The art of assessing aortic stenosis

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ABSTRACT

This review describes the assessment of the aortic valve by echocardiography and also the roles that multidetector CT (MDCT) and cardiac magnetic resonance have to play as complimentary imaging modalities. It describes how to resolve apparent discrepancies in grading aortic stenosis and discusses the management of apparently moderate stenosis associated with cardiac symptoms or left ventricular dysfunction. The role of cardiac imaging including three-dimensional (3D) echocardiography and MDCT scanning in the preparation for transcatheter aortic valve implantation and during and after the procedure are described. While echocardiography remains the mainstay of imaging, 3D modalities, notably MDCT, are increasingly useful and a multimodality approach is likely to become established as routine clinical practice.

Surgery is indicated for severe aortic stenosis (AS) in the presence of symptoms or left ventricular (LV) systolic dysfunction.[1] The management of apparently asymptomatic AS is less clear cut, but in the population potentially suitable for transcatheter aortic valve implantation (TAVI), intervention is only considered for unequivocal symptoms. Therefore recognition of occult symptoms and early LV dysfunction or predicting rapid progression are not necessary. This review discusses the role of imaging in establishing the presence of significant AS and in aiding the TAVI procedure. Although echocardiography remains the mainstay of assessment,[2 3] other three-dimensional (3D) techniques, notably multidetector CT (MDCT), are increasingly important and a multimodality approach is likely to be routine in the future.

IS THE AS SIGNIFICANT ENOUGH TO JUSTIFY TAVI?

Grading the severity of AS

The continuous waveform across the aortic valve must be recorded using steerable continuous wave Doppler but also the stand-alone probe from the apex and at least one other approach, usually suprasternal or right intercostal and occasionally subcostal. The minimum dataset is peak velocity, mean gradient and effective orifice area (EOA) using the continuity equation.[2] The waveform shape may also be helpful.[2] In severe AS it is arched with a peak to mean gradient ratio of less than 1.5, while in mild or moderate AS it is triangular and the ratio is greater than 1.7 (figure 1 and table 1).[4 5]

The mean gradient is more representative of the AS than the peak velocity, which describes only one point on the waveform. It is important to calculate EOA in every case because this is relatively independent of flow. The LV outflow diameter is measured 5–10 mm below the base of the cusps from inner to inner edge with the outflow tract maximally opened out. The pulsed sample is placed in the middle of the left ventricular outflow tract (LVOT) in the five-chamber view at the level of flow acceleration shown on colour. It is then moved up and down incrementally until a clean signal is obtained.

The appearance and mobility of the cusps can aid the grading of stenosis. Severe AS is unlikely if the cusp tips open well or if one cusp opens well despite the other two being immobile. Conversely, a heavily thickened and immobile valve suggests severe AS. Heavy calcification is associated with relatively rapid progression.[6]

When peak velocity, mean gradient and EOA are concordant the grading is straightforward. If there is discordance, the shape of the waveform and appearance of the valve may help decide whether mean gradient or EOA is the more representative.

Overcoming the problem of V_{max} less than 4.0 m/s and EOA less than 1.0 cm^2

This situation is common, occurring in approximately 25% of cases[7] and arises for a number of possible reasons:

1. Borderline discrepancies, typically with an EOA of approximately 0.9 cm^2 and V_{max} 3.5–3.9 m/s in the presence of apparently normal LV systolic function may occur because the cut-offs are necessarily arbitrary. In a European population, a cut-off EOA for severe less than 0.8 cm^2 may be more representative than one less than 1.0 cm^2.[8]
2. Low-flow AS is increasingly recognised even with normal ejection fraction (EF) and is defined by a velocity time integral less than 15 cm, indexed stroke volume less than 35 ml/m^2 or systolic flow (stroke volume/ejection time) below 200 ml/s.[8]
3. The situation is compounded by the fact that EOA should be indexed to body habitus, usually to body surface area (BSA). An EOA of 1.3 cm^2 (apparently moderate) in a small person (BSA 1.5 m^2) gives an EOAi 0.86 cm^2 (mild AS) while in a big person (BSA 2.5 m^2) the EOAi is 0.52 cm^2 (severe AS).
4. EOA may be inaccurate as a result of the LVOT being oval rather than circular as assumed by the conventional formula based on the continuity equation.

Whether borderline AS is truly moderate or severe can usually be resolved from the appearance and mobility of the valve and the waveform shape. If the waveform is triangular and the valve opens well this is moderate AS. If the valve does not open well there is more likely to be low-flow AS. If clinical doubt remains in the presence of low flow, the effect of low-dose dobutamine stress echocardiography on the gradient should be tested.[9]

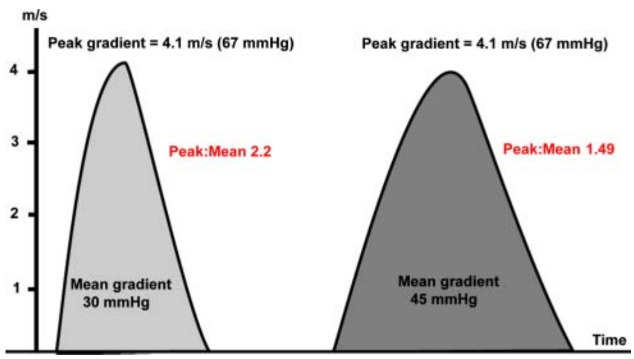

Figure 1 Continuous Doppler waveform shapes in patients with moderate and severe aortic stenosis (AS). The shape of the continuous Doppler waveform maybe useful in differentiating between patients with moderate and severe AS. In patients with moderate AS (left) the waveform is more triangular shaped and the peak:mean ratio is greater than 1.7. In severe AS (right), a more arched waveform is seen with a peak:mean ratio typically less than 1.5.

