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ORIGINAL RESEARCH

Feasibility and Accuracy of 3DTEE Versus CT for the Evaluation of Aortic Valve Annulus to Left Main Ostium Distance Before Transcatheter Aortic Valve Implantation

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OBJECTIVES The aims of this study were to analyze in a large series of patients undergoing transcatheter aortic valve implantation (TAVI): 1) the accuracy of 3-dimensional transesophageal echocardiographic (3DTEE) measurement of left coronary cusp (LCC) length and of the distances from left main coronary ostium (LM) to the aortic annulus (AA) pre-operatively and to the aortic prosthesis post-operatively; and 2) the role of the 3DTEE measurements in predicting the prosthetic deployment and the association between prosthesis position and aortic regurgitation (AR) and/or prosthesis-patient mismatch (PPM).

BACKGROUND Coronary ostia occlusion is a possible complication in TAVI; therefore, the careful pre-operative evaluation of AA-LM and LCC length, and the post-operative analysis of the relationship between the prosthesis and LM, may influence the procedural outcomes. Even though multidetector computed tomography (MDCT) is the gold standard pre-operatively, sometimes it cannot be performed and it is rarely repeated post-operatively.

METHODS In 122 patients undergoing TAVI, pre-operative AA-LM and LCC measurements obtained by 3DTEE and MDCT were compared. Post-operatively, the feasibility of 3DTEE evaluation of the prosthesis-LM distance was performed. The relationship between 3DTEE overlap of the prosthesis with the anterior mitral leaflet and AR/PPM was assessed.

RESULTS Pre-operatively, 3DTEE AA-LM ($r = 0.83$) and LCC ($r = 0.69$) significantly correlated with MDCT. Post-operatively, 3DTEE prosthesis-LM distance was 2.1 ± 1.9 mm. The prosthesis reached or exceeded LM in 6 and 10 cases, respectively. Prosthesis overlap with mitral leaflet was 4.7 ± 1.8 mm. Significant correlation between the 3DTEE computed and nominal length of the prosthesis was found ($r = 0.61$). No correlations were found between prosthesis–mitral leaflet overlap and aortic regurgitation or PPM.

CONCLUSIONS AA-LM distance and LCC length may be accurately estimated by 3DTEE, which may represent a valid alternative to MDCT. Pre- and post-3DTEE data concerning the aortic root, such as LM, aortic valve, and prosthetic morphology, give new insights into TAVI and its complications. (J Am Coll Cardiol Img 2012;5:579–88) © 2012 by the American College of Cardiology Foundation

Transcatheter aortic valve replacement (TAVI) has become a valid alternative to conventional surgery in selected high-risk patients with severe and symptomatic aortic valve stenosis (1,2). One of the major complications reported after TAVI is coronary ostia impairment (3–7) due to the presence of low coronary ostia and/or the occluding effect of aortic leaflets displacement by prosthetic percutaneous implantation.

Therefore, a careful pre-operative evaluation of the distance between aortic annulus (AA) and left main coronary ostium (LM) and of left coronary cusp (LCC) is necessary, and an accurate analysis of the critical relationship between the prosthesis and LM post-operatively should be performed.

Pre-operatively, AA-LM distance and LCC length estimation are generally obtained through multidetector computed tomography (MDCT), which is the gold standard in this context, allowing an accurate assessment of aortic root geometry (7–9). Unfortunately, MDCT cannot be performed in arrhythmic patients or in cases with severely impaired renal function, and it is rarely repeated post-operatively for clinical reasons. Moreover, immediate post-procedural imaging inside the surgical suite is possible only by using echocardiographic or angiographic techniques.

Three-dimensional transesophageal echocardiography (3DTEE) has been demonstrated to be very useful in the management of TAVI in the pre-operative evaluation of AA dimensions (8,10) and may be used as a substitute for MDCT in AA measurement. The incremental value of its application in procedural monitoring of TAVI and of post-procedural result assessment is also well known (11,12). Moreover, few data are available concerning the immediate post-operative relationship between the device and coronary ostia.

Our aims were to study in a large series of patients: 1) the feasibility of pre-operative AA-LM distance and LCC length measurements by 3DTEE; 2) its accuracy in comparison with MDCT-derived measurements; 3) the feasibility of post-operative 3DTEE evaluation of the distance between the prosthesis and LM; 4) the accuracy of 3DTEE-derived measurements in predicting the stent landing zone as defined by the overlap of the prosthesis with mitral leaflet; and 5) the association between prosthesis deployment and regurgitation, positioning, and spatial relation with LM.

ABBREVIATIONS AND ACRONYMS

AA = aortic annulus

AR = aortic regurgitation

HU = Hounsfield units

LCC = left coronary cusp

LM = left main coronary ostium

Max-D = maximum diameter of aortic annulus

MDCT = multidetector computed tomography

Min-D = minimum diameter of aortic annulus

PPM = prosthesis-patient mismatch

TAVI = transcatheter aortic valve replacement

TEE = transesophageal echocardiography

2D = 2-dimensional

3D = 3-dimensional

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METHODS

Study population. From January 2008 to June 2011, 276 consecutive patients underwent TAVI using the Edwards Sapien prosthesis (Edwards Lifesciences, Irvine, California) at the Centro Cardiologico Monzino Istituto di Ricovero e Cura a Carattere Scientifico, Milan, Italy.

