MDCT IMAGING BEFORE TRANSCUTANOUS AORTIC VALVE IMPLANTATION: RATIONALE AND MEASUREMENTS

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Since its introduction in 2002, transcatheter aortic valve implantation (TAVI) has assumed growing importance in the treatment of patients with severe aortic stenosis (AS), because it offers a much less invasive alternative for those in high risk for surgery. Good early results and advances in percutaneous valve technology have led to a substantial increase in procedural success rate and number of patients undergoing this less invasive treatment. Pre-procedural screening of several anatomic factors to assess the feasibility of this technique is important. Multidetector row computed tomography (MDCT) is the technique of choice in assessing these factors. This technical note aims to describe and illustrate the key elements that need to be evaluated before the procedure.

Key-word: Aortic valve.

Aortic valve stenosis is one of the most frequent causes of valvular disease in the elderly population and is often associated with other cardiovascular comorbidities causing these patients to be at high risk for surgery. A study by Iung et al. (1) showed us that about 33% of patients with severe AS and severe symptoms are high-risk candidates for surgery. This emphasizes the need for a minimal invasive technique in this population of patients. Since its first use in 2002 (2), TAVI has become a good alternative for high-risk patients. Procedural success rates between 93-95% and low 30 day mortality rate (3) have led to a dramatic increase in percutaneous procedures and development of new devices.

Although TAVI is less invasive than conventional valve replacement, it needs an accurate preprocedural workup and patient selection to minimize complications and maximize success. Cardiovascular imaging plays an important role in screening and optimal patient evaluation.

At the moment 2 TAVI technologies have received CE-approval (Fig. 1): the CoreValve technology and the Cribier Edwards SAPIEN valve. The CoreValve technique uses a self-expanding valve with an 18 French delivery system, which allows access to the femoral or subclavian artery. The Edwards SAPIEN on the other hand is a balloon-expandable valve with a 24-26 French delivery system, thus only suitable for a retrograde transfemoral or antegrade transapical approach.

Pre-operative imaging

As mentioned before, preprocedural TAVI planning heavily relies on imaging for patient selection and sizing (4). However, to date there isn’t a gold standard for evaluating the aortic valve (5). Echocardiography has emerged as the method of choice in evaluating hemodynamic status and severity of aortic stenosis. However, transthoracic echocardiography may lead to suboptimal results in patients with poor acoustic windows (thick or deformed chest walls, small hearts, obesity, and pulmonary disease). In addition, echocardiography is very operator dependent and limited in quantifying aortic valve calcification, since only indirect signs, such as increased echogenicity and thickening of the aortic valve leaflets are usable. Further, echocardiography is limited by its 2-dimensional character, making it difficult to make correct calculations of the aortic root diameters. Due to the complex anatomy of the aortic root and annulus an adequate 3D imaging modality is required for accurate reproduction of aortic root and annulus measurements (6). Multidetector computed tomography (MDCT) has the advantage of providing reproducible 3-dimensional images with a high spatial and temporal resolution, emerging it as a promising method for non-invasive valve and coronary imaging. Further MDCT has the merit of evaluating peripheral artery and thoracic aorta anatomy and morphology and revealing several incidental nonvascular findings. Still, the major drawback of using MDCT for imaging is the limitation in repetitive scanning because of the hazardous radiation, although development of the new generation MDCT’s has led to significant reduction in radiation dose (7-9).

Scan protocol

All our pre-TAVI examinations are performed with a 128 multi-detector row computed tomography (CT) scanner (Somatom Definition Flash, Siemens Erlangen, Germany), upgraded to allow low-dose acquisitions (Caredose4D, Siemens). Collimation was 128 x 0.6 mm. Tube voltage was 120 kV and current 340 mAs. At our institution we sepe-
ventricle, where without outflow tract, and the left atrium and the aortic root, the left ventricular reconstruction of a plane including oblique transverse view with the lateral angulation calculated on the coronal view. Described by Decramer et al (10) (Fig. 2). We could measure the diameter of the annulus at the hinge points of the leaflets. Second, we obtained a slice perpendicular to the aortic root and measure the diameters of the ascending aorta, the sino-tubular junction, the sinus of Valsalva, the aortic valve annulus and the left ventricle outflow tract (Fig. 3).

**Contribution of MDCT to preoperative screening and presurgical work-up**

Adequate sizing and probe selection are required for correct apposition of the prosthesis into the native aortic root leading to optimal prosthesis stability post-deployment and minimal potential paravalvular leakage or prosthesis migration. Due to the complex anatomy of the aortic root and aortic annulus an accurate 3D imaging technique will be mandatory to acquire sufficient data for reliable reconstruction of the aortic anatomy. In contrary to 2D TTE and TEE, MDCT offers superb spatial and temporal resolution needed for precise reconstruction of the several anatomic dimensions important for preprocedural TAVI planning (11).

