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MDCT evaluation of dynamic changes in aortic root parameters during the cardiac cycle in patients with aortic regurgitation

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Objectives: To investigate the dynamic changes in multiple planes and parameters of the aortic root region at different phases of the cardiac cycle in patients with aortic regurgitation (AR) using multi-detector row computed tomography (MDCT). To provide more reference information and research foundation for preoperative MDCT evaluation of patients with aortic regurgitation undergoing Transcatheter Aortic Valve Replacement (TAVR). Methods: Using MDCT, measurements were taken at the aortic annulus (AA), left ventricular outflow tract (LVOT), and sinotubular junction (STJ) during different phases of the cardiac cycle, including early systole, late systole, early diastole, and late diastole. The analyzed parameters included area, perimeter, diameter derived from area (DA), diameter derived from circumference (DC), long axis, short axis, and average diameter at each phase for each location. The dynamic changes in these parameters were then analyzed. Results: At the AA, the early systolic area, perimeter, DA, DC, and average diameter reached their maximum values, which were significantly greater than those in early diastole ($P<0.05$). At the LVOT, the morphological parameters including area, perimeter, DC, DA, and long diameter reached their maximum values in late diastole, with no significant differences compared to early or late systole ($P>0.05$). However, significant differences were observed between late diastole and early diastole ($P<0.05$).At the STJ, the area, perimeter, DA, DC, long diameter, short diameter, and average diameter reached their maximum values in late systole, but there were no significant differences compared to early systole or early diastole ($P>0.05$), while the difference from late diastole was significant ($P<0.05$). Conclusion: In patients with AR, the measurement parameters of the AA、LVOT and the STJ are critical for the success of TAVR.Preoperative prosthesis selection for TAVR can still be based on MDCT measurements taken during early systole at the AA.

Keywords Aortic regurgitation(AR), Cardiac cycle, Transcatheter aortic valve replacement (TAVR), Multi-detector row computed tomography(MDCT)

Aortic regurgitation (AR) has a prevalence of approximately 4.9% in the global population, and its incidence increases with age, commonly diagnosed between the ages of 40 and 60[1,2]. In Western countries, the prevalence of moderate or severe AR is around 0.5%, whereas in China, the prevalence of moderate to severe isolated AR reaches as high as 1.2%[1,2]. Additionally, in some regions, such as China, aortic regurgitation (AR) is more prevalent than aortic stenosis (AS) among the elderly, making it one of the most common types of valvular dysfunction[2,3]. Common causes of AR include aortic root dilation, congenital bicuspid valves, or the presence of infective, rheumatic, degenerative, or calcific valve diseases, as well as recurrent regurgitation following aortic valve replacement surgery[1,4]. Current guidelines recommend surgical aortic valve replacement only for patients with severe AR who exhibit significant symptoms, left ventricular ejection fraction < 50%, or left ventricular end-systolic diameter > 50 mm, transcatheter aortic valve replacement (TAVR) is considered relatively contraindicated in such cases[1,5].

However, many patients with severe AR often have significant left ventricular dysfunction, a history of stroke, or gastrointestinal bleeding, which makes up to one-fifth of these patients considered high-risk and unsuitable for surgery, leaving conservative treatment such as pharmacological therapyas the only option[5,6]. For these patients, the annual global mortality rate reaches 10–20% [6]. The use of TAVR in AR cases is relatively

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rare; between 2011 and 2019, AR accounted for less than 1.0% of all TAVR procedures in the United States[3,7]. This is because most currently available transcatheter valve prostheses are primarily designed for AS, unlike severe AS, AR patients typically exhibit little aortic valve calcification, and those with severe AR often experience marked degeneration of the elastic fibers in the valve's fibroelastic complex and the ascending aortic wall[7,8]. This leads to impaired strain capacity and enlargement of the aortic root structure, including the aortic annulus (AA), which predisposes to inadequate valve anchoring and sealing, thereby challenging prosthesis fixation, these factors increase the risk of valve migration, the need for a second valve implantation, and significant paravalvular leaks[3,7,8].Therefore, surgical treatment remains the primary approach for AR patients, nonetheless, for high-risk AR patients with contraindications to surgery, TAVR may be the most effective treatment option. Recent studies have shown that, despite the challenges, TAVR is feasible for AR patients[3,5,9]. The development of second-generation prostheses specifically designed for AR, such as the JenaValve (USA) and J-Valve (China), has significantly improved the success rate of TAVR in AR patients[10].

In addition to improvements in prosthetic valve design, preoperative imaging assessments play a crucial role in increasing the success rate of TAVR for AR. Transthoracic echocardiography is the first-line imaging modality used to evaluate the severity and progression of AR by utilizing Doppler and color flow imaging[4]. However, because multidetector computed tomography (MDCT) can more clearly assess the morphology of the aortic valve, the size and shape of the annulus, the degree and distribution of valve and vascular calcification, the risk of coronary artery obstruction, the dimensions of the aortic root, the optimal fluoroscopic projection angles for valve placement, and the selection of vascular access, MDCT is considered the gold standard for pre-TAVR evaluation in AR patients[9–11].Evaluating the anatomy of the aortic root is essential for selecting suitable candidates for TAVR. However, studies focusing on the characteristics of aortic root parameters collected through MDCT in AR patients are scarce. This study aims to explore the dynamic changes in multiple parameters of the aortic root at various phases of the cardiac cycle in AR patients using MDCT, providing a research basis for preoperative MDCT assessment in AR patients.

