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Pre-operative aortic valve implantation evaluation: multimodality imaging

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KEYWORDS
Transcatheter aortic valve implantation, echocardiography, multi-detector row computed tomography, magnetic resonance

Abstract

Transcatheter aortic valve implantation procedures have been one of the main therapeutic breakthroughs of the last decade providing a feasible alternative therapy to patients with severe symptomatic aortic stenosis and high operative risk. To date, more than 10,000 patients have been treated with this novel therapy and promising results, using either a transarterial or transapical approach have been reported. Accurate preprocedural evaluation of candidates for TAVI is crucial to optimise the success rate and minimise the procedure-related complications. Multimodality imaging plays a central role in the preprocedural evaluation of these patients and provides valuable information on aortic stenosis severity, aortic valve anatomy, aortic valve annular dimensions and peripheral vascular anatomy, key issues to accurately select the prosthesis size and the procedural approach (transarterial vs. transapical). A combination of 2- and 3-dimensional echocardiography and multi-detector row computed tomography or magnetic resonance imaging may provide the most comprehensive approach to accurately evaluate these patients. The present article reviews the role of multimodality imaging before the TAVI procedure and provides a practical guide to evaluate patients who are candidates for TAVI.

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Introduction

Valvular heart disease is one of the main public health problems with an increasing prevalence in populations older than 65 years.[1] Degenerative etiology is the leading cause of valvular heart disease in the developed countries and calcific aortic stenosis is one of the most frequent lesions.[1,2] The prognosis of patients with symptomatic severe aortic stenosis is dismal with a mortality rate of 25% per year.[3] Conventional surgical aortic valve replacement is the gold standard therapy. However, up to 30% of elderly patients with symptomatic severe aortic stenosis are denied surgery.[4] The association of comorbidities such as depressed left ventricular function, neurological dysfunction and renal failure or severe chronic obstructive pulmonary disease is rather common in this group of patients and leads to an increased operative risk.[4]

In the last decade, transcatheter aortic valve implantation (TAVI) techniques have shown to be feasible and effective alternative therapies for this high risk subgroup of patients. To date, more than 10,000 patients have been treated with this technique. The procedural success rate ranges between 93-95% and the 30-day mortality rate has fallen to 8-10%.[5] To optimise the TAVI results while minimising the procedural complications, accurate selection of candidates is mandatory. A multidisciplinary approach, including clinical, imaging and interventional cardiologists, cardiothoracic surgeons and anaesthesiologists, provides the most accurate evaluation of candidates for TAVI.[6] Currently, the main issues of concern of this emerging therapy are the incidence and consequences of postprocedural aortic regurgitation, vascular complications, stroke and atrioventricular block with a need for permanent pacing. Cardiac imaging plays a central role during the preprocedural screening by providing information on aortic stenosis severity, aortic valve anatomy, aortic valve annular dimensions and peripheral vascular anatomy, key issues to accurately select the prosthesis size and the procedural approach (transarterial vs. transapical). The present article reviews the role of multimodality imaging before the TAVI procedure and provides a practical guide to evaluate candidates for TAVI.

Current devices and techniques

Two different transcatheter prostheses are currently available and have provided the largest evidence on TAVI procedures: the self-expandable Medtronic CoreValve (Medtronic, Minneapolis, MN, USA) and the balloon-expandable Edwards SAPIEN valve (Edwards Lifesciences, Irvine, CA, USA). The Medtronic CoreValve consists of a nitinol frame that holds a trileaflet porcine pericardiums valve. The valve is currently available in two different sizes (26 and 29 mm for an aortic valve annular diameter ranging between 20-23 mm or 23-27 mm, respectively) and the procedural approach is retrograde, through transarterial access (transfemoral or trans-subclavian), using a 18 Fr delivery sheath (Table 1).[7] The Edwards SAPIEN valve consists of a stainless steel cylindrical frame that holds a trileaflet bovine pericardium leaflet. Two different sizes are also available, according to the aortic valve annular dimensions (23 and 26 mm for an aortic valve annular diameter ranging between 18-22 mm and 21-25 mm, respectively) and the implantation procedure can be performed anterograde (transapical) or retrograde (transfemoral) (Table 1).[7] The delivery systems are different according to the procedural approach and, currently, 22 Fr and 24 Fr sheaths are used during the transfemoral approach (for 23 and 26 mm prosthesis, respectively) and a 26 Fr sheath is used during the transapical approach. Recently, the next generation transcatheter aortic valve and delivery system with a lower crimped profile (Edwards SAPIEN XT and NovaFlex, Edwards Lifesciences, Irvine, CA, USA) has been launched.[8] This new bioprosthetic valve consists of a cobalt-chromium frame that allows a low delivery profile without loss of radial strength andholds a bovine pericardium trileaflet valve. With this system, a 26 mm transcatheter valve prosthesis can be implanted with a 18 Fr sheath.[8]

The TAVI procedure is usually performed at the catheterisation laboratory or hybrid operating rooms that hold the required equipment of conventional cardiologic and surgical procedures (surgical and catheterisation equipment, cardiopulmonary by-pass and ventricular support capabilities, mobile fluoroscopy, sufficient space for transesophageal echocardiography, and complete anaesthetic equipment). Fluoroscopy and transesophageal echocardiography are usually complementary imaging tools to guide the procedure. The valvular plane where the three aortic sinuses are aligned is commonly defined with fluoroscopy (Figure 1). After crossing the aortic valve with the guidewire, the balloon catheter is advanced and conventional balloon valvuloplasty is performed (Figure 1). Afterwards, the transcatheter aortic valve is

Table 1. Anatomical requirements of current available transcatheter aortic valve prosthesis.