Dobutamine is infused at 5 and then 10 μg/kg per min (occasionally higher doses such as 15 and then 20 μg/kg per min are required, especially if there is earlier beta-blockade). This requires medical supervision because of the risk of cardiac arrhythmia, although the risk is not great at low infusion rates. An increase in mean gradient of at least to >30 mm Hg is usually used as a cut point for severe AS. LV contractile reserve[7 8] is defined by an increase in subaortic velocity integral greater than 20%. Mortality at surgery is substantially higher in the absence of contractile reserve. Contractile reserve was also thought to identify those in whom the LVEF would recover after surgery, although long-term recovery now appears to be similar with or without contractile reserve.[10 11] Finally, if doubt still remains, potential inaccuracies in the continuity equation can be resolved using a 3D technique. 3D transthoracic echocardiography (TTE) does not yet have sufficient resolution, but MDCT or 3D transesophageal echocardiography (TEE) can both provide a directly measured cross-sectional area to complement the haemodynamic information derived from TTE. An alternative method, proposed but not routine, is to substitute stroke volume calculated from LV volumes recorded on 3D TTE in place of the calculation based on LV outflow cross-sectional area and the systolic velocity integral.[12]

The problem of symptoms despite only moderate AS

Sometimes, the patient has symptoms despite the AS being moderate on both mean gradient and EOA even taking into account the secondary factors of waveform shape, valve appearance and indexed EOA. There may often be other possible causes including coronary artery disease, obesity, lung disease, or anaemia. The brain natriuretic peptide may be helpful if unequivocally high or normal,[13] in the absence of renal dysfunction. Intermediate levels are still difficult to interpret. The most helpful test is stress echocardiography to reveal LV wall motion abnormalities and to test the compliance of the aortic valve. Compliance means the ability of the valve to open as flow increases during exercise.[14] Most moderately stenotic valves open relatively well, but some do not and become effectively severely stenotic during stress. Stressors used are recumbent bicycle, treadmill and dobutamine, and a guide to severe AS is an increase in the mean gradient by more than 18 mm Hg.[15]

Table 1 Grading aortic stenosis

	Mild	Moderate	Severe
Peak velocity (m/s)	2.5–3.0	3.0–4.0	>4.0
Peak gradient (mm Hg)	<40	40–65	>65
Mean gradient (mm Hg)	<20	20–40 (50)*	>40 (50)*
EOA (cont eq.) (cm^2)	>1.5	1.0–1.5	<1.0
EOAi (cm^2/m^2)	>0.85	0.60–0.85	<0.60
Velocity ratio	>0.50	0.25–0.50	<0.25

*Denotes European Association of Echocardiography (EAE) only.[1] All other parameters are according to both the EAE and American Society of Echocardiography.[2]
EOA, effective orifice area; EOAi, indexed effective orifice area.

The problem of impaired LV function despite only moderate AS

Sometimes there appears to be disproportionate LV dysfunction for the grade of AS. This could arise if there is coexistent severe coronary artery disease, or as a result of alcohol or any other cause of LV dysfunction including myocarditis. However, there is increasing evidence that aortic compliance may interact with AS to modify LV systolic or diastolic function. Patients with moderate AS but a non-compliant aorta may have as much LV dysfunction as those with severe AS because it is the total LV outflow impedance that affects the left ventricle rather than the resistance at the valve alone.[16 17] A reduced arterial compliance also contributes to a blunted rise in cardiac output on exercise, a reduced exercise time and a higher incidence of spontaneous symptoms. There is no consensus on what to measure, although it is likely that the carotid-femoral aortic pulse wave velocity will be the most accurate. However, a simpler measure has been proposed: The valvulo-arterial impedance Z_{VA} (mm $Hg/ml/m^2$)=(systolic blood pressure+mean transvalvular pressure difference)/stroke volume index. A total impedance greater than 5 mm Hg/ml per square metre is considered to be high.[2]

What to do in the presence of high total impedance but only moderate AS is not known. Elderly people with 'burned-out' hypertension may have a normalised blood pressure, but fixed aortic compliance. In such cases, antihypertensive medication may not affect systolic aortic compliance. TAVI may then be the only means of reducing total impedance despite the AS being only moderate.

ECHOCARDIOGRAPHIC ASSESSMENT IN PATIENTS BEING CONSIDERED FOR TAVI

Preparation for the intervention

Not all patients are anatomically suitable and the minimum dataset for AS[2] needs to be supplemented based on the characteristics of the valve to be implanted.[3] There are two valves currently available commercially. The Edwards SAPIEN (Irvine, California, USA) is composed of bovine pericardial cusps within a balloon-expandable, stainless-steel or colbalt chromium stent. It is currently available in three sizes, the 23 mm to fit tissue annulus diameters 18–21 mm, and the 26 mm for annulus diameters 22–25 mm. A 29 mm valve has recently been introduced for annulus diameters 25–28 mm. The stents are 14, 16 and 18 mm long for the 23, 26 and 29 mm valves, respectively (when expanded) and, when implanted, their midpoint lies approximately at the level of the aortic valve so they can be placed above a subaortic septal bulge and are not dependent on the size of the aorta above the annulus.

