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Research paper

# Influence of aortic valve leaflet calcification on dynamic aortic valve motion assessed by cardiac computed tomography

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ABSTRACT

*Background:* Computed tomography is the best noninvasive imaging modality for evaluating valve leaflet calcification.
*Objective:* To evaluate the association of aortic valve leaflet calcification with instantaneous valve opening and closing using dynamic multidetector computed tomography (MDCT).
*Methods:* We retrospectively evaluated 58 consecutive patients who underwent dynamic MDCT imaging. Aortic valve calcification (AVC) was quantified using the Agatston method. The aortic valve area (AVA) tracking curves were derived by planimetry during the cardiac cycle using all 20 phases (5% reconstruction). da/dt in $cm^2/s$ was calculated as the rate of change of AVA during opening (positive) or closing (negative). Patients were divided into 3 three groups according to Agatston score quartile: no AVC (Q2, Score 0, $n = 18$), mild AVC (Q3, Score 1–2254, $n = 24$), and severe AVC (Q4 Score >2254, $n = 14$).
*Results:* In multivariable linear regression, compared to the non AVC group, the mild and severe AVC groups had lower maximum AVA (by $-1.71$ $cm^2$ and $-2.25$ $cm^2$, respectively), lower peak positive da/dt (by $-21.88$ $cm^2/s$ and $-26.65$ $cm^2/s$, respectively), and higher peak negative da/dt (by 13.78 $cm^2/s$ and 18.11 $cm^2/s$, respectively) ($p < 0.05$ for all comparisons).
*Conclusions:* AVA and its opening and closing were influenced by leaflet calcification. The present study demonstrates the ability of dynamic MDCT imaging to assess quantitative aortic valve motion in a clinical setting.


## 1. Introduction

Aortic valve calcification (AVC) is the result of an active inflammatory process and endothelial damage due to mechanical injury, leading finally to calcification.[1] The presence of AVC is associated with a poor prognosis in the general population,[2,3] and in patients with aortic stenosis (AS).[4]

Computed tomography (CT) provides the best noninvasive assessment of AVC among all imaging modalities,[5] and cardiac CT was the first technique used to quantify coronary artery calcification.[6] Although there is some discrepancy between the aortic valve area (AVA) as determined by echocardiography and multidetector CT (MDCT)—the main reason being that CT evaluates the geometric orifice area at the tip of the aortic valve leaflets by planimetry, whereas echocardiography uses time velocity integrals to calculate the effective orifice area—MDCT enables the accurate noninvasive assessment of AVA.[5,7,8] It is currently considered to be the gold standard for assessing geometric measurements with accuracy and reproducibility, and the reference standard for measures derived from 2- or 3-dimensional echocardiography.[8–12]

The newly developed 320 MDCT enables whole-heart dynamic MDCT angiography (MDCT) and allows quantitative assessment of aortic valve motion with acceptable resolution. Thus, it is possible to test the hypothesis that aortic valve opening and closing are influenced by AVC. The aim of this study was to evaluate the

*Abbreviationslist:* AVC, Aortic valve calcification; AVA, Aortic valve area; AS, Aortic stenosis; CT, Computed tomography; HR, Heart rate; MDCT, Multidetector CT.

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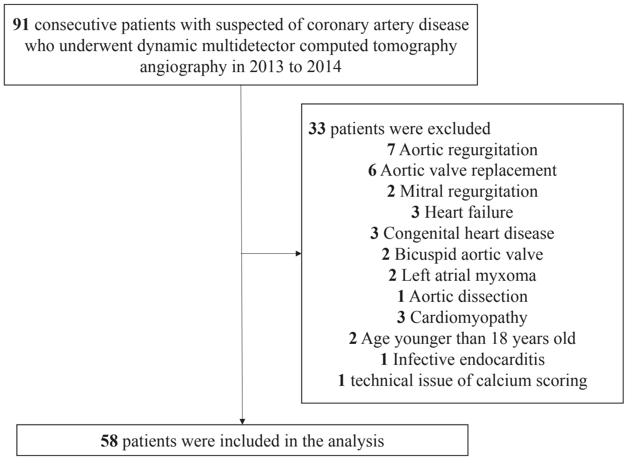


**Fig. 1. Patient enrollment**. We retrospectively evaluated 58 patients who underwent dynamic multidetector computed tomography angiography.

association of leaflet calcification with a quantitative assessment of AVA tracking using dynamic MDCT imaging.

