REVIEW

Imaging

Imaging to select and guide transcatheter aortic valve implantation

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Transcatheter aortic valve implantation (TAVI) is indicated for patients with severe aortic stenosis and high or prohibitive surgical risk. Patients' selection requires clinical and anatomical selection criteria, being the later determined by multimodality imaging evaluation. Echocardiography, multislice computed tomography (MSCT), angiography, and cardiovascular magnetic resonance (CMR) are the methods available to determine the anatomical suitability for the procedure. Imaging assists in the selection of bioprosthesis type, prosthetic sizing and in the decision of the best vascular access. In this review, we present our critical appraisal on the use of imaging to best patients' selection and procedure guidance in TAVI.

Keywords   Transcatheter aortic valve implantation • Imaging • Aortic stenosis

Introduction

Transcatheter aortic valve implantation (TAVI) is an alternative treatment for patients with severe symptomatic aortic stenosis (AS), who are at a high risk for conventional aortic valve replacement (AVR) or considered inoperable.[1] This procedure requires a multidisciplinary team approach, involving interventional cardiologists, cardiac and vascular surgeons, anaesthesiologists, and imaging specialists (*Figure 1*). The Edwards SAPIEN and CoreValve are the current prosthesis approved for TAVI, both with good clinical and haemodynamic results at mid-term follow-up.[2–4] Each valve has specific characteristics and different aortic anatomic requirements. In consequence, cardiac imaging plays an essential task for proper patients' selection and decision-making on procedure access route.

The first Edwards SAPIEN valve commercially available is balloon-expandable, composed of a cylindrical stainless steel balloon-expandable stent into which three symmetric leaflets made of bovine pericardium. It is available in two sizes and approved for clinical use in Europe and USA. The new generation valve, the Edwards SAPIEN XT is a balloon-expandable cobalt–chromium stent matching leaflets made of bovine pericardium. The stent has also a polyethylene terephthalate fabric skirt that decreases paravalvular leaks and it can be deployed by a smaller calibre system (18 F) via transfemoral or transapical route. The CoreValve is made of porcine pericardial tissue sewn to form a trileaflet valve mounted within an asymmetrical self-expanding nitinol frame. The lower portion of the frame affixes the valve to the left ventricle outflow tract (LVOT), the mid-portion has a constrained waist that must be deployed at the level of the sinuses of Valsalva and coronary ostia and the upper section is designed to fix and stabilize the prosthesis in the ascending aorta. The Corevalve is designed for arterial access, generally performed through the femoral or subclavian artery, but direct aortic access is also an alternative and there are case reports of deployment using a transapical route.[5] Both Edwards SAPIEN XT and CoreValve are approved for clinical use in Europe and have four sizes commercially available (*Tables 1* and *2*).

Echocardiography along with angiography have been the cornerstones of imaging for patient's selection and procedure guidance.[6] Additionally, multislice computed tomography (MSCT) has shown to add significant information on aortic valve, aorta and peripheral vessels anatomy, and calcification. Cardiovascular magnetic resonance (CMR) has been underused among TAVI patients, mainly by its limitations in the evaluation of calcification when compared with MSCT, and by the greater cooperation required to patients. Nevertheless, it is a good alternative to echocardiography when the acoustic window is limited.

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Imaging in patients selection for transcatheter aortic valve implantation

Severity of aortic stenosis

Transthoracic echocardiography (TTE) is the first imaging modality in the evaluation of candidates for TAVI. It should be used for detailed anatomic and functional assessment, with description of heart chamber dimensions plus ventricular and valvular morphology. It establishes the presence of severe AS, similarly to the general AS population. It is defined by aortic valve replacement of ≤ 1 cm^2 (<0.6 cm^2/m^2) or a mean aortic valve gradient of ≥ 40 mmHg.[7,8]

In the presence of LV systolic dysfunction or small ventricles with normal ejection fraction, dobutamine stress echocardiography (maximum stress dose 20 μg/kg/min), can support the differential diagnosis between true severe AS and pseudo-severe AS. If the maximum jet velocity rises over 4 m/s with the dobutamine-induced increase in stroke volume and the AVA remains <1.0 cm^2, the valve is truly severely stenotic. Conversely, if stroke volume increases with minimum rise in gradient, causing the valve area to increase significantly, then the AS should be only mild to moderate, being the LV dysfunction due to causes other than AS. Patients with low flow/low gradient AS might present higher AVR surgical mortality, but their survival is still reported to be better if treated surgically, in consequence its referral for TAVI should not be delayed.[9–11]

In most cases TTE is appropriate to estimate the severity of AS, however, in the presence of acoustic window constrains, transoesophageal echocardiography (TOE) can be useful, particularly for the assessment of aortic valve planimetry. As alternative, time-velocity integral ratio, between LVOT and aortic valve, expresses the size of the valvular effective area. It is an approach to reduce the error of imprecise LVOT diameter measurement, and severe stenosis is expected to be present when the velocity ratio is ≤ 0.25 or less.[12] Invasive measurements are exceptionally needed when there is a discrepancy between clinical and echocardiographic assessments.

