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# CHAPTER 9

# Automated Assessment of the Aortic Root Dimensions with Multi-Detector Row Computed Tomography

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# ABSTRACT

**Objectives:** Accurate aortic root measurements and evaluation of spatial relationships with coronary ostia are crucial in pre-operative transcatheter aortic valve implantation (TAVI) assessments. Standardization of measurements may increase intra- and inter-observer reproducibility to promote procedural success rate and reduce the frequency of procedural-related complications. The objective of the study was to evaluate the accuracy and reproducibility of a novel automated multi-detector row computed tomography (MDCT) imaging post-processing software (3mensio Valves$^{TM}$) in the assessment of patients with severe aortic stenosis candidates for TAVI.

**Methods:** Ninety patients with aortic valve disease were evaluated with 64-row and 320-row MDCT. Aortic valve annular size, aortic root dimensions and height of the coronary ostia relative to the aortic valve annular plane were measured with the 3mensio Valves$^{TM}$ software. The measurements were compared to the measurements obtained manually by the Vitrea2$^{TM}$ software.

**Results:** Assessment of aortic valve annulus and aortic root dimensions were feasible in all the patients using the automated 3mensio Valves$^{TM}$ software. There were excellent agreements with minimal bias between automated and manual MDCT measurements as demonstrated by Bland-Altman analysis and intraclass correlation coefficients ranging from 0.97 to 0.99. In addition, the automated 3mensio Valves$^{TM}$ software had better inter-observer reproducibility and required less image post-processing time compared to manual assessment.

**Conclusions:** Novel automated MDCT post-processing imaging software (3mensio Valves$^{TM}$) permits reliable, reproducible, and automated assessments of the aortic root dimensions and spatial relations with the surrounding structures. This has important clinical implications for pre-operative assessments of patients undergoing TAVI.

# INTRODUCTION

Transcatheter aortic valve implantation (TAVI) is a feasible treatment for patients with severe aortic stenosis and contraindications for surgery.[1-3] Accurate assessments of the aortic root dimensions are critical for the selection of appropriate transcatheter valve size and minimize complications such as valve migration and paravalvular leaks. Three-dimensional imaging technique by multi-detector row computed tomography (MDCT) permits accurate assessments of the aortic annulus.[4-6] Pre-operative assessments of the anatomical relationship between the aortic root with the surrounding structures such as coronary arteries, and semi-quantitative evaluation of valvular calcification severity and location, are important in order to anticipate any potential procedural complication such as occlusion of a coronary ostium by a bulky calcified aortic leaflet.[6, 7] As MDCT provides a 3-dimensional, high-spatial resolution data that can be reconstructed in multiplanar reformation planes, it is a suitable technique for comprehensive evaluations of patients prior to TAVI. However, there is currently no general consensus on the methodology for aortic valve annular measurements.[8] In addition, a high level of experience in image post-processing is required to obtain highly repeatable and accurate measurements by MDCT. For example, the aortic valve annular plane is tilted inferiorly at an angle of 30º from the horizontal plane and this may pose some difficulties in image post-processing by novices.[9] Inaccurate manipulation of the multiplanar reformation planes across the aortic valve annulus may result in erroneous measurements of aortic annular dimensions and height of the coronary ostia relative to the annular plane. This has important procedural implications.

Novel automated MDCT post-processing imaging software may provide an accurate automated pre-operative evaluation of patients for TAVI by standardizing all image post-processing to generate highly reproducible and repeatable measurements. This may help to increase pre-operative utility of this technique for a wider clinical community. Thus, the aim of the present study was to evaluate the accuracy of a novel automated MDCT post-processing imaging software in patients with aortic valve disease and compare it to a highly experienced, manual MDCT imaging post-processing method.

# MATHERIAL AND METHODS

### Study population and study protocol

Ninety patients with aortic valve disease were studied with 64-slice and 320-slice MDCT. Sixty-five (72%) patients with symptomatic, severe aortic stenosis (aortic valve area < $1cm^2$) and contraindications for surgery were evaluated for TAVI. The remaining 25 (28%) patients had aortic sclerosis, mild or moderate aortic stenosis or mild, moderate or severe aortic regurgitation and were studied with MDCT as part of ongoing protocols at our institution concerning the evaluation of coronary artery disease. The study was conducted with the approval of the Leiden University Medical Center Institutional Review Board with specific waiver of the need for written individual patient consent.