The Medtronic CoreValve (Minneapolis, Minnesota, USA) is composed of porcine pericardial tissue within a self-expanding nitinol stent. It is currently available in three sizes, the 26 mm is designed for tissue annulus diameters 20–23 mm, the 29 mm for tissue annulus diameters 24–27 mm and a 31 mm size for tissue annulus diameters up to 29 mm. The CoreValve stents are 53 and 55 mm long. Their proximal part anchors the valve within the LVOT, a narrower, waisted middle segment is placed at the level of the sinus of Valsalva and an upper section expands to anchor the valve in the proximal ascending aorta. A 26 mm CoreValve requires a sinus diameter of 27 mm or more and a sinotubular diameter of 40 mm or less. A 29 mm CoreValve requires a sinus diameter of 29 mm and an aortic diameter of 43 mm or less. To ascertain the size and type of device and minimise the risk of events, a comprehensive imaging dataset is essential (table 2), and may affect the choice of procedure (table 3).

The morphology of the LV outflow-valve-root unit

The most common aetiology in the patient of TAVI age is calcific degenerative disease. However, it is important to exclude a bicuspid valve because this may preclude TAVI or make procedural success less likely because of incomplete or misplaced deployment. The orifice needs to be examined in systole because the median raphe may resemble the edge of a cusp in diastole. In calcific degenerative disease, thickening starts at the base of the cusps and progresses towards the orifice. All three cusps are usually affected but one or more may be dominant. It is important to note the presence of heavy calcification towards the tip of the left coronary cusp because this can infrequently be pushed into the left main stem (LMS) during device inflation.

The diameter of the 'echocardiographic annulus' is a key measurement in determining whether a commercially available TAVI device can be fitted, and if so, which size. Undersizing increases the likelihood of a paraprosthetic leak occurring peri and post-procedure, which, if severe, may cause symptoms and is associated with an increased risk of death and non-fatal events including valve migration.[18] Oversizing can cause failure of deployment and central regurgitation.

The annulus diameter should be measured on a zoomed view from inner to inner margin at the base of the cusps in a systolic frame with maximal leaflet separation. However, there is no true aortic valve annulus as there is for the mitral valve. Instead the base of each cusp is crescentic and rises from LV outflow to the level of the sinuses. This means that the diameter can be overestimated by measuring to the rising part of the cusp base instead of the hinge point between the base of the anterior mitral leaflet and the adjacent aortic cusp. The annulus shape is also often slightly ellipsoidal rather than circular and may be underestimated by TTE or two-dimensional (2D) TEE. If there is doubt, particularly if image quality is poor and the diameter is close to the minimum (18 mm) or maximum (28 mm) feasible for TAVI, this diameter should be checked on TEE ideally with 3D (figure 2) or using MDCT before the decision is made. Otherwise it should be checked at the time of implantation. 3D TEE can also be used in place of MDCT for assessing the distance between the annulus and the ostium of the LMS. Although caution is advised for SAPIEN valve implantation when the distance from the annulus to the coronary ostia is less than 10 mm, in practice it is the morphology of the native aortic valve that appears to be more important than the height of the coronary ostia. There is minimal risk of obstructing the coronary arteries using the CoreValve. In the presence of a large subaortic septal bulge, the deployment technique of the SAPIEN valve may need to be modified to avoid upward displacement, or a CoreValve used for implantation.

Severe dilatation of the aorta (>45 mm with a bicuspid valve and >55 mm with a tricuspid valve) usually requires surgery at the same time as aortic valve replacement. However, in elderly patients, a greater degree of aortic dilatation is usually accepted and TAVI may still be performed beyond these thresholds, although an ascending aortic diameter greater than 43 mm may preclude the use of a CoreValve. Heavy aortic calcification may contraindicate conventional surgery and 'porcelain aorta' is an indication for TAVI even in otherwise fit patients (see table 3).

Table 2 Imaging dataset required pre-TAVI

	TTE	TEE	MDCT
Aortic valve morphology	++	+++	+++
Annulus			
Diameter	+	++	+++
Distance to RCA	+	++	+++
Distance to LMS	–	+	+++
Aorta			
Sinus diameter	++	+++	+++
Ascending diameter	+	+++	+++
Calcification	+	+	+++
Other			
LV function	+++	+	+
MR severity	+++	+++	–
RV/PA pressure	+++	++	–

Quality of information acquired from echocardiography and MDCT (+++ highest quality). LMS, left main stem; LV, left ventricular; MDCT, multidetector CT; MR, mitral regurgitation; PA, pulmonary artery; RCA, right coronary artery; RV, right ventricle; TTE, transthoracic echocardiography; TEE, transesophageal echocardiography.

The left ventricle

There is a wide variation in LV geometry and function in relation to wall stress, and the presence or absence of LV hypertrophy does not aid the grading of AS. A reduced EF should alert the operator to the presence of low flow as the cause of a discrepancy between gradient and EOA. However, it is possible to have low flow even with a normal EF in the presence of a small cavity. The extent of scarring helps decide how much recovery may be expected after TAVI while significant scarring at the apex precludes a transapical approach. A very small cavity can make the transapical approach difficult, while pericardial calcification precludes an apical approach and LV thrombus precludes TAVI altogether.

The mitral valve and right ventricle

Mitral regurgitation is common in the presence of severe AS. A small degree will resolve after a fall in LV pressure and progressive LV remodelling. However, mitral valve surgery is usually needed if there is moderate or worse regurgitation in the presence of organic mitral valve disease or if there is severe functional regurgitation.

Table 3 Echocardiographic or other imaging features affecting the procedure

Management decision	Echocardiographic feature
Favour TAVI over conventional surgery	Pulmonary hypertension Porcelain aorta
Favour conventional surgery over TAVI	Severe organic mitral regurgitation LV thrombus
Contraindicate apical approach for TAVI	Very small LV cavity size Pericardial calcium Apical patch

LV, left ventricular; TAVI, transcatheter aortic valve replacement.

