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EDITORIAL COMMENT

Multimodality Quantitative Imaging of Aortic Root for Transcatheter Aortic Valve Implantation

More Complex Than It Appears*

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The anatomy of the aortic valve and that of the aortic root recently have become very relevant to the interventional cardiology community due to rapid development of transcatheter aortic valve implantation (TAVI). The aortic root, the direct continuation of the left ventricular outflow tract, extends from the basal attachment of the aortic valvular leaflets within the left ventricle to their more cranial attachment at the level of the sinotubular junction (1). The entire right leaflet and approximately one-half of the left and noncoronary leaflets are connected to the muscular or membranous ventricular septum, whereas the remaining halves of the left and noncoronary leaflets

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are in fibrous continuity with the mitral valve. The leaflets are attached to the aorta in a crown-shaped manner along the commissures, but the transcatheter valve prosthesis does not anchor to the tissue in a similar way. The hinge points of the valve leaflets appear to be the tissue that provides the first resistance and anchoring force to the stent. Because of the differences in the characteristics of the subleaflet tissue (muscular septum, membranous septum, or aortomitral curtain), distortion of the hinge points of the leaflets depends upon the size of the prosthesis and the forces applied to the tissues at the time of deployment. Appropriate device sizing may therefore be dependent on the observation of anatomy–device interaction. Therefore, the goal to measure the transcatheter valve annulus accurately by imaging to determine eligibility for the procedure and choice of the device size is challenging.

In this context, the report by Messika-Zeitoun et al. (2) in this issue of the *Journal* is of critical interest. The authors examine differences in aortic annulus measurements with echocardiography and computed tomography in patients undergoing evaluation for TAVI. The annulus was defined in the standard fashion at the level of the basal attachment of the leaflets (inferior virtual basal ring), and transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE) measurements of the aortic annulus were performed in the parasternal long-axis view and the 120° to 140° long-axis view, respectively. Using multidetector computed tomography (MDCT), a cross-sectional image was reconstructed at the annulus and the minimal, maximal, and mean diameters were measured. In addition, an MDCT 3-chamber view, similar to the long-axis echocardiographic plane, was reconstructed. Similar to previous studies (3–7), MDCT demonstrated an oval shape of the annulus with significant differences between the minimal and maximal diameter. Mean MDCT diameter was significantly larger than the echocardiographic measurements, although the differences were small. The MDCT 3-chamber measurement also was somewhat larger, but did not reach statistical significance. Using a decision model for the TAVI strategy with the TEE measurement as the gold standard, more patients would have been denied the procedure based on the MDCT measurements, despite good results with the standard TEE-based strategy. These results suggest that annulus measurements with TEE reliably guide clinical decision making. However, this is not surprising, because current clinical experience and recommendations are based on echocardiographic measurements.

It is important to recognize that MDCT measurements do not represent identical anatomic measurements as those obtained with TEE or TTE (Fig. 1). MDCT allows detailed understanding of the complex 3-dimensional aortic root anatomy, including the crown-shaped anatomic aortic annulus, the typically elliptical imaging-defined annulus (i.e., the inferior virtual basal ring), the sinuses of Valsalva with the origin of the coronary arteries, the valve leaflets, and the sinotubular junction (3–7). Beyond diameter measurements, the distance between the annulus and the ostia of the coronary arteries in relationship to the length of the coronary leaflets can be assessed (3–7). The detailed understanding of the anatomy is essential in predicting the final shape of the prosthetic valve, displacement of the native calcified leaflets, and sealing around the prosthesis (8).

Understanding how a particular aortic valve prosthesis interacts with the aortic root anatomy and the left ventricular outflow tract determines proper placement, residual aortic regurgitation, as well as impact on the conduction system, mitral valve, and coronary ostia.

