Preoperative Assessment of Aortic Annulus Dimensions: Comparison of Noninvasive and Intraoperative Measurement

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Background. **Preoperative assessment of aortic annulus diameter is crucial for valve sizing in patients scheduled for transcatheter aortic valve replacement. Computed tomographic (CT) measurements of the aortic annulus are not standardized and may yield different results depending on view due to its elliptic shape. The purpose of this study was to compare the measurement of the aortic annulus during surgery in patients undergoing conventional aortic valve replacement with noninvasive methods.**

Methods. **In 33 patients with aortic valve stenosis (18 males, mean age 77.2 ± 7.9), aortic annulus diameter was measured with cardiac CT and TEE (transesophageal echocardiography) prior to open aortic valve replacement. In CT, aortic annulus diameter was assessed as the calculated average diameter of luminal area at the level of basal attachments of the leaflets by means of planimetry. Operative measurements were performed with a Hegar dilator. A Pearson analysis was applied to test for degree of correlation.**

Results. **Calculated average diameter by CT correlated significantly with intraoperative measurements (r = 0.923, $p < 0.001$) and with the size of implanted valve (r = 0.867, $p < 0.001$), while correlation of TEE and intraoperative measurements was weak (r = 0.523, $p = 0.002$). The TEE tends to underestimate the dimensions of aortic annulus.**

Conclusions. **The CT-measured aortic annulus diameter, assessed as the calculated average diameter of planimetric annulus area, seems to provide adequate dimensions similar to operative measurements with a Hegar dilator. This approach may minimize the dependency of single-view CT measurement on the elliptic shape of the aortic annulus and appears to be a feasible alternative for aortic annulus assessment in terms of candidates' selection for transcatheter aortic valve replacement.**

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Transcatheter aortic valve implantation (TAVI) currently represents a feasible alternative to conventional aortic heart surgery in very high-risk patients with severe symptomatic aortic stenosis. Precise preoperative assessment of the aortic annulus diameter is crucial for optimal valve sizing in patients scheduled for transcatheter aortic valve replacement (TAVR) and determines the procedure outcome. Different methods of preoperative annulus measurements have been used over time: transesophageal echocardiography (TEE), calibrated aortic angiography, and recently, also multislice computed tomography (MSCT) [1, 2]. In clinical practice, TEE measurements in terms of preoperative screening for TAVI have become widely expanded and are reported to be the most reliable tool to measure the diameter of the aortic root [3]. In TEE, the diameter of the aortic annulus, including all cusp calcifications, is measured on the midesophageal long-axis view of the ascending aorta and aortic valve at end-systole, according to guidelines from the American Society of Echocardiography [4, 5].

Although MSCT is able to provide detailed information about the shape of the aortic annulus and its surrounding structures [6], the use of this method in preoperative annulus sizing in TAVR patients is not standardized and is therefore not routine. Both TEE and MSCT may yield different results, depending on the view due to the elliptic shape of the aortic annulus [7], which should be regarded as a serious limitation. We have found no available studies at the moment that could provide evidence as to which of the clinically applied methods of aortic annulus measurement better refer to true annulus dimensions. Therefore, it was the purpose of this study to compare the intraoperative measurement of the aortic annulus during surgery in patients undergoing conventional aortic valve replacement with noninvasive methods by means of TEE and MSCT.

Patients and Methods

All procedures of this study were approved by the Ethics Committee of Freiburg University Medical Centre and followed the Declaration of Helsinki guidelines. The

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need for individual patient consent was waived by the Institutional Review Board as the individual patient data remained not identified.

Study Population

The study population consisted of 33 patients (mean age 77.2 ± 7.9, 18 male). The patients underwent conventional aortic valve replacement for severe aortic stenosis. The median European system for cardiac operative risk evaluation of the patients was 10.1 ± 8.8 and the ventricular ejection fraction was 0.474 ± 0.063. The noninvasive echocardiographic assessment of aortic valve stenosis presented the average valve opening area of 0.7 ± 0.2 cm^2. The mean transvalvular pressure gradient was 48.8 ± 14.0 mm Hg, as assessed invasively. According to the preoperative echocardiography, all patients had a tricuspid aortic valve. The following types of aortic valve prostheses were used: Carpentier-Edwards Perimount Magna (23 patients; Edwards Lifesciences, Irvine, CA), ATS Medical (7 patients; ATS Medical, Minneapolis, MN), and allograft valves (3 patients). The manufacturer's labeled valve size was used for analysis; the respective diameters of the implanted valves for each patient are listed in Table 1.