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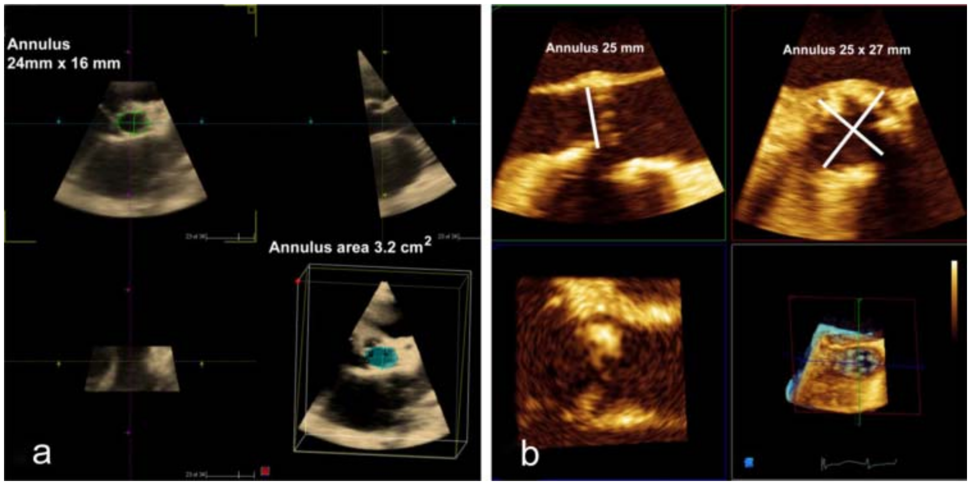

Figure 2 Measurement of the aortic annulus. The measurement of the aortic annulus using three-dimensional (3D) transthoracic echocardiography (A) and 3D transesophageal echocardiography (B). Both techniques demonstrate an ellipsoid shape to the aortic annulus.

Pulmonary hypertension occurs in 25% of patients with severe AS and if severe will increase the mortality of conventional surgery typically to 35%.[19] Severe pulmonary hypertension is most likely with severe AS, low LVEF, evidence of high LV filling pressures and grade 3 or 4 mitral regurgitation,[20] and is a recognised criterion for TAVI in place of conventional surgery.

NON-ECHOCARDIOGRAPHIC IMAGING MODALITIES

MDCT assessment of AS

MDCT is better than echocardiography at detecting the presence of calcium in the aortic valve and root and is also able to quantify it using Agatston units.[21] The degree of valve calcification is related to echocardiographic gradient and orifice area,[22] but cannot yet be used on its own to grade stenosis severity. However, it can image the anatomical orifice at sub-0.6 mm resolution with 3D isotropic imaging at any stage of the cardiac cycle to produce an estimate of geometric orifice area. This correlates with but inevitably overestimates EOA calculated echocardiographically.[23] In a recent meta-analysis of nine studies involving a total of 437 patients, the mean geometric orifice area measured by MDCT was 1.0 ± 0.1 cm^2 compared with a mean EOA of 0.9 ± 0.1 cm^2 measured by TTE.[23]

MDCT shows that the LVOT is ellipsoid in shape and the directly measured LV outflow area is on average 0.6 cm^2 greater than estimated by TTE.[24] Although MDCT 3D imaging data could be integrated into the assessment of AS with a corrected continuity equation,[25] it involves ionising radiation and an intravenous contrast injection. It is also prone to error in the presence of arrhythmia or blooming artefact when there is significant calcium. Accordingly, MDCT is a second-line investigation indicated when discrepancies exist or echocardiographic image quality is significantly reduced secondary to poor acoustic windows.

In preparation for TAVI, MDCT was originally used solely for assessing the dimensions, calcium distribution and tortuosity of the thoracic and abdominal aorta and the iliac and femoral arteries. However, modern systems have a broader application. MDCT is markedly better than TTE or 2D TEE at assessing the height of the coronary artery ostia above the annulus.[26] The height of the LMS varies between 7.7 and 28.5 mm[26] (figure 3), and an accurate assessment may help avoid the potentially fatal complication of LMS occlusion. A distance of more than 10 mm is required for the 23 mm SAPIEN valve and more than 11 mm for the 26 mm SAPIEN valve. MDCT also measures true annulus area thus avoiding the errors implicit in assuming a circular cross-section[26] (figure 3). It can potentially change decisions about sizing the prosthesis and even whether to proceed with TAVI in up to 40% of patients,[25 27] and could reduce the incidence of paravalvular regurgitation[28] by reducing undersizing.[29 30] MDCT can define the angle of the LVOT to the aorta and this might aid deployment of the prosthesis.[31]

CMR imaging

Cardiac magnetic resonance (CMR) can delineate the anatomical orifice area and elucidate haemodynamic information from flow mapping, but is not in routine clinical use.[32] CMR provides better anatomical information than echocardiography regarding the aorta and gives systematically larger and probably more accurate estimates for annulus size. The agreement between CMR and TTE on TAVI size selection in one study[33] was only 14% ($\kappa=-0.06$) compared with 50% ($\kappa=0.31$) between MDCT and CMR. Paraprosthetic regurgitation was uncommon and was associated with large annulus size on CMR but not on TTE, which calls into question the significance of discrepancies between sizing by CMR and TTE. CMR also produces better estimations of LV mass for research studies than using 2D echocardiography, although they are only better than 3D echocardiography if echocardiographic windows are suboptimal.

PERIOPERATIVE 'TIPS AND TRICKS' ON AORTIC VALVE IMAGING DURING TAVI

TTE is always essential for locating the apex for a transapical approach.[3] TEE is not viewed as essential in monitoring the procedure because fluoroscopy can be used to guide positioning of the TAVI device. If the procedure is to be performed under local anaesthesia TEE is not well tolerated, and of the alternatives, pernasal imaging has poorer resolution and intracardiac echo is not widely available. However, many units including ours find 3D TEE very useful for guiding the procedure (figure 4), for managing complications (figures 5 and 6) and for detecting aortic regurgitation after the procedure (figure 7).

