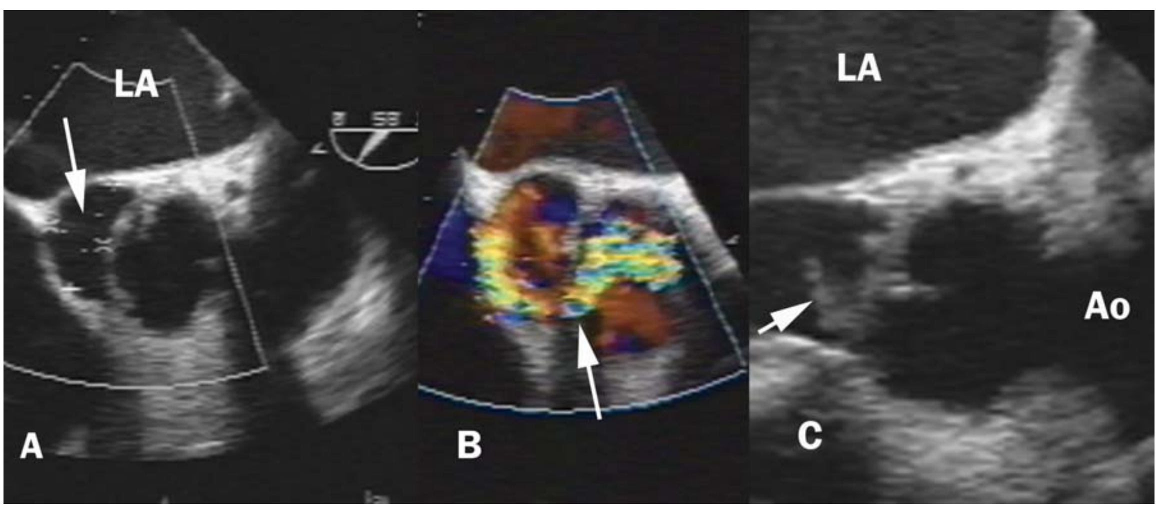

Fig 26. Case 7
Aortic homograft endocarditis. A. Transesophageal short-axis view of aortic valve. Arrow points to abscess cavity. B. Arrow points to communication between aorta and abscess cavity. C. Arrow points to vegetation on the LV side of the homograft leaflets.

Comment: First, *Staph. aureus* endocarditis is destructive. Operative management should proceed without delay. Second, knowledge of cardiac surgical technique on the part of the echocardiographer is helpful. In this situation, the surgeon chose to cannulate the femoral vessels due to the location of the abscess cavity, which was localized specifically by the echocardiographer prior to the incision. Finally, whenever a patient with a prosthetic valve has endocarditis it is critical to assess the cardiac tissue surrounding the valve. An abscess cavity, fistula, or aneurysm may develop secondary to the infection. In this case, it would be well to search for evidence of a fistula between the abscess cavity and the right atrium and left atrium.

8. Composite root fungal endocarditis

A 67 year-old patient had a composite aortic root replacement in 1997 with a St. Jude valve conduit. In 2001 he developed lower extremity embolus that, upon culture, grew hyphae. Despite antifungal therapy he presented with perigraft aortic root abscess formation. The short axis view reveals aortic root thickening and a hypoechogenic area posterior to the valve- sewing ring; the long-axis view confirms the posterior hypoechogenic area and wall thickening (Fig 27 a-d). Both leaflets seem to be without endocarditic lesion, and systolic flow seems unimpeded. A 26-mm homograft was used to replace the composite root.

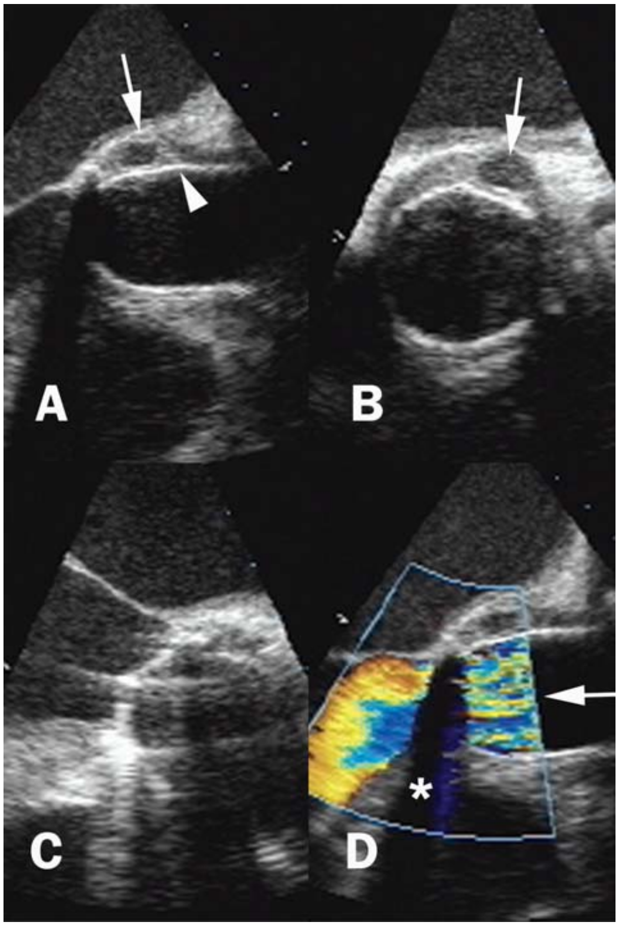

Fig 27. Case 8
St. Jude valved conduit fungal endocarditis. A. Transesophageal long-axis view. Abscess cavity (arrow) posterior to conduit (arrowhead). B. Short-axis view. Abscess seen (arrow) posterior to the conduit. C. Both St. Jude valve leaflets seen without apparent vegetation. D. Normal systolic flow (arrow). Asterisk=acoustic shadow.