Materials and methods

General information

This single-center retrospective study included 30 patients with AR who were treated at the Second Xiangya Hospital of Central South University between September 2021 and December 2023.

Inclusion criteria:1.Patients diagnosed with isolated severe AR via echocardiography.2.Patients deemed unsuitable for surgical intervention and clinically assessed as requiring TAVR.

Exclusion criteria:1.Patients with other valvular diseases in addition to aortic valve disease 2.Patients with aortic aneurysm(Ascending aortic diameter exceeding 5.0 cm) or aortic coarctation 3.Patients with congenital heart diseases (e.g., atrial septal defect, ventricular septal defect, or patent ductus arteriosus) 4.Patients with primary or secondary pulmonary hypertension 5.Patients with allergies to contrast agents or severe cardiac, hepatic, or renal dysfunction 6.Patients with significant arrhythmias, such as atrial fibrillation or atrial flutter 7.Patients with concomitant AS.

Clinical trial ethical considerations

This study was approved by the Ethics Committee of the Second Xiangya Hospital of Central South University (Approval No.: LYF20240152) and all methods were performed in accordance with the relevant guidelines and regulations.All the participants gave their written informed consent to participate in the study.

MDCT scanning protocol and post-processing methods

A SIEMENS SOMATOM FORCE dual-source CT scanner (Germany) was used with a retrospective ECG-gated coronary scanning protocol synchronized with respiration. Automatic trigger scanning was employed, with the region of interest set at the ascending aorta, and a trigger threshold of 100 HU. The scan range extended from 1 cm below the carina to the diaphragm.For contrast enhancement, a bolus injection was administered via the median cubital vein at a rate of 4.5 ml/s with 18 ml of saline, followed by 65 ml of iodixanol contrast agent (400 mg I/ml, Italy) at a flow rate of 3.2–3.5 ml/s, and then an additional 30 ml of saline at 2.5 ml/s.Scanning parameters: CAREDOSE 4D intelligent tube voltage (KV) and current (mAs) matching mode.Detector width: 192 × 0.6 mm.Matrix size: 512 × 512 mm.Rotation time: 0.25 s.Full-phase acquisition with adaptive pitch and volumetric scanningAfter scanning, images were processed using the Ziostation2 (Japan) system. The raw data were reconstructed at 10% RR intervals across 10 phases of the cardiac cycle, from 10 to 100%, with a slice thickness of 0.6 mm and an interval of 0.3 mm. An iterative reconstruction algorithm based on the raw data was employed.

Definitions of early systole, late systole, early diastole, and late diastole

Post-processing software Ziostation2 (Japan) was used to first assess cardiac function, generating an individual left ventricular volume variation curve, the abscissa corresponds to the time point of the cardiac cycle(Fig. 1). Based on this curve, the specific phases of the cardiac cycle were determined for each patient: Early systole corresponds to the phase when the left ventricular volume curve begins to decline; Late systole is defined as the phase where the volume decreases to its lowest point. Early diastole is identified as the phase immediately following the transition from the lowest point of the curve to the initial upward trend, while Late diastole corresponds to the phase when the volume recovers to its maximum value.

Localization and measurement at AA, LVOT, and STJ

Using the post-processing software Ziostation 2 (Japan) and following the expert consensus guidelines of the Society of Cardiovascular Computed Tomography, the lowest points of the three coronary sinuses are