Locating the apex

Immediately before a transapical approach with the patient positioned for the procedure, the apex needs to be localised using a transthoracic four-chamber then two or three-

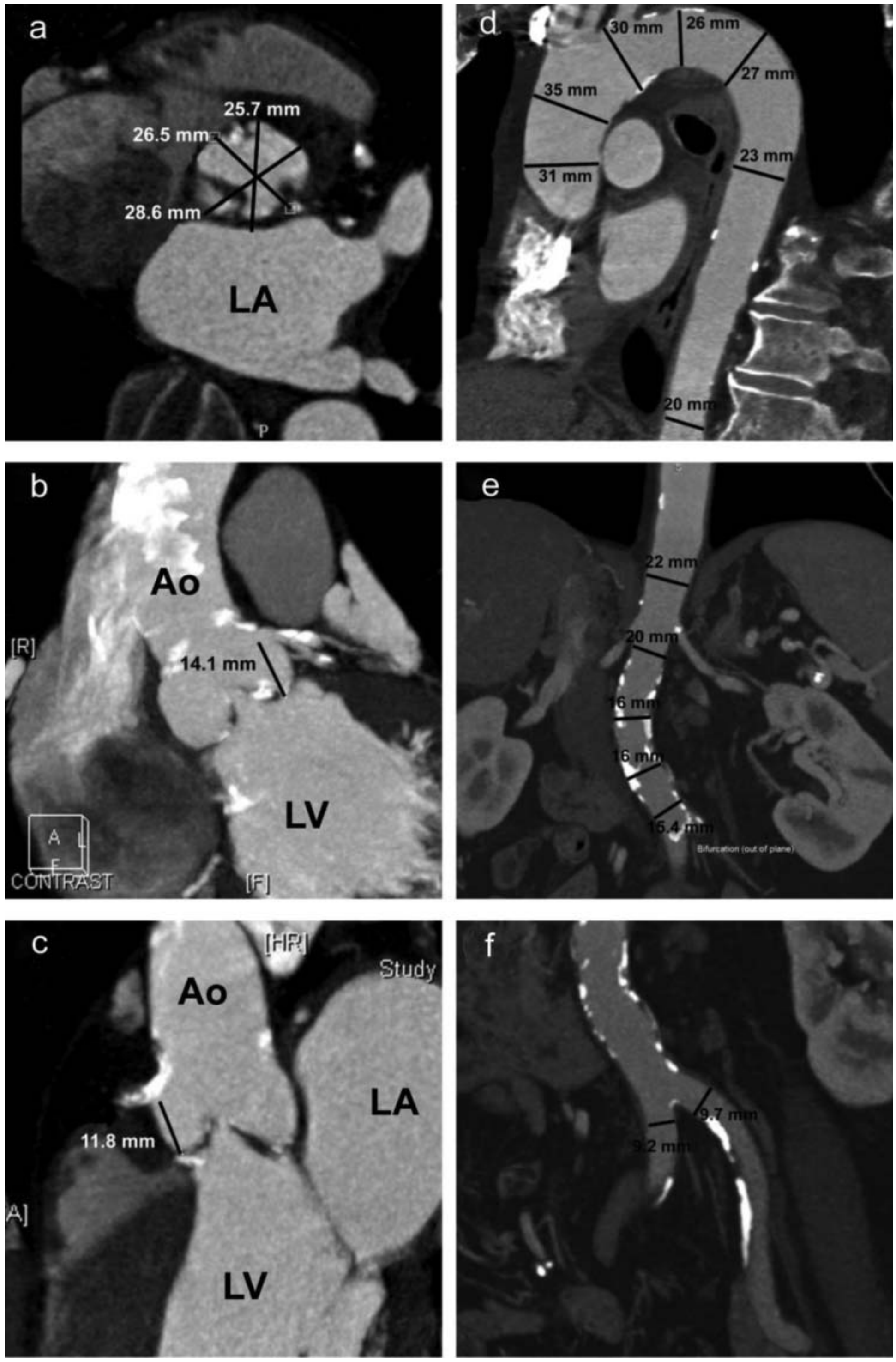

Figure 3 Multidetector CT (MDCT) protocol for transcatheter aortic valve replacement (TAVI) assessment. A standard MDCT protocol for TAVI assessment involves the measurement of the aortic valve annulus in cross section (A), the height of the aortic annulus to the ostia of the left mainstem (B) and right coronary artery (C), and detailed measurements of the thoracic (D) and abdominal aorta (E). For transfemoral TAVI suitability assessment, the iliac and femoral arteries are assessed for size, tortuosity and the extent and distribution of vessel calcification (F). Ao, aorta; LA, left atrium; LV, left ventricle.

chamber view. If the access point is vertically over the apex, too much angulation may be required to pass the guidewire through the aortic valve into the ascending aorta. The appropriate access point should be agreed between the sonographer and surgeon and then marked. The patient must not be moved after this.