Comment: In the aortic site, abnormal thickening suggests the presence of an abscess, particularly when there is an echo-free area within the thickening. Although vegetations can be found on tissue valve leaflets, they are infrequently found directly on mechanical valve leaflets. It is therefore not surprising that the leaflets appear normal in the setting of a paravalvular abscess.

9. Mitral pericardial valve with leaflet restriction

A 79 year-old patient underwent a pericardial mitral valve replacement and a De Vega tricuspid annuloplasty in 2001. The patient's postoperative period was complicated by pleural and pericardial effusions. In 2002 the patient presented with recurrent heart failure. TEE assessment of the valve revealed focal leaflet thickening and impaired motion of one of the leaflets (Fig 28 a-b). Color Doppler revealed moderate mitral insufficiency (Fig 28 c). The mean gradient was 5 mmHg. Surgical inspection revealed a white coating on part of the valve (Fig 28 d). The pathology diagnosis was pannus formation.

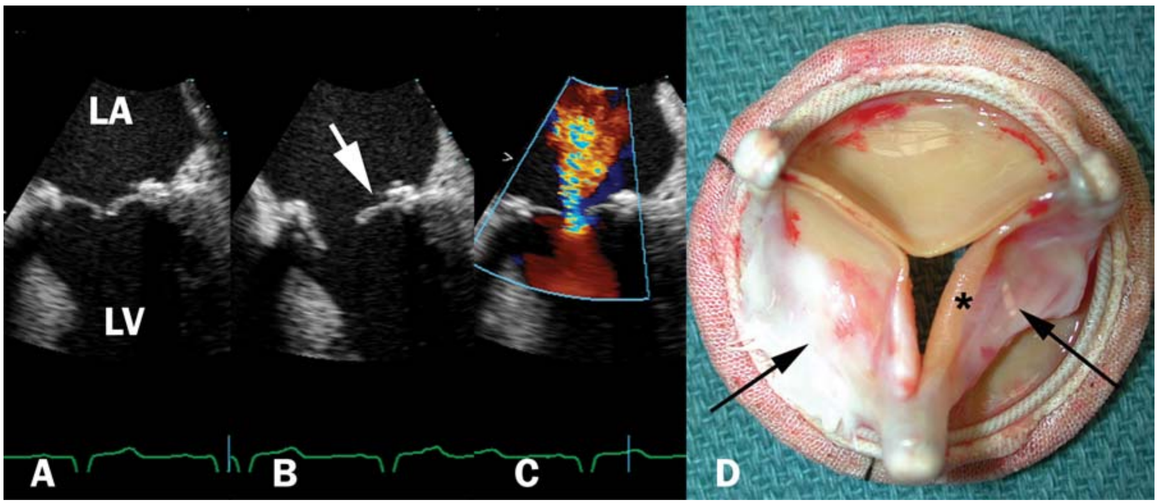

Fig 28. Case 9
Mitral pericardial valve. A-B. Transesophageal views. Arrow defines the restricted leaflet. Both leaflets are thick. C. Regurgitation is central. D. Explanted valve with pannus formation. Leaflet edges are thickened (asterisk).

Comment: Pannus formation, also known as tissue ingrowth, can involve not only the annulus, but also the leaflets in a tissue valve. The leaflets edges in this case were also abnormal, possibly caused by the regurgitation, which was initiated by the pannus-induced leaflet restriction.

Intraoperative TEE Diagnoses

10. Aortic Starr-Edwards valve paravalvular leak

A 45-year-old patient with a history of repaired Tetralogy of Fallot presented with symptoms of right heart failure. At age 17, he had a VSD repair and a RVOT reconstruction. This repair was complicated by injury of the aortic valve that required an AVR with a Starr-Edwards valve. His recent preoperative TTE revealed severe pulmonary insufficiency and severe tricuspid insufficiency. He was noted to have trace-to-mild central aortic insufficiency. He was scheduled to have a pulmonary valve replacement and tricuspid valve reconstruction. Intraoperative TEE revealed a large paravalvular leak around the aortic valve prosthesis. This significantly altered the operation by necessitating an unanticipated AVR (Fig 29 a-b). The surgeon found a defect in the annular tissue at the site of the anatomic commissure between the noncoronary and right coronary cusps.