From the MDCT data, the diameters of the aortic valve annulus, LVOT, sinus of Valsalva, the 3 cusp-commissure distances and sino-tubular junction were measured. In addition, the height of the coronary ostia, the sinus of Valsalva and the sino-tubular junction relative to the aortic valve annular plane were measured. Finally, calcifications of the aortic valve were evaluated semi-quantitatively as previously described (6). These parameters were measured with a novel automated data post-processing software (3mensio Valves$^{TM}$, version 4.1.sp2, 3mensio Medical Imaging BV, Bilthoven, The Netherlands) and compared to the measurements obtained with a manual data post-processing software (Vitrea2, Vital Images, Minneapolis, Minnesota, USA). Two independent, blinded observers performed all the measurements: one observer highly experienced with MDCT valvular assessments (level of proficiency 3) and one observer with less (level of proficiency 1), according to the American College of Cardiology/ American Heart Association statement on competency in cardiac computed tomography imaging.[10] The times taken to perform the entire MDCT evaluation were calculated for both observers and both imaging post-processing softwares.

**MDCT data acquisition**

The MDCT examinations were preformed with a 64-detector row and 320-detector row computed tomography scanner (Aquilion 64 and Aquilion ONE respectively, Toshiba Medical Systems, Otawara, Japan). Accordingly, data were acquired with a collimation of either 64 x 0.5 mm or 320 x 0.5 mm and a gantry rotation time of 400 ms or 350ms respectively. For the Acquilion 64, the tube current was 300-400 mA and the tube voltage was 120 kV or 135 kV as determined by patients' body mass indexes. Similarly for the Acquilion ONE, the tube current was 400-580 mA and tube voltage was 100 kV, 120 kV or 135 kV as determined by patients' body mass indexes.

With a 64-detector row computed tomography scanner, data acquisition was performed gated to the electrocardiogram (ECG) to allow retrospective gating and reconstruction of the data at desired phases of the cardiac cycle (at each 10% of RR interval and at 75%-85% for diastole and 30-35% for systole). In contrast, with a 320-detector row computed tomography scanner, if prospective triggering was used, only selected systolic phase would be available for reconstruction. When prospective dose modulation was used, the tube current outside of the pre-defined interval was 25% of the maximal tube current. The estimated mean radiation for retrospective ECG gating was 17.5 ± 6.8 mSv whereas the estimated mean radiation dose for prospectively ECG triggered modulated scans was 13.1 ± 3.4 mSv.

Patient's heart rate and blood pressure were monitored prior to each scan and beta-blockers (50- to 100mg metoprolol orally) were administered in the absence of contraindications if heart rate exceeded a threshold of 65 beats/min. The entire heart was imaged with a maximum of 16 cm cranio-caudal coverage. In addition, the aortic arch and the supra-aortic vessels were scanned. During the scan, the ECG was registered simultaneously for prospective triggering of the data. All scans were performed during mid-inspiratory breath-hold and 80-90 mL of non-ionic contrast (Iomeron 400, Bracco, Milan, Italy) was injected into the antecubital vein. Subsequently, data sets were reconstructed and off-line post-processing of MDCT images were performed on dedicated workstations.

**Manual MDCT data post-processing**

Early systolic images of the aortic root reconstructed at 30-35% of the RR interval were selected. According to current guidelines, manual post-processing of the MDCT images was performed at the systolic phase of the cardiac cycle using dedicated Vitrea2 workstations (Vital Images, Minneapolis, Minnesota, USA).[11]