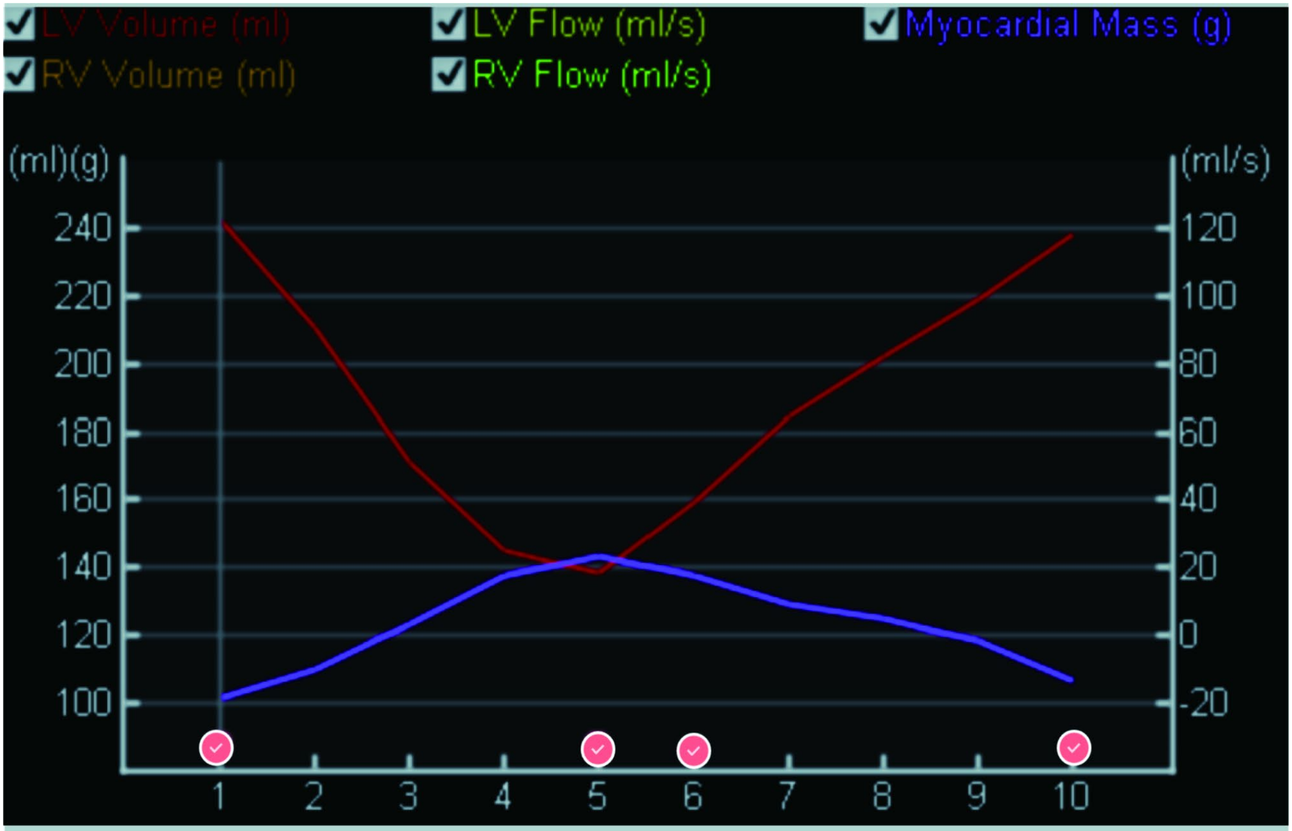

Fig. 1. : The phases of the cardiac cycle, Early systole, Late systole, Early diastole, Late diastole corresponding to x-axis coordinate 1, 5,6, 10.

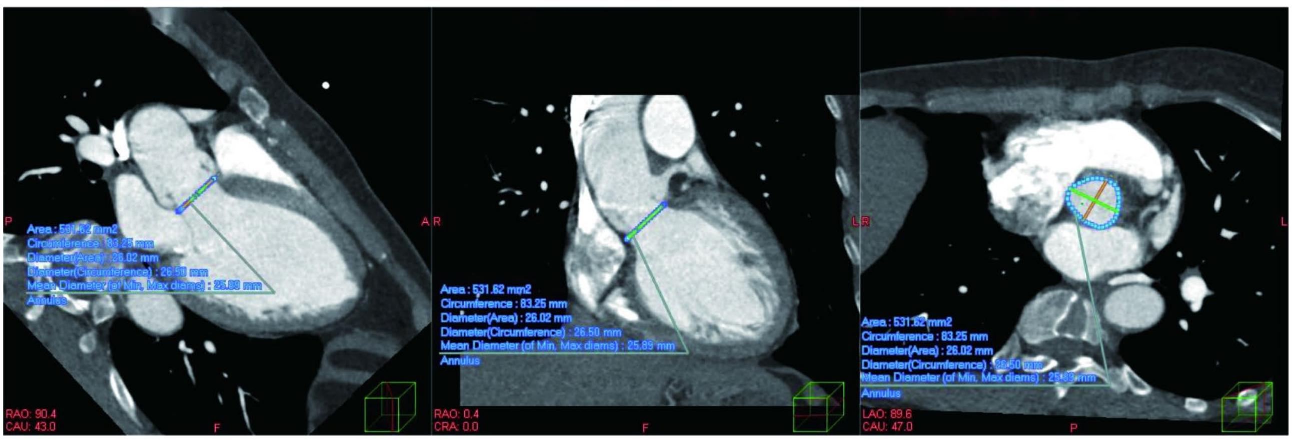

Fig. 2. Determination of the AA plane.

automatically or manually identified on oblique planes (oblique sagittal and oblique coronal views). This allows for the definition of the virtual plane of the AA, which is the plane connecting the bases of the three aortic valve leaflets (Fig. 2). The software automates many of the steps required for the oblique plane measurements and helps reduce variability in aortic annulus measurements between observers. In cases of calcification at the AA, the aortic annulus contour should pass through the area of calcification at its shortest distance between two points[12].The left ventricular outflow tract (LVOT) plane is defined as 5 mm below the AA plane in the oblique sagittal view (Fig. 3)[13]. The sinotubular junction (STJ) plane is defined as the transition between the aortic sinus and the ascending aorta (Fig. 4)[14]. Measurements of the long diameter, short diameter, average diameter, area, perimeter, diameter derived from area (DA), and diameter derived from circumference (DC) at the AA, LVOT, and STJ were performed by two radiologists specially trained in TAVR. The formulas for DA, DC, and