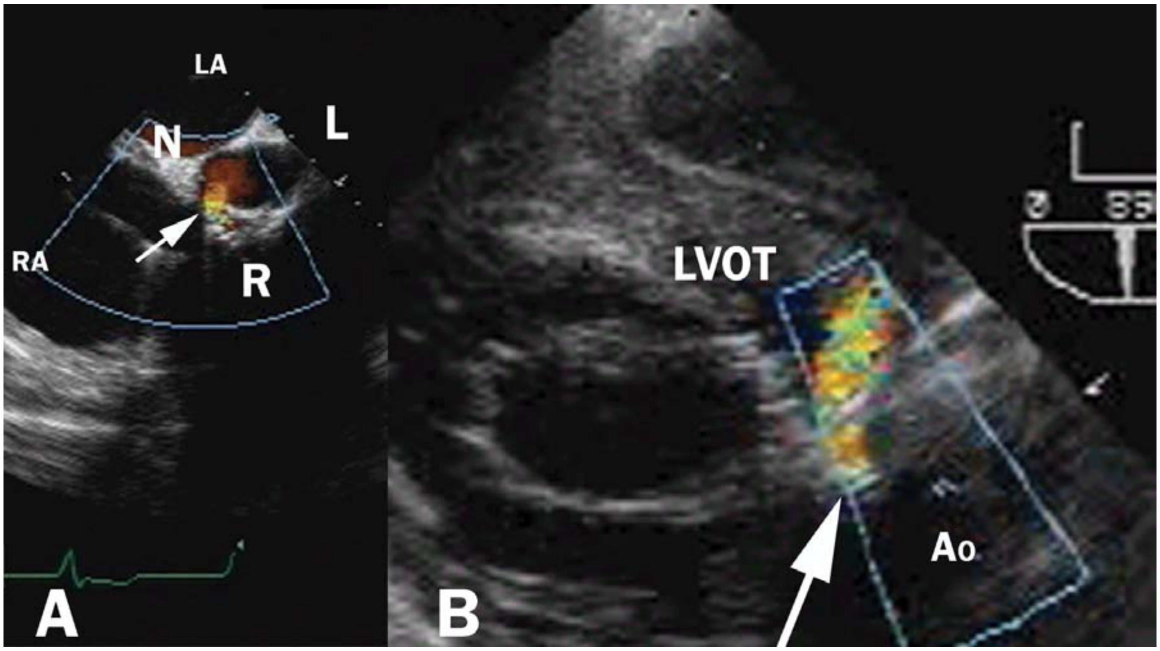

Fig 29. Case 10
Aortic Starr-Edwards valve. A. Transesophageal short-axis view. Arrow defines origin of regurgitation at the position of the annulus that corresponds to the commissure between the right and left cusps. B. Transgastric view with wide, high-velocity and curved regurgitant jet that appears to originate outside of the sewing ring.

Comment: It is important to know what type of regurgitant jet is acceptable for each prosthetic valve. Knowing that a Starr-Edwards valve should not have significant central insufficiency (other than a closing jet) made the anesthesiologist suspicious of the preoperative diagnosis. Although the echo examination was difficult due to the altered cardiac anatomy, the defect was found after careful assessment using the transgastric views.

11. Aortic pericardial valve with post-bypass valvular leak

An 85 year-old patient with severe aortic stenosis presented for surgery in 1999. The bicuspid valve leaflets and annulus were severely calcified requiring extensive surgical debridement. A 23-mm pericardial valve with a reduced sewing ring was inserted. The post-bypass TEE revealed regurgitant jets originating at each of the commissures (Fig 30 a-b). Because the jets were of low velocity and had minimal LVOT penetrance, the valve was not replaced. A postoperative TTE three years later revealed no evidence of aortic insufficiency.

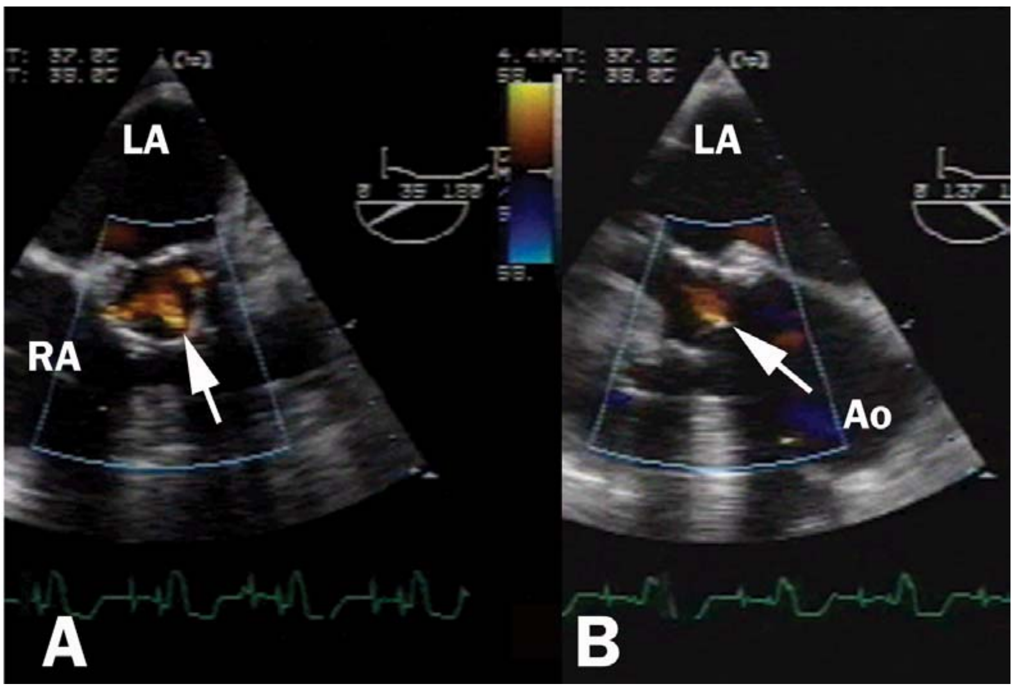

Fig 30. Case 11
Pericardial aortic valve. A. Transesophageal short-axis view. Three regurgitant jets originate along each of the commissures. B. Long-axis view. Regurgitant jet (red arrow) appearing between the sewing ring borders (white arrows)

Comment: When assessing pericardial and porcine valves in the early post-bypass period, several small and low-velocity regurgitant color jets may be seen. These jets can occur in the central aspect of the valve, in the commissures peripherally, or along the sewing ring. The intravalvular jets typically are more significant prior to separation from bypass; thereafter, the jets diminish. Those along the sewing ring are usually due to suture holes and diminish or even disappear after protamine administration. As you are learning TEE, it is wise to notify the surgeon of all jets. Together, you will have to determine which jets require intervention. In general, those jets that penetrate deep into the proximal chamber, those that demonstrate an area of visible proximal flow acceleration, and those that are of high velocity are more likely to require intervention. Of course, it is not this simple; some regurgitant jets occur due to a heavily calcified annulus and the risk of valve revision may be too high. This case is a good example of jets that are most likely benign. The follow-up TTE confirmation that the jets did not persist in the long term is noteworthy. Whenever possible, attempt to review the follow-up echo study done on patients who had a questionable insufficiency jet.

