Transoesophageal echocardiographic assessment of the aortic valve

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Every complete transoesophageal echocardiographic (TEE) examination should include a careful assessment of the aortic valve. Aortic valve disease is very common in Western populations. About 25% of people over 65 years of age have aortic sclerosis and 3% over 75 years have severe stenosis [7]. TEE can define the severity and mechanisms of aortic stenosis (AS) and aortic regurgitation (AR). Although in general cardiology TEE is rarely needed for evaluating the aortic valve, it may be appropriate when transthoracic image quality is poor and to evaluate other structures more fully, including the mitral valve.[1]

Aortic valve anatomy

The aortic valve (AV) forms part of the aortic root together with the three sinuses of Valsalva, two coronary ostia and sinotubular junction. It consists of a crown-shaped aortic annulus (annulus fibrosa) and three similar semilunar cusps called the right coronary cusp (RCC), left coronary cusp (LCC) and the noncoronary cusp (NCC). The leaflets are composed of a dense collagen layer, covered by a thin avascular collagen layer, and endothelium. The RCC and right sinus of Valsalva is positioned anterior and gives rise to the right coronary artery (RCA). The left coronary artery (LCA) originates from LCC and left sinus of Valsalva. The posterior of the three cusps is called the NCC and lies adjacent to the interatrial septum. The fibrous thickenings seen at the central portion of the free edges of the normal leaflets are called the nodules of Arantius. After years of function the leaflets may develop this thickening of the edges, as well as filamentous strands on them. These small filamentous strands connected to the aortic valve (up to 5 mm in length) may appear in the left ventricular outflow tract during diastole, or on the aortic side during systole. This is referred to as Lambl's excrescence and may be misinterpreted as vegetation. This is usually an incidental finding in elderly patients who are otherwise well. [2]

The sinotubular junction (STJ) connects the root to the proximal ascending aorta. It is circular and thicker than the adjacent sinuses, defining the start of the ascending aorta. The STJ plays an important role in suspending the semilunar aortic valve leaflets. The upper limit of the normal aortic valve annulus diameter is 2.6 cm and the sinotubular junction is 3.4 cm. Together with the sinuses of Valsalva and ascending aorta diameters, these are important measurements for surgical decision-making. The plane of the AV is oblique with the right posterior side more inferior to the left anterior side. Therefore the origin of the LCA is superior to the RCA.

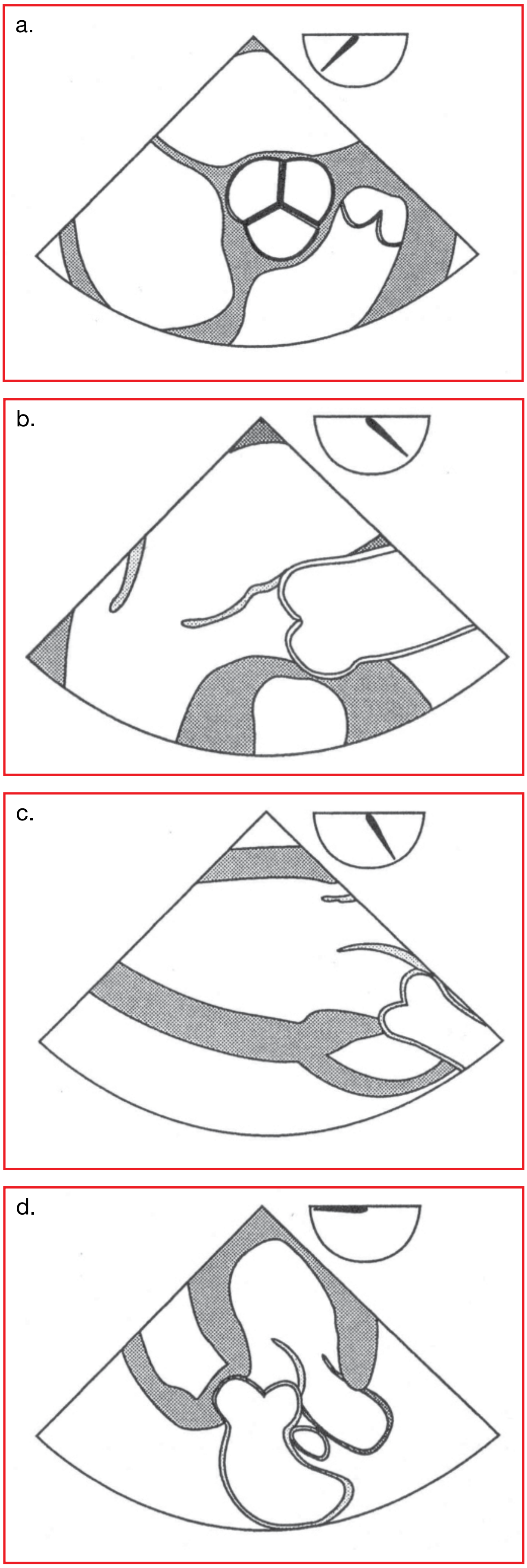
The normal AV area is 2.5-3.5 cm^2 with a normal echo pressure gradient across the valve of 2-4 mmHg assuming a flow velocity of 60-100 cm/sec. The opening and closing of the leaflets inside a normal aortic root is smooth and symmetrical. During systole in a compliant aorta, root dilatation precedes and aids in the opening of the leaflets. This root dilatation pulls the closed leaflets apart and reduces the frictional forces at the commissures.[3] A minimal pressure gradient of around 2 mmHg is therefore enough to open the aortic valve. At maximum displacement of the leaflets during early systole, the aortic valve opening is nearly circular, which is followed by a triangular shape in later systole. The echocardiography appearance of the normal valve orifice may therefore be circular or triangular, depending on whether it was observed earlier or later in systole. There is a gap between the body of the leaflets and the aortic wall (sinuses of Valsalva). If the pressure gradient is increased in a compliant root from 2-8 mmHg, the valve area increases strikingly by about 25%. This effect is absent in a stiff, non-compliant root. When the cardiac output is increased under certain physiological conditions, such as exercise, the normal aortic valve therefore copes by increased dilatation of the root, and increased pushing and bending of the leaflets towards the aortic wall.