Annulus diameter and leaflet calcification

The annulus diameter should be confirmed. Often, in heavily calcified valves the annulus is not circular so a single 2D measurement in the long axis view (110–130°) will not suffice. In addition, the extent and distribution of any calcification is extremely important. If leaflet calcification is eccentric,

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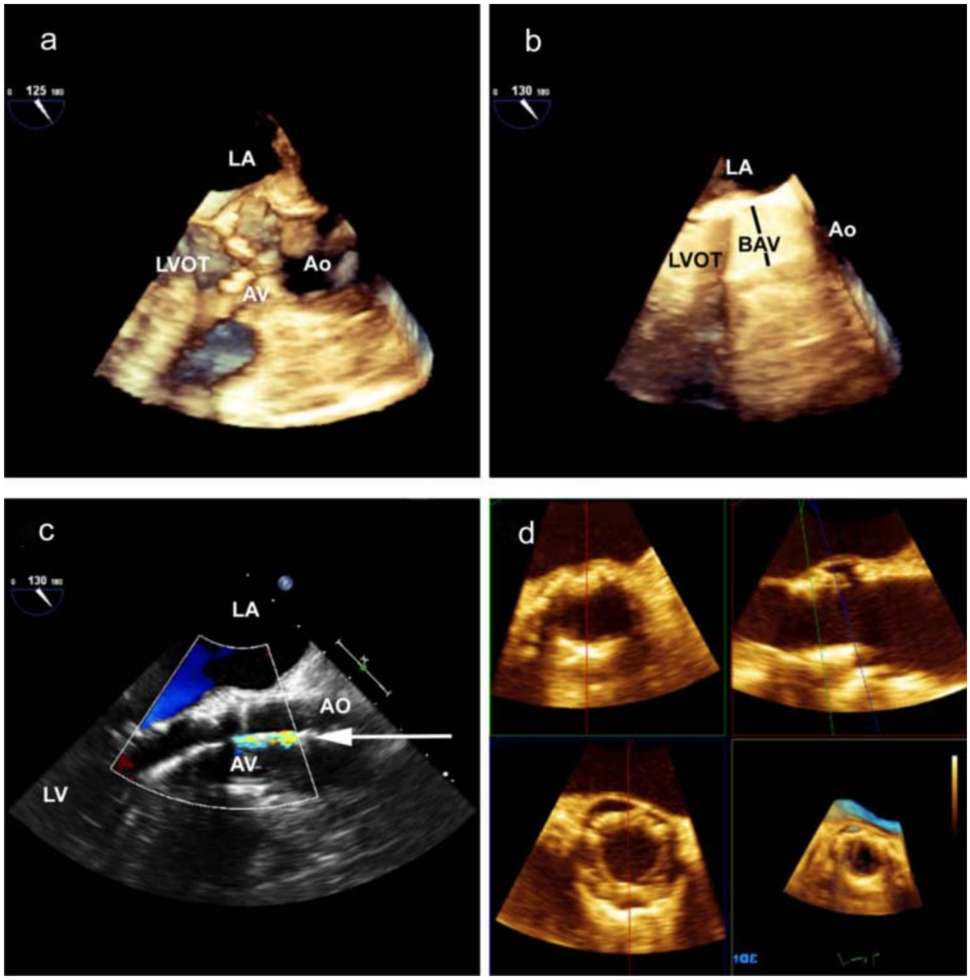


Figure 4 Use of transesophageal echocardiography (TEE) in transcatheter aortic valve replacement (TAVI). (A) Shows the three-dimensional (3D) TEE appearance of severe aortic stenosis in long axis view. Following balloon aortic valvuloplasty (BAV) (B), the guide wire is left positioned within the left ventricle (LV) (C) and is used to guide prosthesis deployment (arrow). (D) Shows the appearance of a successfully deployed TAVI on 3D TEE. The prosthesis is closely opposed to the aortic wall with no encroachment onto the anterior mitral valve leaflet or obstruction of the coronary ostia. The valve leaflets open freely in systole and are flush with the stent border. Ao, aorta; AV, aortic valve; LA, left atrium; LVOT, left ventricular outflow tract.

paravalvar regurgitation is more likely post-deployment. Calcification above the leaflets in the sinuses is important, especially if the leaflet is bulky and the sinuses are not large. During valve deployment this may occlude the coronary ostia or cause aortic rupture. Calcification in the LVOT and valve leaflets can make coaxial positioning of the prosthetic valve difficult, leading to uneven deployment and increasing the risk of displacement.

Guide wire positioning

With an antegrade (transapical) approach, TEE helps in locating the guide wire in the LVOT (figure 4), and ensures that it has not passed through the subvalvar mitral apparatus, which tends to lead to the development of mitral regurgitation. If this occurs, the guide wire should be repositioned if at all possible. Sometimes the guide wire passes through the mitral valve into the left atrium, which can be appreciated on TEE but not on fluoroscopy.

With a retrograde approach, TEE can assist with negotiating the guide wire through the orifice of the aortic valve. The guide wire can be imaged in the left ventricle ensuring that there is a good loop that does not interfere with the mitral valve apparatus. The tip of the wire must not curl back into the LVOT, which risks it being trapped during prosthesis deployment.

Valve deployment

TEE during balloon aortic valvuloplasty (BAV) and subsequent prosthesis positioning and deployment is invaluable, particularly when there is little calcification. Significant aortic regurgitation is rare after BAV, but can be detected easily by TEE allowing immediate implantation of the ready-prepared TAVI prosthesis.

If there is a septal bulge, it is important to know the distance from this to the coronary ostia, to ensure there is sufficient height (>14 mm for a 23 mm SAPIEN and >16 mm for a 26 mm SAPIEN) to position the prosthesis without obstructing coronary flow. For a CoreValve, the lower end of the prosthesis needs to be positioned 4–5 mm into the LVOT to ensure correct anchoring.

Complications

If a patient has a significant drop in blood pressure with or without ECG changes post-BAV or prosthesis deployment, TEE can diagnose occlusion of a coronary artery by detecting the presence of a new wall motion abnormality. Alternatively, a pericardial effusion may be apparent. This is most commonly due to perforation of the right ventricle by the temporary pacing wire, but could be due to aortic rupture or perforation of the left ventricle by the guide wire (figures 5 and 6).

