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Prosthesis sizing for transcatheter aortic valve implantation — Comparison of three dimensional transesophageal echocardiography with multislice computed tomography

Oliver Husser [a,d,e,*,1], Andreas Holzamer [b,1], Markus Resch [a], Dierk H. Endemann [a], Julio Nunez [a], Vicente Bodi [a], Christof Schmid [b], Günter A.J. Riegger [a], Holger Gössmann [c], Okka Hamer [c], Christian Stroszczynski [c], Andreas Luchner [a], Michael Hilker [b,1], Christian Hengstenberg [d,e,*,1]

[a] Klinik und Poliklinik für Innere Medizin II, University of Regensburg Medical Center, Regensburg, Germany
[b] Klink für Herz-, Thorax- und herznahe Gefäßchirurgie, University of Regensburg Medical Center, Regensburg, Germany
[c] Institut für Röntgendiagnostik, University of Regensburg Medical Center, Regensburg, Germany
[d] Klinik für Herz- und Kreislauferkrankungen, Deutsches Herzzentrum München, München, Germany
[e] Deutsches Zentrum für Herz- und Kreislauf-Forschung e.V., Partner Site Munich Heart Alliance, Munich, Germany

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ABSTRACT

Background: The complex anatomy of the aortic annulus warrants the use of three dimensional (3D) modalities for prosthesis sizing in transcatheter aortic valve implantation (TAVI). Multislice computed tomography (MSCT) has been used for this purpose, but its use may be restricted because of contrast administration. 3D transesophageal echocardiography (3D-TEE) lacks this limitation and data on comparison with MSCT is scarce. We compared 3D-TEE with MSCT for prosthesis sizing in TAVI.
Methods: Aortic annulus diameters in the sagittal and coronal plane and annulus areas in 3D-TEE and MSCT were compared in 57 patients undergoing TAVI. Final prosthesis size was left at the operator's discretion and the agreement with 3D-TEE and MSCT was calculated.
Results: Sagittal diameters on 3D-TEE and MSCT correlated well ($r = .754$, $p < .0001$) and means were comparable (22.3 ± 2.1 vs. 22.5 ± 2.3 mm; $p = 0.2$; mean difference: -0.3 mm [-3.3–2.8]). On 3D-TEE, coronal diameter and annulus area were significantly smaller ($p < .0001$ for both) with moderate correlation ($r = 0.454$ and $r = 0.592$). Interobserver variability was comparable for both modalities. TAVI was successful in all patients with no severe post-procedural insufficiency. Final prosthesis size was best predicted by sagittal annulus diameters in 84% and 79% by 3D-TEE and MSCT, respectively. Agreement between both modalities was 77%.
Conclusions: Annulus diameters and areas for pre-procedural TAVI assessment by 3D-TEE are significantly smaller than MSCT with exception of sagittal diameters. Using sagittal diameters, both modalities predicted well final prosthesis size and excellent procedural results were obtained. 3D-TEE can thus be a useful alternative in patients with contraindications to MSCT.

1. Introduction

Transcatheter aortic valve implantation (TAVI) is increasingly used as a therapeutic strategy in elderly high-risk patients with severe symptomatic aortic stenosis performed by an interdisciplinary 'Heart Team' [1,2]. Procedural results reported from large registries and first randomized trials are encouraging [3–6].

A key determinant of procedural success in TAVI is the patient screening process. Apart from the evaluation of the access route, measurement of the aortic annulus for prosthesis size selection is of major importance. Because of the complex anatomy of the aortic valve [7], modalities allowing for three dimensional (3D) assessment of the aortic annulus are of great potential value [8].

Multislice computed tomography (MSCT) has been used for prosthesis size selection in TAVI with increasing experience, yielding good procedural results [8–12]. Nevertheless, due to the administration of contrast medium its use might be restricted in a considerable proportion of TAVI patients, a population with a very high prevalence of impaired renal function or even renal failure.

3D-transesophageal (TEE) has been used for prosthesis size selection in TAVI [13], allows for 3D assessment of the aortic annulus, is increasingly available and lacks the limitation of contrast administration. To date, data on how aortic annulus measures assessed by 3D-TEE compared to MSCT measurements are scarce and the

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Abbreviations: 3D, three dimensional; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography; TAVI, transcatheter aortic valve implantation; MSCT, multislice computed tomography.

[*] Corresponding authors at: Klinik für Herzkreislauferkrankungen, Deutsches Herzzentrum München, Lazarettstrasse 36, 80636 München, Germany. Tel.: +49 89 1218 4025.

E-mail addresses: oliver.husser@gmail.com (O. Husser), christian.hengstenberg@gmail.com (C. Hengstenberg).

[1] These authors contributed equally.

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impact on the choice of prosthesis size for TAVI has not been evaluated, yet.

Here, we report our experience using a multimodal approach for patient screening in a consecutive cohort of patients undergoing TAVI in our center, comparing aortic annulus measurements of 3D-TEE with MSCT and evaluating the impact on prosthesis size selection.

2. Methods

2.1. Study population

From March 2011 to December 2011, 95 consecutive patients with severe symptomatic aortic stenosis underwent TAVI in our institution and were considered for participation in the study. Of these, 57 patients underwent both 3D-TEE and MSCT as part of our TAVI screening protocol. In our institution, this protocol includes a diagnostic coronary angiography, an additional angiography of the aortic arch and of the iliac vessels, a comprehensive transthoracic and transesophageal echocardiographic assessment, including 3D-TEE, and MSCT. Out of the entire patient cohort, 38 patients could only undergo either 3D-TEE or MSCT leading to exclusion from the study. Details of exclusion from one of the modalities are depicted in Fig. 1. All patients signed informed consent for the diagnostic and therapeutic procedures. The authors of this manuscript have certified that they comply with the Principles of Ethical Publishing in the International Journal of Cardiology.