In all patients, a transthoracic echocardiography was performed before surgery to confirm the severity of the aortic valve stenosis (mean transaortic pressure gradient ≥40 mm Hg or an aortic valve area <1 cm^2) (13) and to assess the feasibility of the percutaneous procedure (absence of aortic bicuspid valve, AA dimensions between >18 mm and 26 mm) (12,14). After the TAVI procedure but before hospital discharge, transthoracic echocardiography was repeated and the effective orifice area of the prosthesis was obtained using the continuity equation approach and indexed to body surface area. Prosthesis-patient mismatch (PPM) was defined as the presence of an orifice area ≤0.85 cm^2/m^2 (15–17).

Before the TAVI procedure, invasive coronary and peripheral vascular angiography was performed according to guidelines (14) in order to rule out coronary and peripheral disease. In 190 of 276 patients, a MDCT exam was performed. In 268 patients, periprocedural 2-dimensional (2D) TEE monitoring, completed with 3DTEE acquisitions, was performed. Exclusion criteria were atrial fibrillation or other arrhythmias, impaired renal function, inability to sustain a 10-s breath-hold, presence of esophageal diseases or clinical contraindication to general anesthesia during the procedure, or stenosis of the LM and/or the proximal descending coronary artery. Therefore, 122 of 276 patients were enrolled in this study.

The study protocol was approved by the ethics committee and, prior to participation, informed consent was obtained from all patients.

Transesophageal echocardiography. Patients were imaged during the TAVI procedure using a commercially available echocardiographic system (iE33, Philips Medical Systems, Andover, Massachusetts) equipped with an X7-2t probe, allowing 2D multiplane, real-time 3D, and full volume TEE acquisitions. Image acquisition was performed by an experienced cardiologist. Pre-operatively, in accordance with current clinical practice, a 2DTEE acquisition in zoom mode of the left ventricular outflow tract from the mid-esophageal position with scanning planes from 115° to 160° was performed in all patients in order to assess precise measurements of the AA and aortic root. Moreover, real-time zoomed 3D or full volume images containing the whole aortic apparatus and the proximal ascending aorta were acquired both pre- and post-TAVI for quantitative analysis performed with a commercially available software package (3DQ, Q-Lab version 7.0, Philips Medical Systems). Briefly, before TAVI, the 3D dataset was analyzed moving 3 different orthogonal cut planes. The first cut plane was transversal, oriented to visualize a short-axis view of the AA, and on this plane the maximum diameter (Max-D), the minimum diameter (Min-D), and the area of AA were measured. The second and the third were both longitudinal planes, 1 adjusted orthogonal to the short axis in order to obtain a sagittal view of the ascending aorta. The other longitudinal plane was gradually rotated until the LM appeared, allowing the measurement of AA-LM distance (Fig. 1). In addition, in the same plane, LCC length was assessed as the distance between the tip of the leaflet and the AA (Fig. 2).

In the post-TAVI 3D dataset, we evaluated: 1) L_1 = the overlap of the prosthesis with the anterior mitral valve leaflet, defined as the distance between the ventricular edge of the aortic prosthesis and the native AA; and 2) L_2 = the distance between the distal edge of the prosthesis and the LM. The 3DTEE prosthesis length was calculated as $[(\text{AA-LM distance} + L_1) - L_2]$, and this computed measurement was compared with the nominal prosthesis length (14, 17, and 19 mm for a 23-, 26-, and 29-mm device, respectively) (Fig. 3).

A 3D dataset was considered unsuitable for analysis if it contained artifacts or if the LM was not clearly visible due to artifacts or poor quality of the image.

Finally, after the device deployment and after removal of the catheters, the presence of post-procedural paravalvular aortic regurgitation (AR) was evaluated. Post-procedural AR was quantified according to standard echocardiographic color-Doppler method using the jet width and extension and graded as: 0 (absent) 1 (mild); 2 (mild to moderate); 3 (moderate to severe); or 4 (severe). Paravalvular AR was considered significant if ≥2.

Figure 1. **AA-LM Distance Measured by 3DTEE**

Example of 3-dimensional (3D) transesophageal echocardiography (TEE) measurement of the distance between the aortic annulus (AA) and left main coronary ostium (LM). The 3D dataset was analyzed through 3 different orthogonal cut planes: **green** plane **(A)** is a short-axis view of aortic root crossing the LM; **red (B)** and **blue (C)** planes are sagittal views of the ascending aorta. The **blue** plane was gradually rotated until the LM appeared, allowing the measurement of the distance between the AA and LM **(white arrow)**. **(D)** The position and the relationship of each plane in the 3D dataset are shown.