	Medtronic CoreValve		Edwards SAPIEN	
Technical characteristics	Nitinol frame Porcine pericardium valve		Nitinol frame Bovine pericardium valve	
Prosthesis size	26 mm	29 mm	23 mm	26 mm
Approach and delivery system size	Transarterial (transfemoral/transsubclavian) 22 Fr		Transfemoral 22 Fr Transapical 26 Fr	Transfemoral 24 Fr Transapical 26 Fr
Anatomical requirements				
Aortic valve annulus	20-23 mm	23-27 mm	18-22 mm	21-25 mm
Peripheral arteries diameters	≥6-7 mm		>7-8 mm	>8-9 mm
Sinus of Valsalva diameter	≥27 mm	≥28 mm	NA	NA
Sino-tubular junction diameter	≤40 mm	≤43 mm	NA	NA
Height of the coronary ostia	≥14 mm		≥10 mm	≥11 mm

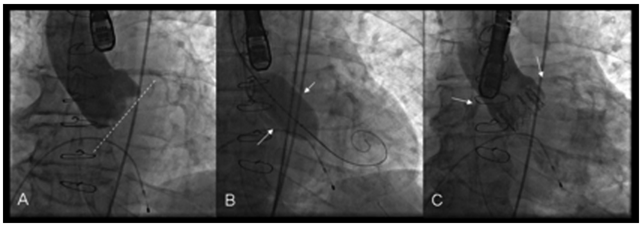


Figure 1. Transcatheter aortic valve implantation. Fluoroscopy is used to guide the procedure. The alignment of the three aortic sinuses in the same plane defines the optimal plane and angiographic projection for TAVI (panel A). Balloon valvuloplasty is performed before implantation of the prosthesis. The waist of the balloon is positioned within the valve (arrows) (panel B). After implantation of the transcatheter aortic valve, the function of the valve and the patency of the coronary arteries (arrows) are evaluated (panel C).

introduced via transarterial access and advanced through the aorta. During the transapical approach, the transcatheter aortic valve is introduced through the left ventricular apex and advanced across the native aortic valve. Fluoroscopy and, frequently transesophageal echocardiography guidance are used to position the prosthetic valve. With the Edwards system, rapid right ventricular pacing is mandatory for stable valve deployment. In contrast, the self-expandable Medtronic CoreValve system does not require rapid right ventricular pacing. Finally, the function of the prosthesis is evaluated by fluoroscopy and transesophageal echocardiography, with special focus on the presence of significant paravalvular leak and the patency of the coronary arteries (Figure 1).

Preprocedural evaluation with multimodality imaging

Patients with symptomatic severe aortic valve stenosis (aortic valve area <1 cm^2) and high operative mortality risk as assessed with the log EuroSCOREs (≥15-20%) or the STS Predicted Risk Mortality score (>10%) may be candidates for TAVI. In the preprocedural evaluation, the feasibility and the exclusion of contraindications have to be accurately addressed. Measurement of the aortic valve annulus size and the assessment of the anatomy and tortuosity of the aorta and peripheral arterial bed are key steps in this screening process. Other factors to be evaluated include the aortic valve anatomy, left ventricular function and presence of significant coronary artery disease.

Assessment of aortic stenosis severity

As mentioned earlier, only patients with symptomatic severe aortic stenosis are candidates for TAVI. Quantification of aortic stenosis severity relies mainly on echocardiographic Doppler techniques. According to current guidelines, severe aortic stenosis is defined by an aortic valve area <1 cm^2 (<0.6 cm^2/m^2) or a mean gradient >40-50 mmHg.[9-11] From the continuous wave Doppler recordings, the maximal and the mean transaortic pressure gradients can be obtained. The maximum transaortic pressure gradient is calculated with the simplified Bernoulli equation ($\Delta P_{max}=4V_{max}^2$) and by tracing the continuous wave Doppler spectral signal, the mean pressure gradient is calculated as the average of the instantaneous gradients over the ejection period. In patients with anatomic severe aortic stenosis and depressed left ventricular ejection fraction (<40%), a low-pressure transaortic gradient (<30-40 mmHg) is commonly observed. In this situation, the diagnosis is challenging and accurate differentiation between true and pseudo severe aortic stenosis has important clinical implications. In true aortic stenosis, the relatively fixed small aortic valve area maintains an increased afterload that ultimately reduces the left ventricular function and the stroke volume. The operative mortality risk of these patients is high and therefore these patients may be candidates for TAVI. In the pseudosevere aortic stenosis, the underlying cardiomyopathy determines a reduction in the opening force that results in incomplete opening of the aortic valve. Therefore, based on aortic valve area quantification, the aortic stenosis severity is overestimated. In these patients, aortic valve replacement is not recommended. Dobutamine stress echocardiography may help to differentiate these two conditions: in pseudosevere aortic stenosis, the aortic valve area will increase gradually with almost no change in transvalvular pressure gradient whereas in the true aortic stenosis the transvalvular pressure gradient will increase while the low aortic valve area remains unchanged.