2.2. Echocardiographic examinations

Echocardiographic examinations were performed by two experienced echocardiographers following the recommendations of the American Society of Echocardiography using a commercially available ultrasound system (IE33, Philips, Best, The Netherlands). TTE was performed using a S5 probe. Left ventricular ejection fraction, and mean and maximal transaortic gradients were obtained. TEE was performed using a commercially available ultrasound system (IE33, Philips, Best, The Netherlands) with a multiplanar probe allowing for 2D and 3D imaging (X7-2t). In the mid-esophageal position at 110–135° a long axis view of the aortic valve was obtained. The aortic valve orifice area was assessed by direct planimetry at 50–70°. After 2D examinations, 3D data sets were acquired, manually adjusting depth and optimizing gain and compression during 3–5 cardiac cycles.

2.3. 3D-TEE measurements of the aortic annulus diameter

In 2D-TEE, aortic annulus diameter was measured in midsystole in the 110° to 135° long-axis view at the insertion of the leaflets using the zoom mode (Fig. 2D). 3D data sets were evaluated offline using multiple plane reconstruction. Aortic annulus measures were performed using previous described methodology [13]. Two orthogonal planes parallel bisecting the aortic valve in the long axis were manually adjusted and the third orthogonal transverse plane was set bisecting the aortic annulus at the insertion points of all three aortic cusps as the short-axis view. Aortic annulus diameters were measured in midsystole in the three-chamber (sagittal view) and in the respective virtual coronal view. The area of the aortic annulus was obtained by direct planimetry in the short axis view (see Fig. 2). Measurements were averaged from three measurements.

2.4. MSCT

Electrocardiogram-gated MSCT was performed using a second generation dual source CT system (Siemens Somatom Definition Flash, Siemens Medical Solution, Erlangen Germany) with tube voltages of 2 × 120 kV. A total volume of 90 ml Iopromid 769 mg/ml (Ultravist 370, Bayer Schering Pharma, Berlin, Germany) was injected at a rate of 5 ml/s. The collimation was 128 × 0.6 mm and the pitch 3.2 avoiding data oversampling. Acquisition was performed in a single breath hold scan from the neck to the groin in a craniocaudal scan direction. To ensure an adequate opacification of the aorta, the acquisition was started 5 s after initial opacification ($>$100 HU) of the descending aorta using bolus tracking. For the evaluation of the aorta, overlapping axial images were reconstructed using a soft tissue kernel (B26F) with a slice thickness of 1 mm. Dose modulation (CARE Dose4D) was used to minimize the radiation.

2.5. MSCT data analysis

Aortic annulus measures were assessed in multiple plane reconstruction using dedicated software (OsiriX 3.9.4, Switzerland). In parallel to the 3D-TEE evaluation, two orthogonal planes were manually set, bisecting the aortic valve in the sagittal and coronal axis. The third orthogonal plane (double oblique view) was set bisecting the aortic annulus at the insertion of all aortic cusps comparable to the echocardiographic short axis view (Fig. 3A). Aortic annulus diameters were measured at the coronal and the single oblique sagittal views with the sagittal plane as a line through the coaptation line of the left and the non-coronary cusps and dividing the right coronary cusp. (Fig. 3B and C) [14–16]. The area of the aortic annulus was obtained by direct planimetry performed in the double oblique

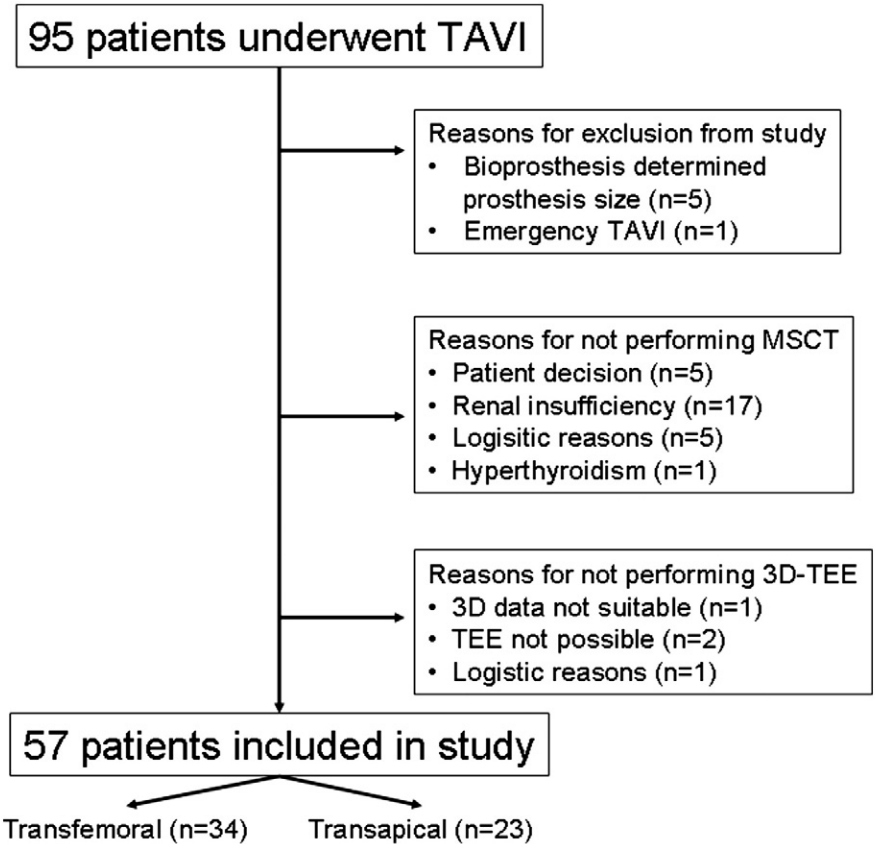

Fig. 1. Patient flow chart. Reasons for exclusion from study and for either MSCT or 3D-TEE.