Using the 3 multiplanar reformation planes (coronal, single oblique sagittal and double oblique transverse views), the aforementioned characteristics and dimensions of the aortic root were evaluated. First, from the double oblique transverse views, the anatomy (tricuspid/bicuspid) and calcification grade of the aortic valve were assessed. The degree of aortic valve calcification was semi-quantitatively scored using the double oblique transverse view: grade 1- no calcifications; grade 2- small isolated calcium spots; grade 3- multiple larger calcium spots; grade 4- extensive calcification of all the cusps.[6] Subsequently, by using two orthogonal multiplanar reformation planes, the long-axis of the LVOT was bisected in parallel and the third, transverse multiplanar reformation plane was used to display the cross-sectional view of the aortic valve annulus, directly beneath the lowest insertion points of all three aortic cusps. The minimum and maximum diameters of the aortic valve annulus were measured in this short-axis view. Thereafter, the transverse multiplanar reformation plane was moved 5 mm into the LVOT to obtain the short-axis view of the LVOT. The minimum and maximum diameters were measured at this level. To measure the 3 cusps-commissure diameters, the transverse multiplanar reformation plane was placed at the level of the free rim of the aortic cusps. The maximum distance between the cusps and their respective opposing commissure was measured. At this level, the height of the sinus of Valsalva relative to the valve annular plane was measured. With the use of the transverse multiplanar reformation plane, the coronary ostia were identified. The other two orthogonal multiplanar reformation planes were oriented to bisect the coronary ostia and at the single oblique sagittal plane, the height of the left and right coronary ostia relative to the valve annular plane was measured.[12] Finally, the transverse multiplanar reformation plane was moved to the level of the sino-tubular junction. As previously described, the plane of the sino-tubular junction does not lie parallel to the valve annular plane and tilts approximately 11º.[9] Therefore, the transverse multiplanar reformation plane was oriented to obtain the cross-sectional view of the sino-tubular junction. At this level, the height of the sino-tubular junction relative to the valve annular plane was measured as the distance between the sino-tubular junction and the lowest insertion points of the aortic cusps.

**Automated MDCT data post-processing**

The same MDCT dataset of the aortic root reconstructed at 30-35% of the RR interval were post-processed with the novel automated 3mensio Valves™ software (3mensio Medical Imaging BV, Bilthoven, The Netherlands). From the 3 multiplanar reformation planes and the 3-dimensional reconstruction, the aortic root was automatically segmented and a centre line across the aortic lumen was displayed (Figure 1). A perpendicular plane along the centre line provided short-axis views of the LVOT, aortic valve annulus, sinus of Valsalva and sinotubular junction. The centre line and the perpendicular plane can be manually adjusted and positioned immediately beneath the lowest insertion points of all three aortic cusps to obtain the most accurate measurements. After validation of the centre line and the perpendicular plane, the software automatically displays the short-axis view of the aortic root in 3 different formats: the transverse multiplanar reformation view, the so-called compass view, that was used for orientation and synchronization of different views, the anatomical visualization with minimum intensity projection view to assess the aortic valvular anatomy, and the volume rendered view with maximum intensity projection for the assessment of valvular calcifications. In addition, two orthogonal curved multiplanar reformation views, the so-called stretched views, and the double oblique views along the centre line were displayed to measure the height of the sinus of Valsalva, coronary ostia and the sino-tubular junction.

Therefore, measurements of the aortic valve and aortic root with this novel software were performed as follows. By using the anatomical visualization with minimum intensity projection view and the volume rendered view with maximum intensity projection, the anatomy and the grade of valvular calcification were evaluated. The minimum and maximum diameters of the aortic valve annulus and the LVOT, the 3 cusp-commissure diameters and the diameter of the sino-tubular junction were measured at the compass view (Figure 1, panels B-D). Simultaneously, the height of the sinus of Valsalva, coronary ostia and sino-tubular junction relative to the annular plane were measured on the stretched views (Figure 1, panel E).

Furthermore, the novel automated post-processing software provides a 3-dimenisonal volume rendering of the aortic root that can be oriented according to the angiographic projections (Figure 2). Therefore, the optimal angiographic plane for TAVI was defined as the plane that permits the identification of the 3 aortic sinuses.[8]

**Statistical analysis**

All continuous variables were normally distributed as tested by Kolmogorov-Smirnov test and presented as mean and standard deviation. Categorical variables are presented as number and frequencies. The agreements between the manual and the automated measurements of the aortic root were evaluated by calculating the intraclass correlation coefficients and by using Bland-Altman analysis method. The agreement between both methods to evaluate the grade of aortic valve calcification was assessed with kappa test. In addition, intra- and inter-observer agreements were evaluated for both techniques by calculating the intraclass correlation coefficients. Finally, the agreement between the angiographic plane obtained with the automated post-processing software and the angiographic orientation used during the TAVI procedure was evaluated by calculating the intraclass correlation coefficient. Excellent agreement was defined as an intraclass correlation coefficient of > 0.8. A 2-tailed p value < 0.05 was considered significant. All statistical analyses were performed using SPSS for Windows (SPSS Inc, Chicago), version 16.