Multidetector computed tomography. All examinations were performed with a LightSpeed VCT XT Scanner (GE Healthcare, Milwaukee, Wisconsin). Scanning parameters were: slice configuration, 64 × 0.625 mm; gantry rotation time, 350 ms; tube voltage, 120 kVp; and effective tube current, 650 mA. Contrast enhancement was achieved with a triphasic injection of an 80-ml bolus of Iomeron 400 mg/ml (Bracco Imaging S.p.A., Milan, Italy) through an antecubital vein at a 5-ml/s infusion rate, followed by 50 ml of saline solution, and a further 50-ml bolus of contrast at 3.5 ml/s. After the threshold level of 200 Hounsfield units (HU) in the right ventricle was achieved, patients were instructed to hold a deep breath, and the scan was started when a threshold of 200 HU was reached in the left atrium, allowing the synchronization of the arrival of the contrast media and the scan. Data acquisition was performed with retrospective electrocardiogram triggering.

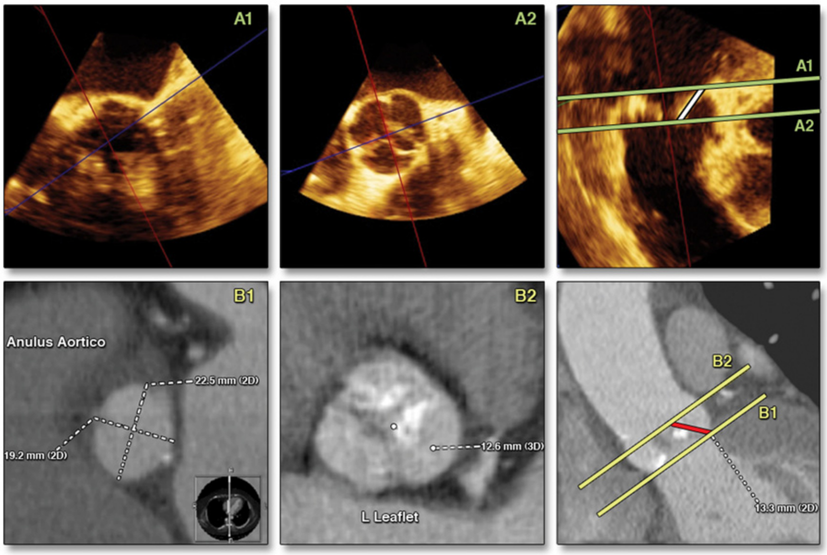

Figure 2. LCC Length Measured by 3DTEE and MDCT

(Top) Example of 3DTEE measurement of the left coronary cusp (LCC) length. A short-axis view **(A1)** at the level of AA **(top, left);** a short-axis view **(A2)** at the level of the tip of the leaflets **(top, middle);** a sagittal view of the ascending aorta with the LCC length **(white line)** measured as the distance between plane **A1** and **A2 (top, right). (Bottom)** Example of multidetector computed tomography (MDCT) measurement of the LCC length. A short-axis view **(B1)** at the level of AA **(bottom, left);** a short-axis view **(B2)** at the level of the tip of the leaflets **(bottom, middle);** a sagittal view of the ascending aorta, with the LCC length **(red line)** measured as the distance between plane **B1** and **B2 (bottom, right)**. Abbreviations as in Figure 1.

Image analysis was performed on a separate computer workstation. AA was defined as a virtual ring formed by joining the basal attachments of the aortic leaflets (18). Max-D, Min-D, and the area of AA were measured in an orthogonal plane on the center line of the aorta in systole. The distance between the AA and the LM was defined as the distance between the short axis at the level of the LM and the short axis at the level of AA (Fig. 4). The LCC length was defined as the distance between 2 orthogonal planes on the center line of the aorta, centered at the basal attachment and apex of the LCC in the end-diastolic phase (Fig. 3).

Statistical analysis. Data are presented as mean ± SD for continuous variables and frequencies and relevant percentages for categorical variables. Linear regression analysis with Pearson correlation coefficient was used to evaluate the relationship between computed and nominal prosthesis length, LCC length and AA-LM distance, and 3DTEE and

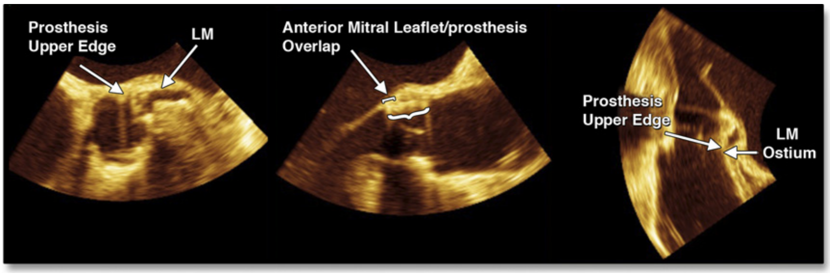

Figure 3. Post-Operative 3DTEE Evaluation

Example of a 3DTEE post-operative evaluation of the aortic root and prosthesis. Three different orthogonal views are shown: **(left)** a short-axis view of aortic root at the level of the aortic prosthesis and the LM; **(middle)** a longitudinal view of the ascending aorta showing the aortic prosthesis length and the overlap of the prosthesis with the anterior mitral valve leaflet; and **(right)** a longitudinal view of the ascending aorta crossing the LM; this view allows the measurement of the distance between the upper edge of the prosthesis and the LM. Abbreviations as in Figure 1.