In a stiff, non-compliant aortic root the valve opening tends to be asymmetric and delayed, with considerable wrinkling of the leaflets.[4] The systolic aortic root dilatation with the active "pull-release" opening mechanism of the leaflets is absent. The leaflets show a lot of inertia and therefore open much later after the development of a gradient between the LV and the aorta. The valve opening remains circular and does not become triangular, as seen in a compliant root. There has been speculation that the leaflet wrinkling inside a non-compliant root may increase leaflet stresses and may be responsible for earlier calcification. A stiff root seems to function at maximum level of efficiency and is not able to increase the valve area during a period of increased cardiac output. The compliance of the aorta and root also has a very important role in directing coronary blood flow to the myocardium.[5] The AV is continuous with the anterior leaflet of the mitral valve (MV). It connects the aortic root to the left ventricular outflow tract (LVOT). The left atrium is immediately posterior to the AV while the pulmonary valve (PV) is anterior. Abnormalities of any of the components of the AV or the adjacent structures can affect the function of the valve.

TEE examination of the AV

Evaluation of the AV should include two-dimensional (2-D) images from several views and angles together with colour flow Doppler (CFD) and spectral Doppler displays. By assessing the AV in the short-axis and long-axis views, all the different components of the valve and root can be examined. The aortic valve can be imaged using the following standard views:[6]

- Midoesophageal short axis view of the aortic valve (ME AV SAX).
- Midoesophageal long axis view of the aortic valve (ME AV LAX).
- Transgastric long axis view (TG LAX).
- Deep transgastric long axis view (deep TG LAX).



Shanewise JS, et al. Anesth Analg. 1999; 89:870-84

The ME AV SAX view is used to assess the structure and function of each of the three individual cusps and to perform planimetry. The typical "Mercedes Benz" sign during diastole is an easy image to obtain at approximately 40° by advancing and withdrawing the transducer slowly until all three commissures of the valve and the leaflet bodies are visible. The RCC is viewed in the anterior position at the bottom of the conventional screen, with the LCC on the right side of the image and the NCC to the left side on the image adjacent to the interatrial septum.