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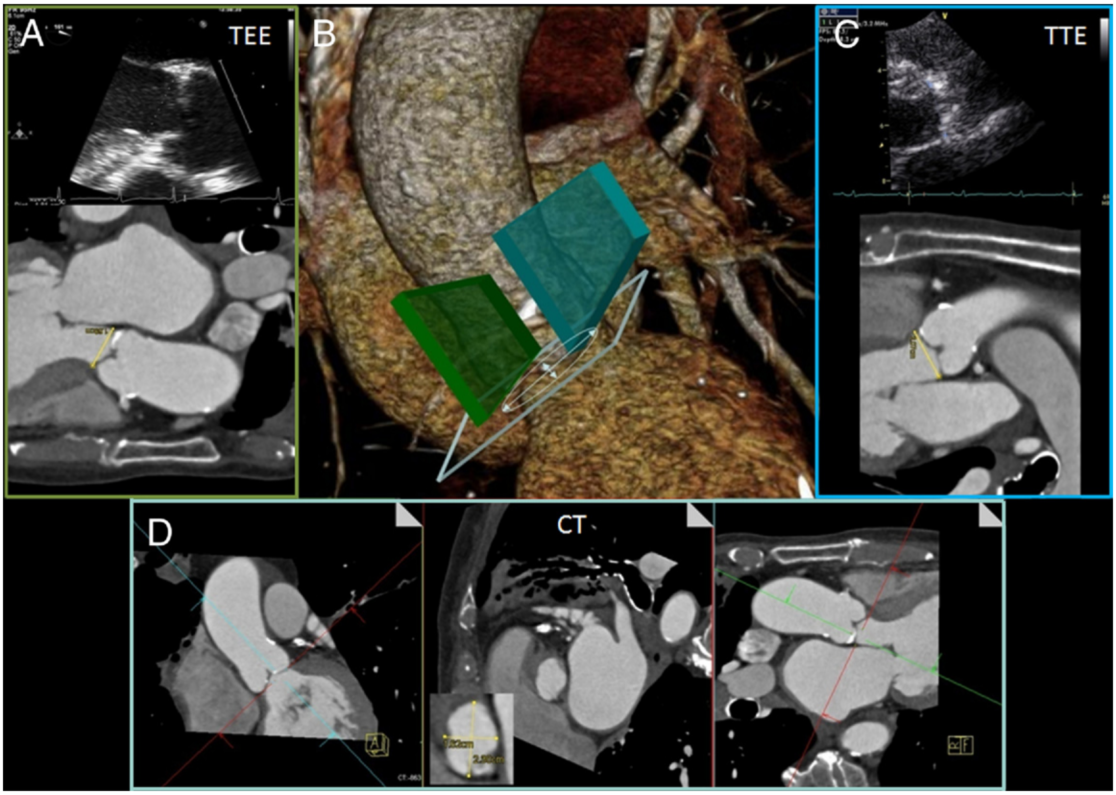

Figure 1 **Multimodality Imaging of the Aortic Root**

Transesophageal echocardiography (TEE), transthoracic echocardiography (TTE), and multidetector computed tomography (MDCT) images of the aortic root in a single patient. In the 3-dimensional reconstruction in **B**, the **green, blue, and white** planes demonstrate the imaging planes of the TTE, TEE, and computed tomography scans. In **A**, the TEE image and corresponding MDCT reconstruction in the exact same angle with measurement are shown. In **C**, the TTE image and the corresponding MDCT reconstruction are shown. In **D**, the cross-sectional MDCT image of the annulus is shown, demonstrating the elliptical shape. The fact that each method measures a different part of the annulus explains the discrepancy between the imaging modalities.

During open aortic valve replacement, while suturing the prosthetic valve to the aortic annulus, the surgeon carefully controls close adaptation of the aortic root to the valve prosthesis. When the interventional cardiologist implants the transcatheter valve, the prosthesis adapts to the anatomy, but if this adaptation is less than optimal, the long-term durability of the valve may be compromised. Because of the differences in the dimensions and characteristics of the diseased native valve and the subleaflet tissue (muscular septum, membranous septum, or aortomitral curtain), the interaction of the prosthesis with the anatomy will remain unpredictable until we can address the sizing issue in a much larger context and design prosthetic valves accordingly.

Emerging multimodality imaging allows detailed insights into the complex anatomy of the aortic root in vivo for better understanding of device–anatomy interactions (9). However, our tools still fall short of providing the desired precision of measurements in preparation for TAVI. It is possible that we need to "feel" as much as we need to "see" when making these quantitative assessments. There are some novel ways to size devices using balloon inflations (10), but the implications of such more complex sizing exercises will bear fruit when more sizes and designs of the devices are available. Although we have some early guidelines (11) for device selection depending on annulus measurements, we are far from calling this art a science!

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Key Words: aortic root imaging ■ transcatheter aortic valve implantation ■ aortic valve.