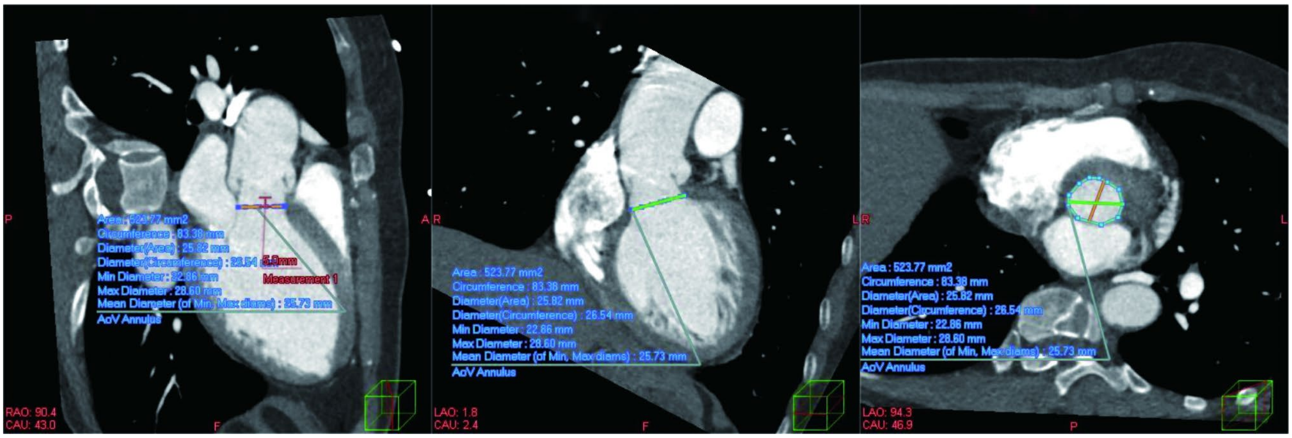

Fig. 3. Determination of the LVOT plane.

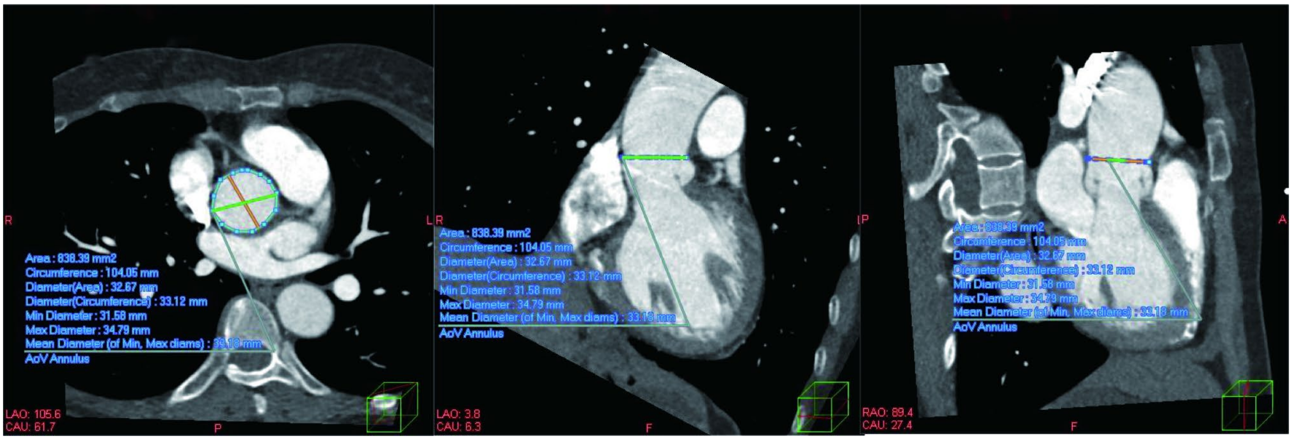

Fig. 4. Determination of the STJ plane.

average diameter are as follows: DA = $2 \times \sqrt{\left(\frac{\text{cross sectional area}}{\pi}\right)}$, DC = $\frac{\text{perimeter}}{\pi}$, Average Diameter = (Long Diameter + Short Diameter) /2.These measurements were automatically provided by the software. In cases where significant discrepancies were noted between the two radiologists' measurements, the results were discussed and agreed upon by both to reach a consensus for each measurement.

Statistical analysis

Data analysis was conducted using SPSS version 27.0 (IBM, Chicago, USA). For continuous variables, the Shapiro-Wilk test was used to check for normality. If normality was satisfied, the data was presented as means and standard deviations ($\bar{X}\pm S$); otherwise, the data was presented as medians and interquartile ranges. To assess the consistency of measurements for AA, LVOT, and STJ taken by two different observers or by the same observer at different times, interclass /Intraclass correlation coefficients (ICC) were calculated. The consistency of the measurement data was categorized as follows: ICC ≥ 0.75 indicates strong consistency, 0.40 ≤ ICC < 0.75 indicates moderate consistency, and ICC < 0.40 indicates poor consistency. If the consistency was deemed good, paired t-tests or Wilcoxon signed-rank tests were performed to compare the average values of the measured parameters at the peak times with those at other times. A p-value < 0.05 was considered statistically significant.

Results

Clinical information

Nine patients were excluded for meeting the exclusion criteria, and one was excluded due to poor image quality. Ultimately, 20 patients (17 males and 3 females) were included in the study.The patients were aged between 50 and 81 years, with an average age of (66.45 ± 1.83) years, and a mean BMI of（23.5 ± 3.1）kg/m^2.