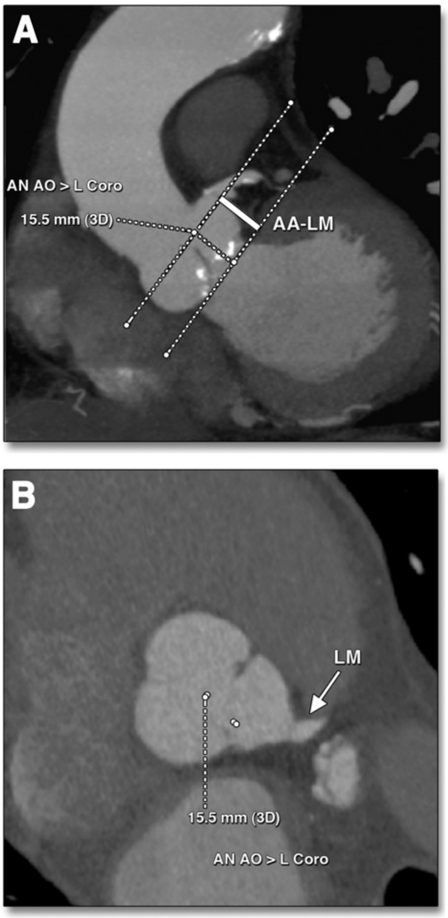

Figure 4. AA-LM Distance Measured by MDCT

Example of MDCT measurement of AA to LM distance. **(A)** A sagittal view of the ascending aorta; AA-LM was measured as the distance between the short axis at the level of the LM and the short axis at the level of the AA. **(B)** A short-axis view at the level of the LM. AN AO = aortic annulus; L Coro = left coronary artery; other abbreviations as in Figures 1 and 2.

MDCT measurements. Also, Bland-Altman analysis was used to assess the intertechnique agreement by calculating the bias (mean difference) and the 95% limits of agreement (defined as 1.96 SD around the mean difference). A chi-square test was performed to investigate the associations among prosthesis-mitral leaflet overlap, the entity of paravalvular AR, and the presence of PPM. To determine the reproducibility of the AA-LM distance, intraobserver and interobserver variability were assessed in a subset of 30 patients as coefficient of variation, defined as the ratio between the SD and the mean of the 2 measurements, expressed as a percentage. During these repeated analyses, investigators were blinded to each other's and prior measurements. A Bland-Altman analysis was performed to evaluate the concordance between the 2 observers and between the first observer and himself. All statistical analyses were performed using SPSS version 17.0 (SPSS Inc., Chicago, Illinois).

RESULTS

All patients underwent TAVI with a balloon-expandable Edwards Sapien valve using the transapical (n = 43) or transfemoral (n = 79) approach. The procedures were performed under general anesthesia with TEE and fluoroscopic guidance. Twenty-three–, 26-, and 29-mm prostheses were implanted in 58, 59, and 5 patients, respectively. Clinical baseline characteristics of the study population are reported in Table 1. Paravalvular AR immediately after TAVI was graded as: 0 in 54 patients (44%); 1 in 52 patients (43%); 2 in 14 patients (11%); 3 in 1 patient (1%); and 4 in 1 patient (1%). Therefore, AR was ≥2 in 16 patients (13%). The incidence of PPM after TAVI was 45% (n = 55), as assessed by transthoracic echocardiography before hospital discharge.

The measurement of AA-LM distance was feasible in 119 of 122 patients (97.5%) with a 3DTEE acquisition focused on the aortic apparatus and in all of the patients with MDCT. 3DTEE estimation of the distance between the LM and the prosthesis was feasible in 110 cases (90%).

Table 2 shows the mean values of the AA-LM distance, LCC length, Min-D, Max-D, and area of AA obtained by 3DTEE and MDCT for all

Table 1. Baseline Clinical and 2D Echocardiographic Characteristics of the Study Population (N = 119)

Age, yrs	81 ± 7
Male/female	39/80
Body surface area, m^2	1.7 ± 0.2
Logistic EuroSCORE	19 ± 11
NYHA functional class, %	
I	0 (0)
II	38 (32)
III	61 (51)
IV	20 (17)
Left ventricular ejection fraction, %	58 ± 12
Aortic valve area, m^2	0.65 ± 0.16
Aortic annulus, mm	21 ± 2
Left ventricular outflow tract, mm	20 ± 2
Sinus of Valsalva, mm	31 ± 4
Sinotubular junction, mm	27 ± 4
Mean transaortic pressure gradient, mm Hg	52 ± 15

Values are mean ± SD, n/n, or n (%).
EuroSCORE = European System for Cardiac Operative Risk Evaluation; NYHA = New York Heart Association; 2D = 2-dimensional.