From the ME AV SAX view, it is easy to demonstrate the ME AV LAX view by keeping the probe in the same position and rotating the angle to around 120-140°. The left ventricular outflow tract (LVOT) is visible together with long-axis view of the valve, the whole aortic root and the ascending aorta. The RCC is anterior at the bottom of the screen with the NCC seen above it. The ME AV LAX view clearly demonstrates the function of the NCC and RCC. If the transducer is slightly rolled to the patient's left side, the LCC will be visible instead of the NCC. In the ME AV LAX view it is easy to measure the diameter of the annulus, sinuses of Valsalva, sinotubular junction and ascending aorta. The midoesophageal short axis, long axis and five chamber views cannot be used for Doppler measurements of flow velocity, because the ultrasound wave is perpendicular to the blood flow.

By advancing the transducer into the stomach and flexing slightly, the transgastric midpapillary short-axis view can be seen. If the operator then rotates the transducer to approximately 110°, the TG LAX view is found with the LVOT and AV on the right bottom of the image. The deep TG LAX view is more difficult to obtain. At 0° the transducer is advanced until the echo image disappears, and is then fully flexed. By gentle withdrawal, the transducer will make contact with the superior wall of the stomach and the deep TG LAX view should appear. The LVOT and AV will be seen in the left bottom part of the conventional image. It is important to find this view very gently in order to avoid damage to the stomach, gastroesophageal junction or oesophagus. In the two transgastric views the Doppler signal can be aligned almost parallel to blood flow through the AV and flow velocity can usually be measured using one or both of the views to calculate the pressure gradient via Bernoulli equation. It is important for the echocardiographer to be familiar with both transgastric approaches because they require considerable practice and expertise and are often difficult to obtain.

When evaluating the aortic valve for AS or AR, it is essential to always assess the geometry and contractility of the left ventricle (LV) in all the views. The recent introduction of real-time 3-D transoesophageal echocardiography (RT-3D) will certainly advance our knowledge of both normal AV physiology and pathology.

The assessment of AV pathology is very much affected by intraoperative changes in hemodynamic conditions, like level of anaesthesia, ventricular filling, inotropic support, and cardiopulmonary bypass.

Conclusion

In conclusion, TEE is valuable in revealing important aspects of aortic valve disease. While TEE may not be appropriate as the primary technique for aortic valve evaluation in the echo laboratory, it is indicated if TTE windows are poor. TEE evaluation of the aortic valve has now become invaluable in the perioperative setting. Although the highly-experienced surgeon may feel comfortable making decisions based on direct surgical inspection alone, most appreciate the ability of TEE to define the abnormality preoperatively, confirm their intra-operative impression and assess the postoperative results, even in routine valve replacement procedures. It is now recommended as routine

Classification of severity of aortic stenosis in adults. Adapted from Bonow et al, ACC/AHA VHD Guidelines: Focused Update. Circulation 2008; 118:e536[9]

Index	Mild	Moderate	Severe
Jet velocity (m/sec)	Less than 3.0	3.0-4.0	Greater than 4.0
Mean gradient (mmHg)	Less than 25	25-40	Greater than 40
Valve area (cm^2)	Greater than 1.5	1.0-1.5	Less than 1.0
Valve area index (cm^2/m^2)			Less than 0.6
Dimensionless severity index (VTILVOT/VTIAV)		0.25-0.5	Less than 0.25

Grading of severity of aortic regurgitation in adults. Modified from Zoghbi WA, et al. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography. J Am Soc Echocardiogr 2003; 16:777-02.[10]

Index	Mild	Moderate	Severe
CFD ratio jet width/LVOT (AR Index)	< 25%	25-65%	> 65%
CFD vena contracta (cm)	< 0.3	0.3-0.6	> 0.6
PWD holodiastolic flow reversal in descending Ao	No	No	Yes
CWD AR jet pressure halftime	> 400 msec		< 200 msec
Deceleration time			
LV enlargement (cm)			LVIDs >5.0 LVIDd >7.0
RV (ml/beat)	< 30		> 60
RF (%)	< 30		> 50
EROA (cm2)	< 0.1		> 0.3

intraoperative practice in cardiac or thoracic aortic surgery.[8] It provides definite information on the mechanisms of pathology, aids planning in aortic valve surgery, and is used by the surgical team to screen patients undergoing other cardiac procedures. However, quantitative assessment by Doppler techniques may be difficult in the perioperative setting using TEE, and measurements should be made with meticulous care if errors are to be avoided. RT-3D imaging will certainly change our approach to evaluating the AV in the foreseeable future.

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