Cardiac magnetic resonance can be also useful in quantifying the severity of AS if there is a discrepancy between clinical and echocardiographic examinations.[13] It provides a detailed anatomic assessment of the aortic valve, which can be used to describe valvular morphology and obtain direct planimetry aortic valve area and precise aortic annulus measurements (*Figure 2*). It can be important to exclude associated aortic valvular regurgitation or significant mitral regurgitation, independently of acoustic windows limitations. In addition, reliably describes LV dimensions and function, myocardial viability and scarring. However, up to now it has been restricted to doubtful cases or to patients with echocardiographic windows constrains.
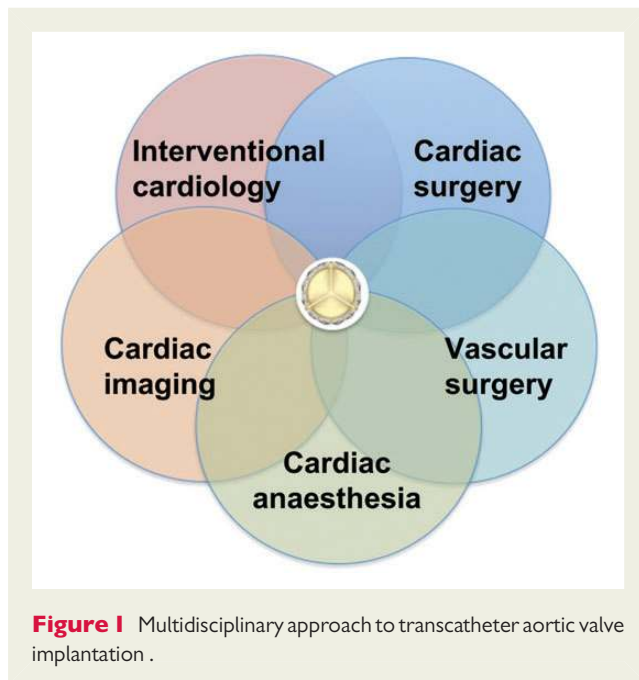

Figure 1 Multidisciplinary approach to transcatheter aortic valve implantation .

Aortic root morphology and aortic annular size

The evaluation of the anatomic characteristics of the aortic valve and aortic annular dimensions is critical for TAVI success. Transthoracic echocardiography and TOE should be used to describe the number of cusps, its mobility, thickness, and calcification. The presence of a bicuspid aortic valve is a relative contra-indication for TAVI because of the risk of spontaneous aortic dissection or

Table I Aortic anatomical requirements of contemporary transcatheter aortic valve prosthesis

	Prosthesis size (mm)	AV annulus (mm)	S. Valsalva (mm)	Sino tubular junction (mm)
CoreValve evolut	23	17–20		
CoreValve	26	20–23	≥ 27	≤ 40
	29	23–27	≥ 28	≤ 43
	31	26–29	≥ 28	≤ 43
Edwards Sapien	23	18–22		
	26	21–25		
Edwards Sapien XT	20	16–19		
	23	18–22	–	–
	26	21–25	–	–
	29	24–27		

Table 2 Imaging methods for the evaluation of patients' anatomical suitability for TAVI according to current practice

	TTE/ TOE	MSCT	CMR	Angiography
AS severity	+++	+	++	+
LV function	+++	+	++	−
LV septal thickness	+++	++	++	−
Concomitant valvular disease	+++	+	+++	−
AV annulus diameter	+++	+++	+++	++
AV anatomy	++	+++	++	−
AV calcification	++	+++	−	++
Aortic root measurements	++	+++	+++	++
AV annulus—coronary arteries distance	±	+++	+++	±
Coronary artery disease	−	++	++	+++
Peripheral arteries anatomy	−	+++	++	++
Peripheral arteries calcification	−	+++	−	+

AS, aortic stenosis; LV, left ventricular; AV, aortic annulus; TTE, transthoracic echocardiography; TOE, transoesophageal echocardiography; MSCT, multislice computed tomography; CMR, cardiac magnetic resonance. +++ Most frequently used, ++ less frequently used, + least used, − unsuitable.

incorrect deployment of the aortic prosthesis, due to the elliptical valvular orifice. However, procedure success on bicuspid aortic valves has been reported by experienced centres.[14]

In patients with poor acoustic windows and/or in the presence of heavy calcification, MSCT can be the best method to differentiate tricuspid from bicuspid valvular anatomy and evaluate calcifications.[15] Associations between severe aortic valve or aortic root calcification, measured either by contrast- or non-contrast MSCT, and post-TAVI paravalvular aortic regurgitation (AR) have been described.[15] Aortic valve bulky calcification increases the risk of gaps between the external surface of the prosthesis and the host native valve, determining paravalvular regurgitation leaks. Moreover, the severity, asymmetry, and the device 'landing zone' calcification may constrain differences in the tension−force across the valve, which can cause asymmetric deployment of the prosthesis and increase the risk of compression of the coronary arteries ostium. Large calcification at the edge of native valvular leaflets may increase the risk of coronary occlusion by displacement over the coronary ostium. Furthermore, heavy calcification in the sinotubular junction may cause restriction during balloon expansion at the aortic end and consequent affecting ventricular displacement of the device at the time of deployment.