Several studies (12,13) have revealed that the annulus has an oval shape instead of a circular one, which might help explain differences in measured aortic annular diameters using TEE, TTE and calibrated angiography (14). These findings suggest that minimum and maximum diameters should be taken in the axial plane to calculate the mean diameter or area of the aortic valve annulus providing more accurate selection of the prosthesis size. Determining inclination of the aortic valve (angle α and β) (Fig. 2) will also be of importance for successful percutaneous aortic valve replacement. Defining the correct plane with MDCT avoids having multiple “trial and error“ angiographic series before the optimal plane is found.

Exact anatomical knowledge of the aortic root is needed for accurate positioning of the prosthesis in the aortic annulus, especially when using the corevalve prosthesis, as an extremely narrow or wide aortic root might be a contraindication for this type of probes (15). Measurements of the aortic root dimensions include maximum diameters of the ascending aorta, the sino-tubular junction, the sinus of Valsalva, and maximum and minimum diameters of the aortic valve annulus and the left ventricle outflow tract (Fig. 3).

It is also important to measure the height of the coronary ostia relative to the aortic valve annular plane to avoid covering of the coronary ostia by the upper part of the prosthesis or one of the native leaflets (Fig. 3) (15,16).

Furthermore, location and quantifying the degree of aortic valve calcifications (Fig. 6) is important,
because heavily calcified valves may hamper the prosthesis in crossing the native valve in percutaneous valve replacement or may interfere with stent expansion and cause paravalvular leakage (17). Willmann et al describes a good correlation between nonenhanced and contrast-enhanced CT and surgical findings, with regard to quantification of the degree of aortic valve calcification (18).

As mentioned above, precise preoperative workout will not only reduce procedural complications, it will also speed up the TAVI procedure and minimize the amount of contrast used during the procedure. One bolus of contrast on ventriculogram/aortogram will be sufficient in most cases, hereby effectively reducing the dose of contrast from an average of 250 ml to 60 ml (10).

**Preoperative anatomic screening variables**

Further knowledge of vascular anatomy and existing comorbidities is needed in determining which way of access is most desirable. MDCT is the imaging modality of choice for evaluating these variables.

First the luminal diameters, tortuosity and wall calcifications of the ilio-femoral arteries should be accurately assessed (Fig. 4, 5). Concentric or circumferential calcifications and complex plaques with thrombus formation are considered as relative contra-indications for the transfemoral approach, as they hamper the advancement of the catheter and increase the risk of inducing emboli (19). Extremely tortuous and small iliacs (diameter smaller than 6 mm) are also a contra-indication, because they don’t allow safe manipulation of the rigid catheter past the iliac artery into the aorta and hereby enlarge the risk of local vascular complications (19). To make an estimation of the tortuosity of an iliac artery we can calculate it’s tortuosity index, which is total length of the external iliac artery divided by the shortest possible distance between the common iliac artery and the femoral artery (Fig. 5) (20).

In such cases, a transapical approach can be considered, hereby access to the left ventricle is achieved through a minithoracotomy with needle puncture, which is a viable alternative for patients who also have advanced peripheral vascular disease, but might be contraindicated in patients with lung disease, pericardial calcifications, extensive epicardial fat, previous left ventricular surgery and dysmorphic chest anatomy (19, 21). This TAVI approach may become an attractive alternative in the future, especially if the incidence of cerebrovascular accidents is significantly smaller compared to the retrograde approach.

Another valuable alternative in patients with unsuitable femoral access includes the subclavian approach with high success rates showed by several small studies (21).

Second, MDCT may serve as an alternative to invasive coronary angiography to rule out significant coronary artery disease, as most practitioners feel compelled to assess coronary anatomy ahead of valve surgery, as severe coronary artery disease might be a relative contraindication (4). As expected,
coronary calcifications are very frequent in patients with aortic valve stenosis.

Complications related to percutaneous valve implantation

The fast growing number of patients treated with TAVI and data provided by longer follow-up studies have resulted in a better knowledge of the complications. Again MDCT is an important tool in preventing the majority of these complications. A detailed insight in vascular anatomy can reduce vascular injuries, such as aortic rupture and iliac perforation. Obtaining accurate measurements of the aortic root and annulus will prevent valve malpositioning, which can lead to coronary obstruction, significant paravalvular leakage and prosthesis migration.

Other complications, such as cardiac perforation and tamponade, conduction abnormalities, myocardial infarction, and stroke with a reported rate of 3% to 9% (11), are procedure related and are therefore more difficult to prevent. Concluding, a detailed evaluation of different anatomical variables is mandatory before any implant.

Conclusion

TAVI has become a widely accepted alternative to conventional open-heart surgery for selected high-risk patients with severe symptomatic aortic stenosis. As techniques and devices evolve, the procedure will become suitable for a wider range of candidates. Pre-surgical work-up is of major importance in reducing complications related to the procedure. Due to its superb spatial and temporal resolution and accurate 3D imaging, MDCT is emerging as the best preprocedural imaging modality, and will inevitably play a vital role in facilitating the selection and evaluation of candidates. So, radiologists should familiarize themselves in using MDCT as a standard work-up tool preceding the TAVI procedure to succeed future demands.

References