Consistency of measurement metrics between two observers

The inter-observer consistency of measurements for AA, LVOT, and STJ in AR patients was analyzed between the two physicians, with results shown in Table 1. The results indicated that the consistency of the various

Measurement Index	AA at ICC	AA at *P*	LVOT at ICC	LVOT at *P*	STJ at ICC	STJ at *P*
Area	0.983	< 0.001	0.970	< 0.001	0.980	< 0.001
Perimeter	0.980	< 0.001	0.947	< 0.001	0.980	< 0.001
DA	0.984	< 0.001	0.970	< 0.001	0.983	< 0.001
DC	0.980	< 0.001	0.949	< 0.001	0.980	< 0.001
Long Diameter	0.970	< 0.001	0.917	< 0.001	0.960	< 0.001
Short Diameter	0.966	< 0.001	0.951	< 0.0 01	0.982	< 0.001
Mean Diameter	0.980	< 0.001	0.968	< 0.001	0.981	< 0.001

Table 1. Inter-observer consistency check of measurement indices between two physicians.

Measurement Index	AA at ICC	AA at *P*	LVOT at ICC	LVOT at *P*	STJ at ICC	STJ at *P*
Area	0.984	< 0.001	0.966	< 0.001	0.936	< 0.001
Perimeter	0.976	< 0.001	0.938	< 0.001	0.942	< 0.001
DA	0.953	< 0.001	0.964	< 0.001	0.936	< 0.001
DC	0.936	< 0.001	0.946	< 0.001	0.934	< 0.001
Long Diameter	0.946	< 0.001	0.938	< 0.001	0.948	< 0.001
Short Diameter	0.936	< 0.001	0.936	< 0.0 01	0.938	< 0.001
Mean Diameter	0.928	< 0.001	0.928	< 0.001	0.946	< 0.001

Table 2. Intra-observer consistency check of measurement indices at different times by one physician.

Group	Phases	Area(mm^2)	Perimeter(mm)	DA(mm)	DC(mm)	Long Diameter(mm)	Short Diameter(mm)	Mean Diameter(mm)
At the AA plane	Early Systole	553.01 ± 124.96	84.85 ± 9.21	26.38 ± 2.95	27.01 ± 2.93	28.98 ± 2.99	24.06 ± 3.04	26.52 ± 2.89
	Late Systole	544.22 ± 131.88	84.32 ± 9.61	26.12 ± 3.10	26.84 ± 3.06	29.21 ± 2.89	23.17 ± 3.21	26.19 ± 2.93
	Early Diastole	510.78 ± 121.20	82.18 ± 9.87	25.33 ± 3.07	26.16 ± 3.14	28.78 ± 3.33	22.24 ± 3.09	25.51 ± 3.09
	Late Diastole	530.77 ± 134.75	83.47 ± 10.20	25.80 ± 3.28	26.56 ± 3.24	29.25 ± 3.75	22.85 ± 3.47	26.05 ± 3.44

Table 3. Measurement results of AA parameters in early systole, late systole, early diastole, and late diastole. *AR: Aortic Regurgitation; AA: Aortic Annulus; DA: Diameter Derived from Area; DC: Diameter Derived from Perimeter.

metrics measured by the two physicians was strong, with Absolute agreement ICC values all greater than 0.900 ($P < 0.001$).

Consistency of measurement metrics by the same physician at different times

The intra-observer consistency of measurements for AA, LVOT, and STJ taken by the same physician, with a one-week interval between measurements, was analyzed. The results are shown in Table 2. The findings indicated that the consistency of the various metrics measured by the same physician at different times was strong, with consistency ICC values all greater than 0.900 ($P < 0.001$).

Measurement parameters at different phases of the cardiac cycle in AR patients

At the AA site, the parameters of area, perimeter, DA, DC, and average diameter during early systole were all significantly greater than those during early diastole ($P < 0.05$). However, although the area, perimeter, DA, DC, and average diameter achieved their maximum values during early systole, there were no significant statistical differences when compared with late systole and late diastole ($P > 0.05$). The short axis diameter was largest during early systole, with statistically significant differences compared to late systole, early diastole, and late diastole ($P < 0.05$). The long axis diameter was largest during late diastole, but there were no statistically significant differences when compared with other phases (long axis diameters were 28.98 ± 2.99, 29.21 ± 2.89, 28.78 ± 3.33, and 29.25 ± 3.75, respectively) ($P > 0.05$). The results are shown in Tables 3, 4 and 5.

At the LVOT, the morphological parameters including area, perimeter, DA, DC, and long diameter reached their maximum values in late diastole, with no significant statistical differences compared to early or late systole ($P > 0.05$). However, significant differences were observed between late diastole and early diastole ($P < 0.05$). The average diameter was largest during early systole, but no significant statistical differences were found when comparing early systole with late systole and late diastole ($P > 0.05$); significant differences were observed between early systole and early diastole ($P < 0.05$). The short axis diameter was largest during early systole, with significant differences compared to late systole, early diastole, and late diastole (short axis diameters were 24.37 ± 2.82, 23.31 ± 3.78, 21.61 ± 4.69, and 22.77 ± 5.06, respectively) ($P < 0.05$). The results are shown in Tables 6, 7 and 8.

Group	Phases		Area	Perimeter	DA	DC	Short Diameter	Mean Diameter
			t-value *p*-value	t-value *p*-value	t-value *p*-value	t-value *p*-value	t-value *p*-value	t-value *p*-value
At the AA plane	Early Systole	Late Systole	0.736 0.471	0.619 0.544	0.932 0.364	0.620 0.543	2.616 0.017	1.506 0.150
		Early Diastole	3.825 0.001	2.892 0.010	3.663 0.002	2.897 0.010	5.756 < 0.001	3.465 0.003
		Late Diastole	1.760 0.095	1.267 0.221	1.788 0.091	1.309 0.207	4.026 < 0.001	1.479 0.156

Table 4. Paired t-test of aortic annulus measurements at early systole, late systole, early diastole, and late diastole.