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Table 2. Correlations Between 3DTEE and MDCT Measurements

	3DTEE	MDTC	r	p Value
All (N = 119)				
AA-LM, mm	13.5 ± 2.2	13.9 ± 2.2	0.83	<0.001
LCC length, mm	13.7 ± 1.8	13.6 ± 1.8	0.69	<0.001
Min-D, mm	21.3 ± 2.1	21.4 ± 2.2	0.70	<0.001
Max-D, mm	24.6 ± 2.3	25.3 ± 2.2	0.68	<0.001
Area, cm^2	4.1 ± 0.7	4.3 ± 0.8	0.76	<0.001
Size = 23 (n = 57)				
AA-LM, mm	12.9 ± 1.6	13.5 ± 1.9	0.77	<0.001
LCC length, mm	13.1 ± 1.8	12.9 ± 1.7	0.60	<0.001
Min-D, mm	19.9 ± 1.4	19.9 ± 1.4	0.44	0.002
Max-D, mm	23.1 ± 1.6	23.9 ± 1.4	0.45	0.001
Area, cm^2	3.6 ± 0.4	3.7 ± 0.4	0.51	<0.001
Size = 26 (n = 57)				
AA-LM, mm	13.9 ± 2.2	14.1 ± 2.3	0.82	<0.001
LCC length, mm	14.2 ± 1.6	14.1 ± 1.7	0.73	<0.001
Min-D, mm	22.5 ± 1.7	22.7 ± 1.6	0.47	0.01
Max-D, mm	25.7 ± 1.8	26.2 ± 1.7	0.49	<0.001
Area, cm^2	4.5 ± 0.6	4.7 ± 0.6	0.32	0.03
Size = 29 (n = 5)				
AA-LM, mm	16.2 ± 3.2	16.2 ± 3.5	0.99	<0.001
LCC length, mm	15.4 ± 1.3	14.5 ± 1.9	0.58	0.31
Min-D, mm	24.0 ± 1.1	25.1 ± 1.3	0.82	0.09
Max-D, mm	28.3 ± 2.2	30.0 ± 0.9	−0.38	0.54
Area, cm^2	5.4 ± 0.6	5.9 ± 0.4	0.37	0.54

Values are mean ± SD.
AA-LM = distance between aortic annulus and left main coronary ostium; Area = aortic annulus area; LCC length = distance between the tip of the left leaflet and the aortic annulus; Max-D and Min-D = maximum and minimum aortic annulus diameters; MDCT = multidetector computed tomography; 3DTEE = 3-dimensional transesophageal echocardiography.

patients and separately for each size of prosthesis implanted. All measurements were significantly correlated, as depicted in the scatterplots of Figure 5, together with the results of Bland-Altman analysis, which showed good agreement between the 2 techniques and minimal underestimation of 3DTEE measurements compared with MDCT.

3DTEE measurements of AA-LM distance were found to be highly reproducible on both intraobserver and interobserver variability analysis as depicted by lower coefficients of variation, 2.1% and 2.6%, respectively. Figure 6 shows the results of Bland-Altman analysis of the agreement between repeated measurements of AA-LM distance together with relevant bias and limits of agreement.

The mean value of overlap with the anterior mitral valve leaflet (L_1) was 4.5 ± 1.9 mm (range −2.0 to 9.5 mm) and the distance between the distal edge of the prosthesis and the LM (L_2) was 2.1 ± 1.9 mm (range −2.0 to 6.5 mm). The upper edge of the prosthesis reached (6 cases) or overlapped (10 cases) the LM. Table 3 shows 3DTEE-derived anatomic data regarding AA-LM distance (pre-operatively) and the characteristics of the prosthesis implantation (post-operatively) in each of these 16 cases. Figure 7 shows 3DTEE reconstruction of the distance between the upper edge of aortic prosthesis and LM in 2 different cases.

There was a good correlation ($r = 0.64$; $p < 0.001$) between the 3DTEE computed and nominal lengths of the prosthesis (Fig. 8). No differences in echocardiographic parameters were found in patients with suboptimal hemodynamic results (PPM or AR >2) and cases with optimal hemodynamic results. In particular, no correlations were found between prosthesis–mitral leaflet overlap and paravalvular AR or PPM. Moreover, no significant correlation was found between LCC length and AA-LM distance.

DISCUSSION

Currently, TAVI is a valid alternative to surgical aortic valve replacement for the treatment of high-risk surgical candidates with severe aortic valve stenosis. As in traditional surgical aortic valve replacement, after prosthesis implantation, an immediate decrease of transvalvular pressure gradient and of systolic left ventricular pressure is expected. These changes are generally associated with a significant increase in coronary flow (19,20).

However, coronary ostia impairment, due to the presence of low coronary ostia and/or to the occluding effect of the calcified native cusps crushed against the aortic wall after the prosthesis deployment, is included between the possible life-threatening complications of the procedure (3–5). Moreover, operator-related factors, such as high valve positioning or implantation of an oversized prosthesis, may also lead to post-operative complications.

Several investigators (8,10,21) have demonstrated the importance of an accurate pre-operative evaluation of the distance between the AA and coronary ostia in the selection of candidates for TAVI in order to avoid LM occlusion due to covering of coronary ostium by the upper part of the prosthesis or by LCC displacement. Therefore, even in the absence of defined guidelines, an AA-LM distance less than 10 to 11 mm is generally indicated as the cutoff value under which a TAVI with Edwards Sapiens prosthesis may be contraindicated (7,12,18).