The measurement of the height of the coronary ostia relative to the aortic annulus is an important requirement before TAVI and comprehensively performed by MSCT. The minimum distance between the coronary ostia and the aortic valve annular plane should be $\geq 10-11$ mm for both commercially available valves. However, particularly for CoreValve, the sinus of Valsalva width and calcification severity should be considered and height classified accordingly, as the CoreValve may only be used for height >10 mm if the native valve is not heavily calcified and it is sufficient wide (≥ 27 mm). The
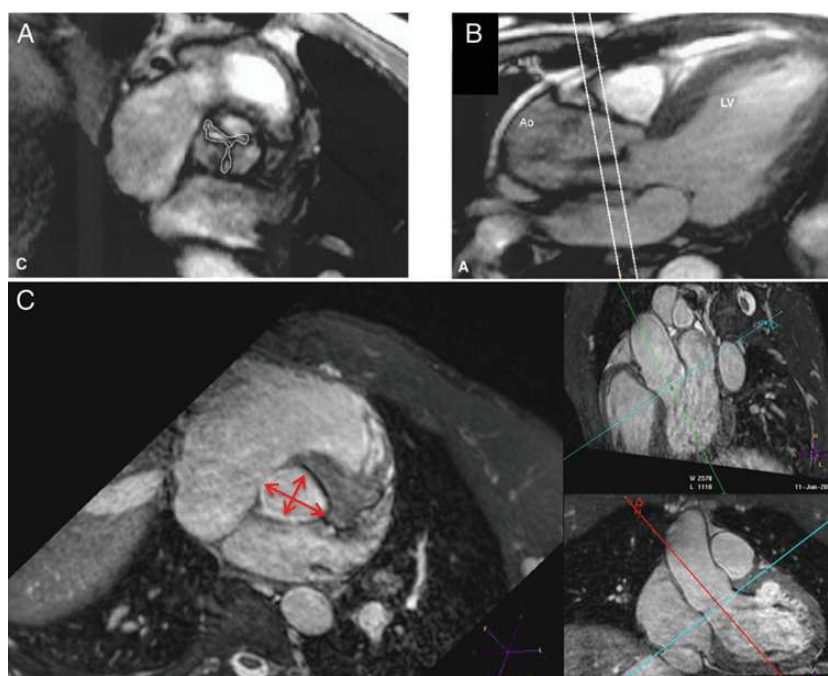

Figure 2 Cardiac magnetic resonance view of aortic valve area planimetry (*A* and *B*) and aortic annulus measurements (*C*).
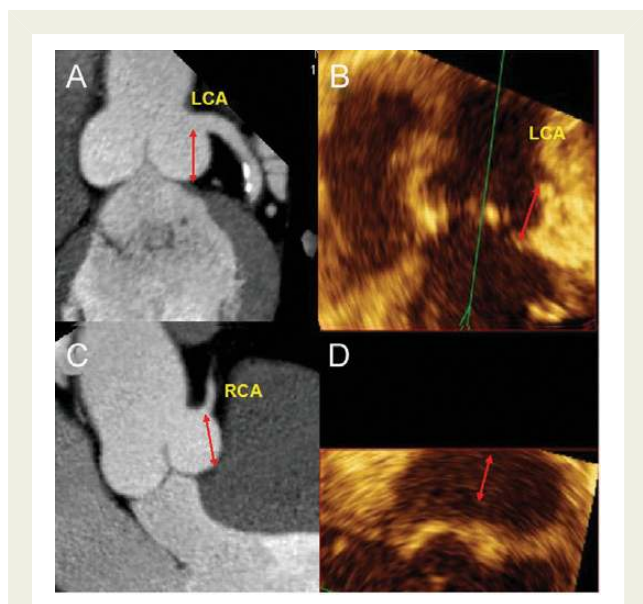
Figure 3 Multislice detector computed tomography (*A* and *C*) and three-dimensional TOE (*B* and *D*) measuring the distance between annulus and coronary ostia. LCA, left coronary artery; RCA, right coronary artery.
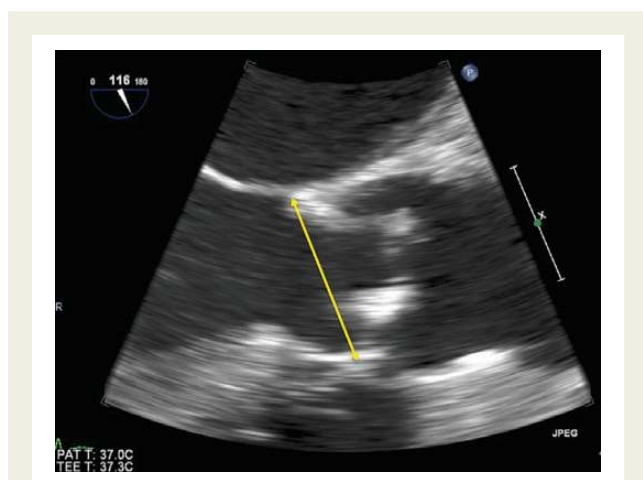