Group	Phases		Long Diameter
			t-value *p*-value
At the AA plane	Late Diastole	Early Systole	0.592 0.561
		Late Systole	0.115 0.909
		Early Diastole	1.424 0.172

Table 5. Paired t-test of long diameter measurements at late diastole compared with early systole, late systole, and early diastolet-value. *AR: Aortic Regurgitation; AA: Aortic Annulus; DA: Diameter Derived from Area; DC: Diameter Derived from Perimeter.

Group	Phases	Area(mm^2)	Perimeter(mm)	DA(mm)	DC(mm)	Long Diameter(mm)	Short Diameter(mm)	Mean Diameter(mm)
At the LVOT plane	Early Systole	631.12 ± 150.92	91.60 ± 11.54	27.98 ± 4.83	29.07 ± 3.64	32.17 ± 4.27	24.37 ± 2.82	28.26 ± 3.40
	Late Systole	602.19 ± 166.75	90.86 ± 12.73	27.43 ± 3.86	28.92 ± 4.05	32.27 ± 4.13	23.31 ± 3.78	27.79 ± 3.70
	Early Diastole	578.21 ± 180.74	90.25 ± 13.05	26.78 ± 4.45	28.73 ± 4.15	32.06 ± 4.44	21.61 ± 4.69	26.84 ± 4.25
	Late Diastole	632.38 ± 205.26	94.02 ± 13.88	28.15 ± 3.40	29.93 ± 4.42	33.56 ± 4.61	22.77 ± 5.06	28.16 ± 4.62

Table 6. Measurement results of LVOT parameters at early systole, late systole, early diastole, and late diastole. *AR: Aortic Regurgitation; AA: Aortic Annulus; DA: Diameter Derived from Area; DC: Diameter Derived from Perimeter.

Group	Phases		Area	Perimeter	DA	DC	Long Diameter
			t-value *p*-value	t-value *p*-value	t-value *p*-value	t-value *p*-value	t-value *p*-value
At the LVOT plane	Late Diastole	Early Systole	0.056 0.956	1.522 0.145	1.925 0.070	1.665 0.113	1.954 0.066
		Late Systole	1.184 0.252	1.690 0.108	0.313 0.758	1.689 0.109	1.553 0.138
		Early Diastole	2.656 0.016	2.448 0.025	3.152 0.006	2.448 0.025	2.258 0.037

Table 7. Paired t-test of LVOT measurements at late diastole compared with early systole, late systole, and early diastole.

Group	Phases		Short Diameter	Mean Diameter
			t-value *p*-value	t-value *p*-value
At the LVOT plane	Early Systole	Late Systole	2.595 0.018	1.236 0.232
		Early Diastole	4.890 <0.001	3.381 0.003
		Late Diastole	2.3357 0.030	0.189 0.852

Table 8. Paired t-test of LVOT measurements at early systole compared with late systole, early diastole, and late diastole. *AR: Aortic Regurgitation; AA: Aortic Annulus; DA: Diameter Derived from Area; DC: Diameter Derived from Perimeter.

At the STJ site, the parameters for area, perimeter, DA, DC, long axis diameter, short axis diameter, and average diameter all reached their maximum values during late systole. However, there were no significant differences between late systole and early systole or early diastole ($P > 0.05$). Significant differences were observed between late systole and late diastole ($P < 0.05$). The results are shown in Tables 9 and 10.

Group	Phases	Area(mm^2)	Perimeter(mm)	DA(mm)	DC(mm)	Long Diameter(mm)	Short Diameter(mm)	Mean Diameter(mm)
At the STJ plane	Early Systole	1171.94 ± 434.36	121.50 ± 21.26	38.07 ± 6.74	38.67 ± 6.77	39.99 ± 7.33	36.38 ± 6.38	38.19 ± 6.82
	Late Systole	1184.28 ± 427.77	121.97 ± 21.13	38.28 ± 6.69	38.82 ± 6.73	40.05 ± 6.79	36.58 ± 6.63	38.31 ± 6.67
	Early Diastole	1159.12 ± 387.01	121.00 ± 19.51	37.94 ± 6.18	38.51 ± 6.21	39.78 ± 6.21	36.48 ± 6.12	38.16 ± 6.19
	Late Diastole	1111.70 ± 414.10	118.37 ± 20.89	37.07 ± 6.59	37.68 ± 6.65	38.83 ± 7.02	35.41 ± 6.37	37.18 ± 6.61

Table 9. Measurement results of STJ parameters at early systole, late systole, early diastole, and late diastole. *AR: Aortic Regurgitation; AA: Aortic Annulus; DA: Diameter Derived from Area; DC: Diameter Derived from Perimeter.