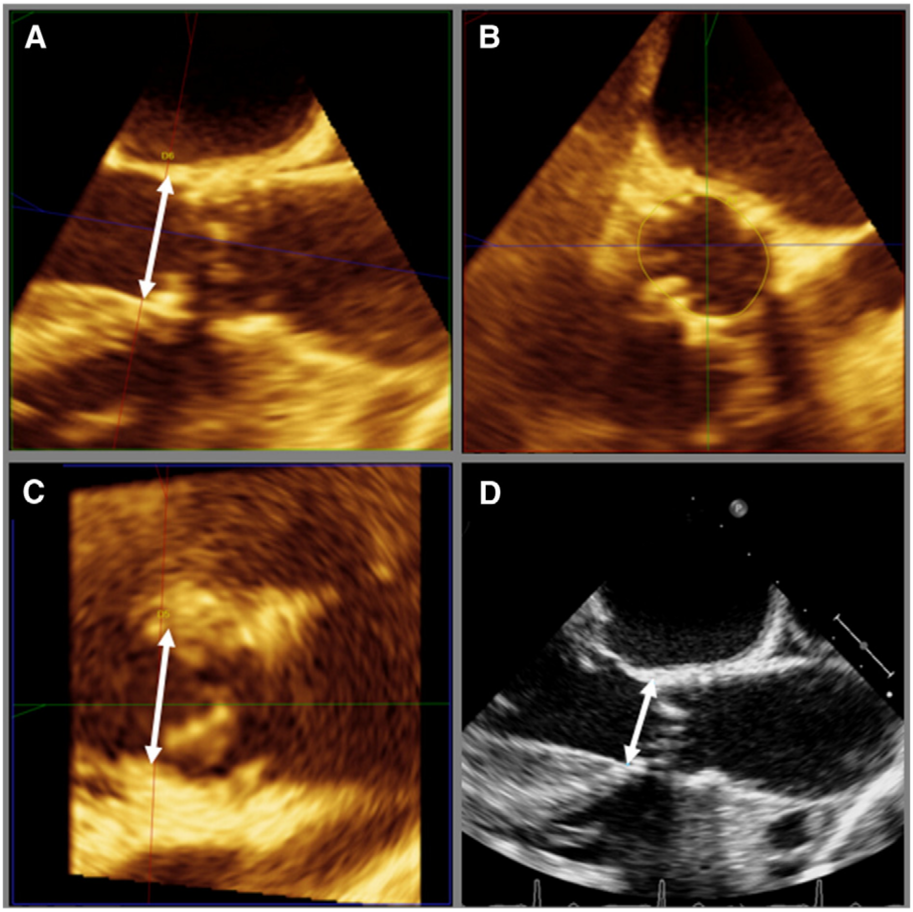

Fig. 2. Example of TEE measurements. Multiple plane reconstruction of the aortic annulus using 3D-TEE. Aortic annulus is measured in the three chamber view (sagittal, panel A) and coronal planes (panel C). Aortic annulus area is assessed by direct planimetry in the short axis view. Panel D shows the 2D-TEE measurement of sagittal aortic annulus diameter in the same patient.

view (Fig. 3D). In order to assess the eccentricity of the aortic annulus, the eccentricity index was calculated using the previously described formula [1 − short diameter / long diameter]. The closer this eccentricity index comes to zero, the more circular is the aortic annulus. Ellipsoid-shaped aortic annulus was considered when the eccentricity index was >0.1 [17]. The amount of aortic valve calcification was qualitatively graded as mild (grade 1), moderate (grade 2) and severe (grade 3). The distance of the coronary ostia from the aortic annulus plane was measured [14].

2.6. TAVI procedure

TAVI was performed either via the transfemoral approach using a balloon expandable (SAPIEN XT™, Edwards Lifesciences, Irvine, CA, USA) or a self-expandable prosthesis (CoreValve™, Medtronic, Irvine, CA, USA) or by the transapical approach using a balloon expandable prosthesis (SAPIEN XT™, Edwards Lifesciences, Irvine, CA, USA). Procedures were performed in the catheterization laboratory under general anesthesia using fluoroscopy and additional TEE guidance.

2.7. Prosthesis size selection

The decision on the final prosthesis size for each patient was based on the 'Heart Team's' decision integrating all information derived from the multimodal screening process and according to the manufacturers' recommendations. At the time of the study, the Edwards-SAPIEN XT™ valve was available in 23 mm and 26 mm. The 29 mm prosthesis was available for the transapical approach only. For all sagittal and coronal measurements in 3D-TEE and MSCT, a 23 mm, 26 mm and 29 mm prosthesis was assigned if the aortic annulus diameter was ≥18 and <21 mm, ≥21 and <25 mm and ≥25 and ≤27 mm, respectively. The prosthesis area was calculated using the formula $[A(\mathrm{cm}^2) = (\text{prosthesis diameter}) / 2 * \pi]$. The CoreValve™ prosthesis was available in two sizes, 26 mm and 29 mm which were assigned, if the annulus diameters were ≥20 to <23 mm and ≥23 to ≤27 mm, respectively.