12. Aortic tissue valve with post-bypass paraprosthetic leak

A 78-year-old patient with three vessel coronary artery disease and severe aortic stenosis underwent an AVR with a 25-mm porcine valve and a three-vessel CABG. The immediate post-bypass TEE revealed a regurgitant jet in the short axis view that appeared to originate in the region of the right coronary cusp—noncoronary cusp commissure (Fig 31 a). A transgastric view confirmed the presence of the jet that appeared to be paravalvular (Fig 31 b). After protamine, the regurgitant leak decreased significantly enough to convince the team that the degree of insufficiency was acceptable (31 c).

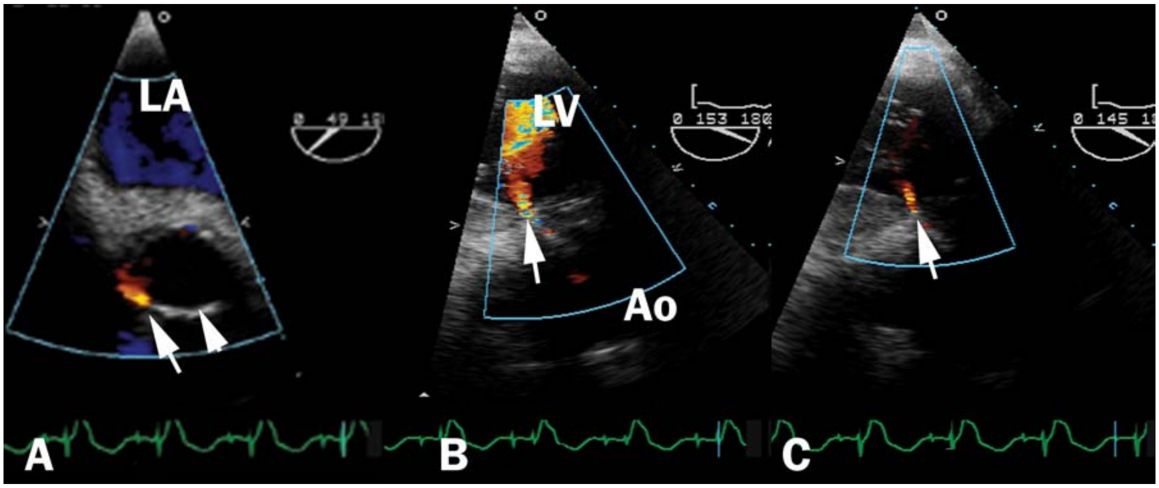

Fig 31. Case 12

Porcine aortic valve. A. Transesophageal short-axis view. Small jet (arrow) appears to originate outside the sewing ring (arrowhead). B. Transgastric long-axis view. Jet appears more significant—higher velocity and deeper penetration. C. After protamine, the jet is diminished.

Comment: This jet should cause concern. It has some potentially worrisome characteristics—high velocity, deep penetration, and wide vena contracta. Many of these jets will get smaller with protamine administration, but not all of them will. A lot goes into a decision of whether or not to repair a significant paravalvular leak in the post-bypass period. If the annulus were heavily calcified, the surgeon may decide it is in the patient's best interest to accept the leak. Also, the surgeon may wait, as in this case, with the expectation that the jet will get smaller after protamine administration. One thing is certain; the jet you see in this (Fig 31 b) is not the kind of jet you want the surgeon to find out about after the chest is closed.

13. Mitral St. Jude leaflet motion impairment

A 57 year-old patient with rheumatic heart disease and a prior percutaneous mitral valvuloplasty presented for an MVR. Her preoperative TEE revealed severely calcified mitral leaflets and a high velocity jet by color flow Doppler. The surgeon completely resected the calcified and thickened mitral valve. A 25-mm St. Jude valve was inserted utilizing Teflon pledgets on the atrial side. The patient was successfully separated from CPB. Both leaflets were moving well (fig 32 a-b). There was no paravalvular leak, and the mean gradient (3 mmHg) was within normal limits. Shortly after protamine was started, the pulmonary artery pressures increased. Initially, a protamine reaction was suspected. However, TEE assessment revealed that one of the leaflets was not moving (Fig 32 c). This was confirmed using several imaging planes. Color Doppler revealed flow acceleration through the functioning side of the valve orifice (Fig 32 d). The gradient had increased to a mean of 8 mmHg. The surgeon decided to resume CPB and inspect the valve directly. Small segments of the chordae tendinae were found between the sewing ring and the immobile leaflet. The chordae were carefully resected while the valve was left in place.