Group	Phases		Area	Perimeter	DA	DC	Long Diameter	Short Diameter	Mean Diameter
			t-value *p*-value	t-value *p*-value	t-value *p*-value	t-value *p*-value	t-value *p*-value	t-value *p*-value	t-value *p*-value
At the STJ plane	Late Systole	Early Systole	0.680 0.505	0.572 0.574	0.822 0.421	0.575 0.572	0.166 0.870	0.749 0.463	0.509 0.616
		Early Diastole	1.577 0.131	1.295 0.211	1.459 0.161	1.296 0.210	0.857 0.402	0.356 0.726	0.707 0.488
		Late Diastole	4.945 <0.001	5.190 <0.001	5.465 < 0.001	5.189 < 0.001	3.413 0.003	4.233 < 0.001	4.575 < 0.001

Table 10. Paired t-test of STJ measurements at late systole compared with early systole, early diastole, and late diastole. *AR: Aortic Regurgitation; AA: Aortic Annulus; DA: Diameter Derived from Area; DC: Diameter Derived from Perimeter.

Discussion

MDCT is widely recognized as the primary non-invasive imaging modality for preoperative assessment in TAVR. In addition to providing crucial measurements of the AA size, which are essential for selecting an appropriate transcatheter valve, MDCT also offers detailed anatomical information on aortic valve and annulus calcification, the morphology of the ascending aorta, and the angle between the ascending aorta and the LVOT, as well as potential vascular access routes for TAVR[11].Currently, TAVR faces several challenges in patients with AR, as a result, surgical aortic valve replacement (SAVR) remains the primary treatment for AR patients. However, for those unable to tolerate SAVR, TAVR is currently the best available option[11,15,16].Recent studies have demonstrated favorable outcomes with TAVR in appropriately selected AR patients. Therefore, detailed MDCT assessment of aortic root changes in AR patients is necessary to identify suitable TAVR candidates[5,15–17]. To date, research on the dynamic changes in aortic root structural parameters pre-TAVR in AR patients is scarce.

In AR patients, the early systolic area, perimeter, DA, DC, and mean diameter at the AA site show no significant changes in late systole or late diastole, with only some variation observed in early diastole.This limited variation during the cardiac cycle in AR patients contrasts with the more pronounced changes observed in AS patients, suggesting that the deformation of the AA in AR patients is less significant throughout the cardiac cycle. This may be due to the pronounced dilation of the AA in AR patients, which could lead to structural fragility and reduced elasticity and compliance of the AA[8,18].

Some studies suggest that during TAVR using balloon-expandable prostheses such as the SAPIEN 3 in AR patients, to reduce the risks of valve malposition and paravalvular leak, the prosthesis size should be 15–25% larger relative to the maximum AA size[15,19–21]. The finding that multiple critical parameters at the AA site in AR patients reach their maximum during early systole indicates that the consensus for valve prosthesis selection used for AS can also be applied to AR patients. Specifically, measuring AA parameters at the time of maximum AA size can maximize the accuracy of prosthesis selection. This approach is currently employed clinically for prosthesis sizing. Therefore, we propose that in AR patients, early systolic AA measurements can also serve as the primary basis for prosthesis size selection[7,18,22].

In this study, 20 subjects underwent evaluation for TAVR selection. However, due to most patients declining TAVR for personal reasons and opting for conservative treatment or transferring to other hospitals, only 3 patients underwent TAVR at our hospitaln this study. We primarily based the selection of prosthesis size on the values of DC and DA at the AA during early systole.Two of the three patients received the Medtronic Evolut R valve, and one received the J-valve. The surgical outcomes were favorable, with no significant paravalvular leakage and no pacemaker implantation(Fig. 5).

Additionally, the study revealed that the maximum value of the long axis diameter at the AA site in AR patients occurred during late diastole. The maximum long axis diameter did not show significant differences compared to other phases, indicating that the long axis diameter remains relatively stable in AR valve disease. In contrast, the short axis diameter was significantly larger during early systole compared to other phases, suggesting substantial changes in the elliptical shape of the AA throughout the cardiac cycle in AR patients.

At the LVOT site, the area, perimeter, DA, DC, and long axis diameter in AR patients were largest during late diastole, and were significantly greater than those observed during early diastole. There were no significant differences compared to early or late systole. We attribute these findings to the fact that the aortic regurgitation during early to late diastole causes prolonged overfilling of the left ventricle, leading to secondary dilation of the LVOT and a notable reduction in tissue compliance.We believe this may lead to a less stable fit between the valve and the outflow tract compared to AS patients. Therefore, a self-expanding valve with a stronger seal may be required during TAVR to address the complexity of LVOT morphology and the risk of post-