2.8. Statistical analysis

Continuous data are expressed as mean ± standard deviation and were compared using Students *t*-test for paired data. For comparisons between 3D-TEE data and MSCT as well as for interobserver variability, Pearson's correlations and the Bland–Altman method [18] were applied. In order to assess the interobserver variability for the annulus measurements in 3D-TEE and MSCT, 30% ($n = 17$) of the studies were assessed by a second blinded observer. The percentage in which 3D-TEE and MSCT-derived sagittal and coronal diameters correctly predicted final prosthesis size was calculated according to the cut-offs exposed in the Methods section. Relative difference of the prosthesis area (calculated for SAPIEN XT™, $n = 52$) and the aortic annulus areas assessed by both modalities was calculated. Statistical significance was considered for a two-tailed $p\text{-value} < 0.05$. The SPSS statistical package (version 13.0, SPSS Inc., Chicago, Illinois) was used.

3. Results

3.1. Baseline characteristics

The clinical and echocardiographic characteristics of the study population ($n = 57$) are displayed in Table 1. Mean age was 79 ± 6 years and 24 patients (42%) were male. The mean logistic EuroScore was 15 ± 10%. Mean aortic valve orifice area was 0.67 ± 0.22 cm^2 with a mean transaortic gradient of 50 ± 16 mm Hg. Left ventricular ejection fraction was normal in 79%, and reduced to 35%–50% in 21% of the patients. No patient displayed a left ventricular ejection fraction <35%. On MSCT, mean distances to the left coronary and right coronary artery were 12.7 ± 2.3 mm and 14.2 ± 3.9 mm, respectively. The mean eccentricity index across the patient population was 0.12 ± 0.07, resulting in a proportion of 58% ($n = 33$) of the patients displaying ellipsoid annuli.

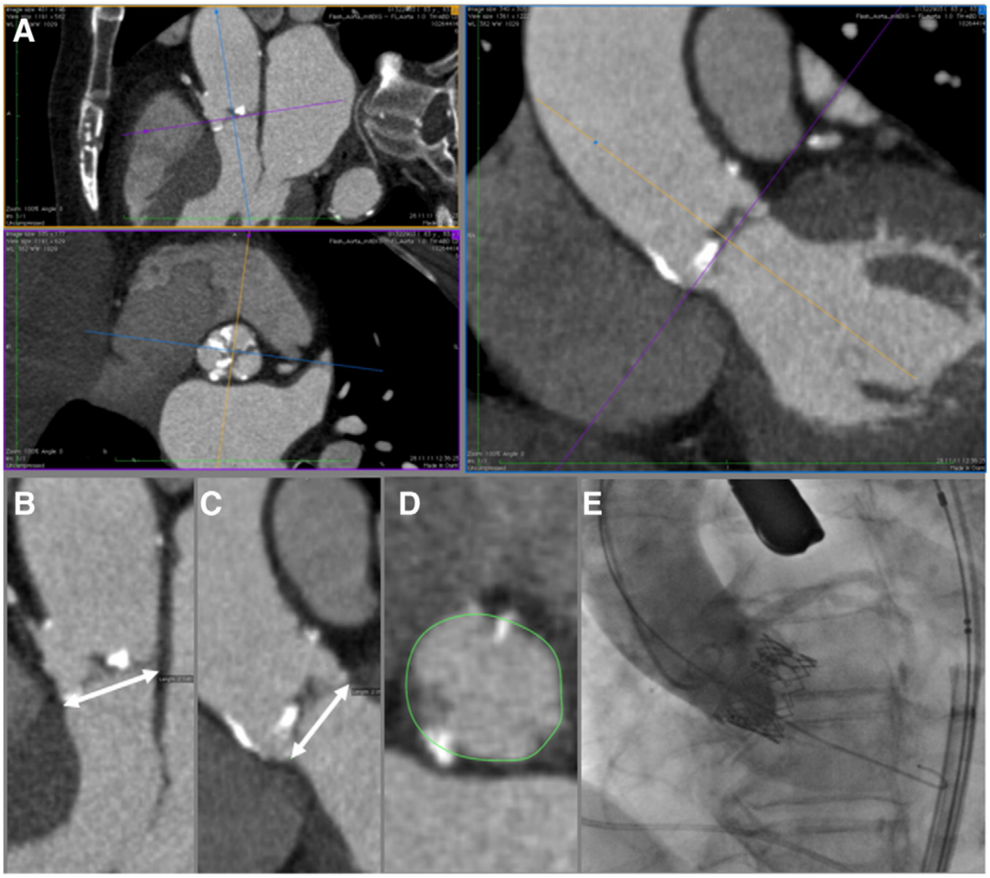

Fig. 3. Example of MSCT measurements. Panel A shows the multiple plane reconstruction of the aortic valve using MSCT in the same patient as in Fig. 2. Three orthogonal planes bisect the aortic valve in the sagittal, coronal axis and double oblique plane. Aortic annulus diameters were measured at the single oblique sagittal (panel B) and the coronal view (panel C). The sagittal plane was aligned as the line through the coaptation line of the left and the non-coronary cusps and dividing the right coronary cusp. Annulus area is assessed by direct planimetry in the double oblique view (panel D). A 23 mm SAPIEN XT™ prosthesis was selected and TAVI was performed integrating all information of the multimodal approach. Panel D shows the successfully implanted prosthesis with no relevant paravalvular leakage.

The degree of calcification of the aortic valve was judged mild, intermediate and severe in 21%, 33% and 46% of the cases, respectively.

3.2. Comparison of 3D-TEE with MSCT for aortic annulus measurements

Aortic annulus diameters on 2D-TEE were significantly smaller as compared to sagittal measures in 3D-TEE (21.7 ± 2.1 vs. 22.3 ± 2.1; $p < .0001$) and MSCT (22.5 ± 2.3; $p < .0001$).