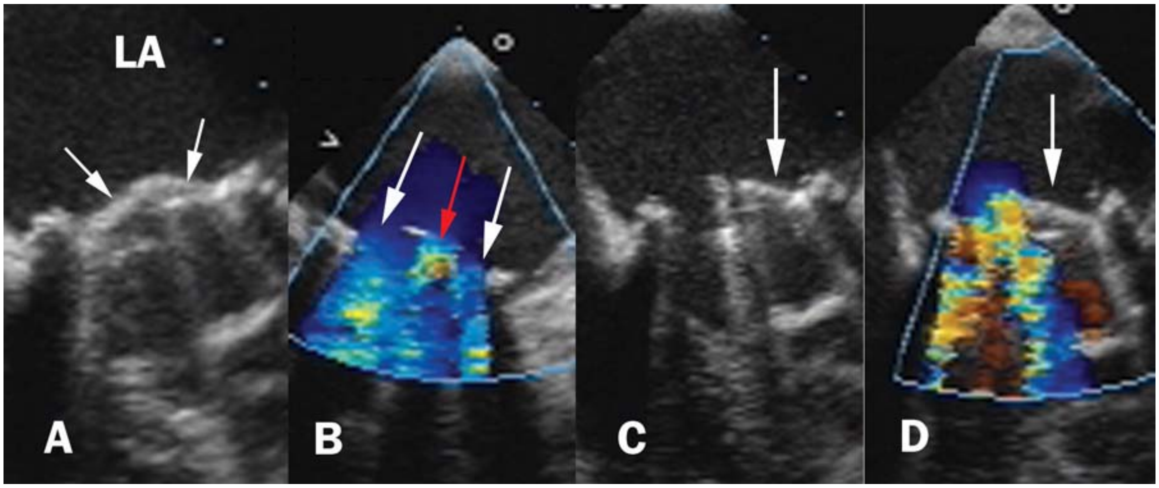

Fig 32. Case 13
Mitral St. Jude valve dysfunction. A. Bileaflet view at 60 degrees. Arrows define each leaflet. B. Normal diastolic flow. Flow in lateral orifices (white arrows). Velocity is slightly higher in central orifice inlet (red arrow). C. After protamine, one leaflet (arrow) is closed in diastole. D. Flow acceleration demonstrated with color Doppler.

Comment: After a mechanical valve has been inserted and the heart incision line has been re-approximated one would expect that the leaflets should move normally. However, there are a few important concepts to remember. First the surgeon may keep the valve incompetent until intracardiac air is evacuated. Frequently this is accomplished with a Foley catheter. Once the Foley catheter is removed the leaflets may still not move properly. Often there is asynchronous leaflet opening due to inadequate flow through the valve. After termination of CPB, the leaflets should begin to move normally. Rarely, one leaflet may be immobile temporarily, but this should resolve quickly. If there is persistence of leaflet immobility, surgical intervention may be required. The decision to replace or inspect the valve is not a simple one, but as in this case, may be the only option.

14. Mitral St. Jude leaflet immobility after AVR

A 66 year-old patient with a history of childhood rheumatic fever developed mitral stenosis and underwent a St. Jude MVR in 1991. Eight years later she developed progressive exertional dyspnea. A cardiac catheterization documented severe aortic stenosis. Intraoperative TEE revealed evidence of several small thrombi on the atrial side of the mitral valve. The surgeon decided to perform a left atriotomy to inspect the mitral prosthesis. He found and removed relatively recent thrombus attached the atrial aspect of the prosthesis. The prosthetic leaflets appeared to move normally. The aortic valve was replaced without difficulty. The initial post-bypass TEE revealed normal mitral prosthesis function. However, shortly after the protamine infusion was started, the pulmonary artery pressure increased. TEE revealed a partially open and immobile anterior leaflet of the mitral prosthesis (Fig 33 a- b). After reinstitution of bypass the surgeon removed the St. Jude valve. Pannus was found on the ventricular side of the sewing ring in addition to fresh thrombus on the left atrial side. A porcine valve was inserted without further complication. The patient was diagnosed with heparin-induced thrombocytopenia several days later.

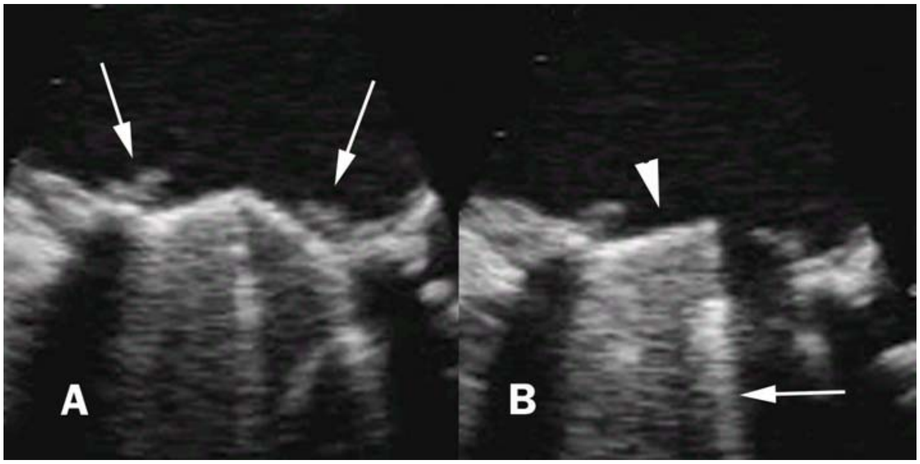

Fig 33. Case 14
Mitral St. Jude valve thrombosis. A. Transesophageal view. Small mobile masses (arrows) on the LA side of the valve annulus. B. One leaflet is closed during diastole (arrowhead) while the other demonstrates adequate opening (arrow).

Comment: This case demonstrates why it is important to evaluate all previously inserted prosthetic valves preoperatively and postoperatively. Detecting these small masses in the otherwise bright OR can be facilitated by temporarily dimming the lights and by using the zoom function.