Figure 4 Transoesophageal echocardiography view for the measurement of aortic annular dimension.

right coronary annular-ostial distance is possible to measure with two-dimensional (2D) TOE, whereas the left coronary annular-ostial distance requires three-dimensional (3D) TOE or MSCT (*Figure 3*). Hence, the precise evaluation of aortic valve anatomy and extent and location of calcification by MSCT may help to improve procedure planning and anticipate and avoid potential complications. In pre-procedural evaluation, MSCT includes a complete assessment of coronary anatomy with conventional coronary angiography; however, it is generally limited by the advanced calcified disease.[16]

The aortic prosthetic size is dictated by the aortic valve annulus dimensions, being its accurate sizing a crucial step for procedure

success. Transcatheter aortic valve implantation bioprostheses are typically oversized by 5–30% relative to the aortic valve annulus diameter. This results in a radial force between the prosthetic valve and aortic valvar complex to ensure adequate anchoring and sealing. The self-expanding and balloon-expandable valves interfere differently with the aortic annulus. The CoreValve recommendations suggest an oversizing percentage between 7 and 30% and Edwards SAPIEN between 4 and 27%.

When using echocardiography the diameter should be measure in systole, zooming in the LV outflow tract, at the point of insertion of the aortic valve cusps, from tissue–blood interface to blood–tissue interface—trailing edge to leading edge (*Figure 4*).[6] There is a good correlation between TOE aortic annular measurements and TTE results; however, TTE slightly underestimates aortic annular size.[17] Most procedures are performed according to the annular diameter measurement by 2D TTE or TOE, but these methods assume annular circularity, which may result in erroneous dimensions in patients whose annuli are more oval shaped. This limitation can be overcome using multiplanar tools of either 3D TOE or MSCT (*Figures 5* and *6*).[6] Those tools allow the assessment of minimal and maximal diameters, circumference, and area measurements. In case of significant asymmetry between the larger and smaller diameters, the results of the area from planimetry should be considered. Three-dimensional TOE planimetry of aortic annulus was shown to improve the prosthesis size decision and to predict significant AR after TAVI.[18] Similarly, cross-sectional MDCT parameters have the highest discriminatory value for post-TAVR paravalvular regurgitation and it has been recommend as the new gold standard for aortic annulus evaluation. In cases of borderline size decisions, the existence of large calcification in the native valve may require a smaller prosthesis than the annular dimension alone would advise and fluoroscopy may also provide an additional measurement at the time of definitive prosthesis sizing decision.

The thoracic aorta evaluation is completed using MSCT and centreline reconstructions by the measurement of the aortic sinus diameter, sinotubular junction, and ascending and descending aorta (*Figure 7*). Important to notice, the presence of significant aneurismal dilatation is a contraindication for the use of CoreValve (*Table 1*).

Additional morphology and function considerations previous to the procedure

Mitral regurgitation is common in TAVI patients and usually improves after the procedure. The aortic-mitral valvular interdependence in TAVI patients was recently described using 3D TOE. The TAVI valve seems to strengthen aortic calcium along the aortic-mitral curtain, reinforcing anterior leaflet MV calcium, resulting in a reduction in mitral annulus height, area and motion, consequently contributing to reduce MR.[19] However, there is the risk of mitral valve anterior leaflet restriction by the prosthesis[6] and mitral valve morphology and function should be evaluated previous to TAVI.