The comparison of 3D-TEE and MSCT measures are displayed in Table 2 and Fig. 4. Sagittal annulus measures showed a good correlation with $r = 0.754$ ($p < .0001$). There was no statistical difference between mean sagittal aortic annulus diameters on 3D-TEE as compared to MSCT (22.3 ± 2.1 vs. 22.5 ± 2.3 mm; $p = .2$). The Bland–Altman analysis for the two modalities revealed a mean difference of aortic annulus diameters of −0.3 mm with limits of agreement between −3.3 mm and 2.8 mm. While coronal annulus measures showed a moderate correlation with $r = 0.454$ ($p < .0001$) its mean diameters on 3D-TEE were significantly smaller as compared to MSCT (23.5 ± 2.1 vs. 25.7 ± 2.5; $p < .0001$) with a mean difference of aortic annulus diameters of −2.2 mm with limits of agreement between −7 mm and 2.6 mm.

The aortic annulus areas were moderately correlated ($r = 0.592$; $p < .0001$). Mean aortic annulus areas on 3D-TEE were significantly smaller as compared to MSCT (3.73 ± .72 vs. 4.68 ± .76 cm^2; $p < .0001$) with a mean difference of aortic annulus diameters of $-0.95\ cm^2$ with limits of agreement between $-2.26\ cm^2$ and $0.35\ cm^2$.

3.3. Interobserver variability for annulus measurement with 3D-TEE and MSCT

The interobserver variability for the different aortic annulus measurements using 3D- and MSCT is displayed in Table 2. Fig. 5A and B displays the correlation and Bland–Altman plots for the interobserver variability of annulus measures using 3D-TEE and MSCT.

3.4. Influence of eccentricity of the aortic annulus

Overall, 3D-TEE yielded statistically significant smaller values than MSCT except in the case of the sagittal diameter. In order to further elucidate this finding, sagittal annulus diameter was stratified according to eccentricity of the aortic annulus on MSCT. When aortic annulus was circular ($n = 24$), mean 3D-TEE measures of the sagittal annulus diameter were significantly smaller compared to MSCT (22.5 ± 2.2 vs. 23.8 ± 2.1 mm; $p = .001$). In contrast, sagittal diameters on 3D-TEE were significantly larger than MSCT measures when aortic annulus was ellipsoid ($n = 33$, 22.1 ± 2.1 vs. 21.7 ± 2.0 mm; $p = .04$).

3.5. Procedural outcome and impact of 3D TEE on prosthesis sizing

TAVI was performed by the transfemoral approach using the CoreValve™ prosthesis ($n = 5$) and the SAPIEN XT™ prosthesis ($n = 29$) or by the transapical approach using the SAPIEN XT™ prosthesis ($n = 23$). Details of the procedural data are displayed

Table 1
Patient characteristics.

Clinical characteristics	n = 57
Age (years)	79 ± 6
Male sex (%)	24 (42)
Logistic EuroScore (%)	15 ± 10
Body mass index (kg/m^2)	27 ± 5
Diabetes (%)	18 (32)
Hypertension (%)	38 (67)
Hypercholesterolemia (%)	14 (25)
Previous valve surgery (%)	0 (0)
Previous CABG (%)	7 (12)
Coronary artery disease (%)	19 (33)
Previous malignoma (%)	5 (9)
Previous myocardial infarction (%)	3 (5)
Previous stroke (%)[a]	8 (14)
Renal failure (%)[b]	9 (16)
Chronic obstructive pulmonary disease (%)[c]	8 (14)
Peripheral arterial disease (%)	9 (16)
Pacemaker (%)	1 (2)
NYHA III + (%)	39 (68)
Echocardiography	
Left ventricular ejection fraction	
>50%	45 (79)
35–50%	12 (21)
<35%	0 (0)
Mean transaortic gradient (mm Hg)	50 ± 16
Maximal transaortic gradient(mm Hg)	84 ± 25
Pulmonary artery pressure (mm Hg)	40 ± 17
Aortic valve area (cm^2)	.67 ± .22

Abbreviations: CABG = coronary artery bypass graft; NYHA = New York Heart Association.

[a] Severely affecting ambulation or day-to-day functioning.

[b] Serum creatinine >200 μmol/l preoperatively.

[c] Longterm use of bronchodilators or steroids for lung disease.

in Table 3. Procedural success was achieved in all cases (n = 57, 100%). There were two intrahospital deaths (4%) due to refractory cardiac failure and due to post-procedural stroke representing also the 30 day mortality of the population. No conversion to open heart surgery occurred. In two cases, a second prosthesis had to be implanted. In one case the prosthesis migrated from the delivery system while trying to cross the heavily calcified native annulus. In the other case, a second valve was required to successfully treat severe aortic regurgitation due to low implantation of the first prosthesis. In 7 cases (12%) post-dilatation was considered necessary in order to minimize paravalvular regurgitation. In total, post-procedural regurgitation was none or mild (0–1+) in all but three patients who displayed a grade 2+ regurgitation after TAVI. Severe regurgitation (>2+) did not occur in any patient. Permanent pacemaker implantation was necessary due to higher grade conduction abnormalities in 6 patients (11%).

The final prosthesis size for implantation was selected integrating all information from 3D-TEE, angiographic and MSCT data. The agreement of final prosthesis size with 3D-TEE and MSCT values is displayed in Table 2. Best agreement of final prosthesis was found with sagittal aortic annulus diameters by 3D-TEE in 84% (48 patients) and by MSCT in 79% (45 patients) of cases. In 44 cases (77%) there was agreement with 3D-TEE and MSCT.