Finally, multi-detector row computed tomography (MDCT) and magnetic resonance imaging (MRI) constitute suitable techniques to quantify the anatomic aortic valve area. By means of planimetry, the aortic valve area can be calculated. In a series of 48 patients with aortic valve disease (27 patients with aortic stenosis), Pouleur et al compared the accuracy of MDCT, MRI and transesophageal echocardiography to measure the aortic valve area.[12] There were no significant differences in the planimetric measurements of the aortic valve area with MDCT, MRI and transesophageal echocardiography (2.5±1.7 cm^2 vs. 2.4±1.8 cm^2 vs. 2.5±1.7 cm^2, respectively).[12]

Aortic valve anatomy and morphology

Echocardiography is the mainstay imaging technique to evaluate the aortic valve anatomy and morphology. From the parasternal short-axis view, tricuspid or bicuspid anatomy can be identified. During diastole, the normal tricuspid aortic valve shows the typical “Y-closure” of the three cusps and during systole, the three sinuses can be visualised. Bicuspid aortic valves show two cusps during diastole, with two sinuses and one linear commissure (Figure 2). In patients with poor acoustic windows, the assessment of the aortic valve anatomy may be challenging with transthoracic echocardiography. In contrast, transesophageal echocardiography provides a superior image quality that permits accurate assessment of aortic valve anatomy. The assessment of the aortic valve anatomy is crucial as bicuspid aortic valves are currently a contraindication for TAVI.[6] However, several successful TAVI procedures performed in bicuspid native valves have been reported.[13,14] Other imaging modalities such as MDCT or MRI provide 3-dimensional high-spatial resolution images of the aortic valve that may help to differentiate between tricuspid and bicuspid anatomy.

In addition, the evaluation of location and amount of aortic valve calcifications may be of interest. The presence of extensive calcification may influence the final results with an increased

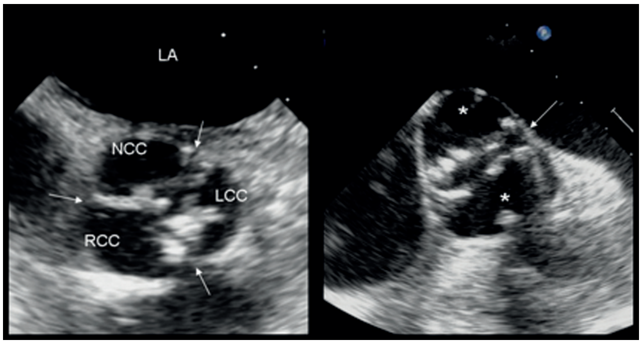


Figure 2. Aortic valve anatomy. Differentiation between tricuspid and bicuspid anatomy is crucial before transcatheter aortic valve implantation procedures. Transesophageal echocardiography is a valuable tool to identify the aortic valve anatomy. Examples of tricuspid and bicuspid aortic valves in patients with severe calcific aortic stenosis are shown in left and right panels, respectively. The tricuspid aortic valve shows three cusps (LCC: left coronary cusp; RCC: right coronary cusp; NCC: non-coronary cusp) and three commissures (arrows). The bicuspid aortic valve shows two cusps (asterisks) and one linear commissure (arrow).

likelihood of paravalvular regurgitation.[15,16] Zegdi and co-workers demonstrated that in severely calcified aortic valves, the deployment of the transcatheter prosthesis may be less optimal, with more oval- or triangular-shaped deployed frames.[16] Severely calcified valves may pose an increased resistance to be displaced during the prosthesis deployment. This may result in gaps between the native valve and the external surface of the prosthesis and, consequently, may favour the presence of paravalvular regurgitation.[16] In this regard, MDCT has provided further insight. The superb spatial resolution of this imaging technique permits accurate evaluation of aortic valve anatomy and location and extent of valvular calcifications (Figure 3). In a series of 53 patients with symptomatic severe aortic stenosis, the anatomy of the aortic valve and the extent of valvular calcifications were assessed with 320-row MDCT before TAVI.[15] At one month follow-up after TAVI, the MDCT was repeated to evaluate the positioning and deployment of the prosthesis. The presence of postprocedural aortic regurgitation assessed with echocardiography was related to the positioning and deployment of the transcatheter aortic valve. The incidence of moderate postprocedural aortic regurgitation was 5%. Those patients with moderate post-procedural aortic regurgitation showed significantly more calcified aortic valves and less favourable prosthesis deployment (less circular).[15] Interestingly, patients with moderate postprocedural aortic regurgitation showed more extensive calcification of the native aortic valve commissures than patients without postprocedural aortic regurgitation (Figure 3).

Aortic valve annular dimensions

The measurement of the aortic valve annulus is one of the key issues of the preprocedural evaluation of patients who are candidates for TAVI. The selection of the prosthesis size relies on accurate assessment of the aortic valve annular dimensions. In most centres, the measurement of the aortic valve annular diameters is usually performed with 2-dimensional echocardiography. From the parasternal long-axis view, during transthoracic echocardiography, or from the 120° long-axis view, during transesophageal echocardiography, the aortic valve annular diameter can be measured (Figure 4). However, 2-dimensional echocardiography may not be the ideal approach as only one dimension of the aortic valve annulus is measured. As previously shown, the aortic valve annulus has an oval shape that can be accurately visualised with 3-dimensional imaging techniques.[17] Therefore, the measurement of the minimum and the maximum diameters or the area of the aortic valve annulus with 3-dimensional