Because MDCT provides precise information about the aortic valve anatomy, it is considered the

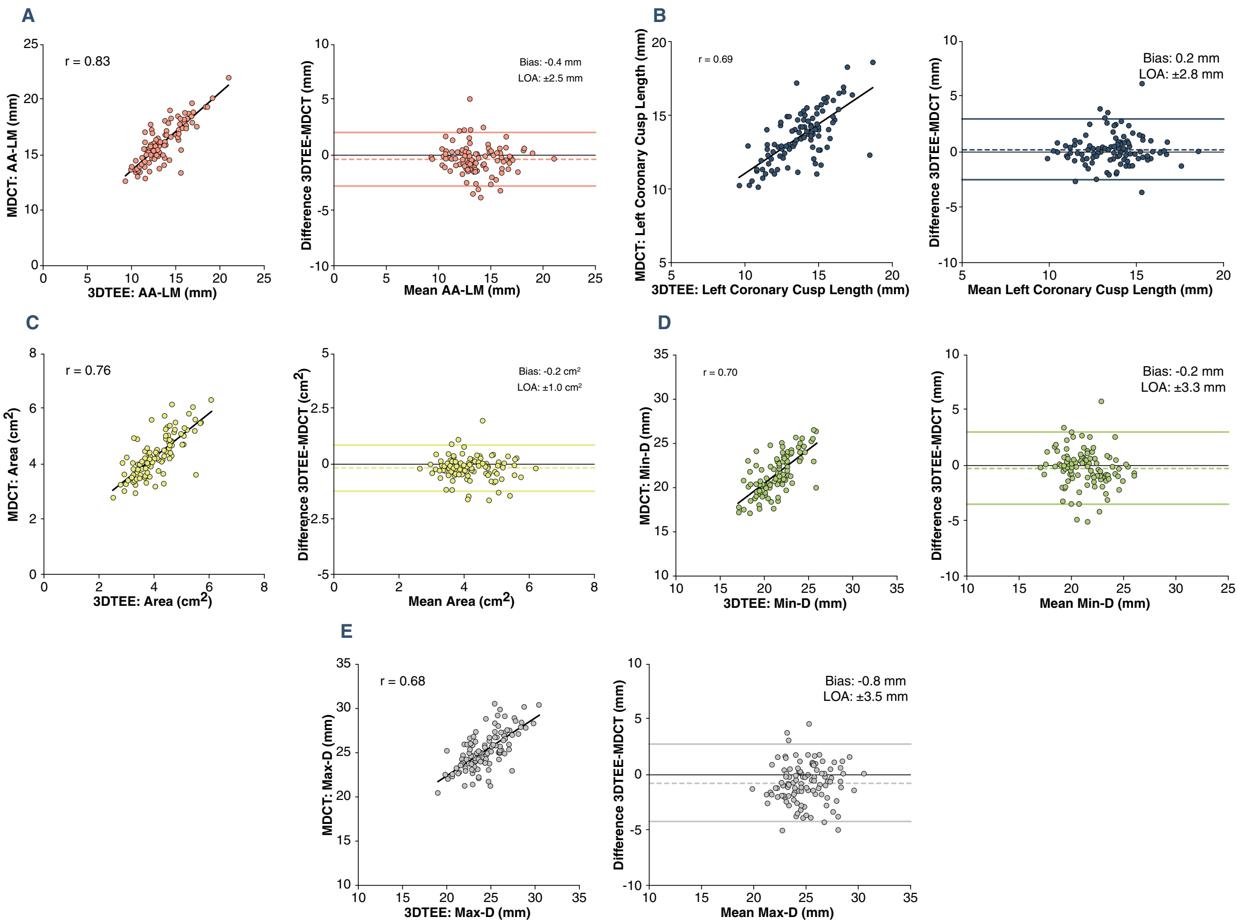

Figure 5. 3DTEE and MDCT Correlations and Agreements

Results of linear regression **(left)** and Bland-Altman analysis **(right)** for **(A)** AA-LM distance, **(B)** LCC length, **(C)** AA area, **(D)** minimum (min-D), and **(E)** maximum (max-D) diameters, measured by 3DTEE and MDCT. Abbreviations as in Figures 1 and 2.

gold standard for the pre-operative assessment of TAVI candidates. However, in these critical patients, impaired renal function, severe breathlessness, atrial fibrillation, or other arrhythmias are frequently present and may contraindicate the employment of MDCT or limit its image quality.