4. Discussion

TAVI has become a very good therapeutic option for elderly patients suffering from severe and symptomatic aortic stenosis. However, correct sizing of the prosthesis is crucial for both procedural and long term success. In our study we addressed this issue of sizing by comparison of 3D-TEE with MSCT. We found that firstly, 3D-TEE measures of the aortic annulus diameters and areas in general yield smaller values with the exception of the sagittal diameter which is currently recommended for prosthesis sizing. Secondly, when stratified according to aortic annulus eccentricity, sagittal diameter from 3D-TEE and MSCT differed significantly. Thirdly, both modalities performed comparably as far as prosthesis sizing is concerned using the sagittal annulus diameter. Since MSCT might not be suitable for all patients screened for TAVI due to impaired renal function, 3D-TEE represents a promising alternative for the purpose of pre-procedural patient screening for TAVI.

4.1. 3D-TEE in TAVI

Echocardiography is widely available, free of ionizing radiation and contrast administration, and is moreover routinely used for diagnostic purposes. Echocardiography thus represents the ideal modality for prosthesis sizing in TAVI. Since the aortic annulus is a complex anatomic structure with a high degree of variability [7,19], a comprehensive assessment of the anatomy, using 3D-reconstruction, is desirable.

3D-TEE becomes increasingly available, but up to date has mainly been used for intraprocedural guidance in TAVI [20,21]. In comparison with 2D-data, 3D-TEE has been shown to yield larger annulus diameters [13,22] resulting in a considerable difference in predicted prosthesis size [13].

Here, we show that 3D-TEE can be carried out in a large proportion of TAVI patients, is reproducible, and yields comparable values to MSCT as far as the sagittal annulus diameter is concerned. A major strength of 3D-TEE as a 3D imaging modality is the accurate visualization of this plane which is crucial for prosthesis sizing. In our study, we achieved comparable values to sagittal diameters on MSCT, but also found a strong dependence on annulus eccentricity. Less important, is the ability of 3D-TEE to provide virtual coronal plane reconstructions. These reconstructions often have a relatively poor image quality, especially in the presence of severe calcifications being highly prevalent in our study population and limiting the use for reliable prosthesis sizing. Concerning the coronal plane and the annulus area, 3D-TEE values were significantly smaller than MSCT.

4.2. MSCT in TAVI

MSCT has been extensively used for patient screening in TAVI. Apart from aortic annulus measures for prosthesis size selection, this modality indeed offers a wide range of information for the purpose of patient

Table 2
Comparison of 3D-TEE and MSCT measures of the aortic annulus, interobserver variability and agreement with final prosthesis size.

n = 57	3D-TEE			MSCT			p-Value[a]
	Mean	Interobserver variability	Agreement with final prosthesis	Mean	Interobserver variability	Agreement with final prosthesis	
Sagittal diameter (mm)	22.3 ± 2.1	4.3 ± 4.1%	84% (48/57)	22.5 ± 2.3	4.0 ± 3.1%	79% (45/57)	.2
Coronal diameter (mm)	23.5 ± 2.1	4.8 ± 4.9%	58% (33/57)	25.7 ± 2.5	3.7 ± 4.4%	33% (19/57)	<.0001
Area (cm^2)	3.73 ± 0.72	9.1 ± 11.1%	26 ± 10%[b]	4.68 ± 0.76	8.7 ± 9.2%	7.5 ± 11.6%[b]	<.0001

[a] p-Value for comparison of mean values between 3D-TEE and MSCT.

[b] Relative difference of the prosthesis area (calculated for SAPIEN XT™ (n = 52) using the formula [$A(cm^2) = (\text{prosthesis diameter}) / 2 * \pi$]) and the determined aortic annulus area.