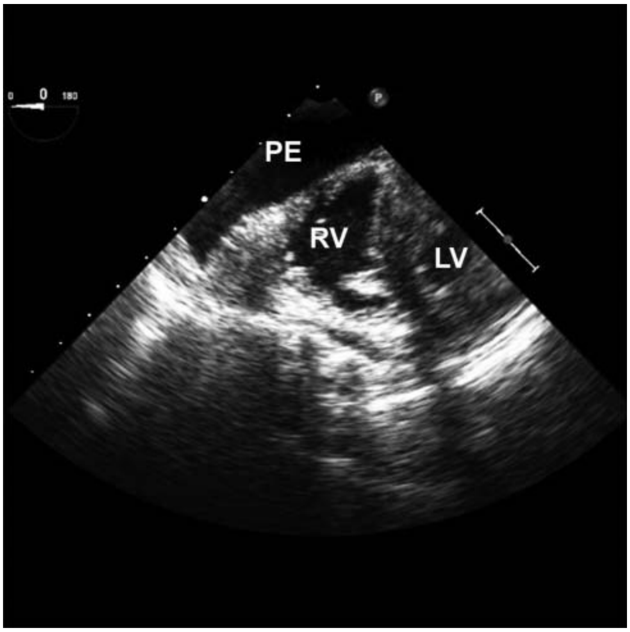


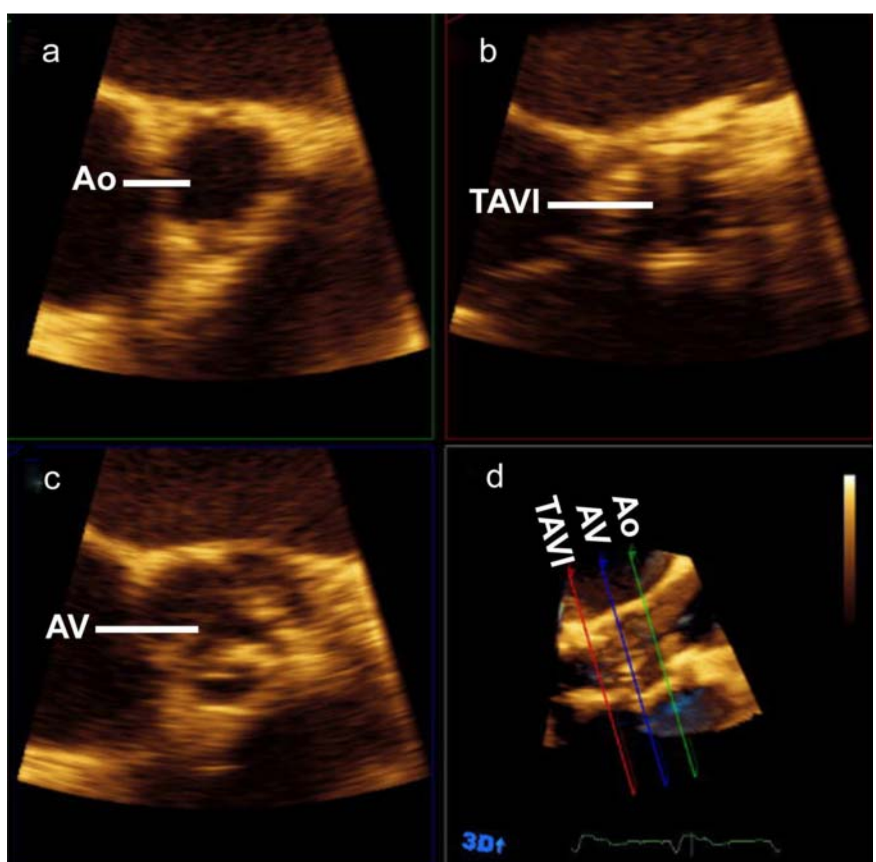
Figure 5 Transcatheter aortic valve replacement (TAVI) complication: pericardial effusion (PE). Transoesophageal echocardiogram (transgastric plane) demonstrating a large pericardial effusion that progressed rapidly to tamponade in a patient undergoing TAVI. Pericardial tamponade is a rare complication of TAVI and can occur with guide wire perforation of the left ventricle (LV) or pacing wire perforation of the right ventricle (RV).

Valvar and paravalvar regurgitation will be assessed. Usually any valvar regurgitation will resolve once the guide wire is removed, but occasionally a valve leaflet fails to function. A degree of paravalvar regurgitation is almost invariable, so is not really a complication, but significant paravalvar regurgitation may be a problem. It may be necessary to attempt to expand the stent further with a second balloon inflation in order to reduce this. Occasionally, a second prosthesis may need to be inserted overlapping with the first in order to resolve this situation. If the prosthesis has been deployed too far into the LVOT it may impinge on the anterior mitral valve leaflet and cause a degree of mitral stenosis. There is also the theoretical risk of a perforation developing in the anterior mitral leaflet.

Post-deployment and follow-up

Correct functioning of the aortic prosthesis is assessed by TEE immediately post-deployment and subsequently with TTE as for any biological aortic valve replacement.[34] A degree of central aortic regurgitation is always associated with the guide wire. Paraprosthetic regurgitation is common (figure 7A), but is generally mild. Nonetheless, this can be very difficult to assess accurately, as the jets are eccentric and may splay widely even from a narrow origin. This means that, when looking at a short axis view, it is possible to cut across the jet in a way that makes it appear far more significant than it really is. In general, any paraprosthetic regurgitation tends to reduce over time, particularly for the CoreValve because it continues to expand. An increase in paraprosthetic regurgitation would only occur if the valve displaced, which usually happens during the procedure or very soon afterwards. A late increase in paravalvar regurgitation

Figure 6 Transcatheter aortic valve implantation (TAVI) complication: valve migration. Three-dimensional transesophageal echocardiography (parallel multiplanar reformatted images) of a patient in whom low deployment of the TAVI valve left the native aortic stenosis untreated. In heavily calcified aortic annuli there is a possibility of TAVI migration. In this case the patient was treated with a further TAVI at the level of the aortic valve at a later date. Ao, aorta.