The presence of LV thrombus or haemodynamically significant LV out flow tract obstruction by septal hypertrophy represents contraindications for the procedure.[20] The existence of a patch in the LV as well as significant pericardial calcification is a contraindication for TAVI through the transapical approach.[1]
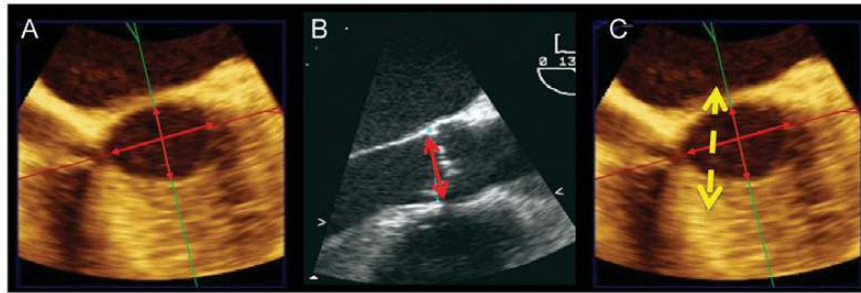
Figure 5 Three-dimensional transoesophageal echocardiography assessing shape and measurements of the aortic annulus (*A* and *C*). The aortic annulus measured by two-dimensional echocardiography (*B*) acquires images (yellow dotted line) that are in-between the short- and long-axis views of the oval-shaped annulus.
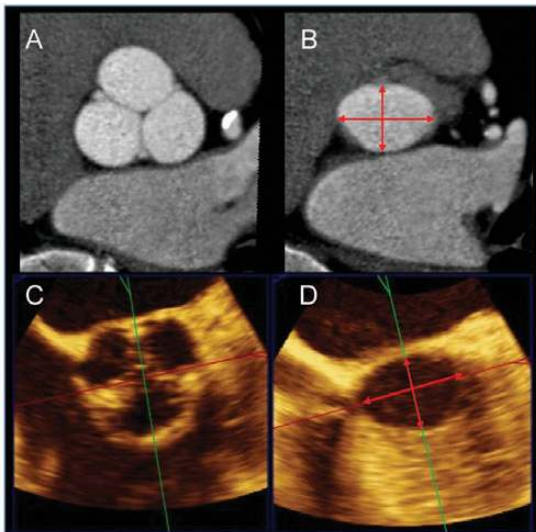

Figure 6 Cardiac CT (*A* and *B*) and three-dimensional transoesophageal echocardiograph (*C* and *D*) can be interchangeably used to assess the shape and obtain measurements of the aortic annulus.

Access route

MSCT provides detailed anatomic and calcification evaluation of the thoraco-abdominal aorta and the iliofemoral arteries, assessing in the decision of the best access route. It allows the evaluation of peripheral vasculature, considering calibre, tortuosity, and calcification (*Figure 8*). Currently, a minimum vascular calibre of 6 mm is required for both Edwards-XT and CoreValve**.** According to manufacture guidelines, the 18 French (Fr) CoreValve and 22/24 Fr Edwards SAPIEN delivery sheaths require 6, 7, and 8 mm diameter femoral arteries, respectively. The newer Edwards SAPIEN XT system requires 6 and 6.5 mm femoral artery diameters for the 18 and 19 Fr systems, respectively.[21]

Tortuosity and calcification are not prohibitive factors, but its combination is an adverse feature for site complications and central embolization. The transfemoral approach is typically used as the default vascular access, being the subclavian, transaortic, or transapical the alternatives. Peripheral vascular disease increases the risk of complications significantly. Using contrast angiography, a SFAR ratio ≥ 1.05 (outer Sheath diameter to Femoral Artery minimal luminal diameter Ratio) has been identified as a predictor of major vascular complications and 30-day mortality by the valve academic research consortium (VARC).[22] The alternative approach to femoral access is usually selected in cases of prohibitively small or diseased iliofemoral arterial system, the presence of mobile plaque, excessive calcification, or extreme tortuosity of the descending thoracic aorta.

Regarding the subclavian access, the left subclavian artery is more straightforward and the most commonly selected; however, the presence of an internal mammary coronary artery bypass graft is a relative contraindication to the subclavian approach.[23]

To date, few studies have directly compared clinical outcomes between transfemoral and non-transfemoral TAVI. Patients undergoing non-transfemoral approaches (largely transapical) tend to present a higher risk profile, and an increased risk of 30-day and 2-year mortality.[24] This mortality difference may be due to the more advanced risk profile, but it is possible that these procedures themselves confer increased risk. Transaortic approach is an encouraging technique that appears to have a short learning curve, it does not interfere with left ventricular function and it is commonly the second preferred approach, after the transfemoral artery, from experienced operators.[25]

At time of evaluating anatomy, it is important to consider that MSCT is associated with the administration of iodinated contrast and exposure to ionizing radiation exposure, thus its use should be considered for individual patients based on risk and benefit. Dual source high-pitch spiral CT with minimized contrast volume may overcome this limitation. Conversely, angiography is mandatory previously to the procedure to analyse coronary arteries. Besides the thoracic and abdominal aorta, and the measurement of peripheral vessel diameters can be performed.