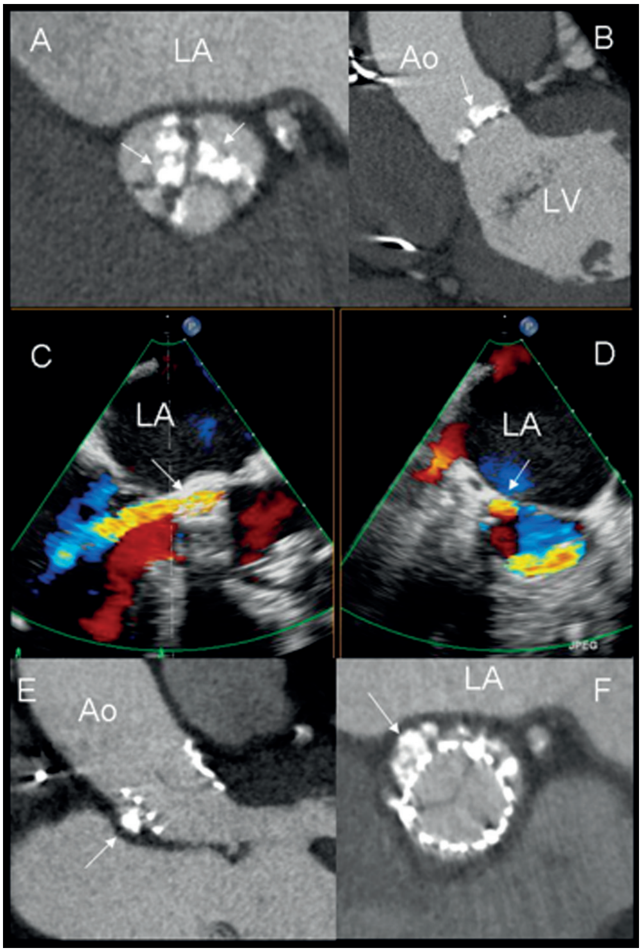


Figure 3. Aortic valve calcifications: implications for transcatheter aortic valve implantation. The presence of a heavily calcified aortic valve may influence the TAVI results, by increasing the risk of prosthesis inaccurate deployment and paravalvular leak. The example shows a severe calcified tricuspid aortic valve with bulky calcified cusps (panel A and B). After TAVI, a significant aortic paravalvular leak (arrows) can be observed with colour Doppler transesophageal echocardiography in the long-axis view (panel C) and in the short axis view (panel D). MDCT can demonstrate the deployed bioprosthesis in relation to the native calcified valve as a cause for paravalvular leak (panels E and F). In this example, the bulky calcified cusps precluded an optimal deployment of the prosthesis with gaps between the prosthesis frame and the native aortic valve (arrows) that coincide with the location of the paravalvular leak. Ao: aorta; LA: left atrium; LV: left ventricle.

imaging modalities may provide a more accurate sizing of the aortic valve annulus and, subsequently, a highly accurate selection of the prosthesis size (Figure 4). This was recently demonstrated by Smid et al in a series of 15 patients undergoing surgical aortic valve replacement.[18] The accuracy of MDCT, MRI and 2-dimensional transesophageal echocardiography to measure the aortic valve annulus was evaluated using the peri-operative measurements as reference. MRI and MDCT were the most accurate methods to measure the aortic valve annulus showing minimal bias compared to peri-operative measurements (–0.07±0.42 cm and –0.15±0.35 cm, respectively).[18] In contrast, 2-dimensional transesophageal echocardiography-based measurements resulted in significant underestimation of the aortic valve annulus compared to peri-operative measurements (–0.55±0.20 cm).[18] In addition, Ng et al demonstrated the accuracy of 3-dimensional transesophageal echocardiography to size the aortic valve annulus.[19] In 53 patients undergoing TAVI, the aortic valve annular areas were assessed with 2-dimensional and 3-dimensional transesophageal echocardiography and compared to the measurements performed with MDCT, used as reference method (Figure 5).[19] Planimetric aortic valve annular areas as measured with 3-dimensional transesophageal echocardiography had the best agreement with MDCT planimetric areas (–0.45±0.28 cm^2; 95% confidence interval –0.53 cm^2 to –0.37 cm^2). In contrast, circular areas calculated with 2-dimensional transesophageal echocardiography showed the largest bias with the widest limits of agreement (–0.77±0.44 cm^2; 95% confidence interval –0.89 cm2 to –0.64 cm^2).[19] Therefore, the measurement of the aortic valve annulus with 3-dimensional imaging techniques may be a more appropriate approach than 2-dimensional echocardiography in order to obtain the most accurate prosthesis size selection. However, faced with the lack of an established gold standard, there is still ongoing debate on which

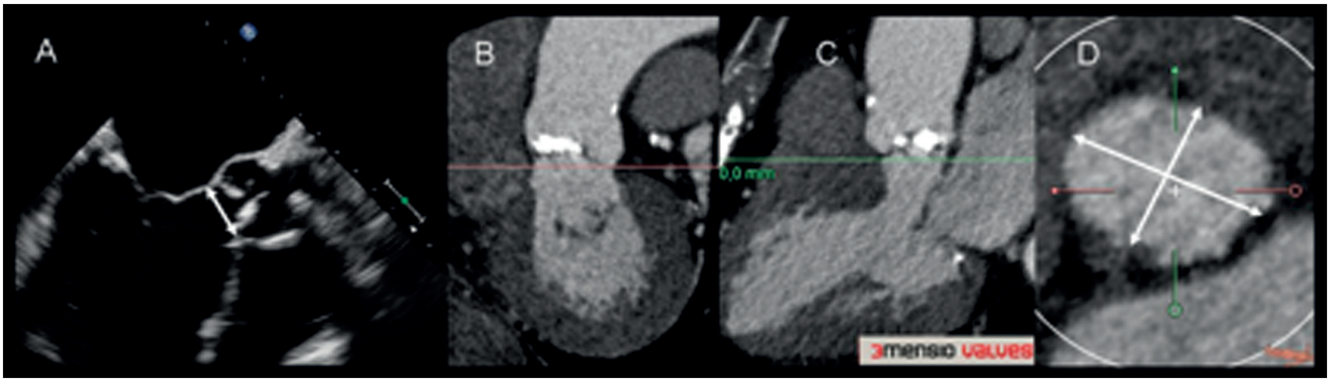


Figure 4. Aortic valve annular dimensions. The aortic valve annulus is sized by 2-dimensional echocardiography (transthoracic or transesophageal) (panel A). The aortic valve annular diameter is usually measured from the long-axis view. Multi-detector row computed tomography provides 3-dimensional datasets that demonstrate the oval shape of the aortic valve annulus. The correct alignment of the orthogonal multiplanar reformation planes (panels B and C) provides the true cross-sectional plane of the aortic valve annulus and the minimum and maximum diameters can be measured (panel D) (3mensio Valves™, version 4.1., 3mensio Medical Imaging BV, Bilthoven, The Netherlands).