# RESULTS

Table 1 summarizes the clinical characteristics of the study population. A total of 90 patients (52% male, mean age 75 ± 13 years) with aortic valve disease were evaluated. Severe aortic valve stenosis, defined by an aortic valve area < $1cm^2$ on echocardiography, was observed in 65 (72%) patients. All patients had good quality MDCT images suitable for manual and automated offline quantification of the aortic root dimensions.

**Manual and automated MDCT assessment of the aortic root**

With the manual assessment, the calcifications of the aortic valve were graded with a score of 1 in 28 patients, score of 2 in 12 patients, score of 3 in 31 patients and score of 4 in 19 patients. With the automated assessment, the aortic valve calcifications were graded with a score of 1 in 26 patients, score of 2 in 13 patients, score of 3 in 30 patients and score of 4 in 21 patients. There was good agreement between both methods with a kappa value of 0.76 (p < 0.001).

The mean values of the aforementioned variables measured with the manual and automated softwares are presented in Table 2. There were good agreements in the aortic root measurements between the manual and the automated software with all intraclass correlation coefficients > 0.8 (p < 0.001). Similarly, Bland-Altman analyses showed good agreements between both aortic root assessment techniques without significant biases (Table 3). Figure 3 shows the Bland-Altman plots for the dimensions of the aortic valve annulus, key to select the prosthesis size.