15. Mitral porcine valve with post-bypass mitral insufficiency

An 80-year-old patient who had a three-vessel CABG in 1998 presented with progressive dyspnea on exertion and abdominal swelling. Preoperative TTE revealed severe MR and moderate tricuspid insufficiency. A coronary angiogram revealed patent vein and left internal mammary artery—left anterior descending grafts. The surgeon decided to use a right anterolateral thoracotomy incision to avoid the patent grafts. Exposure was challenging. Through a left atrial incision, the surgeon inspected the valve and found that it was not amenable to repair. The anterior leaflet was removed; the posterior leaflet was not resected. A 31 mm Medtronic Mosaic porcine valve was implanted with difficulty due to difficult exposure posteriorly. After the left atrial incision was closed, a DeVega tricuspid annuloplasty was performed. After air evacuation, the mitral prosthesis was inspected with TEE. The posterior aspect of the valve ring was separated from the annulus (Fig 34 a-d). A paravalvular leak was present at the posterior aspect (6 o'clock) of the sewing ring. In addition, there was a significant intravalvular leak. The patient was cooled to 30 degrees and the valve was inspected. A suture had looped over the posterior commissural support (strut), which created a gap between the sewing ring and the annulus. It also caused the intravalvular leak. The valve was removed and replaced with a 29 mm Carpentier-Edwards porcine valve without further difficulty.

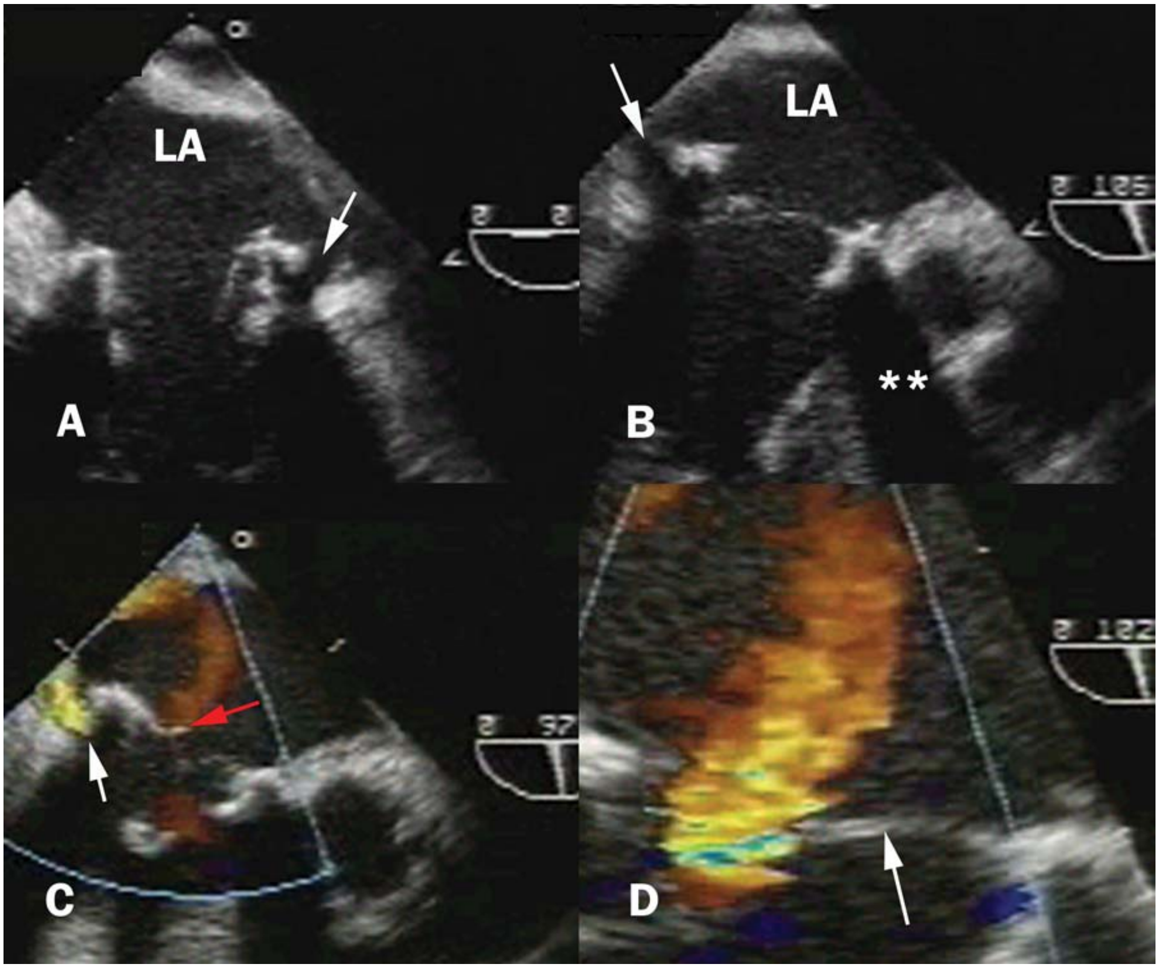

Fig 34. Case 15

Mitral porcine valve dysfunction. A. Transesophageal view at 0 degrees. Arrow defines confirmation of separation at 109 degrees. Asterisks define acoustic shadow from strut. C. Paravalvular regurgitation (white arrow) and transvalvular regurgitation (red arrow) at 97 degrees. D. Transvalvular regurgitation zoom image at 102 degrees.

Comment: The anesthesiologist should always be aware of the surgical challenges. TEE is not done for the surgeon; it is done with the surgeon. In this case, early diagnosis of this problem avoided potential protamine reversal and reheparinization.