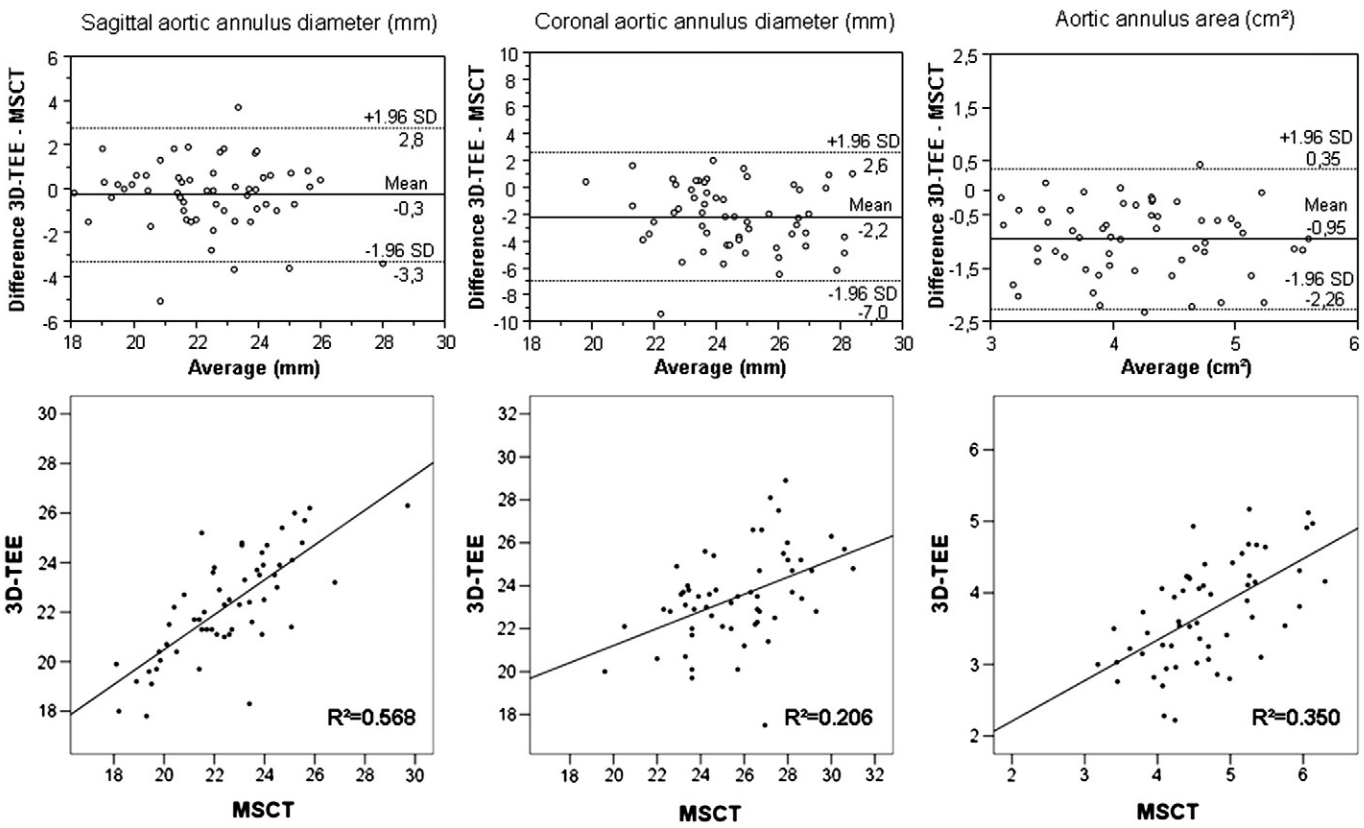

Fig. 4. Agreement between 3D-TEE and MSCT measures. Linear regression analysis and Bland–Altman plots for 3D-TEE versus MSCT.

screening in TAVI. This additional information includes exact delineation of the access rout with accurate visualization of kinking, stenosis and calcification which is crucial for adjudication to a transfemoral versus a transapical approach. Further, important information can be obtained, such as the distance of the coronary ostia [14] and the exact location and amount of valvular calcifications [23]. As far as prosthesis sizing is concerned, MSCT yielded larger diameters and possesses a higher reproducibility compared to echocardiography and aortography [9,11]. In the present study, we found a good reproducibility of MSCT measures displayed by a very low interobserver variability. Nevertheless, when using MSCT as a sizing modality one has to keep in mind that manufacturers' recommendations are based on echocardiographic measures of the sagittal diameter, being the only diameter that can be assessed on 2D echocardiography. Accordingly, as shown in the present study, a large proportion of patients was found not suitable for TAVI, if screening would have been based on other diameters than the sagittal on MSCT [11]. This reflects the difficulty in determining the ideal modality for prosthesis sizing.

4.3. Patient screening for TAVI — a multimodal approach

The gold standard modality for prosthesis sizing in TAVI has not been defined yet. Manufacturers' recommendations are at the moment are based on sagittal aortic annulus measures obtained by echocardiography. Nevertheless an accurate assessment of the patient anatomy in order to correctly size the prosthesis is of utmost importance and impacts on both post-procedural and long term outcome by minimizing paravalvular regurgitation and serious adverse events during implantation, such as embolization of the prosthesis or rupture of the aortic annulus.

So far several diagnostic modalities for this purpose, such as TTE, TEE, MSCT or angiography exist. In our experience, a multimodal approach using a combination of several modalities should be employed in order to combine both, high spatial resolution and 3D-reconstruction. Moreover, a multimodal approach also can prove useful in the presence of contraindications (impaired renal function and hyperthyroidism in the case of MSCT), technical problems (heavy calcifications in the case of echocardiography) or logistic reasons (for both modalities) when one modality cannot be successfully employed. This way the required information can be reliably obtained with another modality. As seen in our study, about one fifth of all patients undergoing TAVI during the study period did not undergo MSCT due to renal insufficiency. In these cases, 3D-TEE constitutes a valid and valuable alternative for prosthesis sizing.

Therefore, in our institution we use a comprehensive screening regime for TAVI which includes 2D-TTE and TEE for diagnostic purposes and as a preliminary sizing modality. During this examination 3D-TEE data sets are acquired. All patients undergo diagnostic catheterization with angiograms of the aortic arch and the ilio-femoral arteries if renal function allows so. Finally, in order to further assess aortic annulus diameters, the access route, distance to coronary ostia and degree of calcification, MSCT is performed if permitted by the patient's comorbidities. When the patient has been accepted for TAVI by consensus of the interdisciplinary ‘Heart Team’, 3D-TEE and MSCT data sets are evaluated in order to determine the exact prosthesis size. Our present study shows that, using this multimodal approach in the preparation of the TAVI patient, excellent results can be achieved with high procedural success and a low rate of severe post-procedural aortic regurgitation.

4.4. Prosthesis size selection

Prosthesis size selection for TAVI is a complex issue not only involving echocardiographic measurements, but also the review of angiographic and MSCT data. Several factors have an impact on prosthesis size selection. Most importantly, especially in the case of borderline annulus diameters, the degree of calcification and the presence of an elliptical annulus