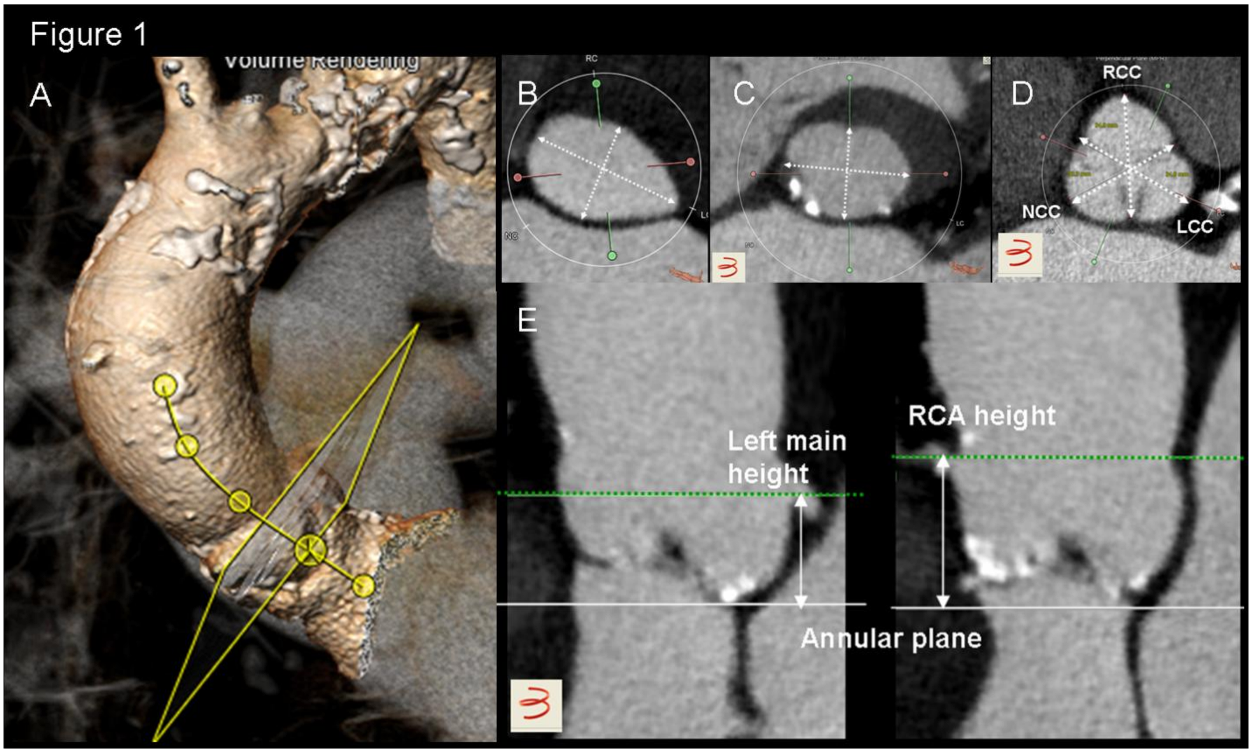


**Figure 1. MDCT data analysis with the novel automated approach.** With the automated post-processing MDCT data software (3mensio Valves™, 3mensio Medical Imaging BV, Bilthoven, The Netherlands) the aortic root is segmented. A center line across the aorta (superimposed on 3D volume rendering) permits fast orientation of the orthogonal multiplanar reformation planes (panel A). By moving the transverse plane along the center line, the diameters of the LVOT (panel B), aortic valve annulus (panel C), sinus of Valsalva (panel D) and relative distances between the coronary ostia and the aortic valve annular plane (panel E) can be measured on the stretched views or in the double oblique views.

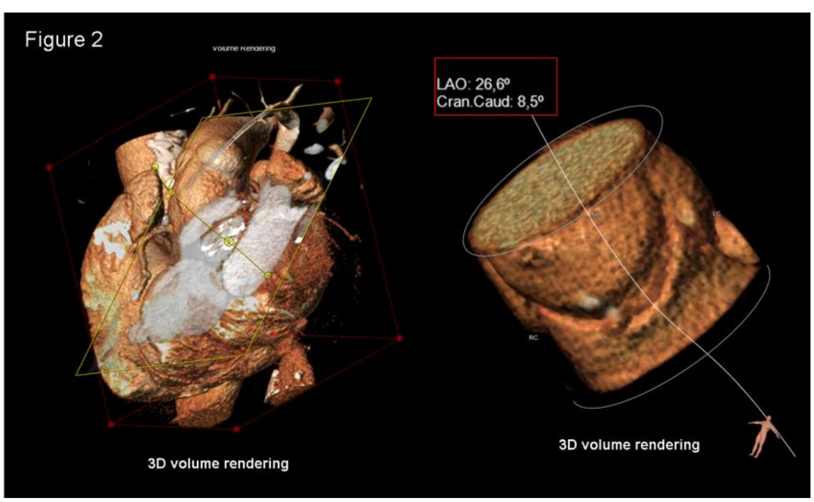


**Figure 2. Selection of the most appropriate angiographic projections for TAVI.** Left panel shows the 3-dimensional volume render of the aortic root with the transversal plane across the center line. Panel right shows the volume rendering of the region of interest (aortic root) that can be automatically obtained and oriented to define the most appropriate angiographic projections during the TAVI procedure. Abbreviations: LAO: left anterior oblique; Cran.Caud: craneo-caudal.

**Table 1. Study population**

| | N=90 |
|---|---|
| Age, years | 75±13 |
| Gender, male (%) | 47 (52) |
| BSA ($m^2$) | 1.9±0.2 |
| Hypertension, n (%) | 54 (60) |
| Hypercholesterolemia, n (%) | 44 (49) |
| Diabetes mellitus, n (%) | 25 (28) |
| Smoking, n (%) | 22 (24) |
| Peripheral vascular disease, n (%) | 16 (18) |
| Family history, n (%) | 19 (21) |
| Aortic stenosis, n (%) | |
| • Sclerosis | 18 (20) |
| • Mild | 5 (6) |
| • Moderate | 2 (2) |
| • Severe | 65 (72) |
| Aortic regurgitation, n (%) | |
| • None | 32 (36) |
| • Mild | 49 (54) |
| • Moderate | 8 (9) |
| • Severe | 1 (1) |

Abbreviations: BSA=body surface area

The mean time to perform the entire analysis with the manual post-processing software was 7 ± 1 min for the experienced observer and 10 ± 1 min for the less experienced observer. In contrast, the mean time to perform the complete analysis with the automated post-processing software was shorter, being 3 ± 1 min for the experienced observer and 5 ± 1 min for the less experienced observer.