16. Residual mitral St. Jude paraprosthetic leak

A 76 year-old patient who had a prior St. Jude AVR and MVR presented with severe hemolysis. Preoperative TEE revealed a posterior paravalvular leak in the mitral position. In the OR the TEE also revealed a smaller anterior jet (Fig 35 a-b). The surgeon repaired the visible posterior defect and placed several pledgeted sutures anteriorly in the area of poor tissue quality. The post-bypass TEE confirmed the repair of the posterior mitral prosthetic leak, but revealed a residual anterior jet. The surgeon needed to know exactly where the residual jet originated. The defect was mapped to approximately 1 o'clock. The surgeon reopened the left atrium and repaired the anterior defect by placing sutures in the area defined by TEE. Post-bypass, the leak was gone (Fig 35 c).

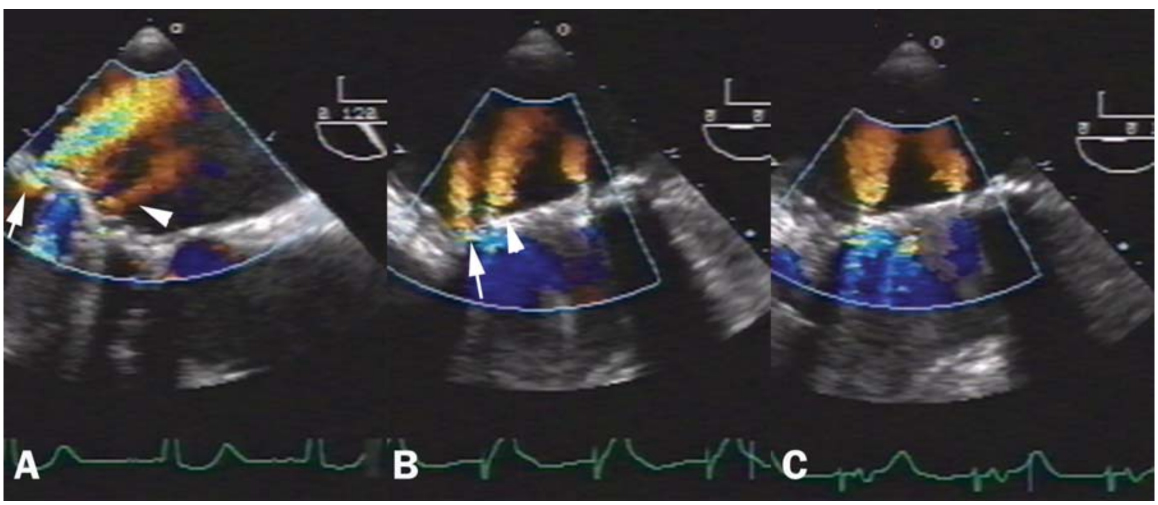

Fig 35. Case 16

St. Jude mitral valve. A. Transesophageal view pre-bypass. Omniplane at 120 degrees. Posterior paravalvular leak (arrow) and washing jet (arrowhead). B. Post-bypass I. Omniplane at 0 degrees. Residual anterior paravavlular leak (arrow) and washing jet (arrowhead). C. Post-bypass II. Anterior jet no longer present.

Comment: The repair of paravalvular leaks with sutures rather than with valve replacement requires that the echocardiographer localize the jet locations as specifically as possible. In cases of complex paraprosthetic regurgitation it is often helpful to have another experienced echocardiographer assist in the examination.

17. Aortic pericardial valve dysfunction

An 85 year-old patient presented with single-vessel coronary artery disease and critical aortic stenosis. Surgical findings included a severely calcified trileaflet aortic valve with calcification extending into the sinuses and annulus. Extensive debridement was necessary. A 23 mm Carpentier-Edwards pericardial reduced sewing ring valve was inserted. Prior to terminating bypass, the TEE revealed an atypical position of the aortic prosthesis and a wide-eccentric jet of aortic insufficiency (Fig 36 a-b). The surgeon clamped the venous lines transiently to further assess the valve. The regurgitation was moderate. After returning to full bypass, the valve was removed. The leaflet coaptation appeared inadequate (Fig 36 c). A 23 mm Carpentier-Edwards porcine aortic valve was inserted and the patient recovered uneventfully.