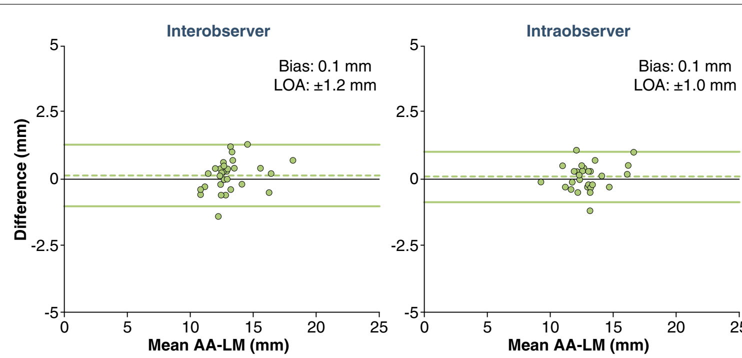

Figure 6. Interobserver and Intraobserver Variability

Results of Bland-Altman analysis of the agreement between repeated 3DTEE measurements of the AA-LM distance for interobserver **(left)** and intraobserver **(right)** variability obtained in a subset of 30 randomly selected patients. Abbreviations as in Figure 1.

Table 3. Pre- and Post-Operative 3DTEE Measurements in Each of the 16 Cases in Which the Upper Edge of the Aortic Prosthesis Reached or Overlapped LM

Case No.	3DTEE AA-LM Distance (mm)	3DTEE PR-LM Distance (mm)	PR-Anterior Mitral Leaflet Overlap (mm)	PR Size (mm)	Nominal PR Length (mm)	Computed PR Length (mm)
1	12.8	0	2.0	23	14	14.8
2	12.3	0	3.0	23	14	15.3
3	12.4	0	5.4	26	17	17.3
4	11.7	0	3.0	23	14	14.7
5	12.2	0	4.6	26	17	16.8
6	11.4	0	6.0	26	17	17.4
7	11.2	−1.0	3.7	23	14	14.8
8	15.6	−1.0	3.0	29	19	19.8
9	15.0	−1.0	2.0	23	14	15.4
10	14.8	−1.5	1.0	23	14	16.5
11	12.8	−1.6	1.8	23	14	15.9
12	10.7	−1.6	4.0	26	17	16.4
13	11.3	−2.0	4.0	26	17	17.0
14	9.3	−2.0	3.0	23	14	14.3
15	10.7	−2.0	1.5	23	14	15.6
16	9.9	−2.0	4.0	26	17	17.6

AA = aortic annulus; LM = left main coronary ostium; PR = aortic prosthesis; 3DTEE = 3-dimensional transesophageal echocardiography.

The position of the coronary arteries relative to the AA can also be assessed using invasive angiography, which is often performed in most of the patients pre-operatively in order to study coronary arteries and peripheral vessels. However, the angiographic procedure shows the bias due to its 2D nature, and, in some cases, it may carry a high risk of complications. Therefore, MDCT has been reported as a valid alternative to angiography (9).

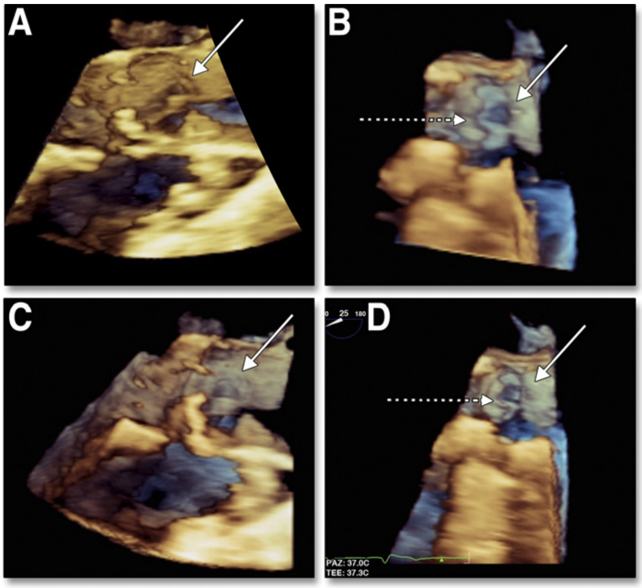

Figure 7. Pre- and Post-Operative 3DTEE LM Visualization

3DTEE reconstruction of the aortic root and LM in 2 patients before **(A, C)** and after **(B, D)** transcatheter aortic valve replacement. **Solid arrows** indicate the LM; **dotted arrows** indicate the upper edge of the prosthesis in the post-operative reconstruction. **(A, B)** Pre- and post-operative reconstruction in a patient with the LM in a high position; the upper edge of the prosthesis is a few millimeters distance from the LM. **(C, D)** Pre- and post-operative reconstruction in a patient with the LM in a low position; in the post-operative image, the upper edge of the prosthesis is partially superimposed on the LM. Abbreviations as in Figure 1.

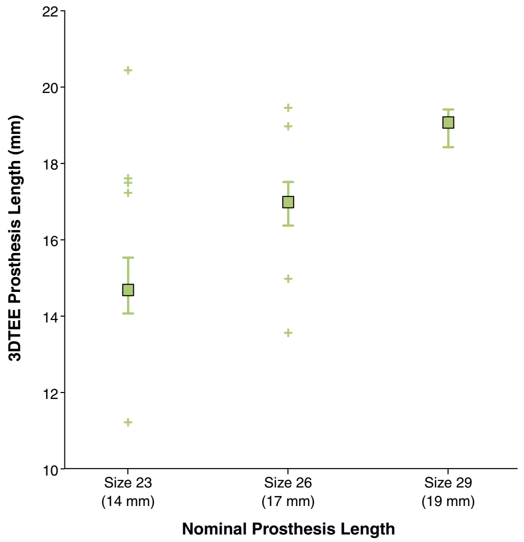

Figure 8. Nominal Versus 3DTEE Prosthesis Length

Correlation between prosthesis nominal length and prosthesis length as measured by 3-dimensional transesophageal echocardiography. Median values are depicted as **squares; whiskers** extend from the first quartile to the third quartile; outliers are shown as + symbols.