Finally, the automated post-processing software enabled to anticipate the most suited angiographic projections to perform the TAVI procedure. The optimal angiographic aortic valve annular plane was oriented at a median of 12.8º in the LAO (interquartile range 4.8º, 19.2º) and at a median of 3.5º cranial (interquartile range -2.3º, 8.1º). During the TAVI procedures, the optimal angiographic aortic valve annular plane was oriented at a median of 17º in the LAO (interquartile range 4º, 21º) and at a median of 0º cranial (interquartile range -8º, 4º). The intraclass correlation coefficients for the angiographic projections demonstrated an excellent agreement between the automated post-processing software and angiography with a value of 0.97 for the LAO projection and 0.97 for the cranio-caudal projection.

**Table 2. Aortic root dimensions: comparison between the manual and the automated software**

| | Vitrea2 (manual assessment) | 3mensio Valves (automated assessment) | ICC | Bias±2SD |
|---|---|---|---|---|
| N=90 | | | | |
| Aortic valve annulus | | | | |
| • Minimum diameter (mm) | 22.8 ± 2.2 | 22.9 ± 2.2 | 0.98 | -0.07 ± 1.0 |
| • Maximum diameter (mm) | 28.1 ± 2.8 | 28.0 ± 2.9 | 0.98 | 0.04 ± 1.2 |
| LVOT | | | | |
| • Minimum diameter (mm) | 21.5 ± 2.7 | 21.4 ± 2.6 | 0.98 | 0.04 ± 1.1 |
| • Maximum diameter (mm) | 28.7 ± 3.2 | 28.6 ± 3.2 | 0.99 | 0.18 ± 1.1 |
| Cusp-commissure diameter | | | | |
| • Left coronary cusp-commissure (mm) | 33.9 ± 3.4 | 33.9 ± 3.5 | 0.98 | 0.01 ± 1.6 |
| • Right coronary cusp-commissure (mm) | 32.2 ± 3.5 | 32.2 ± 3.6 | 0.99 | 0.01 ± 1.4 |
| • Noncoronary cusp-commissure (mm) | 33.9 ± 3.3 | 33.8 ± 3.3 | 0.99 | 0.05 ± 1.0 |
| Sinus of Valsalva height (mm) | 11.3 ± 1.7 | 11.2 ± 1.7 | 0.96 | 0.12 ± 1.2 |
| Left coronary ostium height (mm) | 17.1 ± 2.5 | 17.1 ± 2.6 | 0.98 | 0.02 ± 1.4 |
| Right coronary ostium height (mm) | 18.7 ± 2.8 | 18.6 ± 2.8 | 0.98 | 0.12 ± 1.5 |
| Sino-tubular junction | | | | |
| • Diameter (mm) | 29.1 ± 3.2 | 29.3 ± 3.2 | 0.99 | -0.05 ± 1.2 |
| • Height (mm) | 22.2 ± 3.2 | 22.5 ± 3.1 | 0.97 | -0.38 ± 2.0 |

Abbreviations: ICC=intraclass correlation coefficient; LVOT=left ventricular outflow tract; SD=standard deviation

**Intra- and inter-observer agreements**

In 10 randomly selected patients, the manual and automated measurements were repeated by the same observer to evaluate the intra-observer agreement. In addition, a second observer, blinded to the measurements of the first observer, repeated the aortic root measurements with the manual and the automated dedicated softwares. The interclass correlation coefficients for the intra- and inter-observer agreements were good for both the manual and automated assessment softwares. However, the automated assessment software showed better inter-observer reproducibility with all the intraclass correlation coefficients > 0.90 ($p < 0.001$) (Table 3).