All patients underwent preoperative electrocardiographic-gated dual source computed tomography (CT) of the chest and TEE as part of their preoperative assessment. In addition, patients underwent an intraoperative measurement of the aortic annulus diameter with the Hegar dilator.

Computed Tomographic Protocol

All CT examinations were performed using a dual source CT scanner (Somatom Definition, Siemens Medical Solutions, Forchheim, Germany). For contrast-enhanced data acquisition a bolus of 90 mL iodinated contrast agent (Imeron 350; Bracco Imaging, Konstanz, Germany) was injected at a flow rate of 4.5 mL/second through an 18-gauge needle in an antecubital vein, followed by a saline bolus chaser administered at a flow rate of 4 mL/second with a total volume of 50 mL. The scan was started with a delay of 6 seconds after the attenuation in the aortic root reached 120 Hounsfield units by means of bolus tracking. Scan parameters for cardiac CT were as follows: tube current time product, 350 mAs/rotation; collimation, 2 × 32 × 0.6 mm; slice acquisition, 2 × 64 × 0.6 mm using the z-flying focal spot technique; pitch, 0.2 to 0.43 adapted to the heart rate; gantry rotation time, 330 ms; tube potential, 120 kV; scan direction, craniocaudal. Scan range extended from the carina to the diaphragm. The CARE Dose4D tube current modulation (Siemens Medical Solutions) and prospective electrocardiographic-triggered tube current modulation [8] were employed for radiation dose reduction, the latter with a pulsing window between 30% and 80% of the RR cycle (interval between the R waves on ECG) and reduction of tube current to 20% of maximum outside the pulsing window. Given the clinical characteristics of the study population with severe symptomatic aortic stenosis, no additional beta blockade was administered to achieve slower heart rates.

Computed tomographic data sets were reconstructed at 300 ms past the R-peak (end-systole) with a slice thickness of 0.6 mm and an increment of 0.4 mm using a medium soft tissue convolution kernel B20f. All data sets were transferred to a dedicated post-processing workstation equipped with Aquarius iNtuition (Terarecon Inc, San Mateo, CA).

Preoperative Aortic Annulus Measurement by Dual Source Computed Tomography

Two predefined approaches were undertaken for assessment of aortic annulus diameters. First, as reported by Tops and colleagues [6], coronal oblique and sagittal oblique views through the aortic valve were reconstructed (Fig 1A, B), the latter one with a similar orientation as the parasternal long-axis view on TTE and the midesophageal long-axis view on TEE. By reviewing the reconstructed double oblique transverse view at the level of the aortic valve (Fig 1C), the correct position of the intersection of both views in the center of the aortic valve, defined as the conjuncture of the three cusps, was ensured. Using the coronal and sagittal oblique views, the diameter of the aortic annulus was determined as the distance between the depicted hinge points of the aortic valve cusps ("hinge-to-hinge"; Fig 1D).

Second, the dimensions of the aortic annulus were further assessed employing the concept of a virtual ring joining the basal attachments of all three aortic valve cusps, representing the inlet from the left ventricular

Table 1. Summary of Intraoperative (Hegar) and Transesophageal Echocardiographic (TEE) and Computed Tomographic (CAAD) Measurements, Grouped by the Size of the Surgically Implanted Aortic Valve Prosthesis (Implanted Valve Size), Expressed as Mean Value ± Standard Deviation. There Was no Statistically Significant Difference in Annulus Dimension Between the Groups; Depicted p Values Are Bonferroni Corrected

Implanted Valve Size (mm)	Hegar (mm)	CAAD (mm)	TEE (mm)	*p* Values Between Groups
19 (n = 1)	19.0	20.46	22.0	—
21 (n = 15)	22.5 ± 1.1	22.8 ± 1.4	22.3 ± 2.7	0.705
23 (n = 7)	24.1 ± 1.3	24.4 ± 1.0	24.1 ± 1.2	0.923
25 (n = 6)	25.7 ± 1.0	26.1 ± 1.7	24.3 ± 2.5	0.254
27 (n = 3)	28.3 ± 1.5	28.5 ± 1.7	26.0 ± 1.7	0.2
29 (n = 1)	30.0	31.44	24.0	—
All sizes (n = 33)	24.1 ± 2.5	24.5 ± 2.6	23.4 ± 2.4	0.252