Role of imaging: guiding the procedure

During TAVI, fluoroscopy is the basis for procedure guidance. Nevertheless, the combination of other imaging techniques, particularly
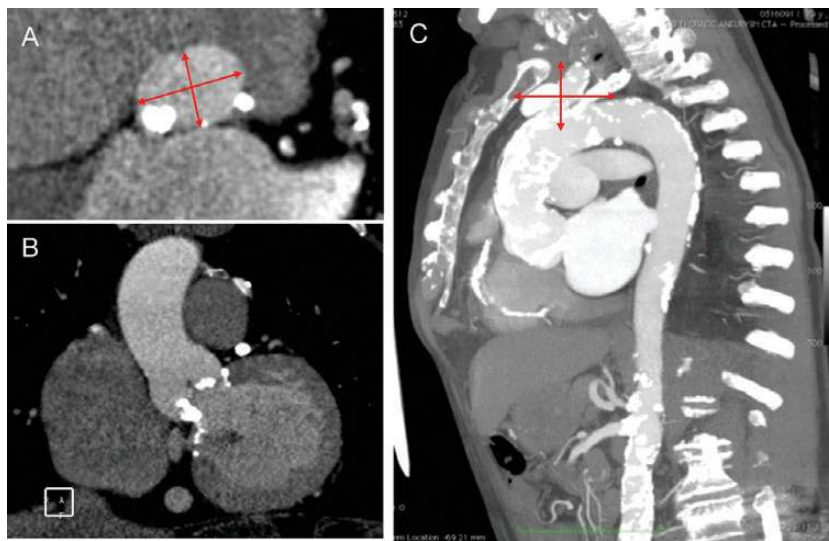
Figure 7 Multislice computed tomography assessing aortic valve calcification and reconstruction of the aortic root and ascending aorta. Additionally, the minimal and maximal diameters are measured at the level of aortic annulus (A).
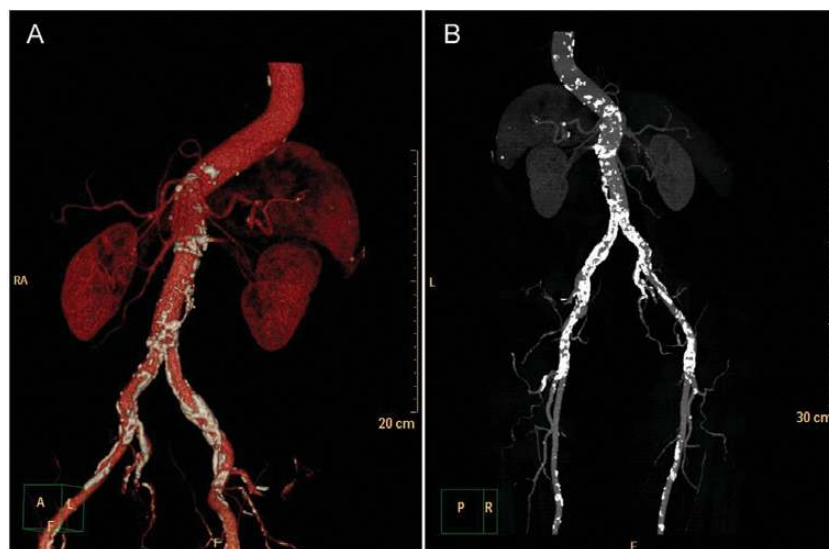

Figure 8 Multislice computed tomography (*A*, rendered image and *B*, MIP) view of the femoral arteries depicting calibre, tortuosity, and calcification.

TOE may overcome the lower soft tissue contrast resolution of fluoroscopy, particularly in less significant calcified valves. The use of 3D, by its larger spatial resolution, compared with 2D TEE allows a better visualization of the guide wire path and permits a better evaluation of the prosthesis position on the balloon, relative to the native valve annulus and surrounding structures. The mid-oesophagus long-axis view enables visualization of the guide wire through the aortic valve that might be delivered retrogradely (transfemoral, transubclavian or transaortic) or anterogradely (transapical). Using the 3D probe, it is possible to obtain simultaneous visualization of orthogonal planes, the long-axis and short-axis views of the aortic valve in real-time. Aortic valve crossing, balloon dilatation, and prosthesis deployment are key steps during TAVI. Peri-procedural TOE can contribute for these steps guidance and to confirm prosthesis function and potential complications, immediately after implantation. It can be used to confirm a secure position for inflation and to monitor the behaviour of the balloon and its effect on the calcified aortic cusps during inflation, as it may accidentally migrate (*Figure 9*). During prosthesis
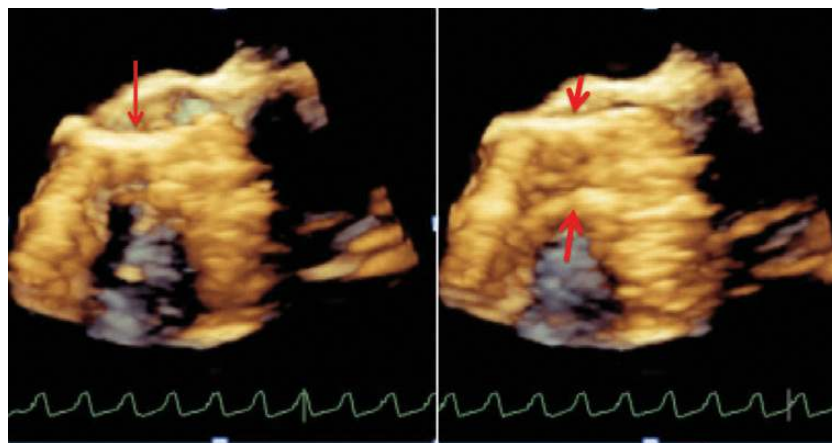
Figure 9 Three-dimensional transoesophageal echocardiography showing the catheter and the prosthesis through the native aortic valve while being deployed.
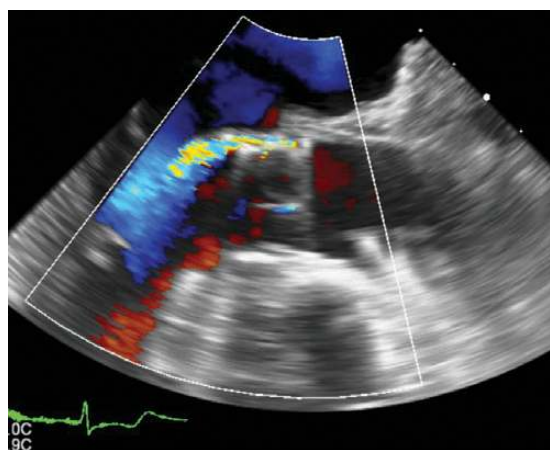