**Table 3. Intra- and inter-observer reproducibility**

| | Vitrea2 (manual assessment) | | 3mensio Valves (automated assessment) | |
|---|---|---|---|---|
| | Intra-observer ICC | Inter-observer ICC | Intra-observer ICC | Inter-observer ICC |
| Aortic valve annulus | | | | |
| • Minimum diameter (mm) | 0.92 | 0.87 | 0.96 | 0.92 |
| • Maximum diameter (mm) | 0.96 | 0.92 | 0.98 | 0.95 |
| LVOT | | | | |
| • Minimum diameter (mm) | 0.95 | 0.94 | 0.99 | 0.93 |
| • Maximum diameter (mm) | 0.96 | 0.96 | 0.98 | 0.97 |
| Cusp-commissure diameter | | | | |
| • Left coronary cusp-commissure (mm) | 0.97 | 0.95 | 0.99 | 0.99 |
| • Right coronary cusp-commissure (mm) | 0.96 | 0.92 | 0.99 | 0.96 |
| • Noncoronary cusp-commissure (mm) | 0.92 | 0.91 | 0.97 | 0.93 |
| Sinus of Valsalva height (mm) | 0.95 | 0.86 | 0.95 | 0.91 |
| Left coronary ostium height (mm) | 0.96 | 0.90 | 0.95 | 0.92 |
| Right coronary ostium height (mm) | 0.96 | 0.94 | 0.96 | 0.94 |
| Sino-tubular junction | | | | |
| • Diameter (mm) | 0.99 | 0.97 | 0.99 | 0.99 |
| • Height (mm) | 0.95 | 0.86 | 0.95 | 0.90 |

Abbreviations: ICC=intraclass correlation coefficient; LVOT=left ventricular outflow tract.

Figure 3

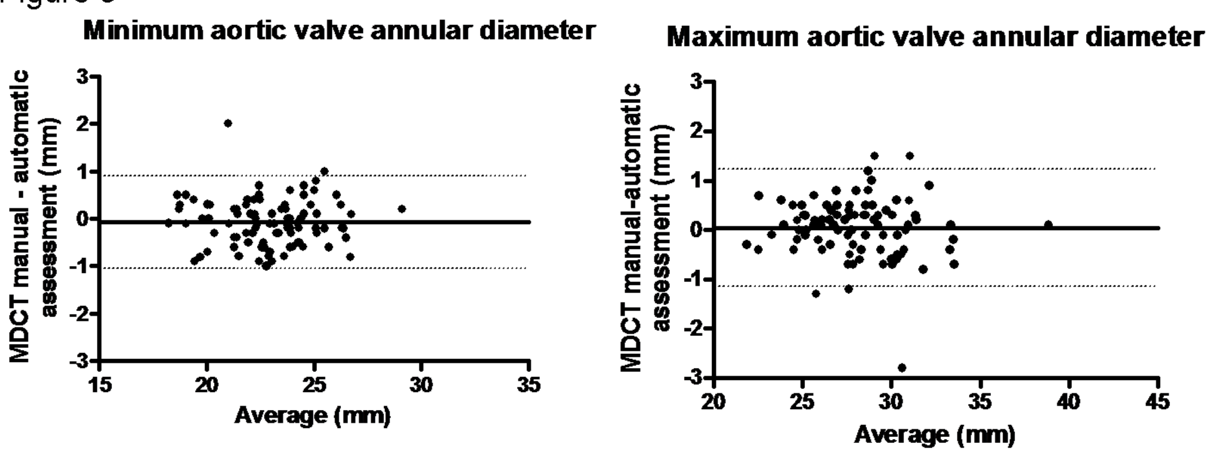


**Figure 3.** Bland-Altman plots showing the agreements between MDCT manual and automated assessment of the aortic valve annular dimensions: minimum (left panel) and maximum (right panel) diameters. Abbreviations: MDCT=multi-detector row computed tomography.

# COMMENT

The novel automated MDCT post-processing imaging software (3mensio Valves$^{TM}$) allows a reliable, automated, pre-operative evaluation of potential candidates for TAVI. It provides accurate and repeatable measurements of aortic annular dimensions, relative distance of the coronary ostia to the annular plane and extent of valvular calcifications. This novel technique standardizes all image post-processing and may enable a more widespread use of MDCT to assess these anatomic parameters prior to TAVI.