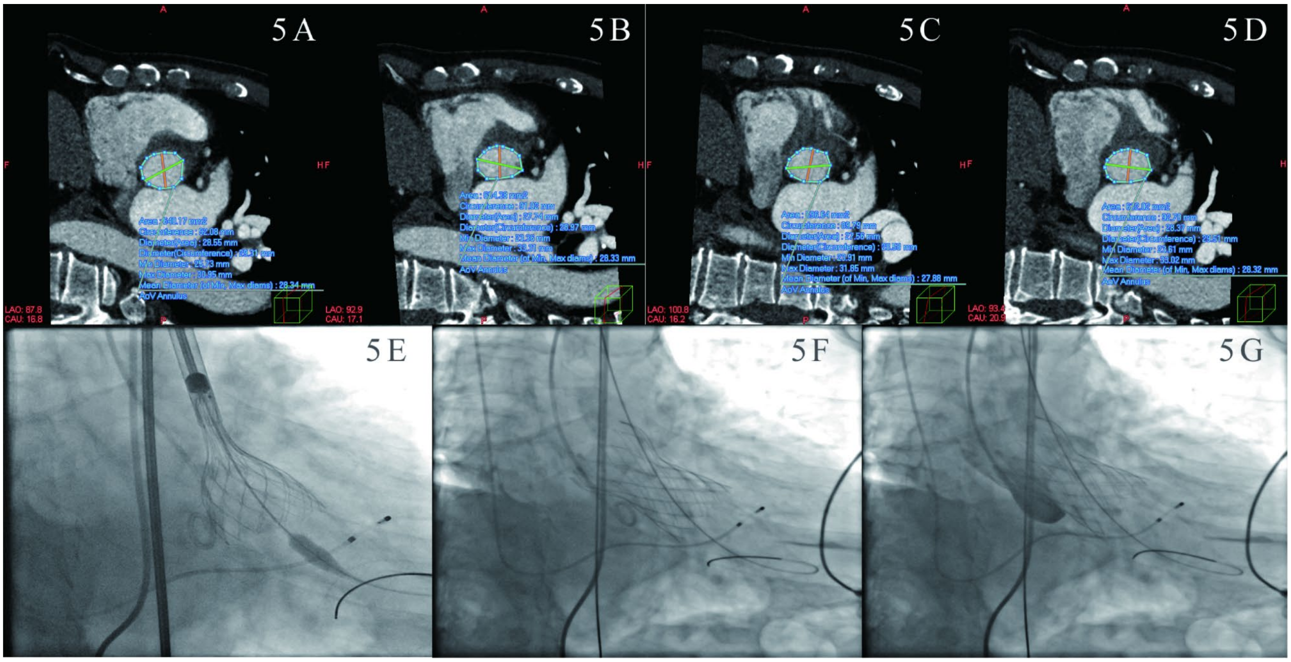

Fig. 5. A patient with AR underwent a successful TAVR procedure based on preoperative MDCT evaluation. Figures A-D show the annulus assessment at early systole, late systole, early diastole, and late diastole, respectively. Figures E, F, and G show post-procedure angiography of the prosthetic valve, with no significant contrast regurgitation or paravalvular leak observed, and the stent was well-seated.

procedural regurgitation. Additionally, precise measurement of the LVOT size during late diastole is necessary preoperatively to avoid issues of undersizing or incomplete sealing due to dilation.The average diameter at the LVOT site was largest during early systole, with minimal changes compared to late systole and late diastole, but showed significant differences when compared to early diastole. The short axis diameter was also largest during early systole, with marked differences compared to other phases of the cardiac cycle. These observations suggest significant hemodynamic changes in this region throughout the cardiac cycle in AR patients.

At the STJ site, in AR patients, the area, perimeter, DA, DC, long axis diameter, short axis diameter, and average diameter all reached their maximum values during late systole. However, while the values of these parameters during late systole were not significantly different from those observed during early systole and early diastole, they were significantly greater than those during late diastole. We speculate that this discrepancy is due to the peak ventricular ejection volume occurring during late systole and the maximum regurgitant flow during late diastole, leading to the largest differences in STJ parameters between these two phases.Although the significance of STJ parameters for prosthesis sizing requires further investigation, existing studies have shown that a larger STJ can increase the risk of prosthesis misalignment when using the Venus-A valve for TAVR[2]. Therefore, assessing the STJ is beneficial for preoperatively predicting and identifying patients at high risk for severe prosthesis malposition[2]. Additionally, research has demonstrated that a smaller AA, LVOT, and STJ is advantageous when using self-expanding valve systems like the VitaFlow and Venus A in severe AR patients, as it provides better anchoring of the valve and helps prevent valve displacement due to a better fitting of the valve's "crown" design[9].

In summary, we believe that when extending the use of prosthetic valves designed for AS to patients with AR, it is crucial to thoroughly assess the structural characteristics of the aortic root preoperatively. Fundamentally, the design of valve prostheses specifically tailored for AR should be considered for TAVR treatment.

The study has several limitations. First, the small sample size of 20 patients restricts the statistical power of the analysis and limits the generalizability of the findings. With a larger sample, the results could be further validated, and the impact of potential confounders could be better controlled. Second, the single-center design of the study introduces a degree of homogeneity in the patient population, as patients from a single institution may share similar demographics, healthcare access, and treatment protocols, which may not reflect the broader population of AR patients. Additionally, the training and experience of physicians involved in the study were consistent across the center, which may have reduced variability in measurements but limits the external validity of the findings to institutions with different practices or expertise. Third, the majority of patients in this study did not undergo TAVR during the study period, despite being clinically assessed as suitable candidates. This was largely due to patients opting for conservative treatment or transferring to other hospitals, which may indicate a potential selection bias in the study cohort. The relatively low number of TAVR procedures conducted limits the ability to assess the real-world effectiveness of prosthesis selection based on the MDCT parameters.

Conclusion

In AR patients, the selection of prostheses can be guided by MDCT parameters, with early systole serving as the optimal phase for prosthesis selection. Prospective studies focusing on patients with aortic regurgitation remain limited, highlighting the urgent need for further clinical research to validate the application and limitations of MDCT in this patient population.

Data availability

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions

Conceptualization and design of the study: S.Z.,T.H, Q.S.;Analysis and interpretation of data: T. H.,X.G.;Writing - original draft: S.Z.,T.H.,Q.S, Y.L.;Data curation: T. H.,Y.L. ;Formal analysis: S.Z.,Y.L.,Q. S.All authors reviewed the manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

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