Figure 10 Two-dimensional transoesophageal echocardiography showing paravalvular aortic regurgitation.

deployment, TOE gives support to confirm the correct position of the valve in conjunction with fluoroscopy. The Edwards SAPIEN valve optimal position is with the ventricular side of the prosthesis located 2−4 mm below the annulus, while the CoreValve is recommended to have the ventricular edge of the prosthesis placed 5−10 mm below the aortic valve annular plane. After the deployment, it is important to confirm that all the prosthetic cusps are moving well, the valve stent has a circular configuration and to exclude significant valvular or paravalvular AR. Mild AR through the prosthesis, until the guidewire is removed and at the next few minutes after deployment is common. Small jets of paravalvular AR are frequent and it may occur even in a successful procedure. However, severe AR is a serious complication and additional balloon inflation may be required in spite of the increased risk of cerebrovascular events.[26]

There is growing interest in fusion imaging modalities (echocardiography, MSCT, or CMR with fluoroscopy) for procedure guidance, providing supplementary data to fluoroscopy. The Syngo DynaCT system acquired volumetric reconstructions similar to MSCT images intra-operatively with the angiography C-arm. The resulting images are not comparable with modern cardiac CT images, but it has been shown that when acquired under rapid pacing, they are sufficient for pre-operative implant selection and automatic generation of a 3D model, containing all relevant anatomical landmarks. Moreover the optimal perpendicular view onto the aortic root can be identified and a 3D model extracted from the DynaCT can be superimposed on the angiography images to guide catheter placement.[27]

Real-time CMR was shown to be feasible in CoreValve prosthesis implantation is animal model, allowing improved procedural guidance, immediate detection of complications and direct functional assessment with reduction of radiation and omission of contrast media.[28] Nevertheless, further studies on these techniques for validation and clinical use assessment are still needed.

Assessment of complications
Aortic regurgitation
Aortic regurgitation is the most common complication after TAVI and it is associated with short- and long-term mortality.[2,4,29] It may occur as a consequence of incomplete expansion, incorrect positioning, restricted cusp motion, or inappropriate prosthetic size.[30] An undersized prosthesis may result in paravalvular AR (*Figure 10*), while an oversized prosthesis has the risk of under expansion and central AR. Moreover, as well as the previous mentioned aortic valve calcification or larger size annulus, the higher cover/ non-coaptation/ mismatch indexes are associated with the occurrence of AR.[18,31]

The regurgitation evaluation should include an assessment of both central and paravalvular components, combining the measurements for total AR estimation, using quantitative and semi-quantitative data.[22] Paravalvular jets colour Doppler evaluation must be

performed just below the valve and for central regurgitation at the coaptation point. The VARC recommendations suggest that for para-valvular jets, the proportion of the circumference of the sewing ring occupied by the jet gives a semi-quantitative guide to severity: <10% of the sewing ring suggests mild, 10−29% suggests moderate, and ≥30% suggests severe.[32] For the quantitative approach, the width of the vena contracta is a robust estimate of regurgitant severity, but in the setting of prostheses, portions of the sewing ring may not be imaged due to acoustic shadowing. In addition, there has been no validation for adding the vena contracta widths of multiple jets as it may be encountered post-TAVI. Three-dimensional vena contracta planimetry might be an alternative for quantitative evaluation and moderate AR recognition of paravalvular AR after TAVI.[33] However, it is challenging at the acute setting and it requires 3D echocardiography on site. In consequence, the final interpretation should follow the principle of a comprehensive evaluation and integrated approach. Additionally, using blood pressure and end-diastolic LV pressure, the index calculated as the ratio of the gradient between diastolic blood pressure (DBP) and left ventricular end-diastolic pressure (LVEDP) to systolic blood pressure (SBP): $[(DBP - LVEDP)/SBP] \times 100$ was shown to independently predict 1-year mortality after TAVI, and to provide additional prognostic information, complementary to the echocardiographically assessed severity of paravalvular AR. Its use can be considered for the complementary evaluation of AR.[34]

Transcatheter aortic valve implantation migration or displacement

Prosthetic embolism can occur towards the aorta or the left ventricle and it might require surgical removal if transcatheter repositioning reveals impossible.[35] Besides, the prosthesis displacement towards the LVOT can result in worsening of MR by anterior mitral leaflet restriction or even direct damage or distortion of the subvalvular apparatus.[36] The displacement towards the aorta can cause coronary ostial occlusion by an obstructive portion of the valve frame and consequent anew LV dysfunction.