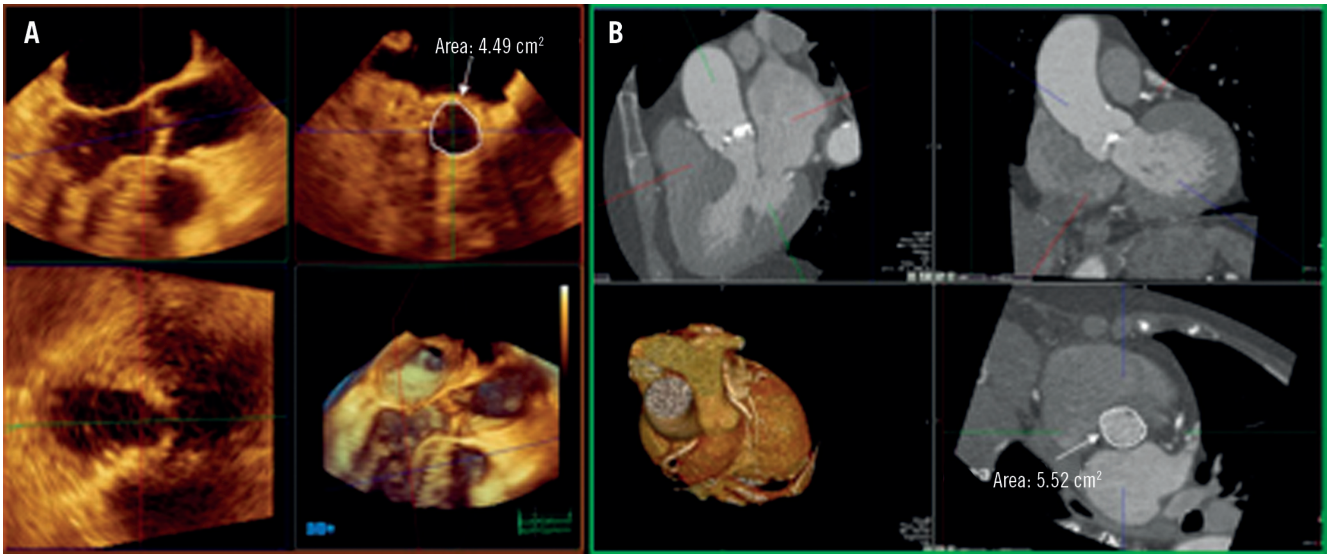


Figure 5. Measurement of the aortic valve annular dimensions by means planimetry. Three-dimensional transesophageal echocardiography (panel A) and MDCT (panel B) permit the alignment of orthogonal multiplanar reformation planes that yield the cross-sectional area of the aortic valve annulus. By planimetry, the area of the aortic valve annulus can be obtained.

imaging technique should be preferably used for aortic valve annulus sizing.[6] Two recent series including 75 and 50 patients undergoing TAVI respectively, have demonstrated that the prosthesis size selection may significantly change according to the imaging modality used to measure the aortic valve annulus.[20,21] In both series, MDCT measurements of the aortic valve annulus would have had a significant influence on TAVI strategy.[20,21] However, at this early stage of the TAVI techniques, these results need further confirmation including larger series of patients.

Aortic root dimensions and spatial relationship with coronary ostia

The aortic root includes the aortic valve annulus, the sinus of Valsalva, the sino-tubular junction and the ascending aorta. The measurement of the aortic root dimensions is of relevance, mainly when a Medtronic CoreValve is implanted. The frame of this self-expandable prosthesis is 53-55 mm long and has three different levels: the upper level of the prosthesis is placed in the ascending aorta and permits us to orient the prosthesis in the direction of the aortic root and blood flow; the middle level of the prosthesis holds the valve leaflets and has a constrained shape to avoid occlusion of the coronary ostia; the lower level of the prosthesis is placed within the left ventricular outflow tract and annulus of the native valve and exerts a high radial force against these anatomic structures to assure the anchorage. Therefore, an extremely narrow or wide aortic root may contraindicate the implantation of this type of prosthesis. The anatomical requirements are summarised in Table 1: the width of the sinus of Valsalva should be ≥27 mm and ≥28 mm and the sino-tubular junction and ascending aorta should be ≤40 mm and ≤43 mm for a 26 and 29 mm prosthesis, respectively.[22] The dimensions of the aortic root can be measured with 2-dimensional echocardiography (Figure 6). However, 3-dimensional imaging techniques, by allowing proper orientation of the orthogonal multiplanar reformation planes through all the levels of the aortic root, provide highly accurate measurements. MRI and MDCT are considered the gold standard imaging techniques to evaluate the aortic root and, particularly, MDCT permits the evaluation of the extent of aortic root calcifications (Figure 6). The presence of extensive atherosclerotic plaques may indicate a transapical rather than transarterial TAVI due to the high risk of stroke during manipulation of the catheters within the aorta in the latter approach. In addition, these imaging modalities permit the evaluation of the spatial relationship of the aortic root and the left ventricle.