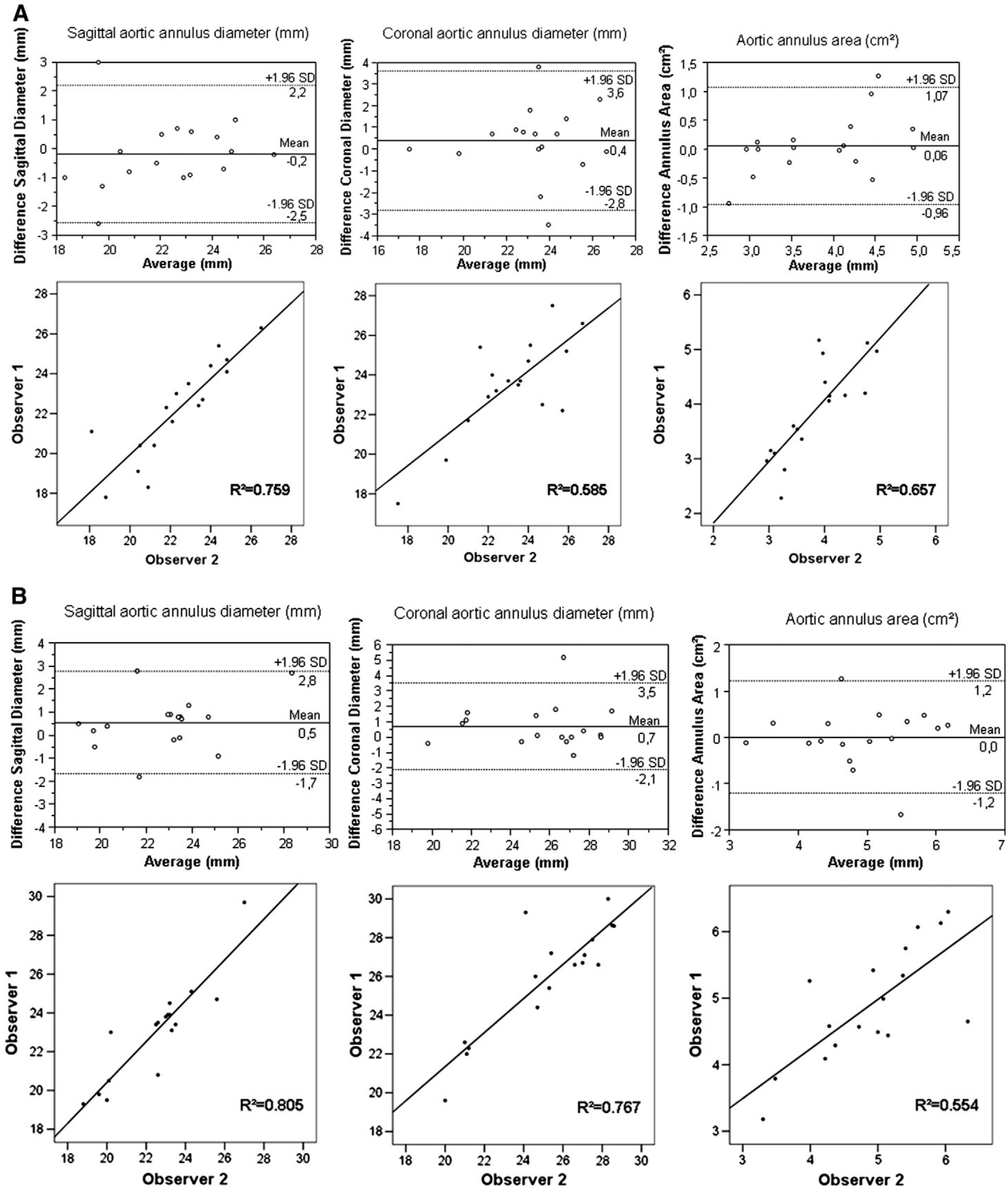

Fig. 5. A. Interobserver agreement of 3D-TEE. Linear regression analysis and Bland–Altman plots for interobserver variability of 3D-TEE. B. Interobserver agreement of MSCT. Linear regression analysis and Bland–Altman plots for interobserver variability of MSCT.

determines whether to oversize or to undersize the prosthesis. MSCT represents an excellent modality for these purposes.

Recently, manufacturers' recommendations have been changed, now offering an overlap between the different prosthesis models. This offers the possibility to over- or undersize according to the individual features found in each patient. When applying these newer recommendations, 23% of the cases in the present study would have been in the borderline range using MSCT and in 36% of the cases using 3D-TEE. This highlights

Table 3
Intra- and post-procedural data and outcome.

	n = 57
Procedural success (%)	57 (100)
Procedural related death (%)	1 (2)
Intra-hospital mortality (%)	2 (4)
30 days mortality (%)	2 (4)
Myocardial infarction (%)	0 (0)
Stroke (%)	1 (2)
Cardiac tamponade (%)	0 (0)
Conversion to conventional surgery (%)	0 (0)
Procedural time (min)	62 ± 33
Contrast administration (ml)	117 ± 58
Fluoroscopy (min)	13 ± 10
Access site complications (%)	2 (4)
Transfusion (≥2 units)	3 (5)
Post-dilatation (%)	7 (12)
Need for multiple valves (%)	2 (4)
Post-procedural regurgitation (>1)	3 (5)
Need for ECMO (%)	2 (4)
Need for acute dialysis (%)	2 (4)
Need for permanent pacemaker (%)	6 (11)
Days on intensive care unit (median)	1 [1–2]
Days in hospital (median)	8 [7–13]

Abbreviations: ECMO = extracorporeal membrane oxygenation.

the importance of a multimodal assessment of the aortic valve for TAVI [15] and shifts the focus from mere aortic annulus diameters to other important anatomical features like eccentricity, annulus area and perimeter and degree of calcifications which should be included in the decision making process of prosthesis sizing.

5. Conclusions

The present study shows that 3D-TEE measures of the aortic annulus diameters and areas yield smaller values with the exception of the sagittal diameter which is currently recommended for prosthesis sizing. Both modalities performed comparably using the sagittal annulus diameter as far as prosthesis sizing is concerned and had comparable reproducibility. Since MSCT might not be suitable for all patients screened for TAVI due to impaired renal function, 3D-TEE represents a promising alternative for the purpose of pre-procedural patient screening for TAVI.

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