Additional complications

Exceptional complications already experienced are the cardiac tamponade, secondary to wire perforation of the left or right ventricle and tear or ruptures of the aortic root. The later has been observed after balloon valvuloplasty or prosthesis deployment, especially in the presence of extensive annular calcification or prosthesis oversizing (*Table 3*).[37]

Comparing both valves, the main difference is the higher incidence of permanent pacemaker requirement using the Corevalve device (15−47%) vs. 4−21% with Edwards SAPIEN implantation.[38] As Corevalve is self-expandable, it can lead to conduction disturbances following implantation, mainly in patients who had peri-procedural atrioventricular block, larger interventricular septum diameter, and a prolonged QRS duration. Patients having balloon pre-dilatation, or implantation of larger devices are also more likely to require a pacemaker. However, new pacemaker implant does not appear to be associated with long-term mortality, thus the decision should be based on operators experience, devices availability, and anatomic specifications.[39]

Table 3 Description of echocardiography utility during and post-transcatheter aortic valve implantation
Prosthesis positioning and deployment
Valve competence
Complications
Aortic prosthesis misplacement
Aortic regurgitation
Mitral valve damage
Acute coronary ostial occlusion
Cardiac tamponade
Dissection or rupture of the aortic root

Transoesophageal echocardiography is not mandatory during TAVI, as it usually requires general anaesthesia and the probe may also partially obstruct the optimal fluoroscopic view. However, it is the main technique for procedure guidance and assessment of complications, particularly in patients with limited native valve calcification.[6] The intracardiac ultrasound catheter provides high-quality, ultrasound images, and Doppler blood flow information and it does not require transoesophageal intubation. It has been, recently, released with 3D capabilities and although the image has limitations compared with 3D TOE forthcoming experience will evaluate its part as an alternative for procedure guidance.

Conclusion

As the number of patients undergoing TAVI is growing, procedure safety requirements are better known. However, TAVI is an invasive technique whose success depends on multidisciplinary team approach, where imaging plays a definite part. The multimodality imaging currently available, echocardiography, MSCT, and CMR, besides angiography, allows proper planning and selection, optimizing the procedure and increasing TAVI success. Echocardiography is the cornerstone of pre-procedure evaluation, complemented by MSCT. In the future, as patients undergoing TAVI might be younger, CMR might gain significance by the absence of radiation issues.

During TAVI, 2D, and particularly 3D echocardiography can be used for guidance, increasing the procedure safety. Upcoming results on the use of fusion imaging modalities during the procedure might contribute for a complementary, and even better approach for the new invasive treatment modalities of valvular disease.

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CARDIOVASCULAR FLASHLIGHT

Corevalve prosthesis causes anterior mitral leaflet perforation resulting in severe mitral regurgitation and subsequent endocarditis

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An 84-year-old patient presented at our outpatient clinic with recurrent dyspnoea (NYHA class III) and fever. Medical history included transcatheter aortic valve replacement (TAVR) using a 31 mm Corevalve prosthesis 6 months ago. Trans-thoracic echocardiography revealed moderate aortic regurgitation and also perforation of the anterior mitral leaflet (AML) causing severe mitral regurgitation (MR; *Panels A1* and *A2*). Thus, the patient was scheduled for open heart surgery.

On admission to the hospital 2 weeks later, trans-oesophageal echocardiography showed evidence of acute new onset endocarditis with small vegetations on the AML and an increase in MR (blue arrow; *Panels B1* and *B2*). Blood smear analyses (six out of six) were positive for *Staphylococcus epidermidis*, and immediate intravenous antibiotic treatment was administered.

Aortic valve (SJM Trifecta 27 mm) and mitral valve (SJM Epic 33 mm) replacement was performed. Trans-aortic *in situ* video-assisted examination confirmed both endocarditis and AML perforation due to the Corevalve prosthesis stent (green arrow; *Panels C1* and *C2*).

Intra- and post-operative course was uneventful. The patient recovered well and was discharged without symptoms and normal valve functions 10 days post-operatively.

This report highlights three issues: (i) the danger of AML injury following catheter-based aortic valve replacement, which has not been described thus far; (ii) the potential risk of subsequent endocarditis following TAVR; and (iii) the need for meticulous patient evaluation for TAVR. Although this patient was considered at a high surgical risk, based on his age in the first place, he recovered well from standard double-valve replacement.

Supplementary material is available at *European Heart Journal* online.