In addition, the height of the coronary ostia relative to the aortic valve annular plane is of relevance in order to anticipate the risk of an infrequent but lethal complication: the occlusion of one of the coronary ostia by one of the native leaflets.[23] The strut design of the transcatheter aortic valve prosthesis preserves coronary blood flow and is accessible for percutaneous coronary interventions if needed.[24]

MDCT has demonstrated to accurately measure the distance between the annular plane and the coronary ostia (Figure 7). Based on several series studied with MDCT, the height of the right coronary ostium is usually higher than the left coronary ostium (17.2±3.3 mm vs. 14.4±2.9 mm) and the length of the right and left coronary cusps are around 13.2±1.9 mm and 14.2±1.8 mm, respectively.[17] In patients with calcific aortic stenosis, the aortic root may show a longitudinal remodelling and the distance between the aortic annular plane and the coronary ostia may decrease significantly (13.6±2.8 mm for the right coronary ostium and 13.4±3.2 mm for the left coronary ostium).[25] If the length of a bulky calcified right or left coronary cusp exceeds the distance between the coronary ostia and the aortic valve annular plane, the risk of coronary occlusion may increase.

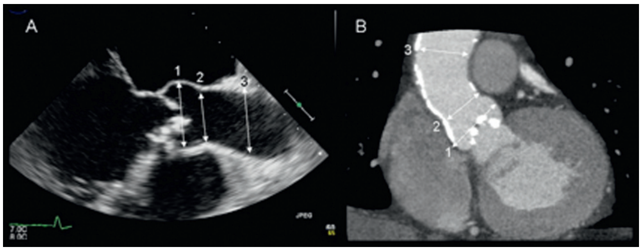


Figure 6. Aortic root dimensions. The aortic root includes the sinuses of Valsalva (1), the sino-tubular junction (2) and the ascending aorta (3). Two-dimensional transesophageal echocardiography (panel A) and MDCT (panel B) permit the measurement of the different components of the aortic root. In addition, MDCT provides information on the extent and location of calcifications within this anatomic structure. Panel B shows an example of a heavily calcified aortic root that may challenge the TAVI procedure.

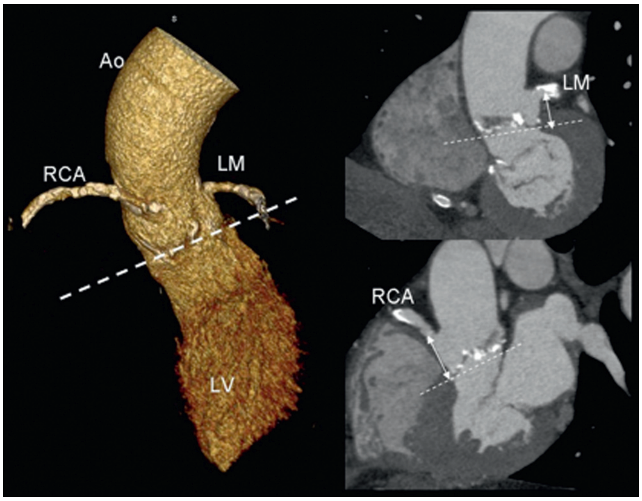


Figure 7. Height of the coronary ostia relative to the aortic valve annular plane. MDCT enables measuring the distance between the aortic valve annular plane and the coronary ostia. The volume-rendered reconstruction(left panel) permits visualisation of the right coronary artery (RCA) and the left main stem (LM) simultaneously in relation to the aortic valve annular plane. From the multiplanar reformation planes (right panels) the distance of the left main and the right coronary artery can be accurately measured. Ao: aorta; LM: left main; LV: left ventricle; RCA: right coronary artery.

Finally, MDCT permits spatial orientation of the aortic root and anticipates the fluoroscopy planes that will be used during the TAVI procedure (Figure 8). In a series of 40 patients undergoing TAVI, MDCT was performed to evaluate the aortic valve anatomy, aortic valve annulus size and aortic root dimensions.[26] In addition, the

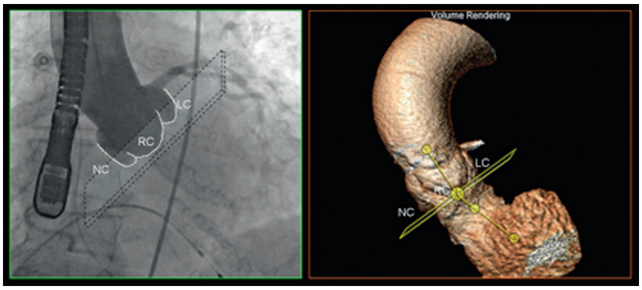


Figure 8. Multi-detector row computed tomography to anticipate the fluoroscopic projections during TAVI. Fluoroscopy is used to determine the aortic valve annular plane during TAVI (left panel). The most appropriate fluoroscopic projection is the one that allows the alignment of the three sinuses (non-coronary [NC], right coronary [RC] and left coronary [LC]) in the same plane. With current MDCT imaging post-processing software (3mensio Valves™, version 4.1., 3mensio Medical Imaging BV, Bilthoven, The Netherlands), the fluoroscopic projection can be anticipated reducing the use of iodinated contrast volume and shortening the procedure (right panel).

oblique MDCT images of the aortic root were used to anticipate the fluoroscopic angiographic left anterior and right anterior oblique projections. There was good agreement between the left anterior oblique projections on fluoroscopic angiography and MDCT. The use of this MDCT application may reduce the fluoroscopy time, the iodinated contrast volume needed to obtain the angulation of the aortic valve annular plane and, consequently, the TAVI procedure.