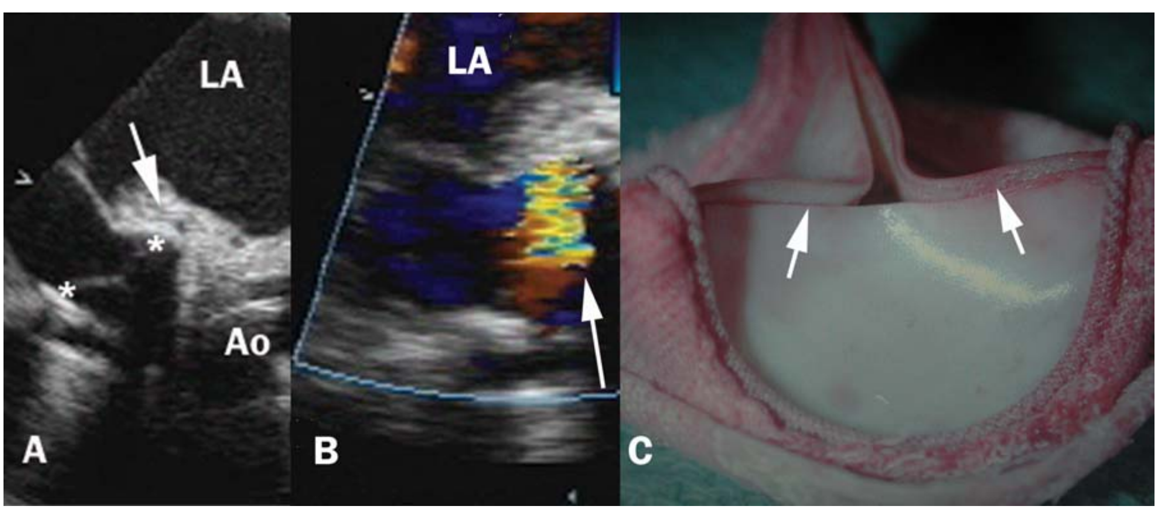

Fig 36. Case 17

Pericardial aortic valve. Transesophageal long-axis view. A. Valve angle appears atypical. Asterisks=sewing ring borders. Arrow points to periaortic thickening often seen after an AVR. B. Wide and eccentric aortic regurgitant color jet. C. Inadequate coaptation along one of the commissures (arrow).

Comment: It is very important to assess prosthetic valves as soon as possible. Hemodynamic stability does not guarantee proper valve function. The sooner a defect is detected, the less likely the patient will have received protamine. In this case, the angle between the LVOT and the prosthesis was atypical. This, along with the eccentric and wide jet of aortic insufficiency was enough to convince the surgeon to inspect the valve.

18. Mitral porcine valve replacement complicated by AI

A 74 year-old patient who underwent bioprosthetic MVR in 1988 presented with mitral stenosis and mitral insufficiency. During resection of the prosthesis, the surgeon noticed an area beneath the aortic valve that appeared to have granulation tissue and fibrin—possibly representative of vegetation. Her mitral prosthesis was subsequently replaced with a 27 mm porcine valve. Prior to separation from bypass, the TEE revealed new-onset aortic insufficiency (Fig 37 a-c). Close inspection while on partial bypass revealed apparent restriction of the left coronary cusp. The surgeon performed an aortotomy to investigate the problem. One of the mitral valve reinforcement sutures had passed through the base of the left coronary cusp. A pericardial patch was used to facilitate a repair of the left coronary cusp. Post-operative TEE revealed trivial aortic insufficiency.

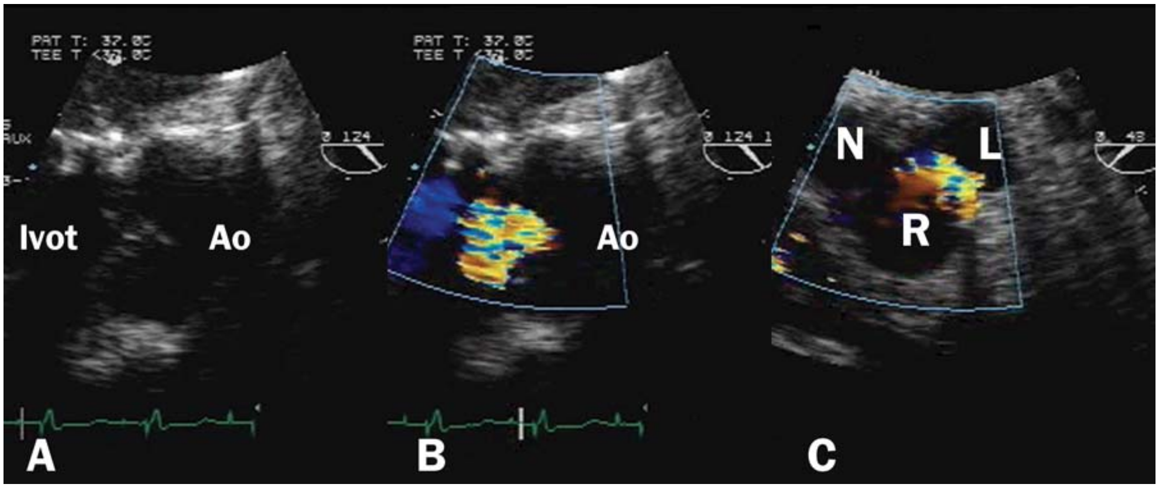

Fig 37. Case 18

Post-operative aortic insufficiency. Transesophageal views. A. Long-axis view. 2-D image of aortic valve. B. New onset wide aortic insufficiency color jet. C. Short-axis view of aortic valve. Regurgitant jet follows the border of the left coronary leaflet.

Comment: Again, be aware of surgical issues. And always inspect any valve that is close to the repaired valve, particularly in cases of poor surgical exposure. Make these diagnoses as quickly as possible. Some of the collateral damage needs to be surgically addressed as in this case. This patient might have left the operating room without recognition of the problem had the TEE not identified the new onset aortic insufficiency. Thus, it is critical to assess not only the prosthetic valve, but the surrounding structures as well, both preoperatively and postoperatively.

Summary

1. Spending the time required to obtain and carefully study the commonly used prosthetic valves will dramatically improve your diagnostic capability.
2. A systematic examination sequence should be developed and followed during the assessment of every prosthetic valve.
3. The zoom, slow-motion replay, and color suppress functions will improve your ability to assess leaflet motion and valve regurgitation.
4. All mechanical valves except the Starr-Edwards valve have specific washing jets. For any given valve, the washing jet appearance may be significantly different when viewing the valve in orthogonal planes.
5. Most valves are mildly stenotic. The gradients across valves depend on the valve size, the valve position, and the cardiac output. In general, the mean echo gradient correlates well with the direct pressure measurement gradient.
6. Spend as much time as possible in the OR studying the correlation between your TEE findings and the surgical findings.

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