**Evaluation of candidates to TAVI**

Recently, the European Association of Cardio-Thoracic Surgery and European Society of Cardiology, in collaboration with the European Association of Percutaneous Cardiovascular Interventions proposed recommendations for the use and development of TAVI techniques.[13] Procedural technical feasibility for TAVI should be evaluated pre-operatively, and this includes measurements of the aortic valve annulus and aortic root dimensions, and the height of the coronary ostia relative to the aortic valve annular plane. In particular, accurate measurements of the aortic valve annulus is of vital importance as it determines the transcatheter prosthesis size. To date, a gold standard method of measurement has not been established. Currently, the aortic valve annulus sizing is performed with 2-dimensional echocardiography in most centers.[3, 14, 15] However, this measurement may be inaccurate since it assumes a circular shape of the aortic valve annulus. Three-dimensional imaging techniques provide a more accurate assessment of the aortic valve annulus and may help to better select the prosthesis size, and reduce the number of potential complications (paravalvular leak, prosthesis migration). Recently, Smid et al. compared the accuracies of transthoracic and transesophageal echocardiography, cardiac magnetic resonance and MDCT to assess aortic valve annulus and aortic root dimensions in 15 patients with severe aortic stenosis undergoing surgical aortic valve replacement.[16] Three-dimensional imaging techniques by cardiac magnetic resonance and MDCT were the most accurate techniques and showed the less bias as compared to surgical measurement (-0.15 ± 0.35 cm for MDCT and -0.07 ± 0.42 cm for magnetic resonance).[16] However, the implementation of these techniques in the routine workup of patients prior to TAVI depends on their availability and on the experience of the clinical team involved in the patient selection process.

The present study shows the reliability of novel MDCT post-processing imaging software that automatically estimates the dimensions of the aortic valve annulus, aortic root and the height of the coronary ostia relative to the annular plane. A proper orientation of the multiplanar reformation planes across the aortic valve annular plane is crucial to obtain accurate demonstration of the spatial relationships with the coronary ostia.[17, 18] The automated and standardized display of post-processed images results in faster measurements of all the aforementioned parameters whilst maintaining the highest accuracy and reproducibility. The better inter-observer reproducibility of these measurements compared to manual MDCT assessments have important implications for transcatheter valve size selection. Finally, the novel automated post-processing software provides information on the most appropriate angiographic projections during the TAVI procedures. This feature may be of interest, since may reduce the fluoroscopy and procedure times and simplify the TAVI procedure. All these features make this novel software a valuable tool to evaluate candidates to TAVI.

**Study limitations**

Some study limitations should be acknowledged. First, the present study is a head-to-head comparison of two different post-processing MDCT imaging softwares and true gold standard (anatomically) has not been used. However, previous studies have demonstrated that MDCT is one of the most accurate imaging techniques to assess the aortic annulus dimensions when compared to peri-operative measurements. In addition, changes in prosthesis size selection based either automated or manual analysis have not been analysed. Nevertheless, the high agreement between the two techniques may preclude us to observe significant changes in selection of the prosthesis size. Moreover, the impact of automated and manual measurements of the aortic root dimensions on procedural outcomes, such as post-procedural paravalvular aortic regurgitation, was not analyzed. Finally, although two different MDCT data acquisition protocols were utilized, the differences in spatial and temporal resolution were minimal and did not influence the image quality and the analysis accuracy.

**Clinical implications**

Several studies have demonstrated the accuracy of 3-dimensional imaging techniques to evaluate patients with severe aortic stenosis who are candidates to TAVI. [18, 19] In addition, the role of these imaging techniques to evaluate the immediate results of the TAVI procedure and the deployment and positioning of the prosthesis have been shown in several small series of patients.[19, 20] Particularly, real-time 3-dimensional transesophageal echocardiography and MDCT have demonstrated changes in the geometry and dimensions of the left ventricular outflow tract and aortic valve annulus after TAVI.[19] These studies provide novel insights into the impact of this therapeutic technique on left ventricular and aortic root geometry and may help to design and model transcatheter valve prosthesis that perfectly fit in, reducing the risk of prosthesis migration, paravalvular aortic regurgitation and improving the immediate and late results. Nonetheless, further studies are needed to elucidate the gold standard imaging to accurately measure these anatomic structures.

In addition, the implementation of MDCT as a routine imaging technique to evaluate candidates for TAVI may require the advent of automated tools that provide robust and reliable measurements. The present study demonstrated that the novel automated post-processing software (3mensio Valves$^{TM}$) provides reliable and reproducible measurements of aortic root and is less time-consuming than the manual assessment.

In conclusion, the novel automated MDCT post-processing imaging software (3mensio Valves$^{TM}$) permits reliable, reproducible, and automated assessments of the aortic root dimensions and spatial relations with the surrounding structures. This has important clinical implications for pre-operative assessments of patients undergoing TAVI.

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