Imaging the Aortic Annulus with Multi-Detector Computed Tomography and 3-Dimensional Transesophageal Echocardiography

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KEYWORDS

• Aortic annular sizing • Transcatheter aortic valve replacement
• Transcatheter aortic valve implantation • 3-dimensional transesophageal echocardiography
• Multidetector computer tomography • Paravalvular aortic regurgitation • Balloon expandable valve
• Self-expandable valve

KEY POINTS

- Aortic annular measurements by both multidetector computed tomography (MDCT) and 3-dimensional transesophageal echocardiography (3D TEE) are feasible, accurate, and reproducible.
- MDCT and 3D TEE provide multiplanar imaging capabilities that allow precise measurements of the noncircular aortic annulus and complex anatomy of the aortic root.
- MDCT measurements tend to be larger than those obtained from 3D TEE; this has implications for prosthesis sizing, complication rates, and clinical outcomes.
- Each modality has strengths and weaknesses; imaging integration needs to be tailored to the individual with procedural guidance and transcatheter heart valve type and size selection remaining a multimodality decision.
- Three-dimensional imaging augments transcatheter aortic valve replacement and helps to improve clinical outcomes, with inherent advantages of both CT and 3D TEE.

INTRODUCTION

In Western nations, aortic stenosis is the most common cause of valvular heart disease. Its prevalence continues to dramatically increase with the aging of the population.[1,2] Since its introduction in 2002, transcatheter aortic valve replacement (TAVR) has emerged as an alternative therapy for inoperable or high-risk surgical patients with symptomatic severe aortic stenosis.[3,4]

The success and safety of TAVR is directly related to proper imaging.[5] This dependency is greater than in surgical aortic valve replacement, because in TAVR there is no opportunity to directly

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inspect or size the annulus. Three-dimensional imaging techniques such as multidetector computed tomography (MDCT) and 3-dimensional (3D) transesophageal echocardiography (TEE) provide multiplanar imaging capabilities that allow precise measurements of the aortic annulus and aortic root.[6] The multiplanar capabilities of these 3D imaging modalities are essential owing to the complex, noncircular nature of the aortic annulus. These granular measurements influence eligibility of patients for TAVR, allow adequate prosthesis sizing,[7] and determine the success of implantation[8] as well as the likelihood of complications.[9,10]

At present, there is no gold standard imaging modality for the assessment of the aortic annulus. It is, therefore, important to understand the accuracy, reproducibility, and sources of variability in the measurement of aortic annulus diameter, between these 2 imaging modalities.[11] This review compares MDCT and 3D TEE and addresses the strengths and weaknesses of each modality in its ability to assess the aortic annulus and other aortic root structures.

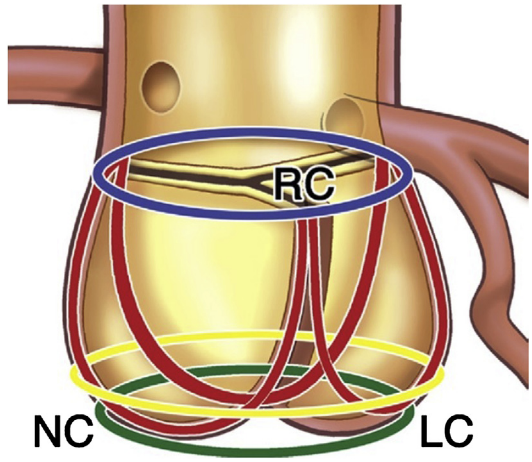

Fig. 1. Aortic root and anatomic location of aortic annulus. The 3 red rings represent the aortic valve cusps, with the green circle placed at the nadir of the aortic cusps denoting the annular plane. LC, left coronary cusp; NC, noncoronary cusp; RC, right coronary cusp. (*From* Leipsic J, Gurvitch R, Labounty TM, et al. Multidetector computed tomography in transcatheter aortic valve implantation. JACC Cardiovasc Imaging 2011;4(4):423; with permission.)

AORTIC ROOT ANATOMY

The aortic root is bounded inferiorly by the left ventricular outflow tract and superiorly by the sinotubular junction. It extends from the basal attachment of the aortic leaflets to their superior attachment at the sinotubular junction. It is composed of 3 circular rings and 1 crownlike ring with the 3 valvular leaflets attached along the length of the root, thereby taking the shape of a 3-pronged coronet. The aortic annulus forms the base of this crown, which is a theoretic ring formed by joining the basal insertion points of the 3 leaflets (**Fig. 1**).[12] The virtual annulus represents the narrowest part of the aortic root.[13]

Adding to the complexity of the aortic root's anatomy is its dynamic nature throughout the cardiac cycle, as a response to changes in pressure.[14] Willson and colleagues[15] demonstrated that all commonly used annular measures including mean annular diameter, area, and circumference are significantly larger in systole than in diastole; however, annular eccentricity does not change through the cardiac cycle. Blanke and colleagues[16] confirmed significant dynamism of the annulus throughout the cardiac cycle, which impacted all measurements, including the annular perimeter, which has been felt by others to be impervious to the cardiac cycle. Based on this and correlative echocardiographic data, all currently applied sizing algorithms integrate systolic measurements of the annulus for sizing.[17] Therefore, by convention measurements are obtained in systole during maximum valve opening at typically 25% to 35% of the R–R interval.[15,17]

Ellipsoid Annular Geometry

In the early years of TAVR, 2-dimensional (2D) TEE was the most frequently used modality for measuring the diameter of the aortic annulus. It used the assumption that the annulus was a circular structure. However, studies using MDCT, 3D TEE, and MRI for 3D imaging have revealed that the annulus has an ellipsoid geometry.[18–20] This fact is well-demonstrated in a study of 169 patients with nil to severe aortic stenosis undergoing evaluation of the aortic annulus with MDCT. The annular diameters in the coronal and sagittal views were 26.3 ± 2.8 and 23.5 ± 2.7 mm, respectively, indicating an ellipsoid shape of the aortic annulus.[19] The ellipsoid nature of the annulus can be quantified by the eccentricity index, which is calculated as 1 – short diameter/long diameter.[9] A value greater than 0.1 indicates an ellipsoid annulus whereas a value of less than 0.1 suggests a circular annulus. This noncircularity drives home the importance of 3D annular assessment to provide adequate information regarding annular geometry to enable granular sizing and appropriate device selection.