The role of echocardiography in the assessment of TAVI patients is well known. The incremental value of 3D echocardiographic technology and its accuracy in comparison to MDCT in the measurement of the AA and ascending aorta dimensions has been demonstrated previously (8,12,22). Otani et al. (23) evaluated 3DTEE AA-LM in a large series of patients; however, 3D accuracy in comparison with MDCT was calculated only in a few cases, all without aortic valve stenosis. Unfortunately, in aortic valve stenosis, AA-LM is generally shorter than in control subjects, and the presence of leaflets and AA calcifications may markedly impair the accuracy of 3DTEE measurements. Moreover, few post-operative data have been reported concerning the distance between the LM and aortic prosthesis (8).

The main findings and novelties of our study are 2-fold. First, we demonstrated in a large series of patients with aortic valve stenosis that a 3DTEE pre-operative estimation of AA-LM distance is possible in most cases (97%). Only in 3 of 122 cases was the LM not adequately visualized due to poor quality of TEE images. AA-LM measurement was accurate, comparable to MDCT data, and highly reproducible on intraobserver and interobserver variability. As expected, patients with larger AA dimensions had longer AA-LM distances, and, for this reason, larger prostheses could be implanted without coronary impairment.

The second important result is that 3DTEE allows an immediate evaluation of the distance between the LM and aortic prosthesis after the implantation. This measurement is feasible in most of the cases (90%) and also accurate. In fact, the 3DTEE-computed prosthesis length (calculated as the difference between 3DTEE AA-LM distance plus prosthesis–anterior mitral leaflet overlap, and the distance between the LM and the prosthesis) is similar to the prosthetic nominal value. Interestingly, in 16 cases, the upper edge of the prosthesis exceeded the LM, even though none of the enrolled patients had signs or symptoms of ischemia. These data are in accordance with the radiologic (MDCT) observation of Delgado et al. (8). A possible explanation is the limited extension of the overlap in our cases (≤2 mm) involving a portion of the prosthesis where its struts allow coronary inflow, without reaching the reinforced inferior part of the structure where the pericardial leaflets are inserted.

No relationship was found between the presence of prosthesis/LM overlap and the prosthesis size or the AA-LM pre-operative distance, which supports the importance of a correct implantation procedure, because even very small changes in the prosthesis positioning may interfere with the coronary flow. This result does not detract much from the necessity of an accurate evaluation of AA-LM distance. In fact, in high-risk patients, the knowledge of a small AA-LM distance is important information for the operator who may consequently adapt the prosthesis implantation. Indeed, our data demonstrate the absence of a significant relationship between prosthesis overlap and clinical variables such as PPM or paravalvular AR. This observation reinforces the importance of a correct and precise knowledge of the AA-LM distance, facilitating optimal and safe procedural maneuvers by the operator.

Moreover, after prosthesis deployment in the case of abrupt coronary artery occlusion, the pre-operative awareness of a high occlusion risk may favor the immediate recognition of this life-threatening complication, inducing a prompter circulatory support and the hemodynamic procedure of percutaneous recanalization in order to restore normal coronary flow. In this regard, even though the LCC length has been postulated to be involved in this complication, in our patients we did not find prospectively any correlation between this measurement and AA-LM.

CONCLUSIONS

3DTEE may estimate the AA-LM distance as an alternative technique to MDCT. Pre- and post-3DTEE data concerning the valve and prosthesis morphology and simultaneous real-time evaluation of the aortic root, including the LM, give new insights regarding TAVI and its complications.

Study limitations. Even though we included in the study a large number of cases, only a few patients received a 29-mm prosthesis, and, for this reason, the statistical analysis for this group has an important bias as shown in Table 2 (no significant correlation was observed between 3DTEE and MDCT for Max-D and area of AA measurements). However, the high correlation in the overall population between 3DTEE and MDCT measurements confirms the value of the 3D modality, and the reported limitation does not detract much from our results.

The right coronary artery was not evaluated in our study, and we chose to focus our analysis only on the LM. Few data concerning the measurement by 2DTEE and not 3DTEE have been published regarding the measurement of the distance between

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the right coronary ostium and the AA (12); moreover, the right ostium is generally more distant from the AA in comparison with the LM, and its occlusion post-TAVI procedure is very uncommon. Right coronary artery imaging by real-time 3DTEE is more difficult in comparison with imaging the LM. Even though the incidence of right coronary artery occlusion is low, future studies may define the role of 3DTEE, particularly with the new technologies in the evaluation of both coronary ostia before and after TAVI.

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Key Words: left main coronary artery occlusion ■ 3-dimensional transesophageal echocardiography ■ transcatheter aortic valve implantation.