Peripheral artery and thoracic aorta anatomy and morphology

To plan the TAVI procedural approach, the assessment of size, calcifications and tortuosity of the peripheral arteries and thoracic aorta is crucial. In patients with symptomatic severe aortic stenosis, the prevalence of peripheral arterial disease is high and increases the risk of procedural complications. Small calibre femoral arteries <6-9 mm (according to the device used), extremely calcified and tortuous ilio-femoral arterial tree or a porcelain aorta, may favour a transapical approach rather than a transfemoral one.[7] The Medtronic CoreValve can be implanted through transsubclavian access in case of non-favourable ilio-femoral arterial anatomy. Invasive angiography has been the method of reference to assess the luminal diameter of the femoral and iliac arteries. However, recent advances in MDCT and MRI technologies permit not only the measurement of the endoluminal diameter but also the location and extent of calcifications and the presence of severe atherosclerosis of the arterial wall that may increase the risk of vascular injury and embolic complications. Recently, Joshi et al. evaluated the feasibility of a standardised preprocedural evaluation of the aorto-ilio-femoral arterial tree with intra-arterial contrast injection CT angiography.[27] Following diagnostic coronary angiography, 37 patients underwent intra-arterial contrast injection CT angiography. With the use of only 10-15 ml of iodinated contrast, 3-dimensional datasets of the arterial tree were obtained and analysed offline. Proper alignment of the multiplanar reformation planes across the arterial vessel provides accurate cross-sectional planes of the vessel and accurate sizing of the lumen (Figure 9).[27] In addition, the volume-rendered images are useful to evaluate the tortuosity of the arteries (Figure 9). Further advances in post-processing software have allowed for semi-quantitative evaluation of the severity of these tortuosities (Figure 9).

Nevertheless, the use of iodinated contrast may be contraindicated in patients with severe renal dysfunction, a common comorbidity in patients with symptomatic severe aortic stenosis. In these clinical conditions, true-fast imaging with steady-state precession (FISP) MRI sequences may constitute useful imaging technique to evaluate the anatomy and morphology of the peripheral arteries.[28] With this technique, the presence of arterial wall thrombosis and atherosclerosis can be accurately detected (Figure 9).

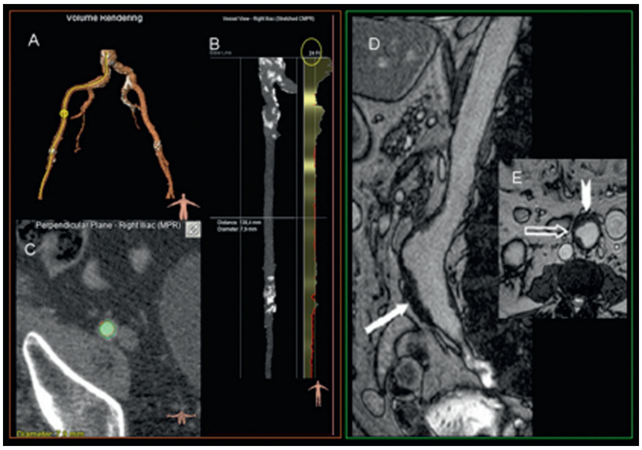


Figure 9. Peripheral artery anatomy, tortuosity and calcification. Multi-detector row computed tomography (MDCT) and magnetic resonance angiography (MRA) provide invaluable information on peripheral arterial anatomy, a key issue in the pre-procedural evaluation of candidates for TAVI. With MDCT, the volume-rendered images permit visualisation of the tortuosity and calcifications of the ilio-femoral arterial tree (panel A). Novel imaging post-processing softwares (3mensio Valves™, version 4.1., 3mensio Medical Imaging BV, Bilthoven, The Netherlands) enable the assessment of these two characteristics on the stretched views of the vessel and colour-code the tortuosity in shades of yellow (panel B). Finally, the cross-sectional views along the arteries permit the measurement of the luminal diameter and area (panel C). MRA allows the assessment of the arterial wall providing information on the presence of significant atherosclerosis or mural thrombosis (arrows) in the longitudinal views (panel D) or cross-sectional views (panel E) (adapted with permission from Iozzelli et al, Eur J Radiol 2009).

Assessment of left ventricular dimensions and function, and evaluation of the coronary arterial anatomy

Finally, evaluation of left ventricular dimensions and function, presence of intracardiac masses and anatomy of the coronary arteries complete the pre-procedural screening of candidates for TAVI. Echocardiography is the cornerstone to evaluate left ventricular dimensions and function. The use of echocardiographic contrast agents improves endocardial border definition, yielding an increased accuracy for left ventricular volume and function quantification, and permits the visualisation of intraventricular masses (thrombus) that will contraindicate the procedure.[6] The presence of depressed left ventricular ejection fraction may challenge the procedure as the risk of haemodynamic instability may increase during the implantation. During the procedure, transesophageal echocardiography has been used to decide the best site to insert the delivery device and the guidewires. The aortic root should be aligned with the axis of the insertion. The advent of novel MDCT image post-processing software has enabled to anticipate the best insertion site of the delivery devices if a transapical TAVI is planned (Figure 10). In addition, the coronary arterial anatomy should be accurately evaluated as the presence of significant coronary artery disease not amenable to percutaneous intervention may be a relative contraindication for TAVI.[6] Invasive coronary angiography is the method of choice to evaluate the coronary artery anatomy. Although MDCT has demonstrated good accuracy to evaluate the coronary anatomy, this may not be the preferred technique in candidates for TAVI. The high probability of extensive arterial wall calcifications may reduce the accuracy of this method to evaluate significant coronary artery stenosis. In this regard, MRI may constitute a feasible alternative to assess the coronary artery anatomy, although more experience with MRI angiography is needed.[29]