## 2. Methods

### 2.1. Study population

We retrospectively enrolled 91 consecutive patients with suspected coronary artery disease who underwent dynamic MDCT angiography for clinical indications using 320 MDCT between January 2013 and April 2014. Of these, 33 patients were excluded, as shown in Fig. 1. Thus, a total of 58 patients were evaluated. The Ethics Committee of St. Marianna University School of Medicine approved the study.

### 2.2. MDCT image analysis

All examinations were performed using a 320-detector row CT scanner (Aquilion® ONE, Toshiba Medical Systems). Details of the image acquisition are provided in the supplementary material (Online Appendix 1). AVC was defined as any calcified lesion within the aortic valve leaflets and was quantified using the Agatston method, which takes account of both lesion volume and calcium density (using Hounsfield brightness). If AVC was not detected, the Agatston score was recorded as 0. We subjectively graded the presence of AVC based on both a calcium scan and dynamic MDCT images, following a 4-point scale: 0 – absence of any AVC; 1 – presence of any calcification on one leaflet; 2 – presence of any calcification on two leaflets; and 3 – presence of any calcification on three leaflets.

AVA measurements were made during all phases of the cardiac cycle from 3 multiplanar reconstructions: left sagittal oblique view of the aortic valve, left coronary oblique view, and a cross-sectional view. The images in the plane perpendicular to the left ventricular outflow tract were adjusted to achieve a circular aorta in the cross-sectional views. Finally, the AVA (planimetry) was manually traced on the multiplanar reconstruction images at the level of the tips of the AV leaflet in the cross-sectional view, as previously described,[10] using all 20 phases (5% reconstruction). The AVA tracking curves were derived from each scatter using a smoothing function in Microsoft Office Excel 2007 software (Microsoft Corp, USA). The rate of change in AVA (da/dt) in $cm^2/s$ is the rate at which deformation occurs during the cardiac cycle and is calculated as the time derivative of AVA, as shown in Fig. 2. The median temporal resolution was 50 ms (interquartile rage [IQR] 42–55 ms).

### 2.3. Echocardiography

Two-dimensional transthoracic echocardiography was performed using a commercially available ultrasound system (Artida, Toshiba Medical Systems, Japan) within 3 months before and after dynamic MDCT. Details of the echocardiography measurements are provided in the supplementary material (Online Appendix 2).

### 2.4. Statistical analysis

The median and 25th and 75th percentiles (IQR) are reported for all continuous values, while categorical variables are expressed as percentages. The chi-square test was used for comparisons of

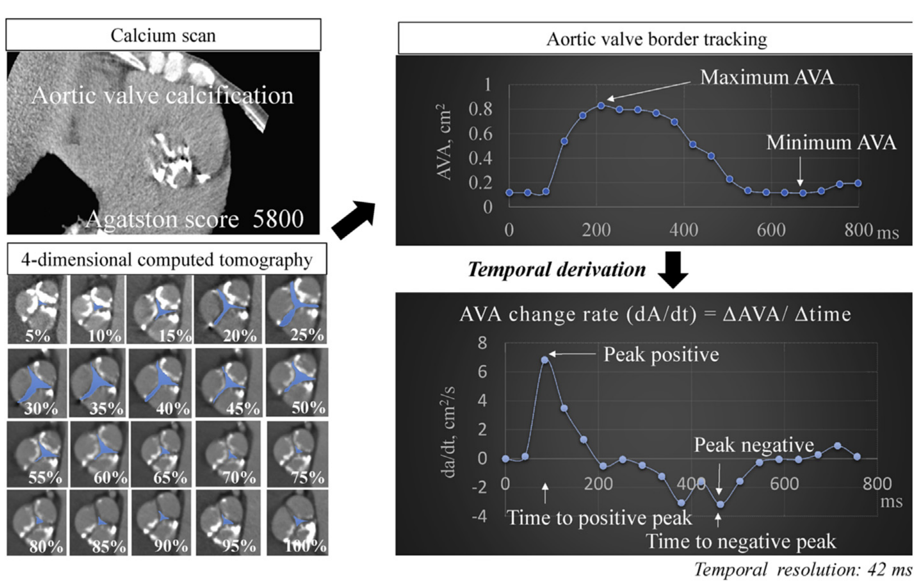


**Fig. 2. Quantitative assessment of aortic valve area tracking using dynamic multidetector computed tomographic imaging**. Maximum and minimum aortic valve areas, peak da/dt, and time to peak da/dt were determined from the curves. da/dt represents the rate of change of aortic valve area during opening (positive) or closing (negative).