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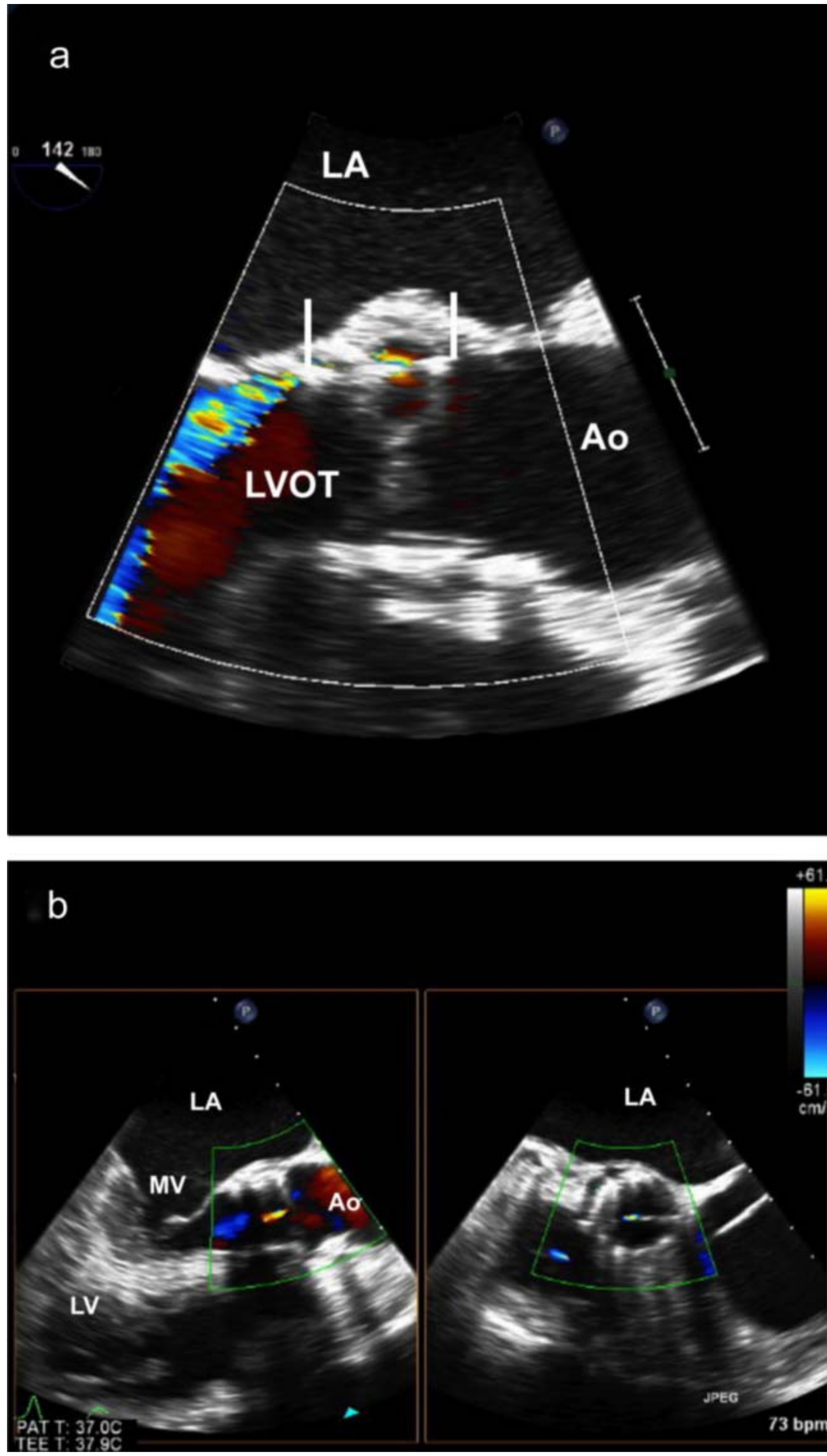

Figure 7 Regurgitation after transcatheter aortic valve implantation (TAVI). (A) Two-dimensional transesophageal echocardiography (TEE) demonstrating the presence of moderate paravalvular regurgitation following TAVI. (B) Three-dimensional TEE demonstrating the presence of mild transvalvular regurgitation in two orthogonal planes following TAVI. Ao, aorta; LA, left atrium; LV, left ventricle; LVOT, left ventricular outflow tract; MV, mitral valve.

suggests endocarditis, while an increase in regurgitation through the valve would suggest endocarditis or primary failure.

CONCLUSION

The nature of AS has evolved. Patients are now older with more comorbidities and are harder to assess. Rather than using resting echocardiographic measures alone we increasingly need to assess left ventricle–aortic valve–aortic coupling, assess the effect of exercise and take account of biomarkers of cardiac function, notably brain natriuretic peptide. There is a trend towards multimodality imaging with echocardiography providing flow data while MDCT gives more accurate and detailed anatomical data, especially of the aortic root and coronary arteries. It is increasingly important that every surgical centre and ideally every large district general hospital should have physicians specialising in valve disease and cardiac imaging.[35]

Conflict of interests None.

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