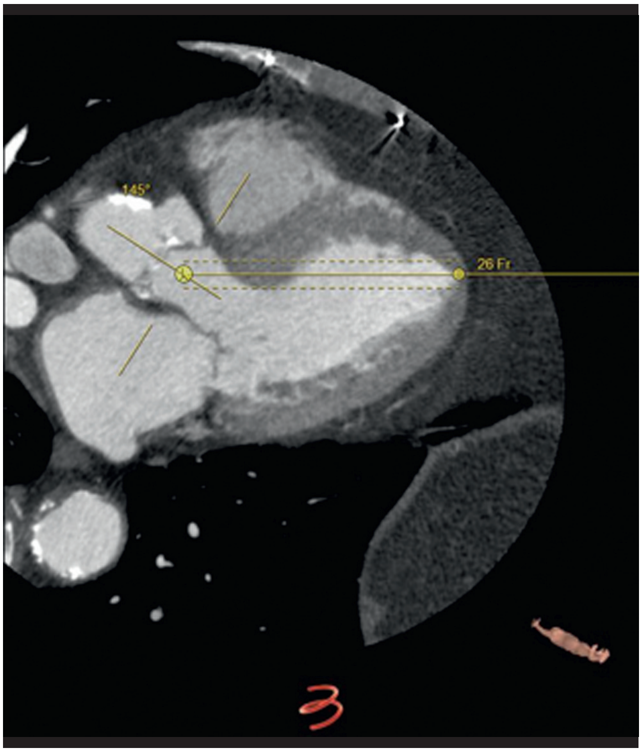
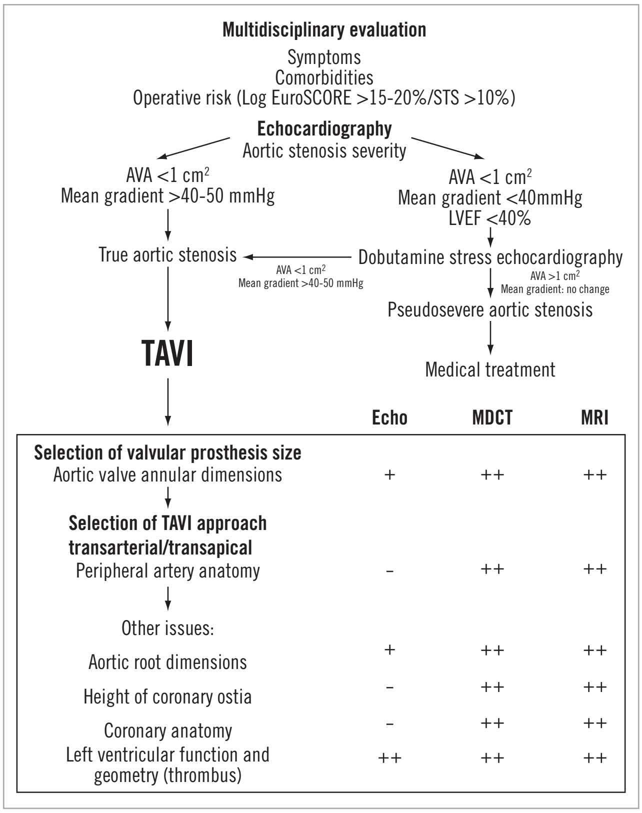


Figure 10. MDCT preprocedural evaluation of the transapical approach. Novel MDCT imaging post-processing software (3mensio Valves™, version 4.1., 3mensio Medical Imaging BV, Bilthoven, The Netherlands) allows the analysis of the left ventricle in relation to the aorta and the aortic valve annular plane in order to plan the transapical TAVI. The left ventricular apex is identified and the optimal insertion point and direction of the delivery system towards the aortic valve can be anticipated.

Future directions and conclusions

In this emerging field of TAVI procedures, standardisation of the preprocedural evaluation may help to improve the selection of candidates for this therapy, optimise the results and minimise the complications. Since the first position statement from the European Association of Cardio-Thoracic Surgery and the European Society of Cardiology in collaboration with the European Association of Percutaneous Cardiovascular Interventions (EAPCI), the number of TAVI has dramatically increased providing a large amount of data that have helped to improve the techniques, the selection of patients and the results. Multimodality cardiac imaging has played a central role in the preprocedural evaluation of candidates for TAVI and ongoing research is performed in order to define the gold standard method to size the aortic valve annulus and to establish a standardised approach to evaluate these patients. Figure 11 summarises a potential standardised protocol, based on multimodality imaging, to evaluate candidates for TAVI. The assessment of the aortic valve anatomy and function, the spatial relationship of the aortic valve annulus and the coronary ostia, the anatomy and calcifications of the peripheral arteries and thoracic aorta as well as left ventricular function and coronary artery anatomy should be included in this pre-procedural evaluation. The implementation of such an algorithm may help to define the role of multimodality imaging in the selection of candidates for TAVI. Finally, the cumulative data from randomised multi-centre trials, such as the PARTNER-US trial, may provide the basis to extend this therapy to lower risk populations.



	Echo	MDCT	MRI
Selection of valvular prosthesis size Aortic valve annular dimensions	+	++	++
Selection of TAVI approach transarterial/transapical Peripheral artery anatomy	-	++	++
Other issues:			
Aortic root dimensions	+	++	++
Height of coronary ostia	-	++	++
Coronary anatomy	-	++	++
Left ventricular function and geometry (thrombus)	++	++	++

Figure 11. Preprocedural evaluation of candidates for TAVI: proposal of flowchart.

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