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4DCT-Derived Endocardial Left Ventricular Torsion Correlates With CMR Tagging–Derived Torsion in the Same Subjects

Left ventricular (LV) torsion is an important prognostic parameter (1). We introduce here a new algorithm for measuring endocardial LV torsion from standard four-dimensional computed tomography (4DCT) imaging validated with cardiac magnetic resonance (CMR) tagging. We analyzed 16 consecutive subjects who had retrospectively gated computed tomography angiography (CTA) and CMR tagging examinations on the same day and satisfied the following criteria: 1) ejection fraction (from 4DCT) ≤75% to provide sufficient LV endocardial surface; and 2) LV blood pool-myocardium contrast-to-noise ratio (from 4DCT) >8 (2).

All subjects were scanned under institutional review board-approved protocols at the U.S. National Institutes of Health (Bethesda, Maryland) with an average time between the CMR and CT examinations of 3.9 ± 1.7 h. Patients were in a study evaluating coronary artery disease from CTA and valve and aortic disease using CMR. No patients had obstructive coronary artery disease. Four patients had cardiovascular abnormalities: 1 had an aortic valve replacement, 1 had mild aortic stenosis (AS), 1 had moderate AS, and 1 had mild AS with a small myocardial infarction and pacemaker.

CMR examinations were conducted on a 1.5-T MAGNETOM Aera (Siemens Medical Solutions, Malvern, Pennsylvania). Apical and basal short-axis planes were acquired with an electrocardiography-triggered, segmented k-space, grid-tagged gradient echo imaging protocol with 6- to 8-mm slices. The two-dimensional myocardial displacement field between end-diastole and end-systole was derived from the CMR images (3). An affine transformation was fit to the deformation of the innermost points to obtain a rotation angle for the 2 planes. LV torsion was computed as: (apical − basal rotation)/distance between apical and basal planes.

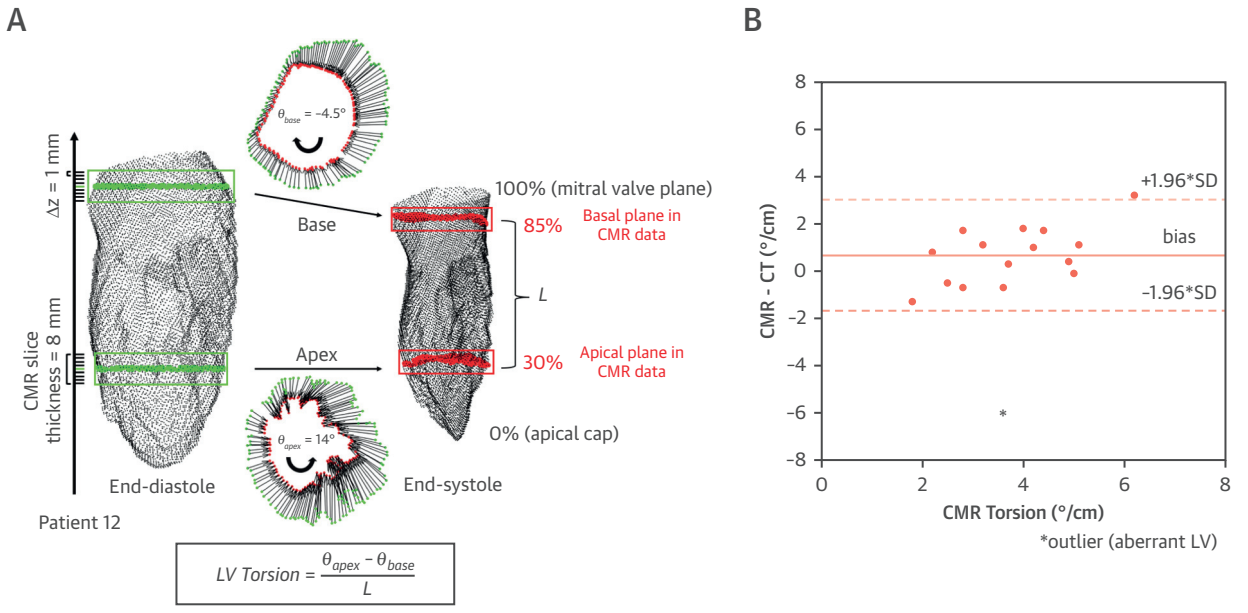
Single-heartbeat, retrospectively gated CTA examinations were obtained during an inspiratory breath-hold on a 320-detector row Aquilion ONE (Canon Medical Systems, Tustin, California) scanner with a gantry rotation time of 275 ms; 55 ml of iodine contrast was injected followed by a 30-ml saline flush. Maximum mA was during diastasis, with 20% mA at other time points. Images were reconstructed in the axial plane with slices 0.5 mm thick and 0.4 × 0.4 mm pixel spacing. Dose-length product (DLP) was variable among the patients; 12 had DLP 60 to 150 mGy × cm and 4 had DLP 170 to 451 mGy × cm. The LV blood pool was segmented from each time frame, and a deterministic point cloud of the surface was extracted (2). Three-dimensional endocardial deformation fields were derived using point-cloud registration. Rotation about the long-axis was measured from the registered point clouds in 2-dimensional short-axis slices 1 mm thick. Apical and basal regions of the left ventricle in the CT images were determined for analysis (**Figure 1A**).

Fifteen of 16 patients were successfully analyzed. One had aberrant LV morphology (3 papillary muscles) leading to failure of the tracking algorithm. This outlier was excluded from the statistical analyses performed. There was good agreement between the 4DCT and CMR-derived rotation estimates. A two-tailed Student's *t*-test ($\alpha = 0.05$) showed no significant difference between apical rotation values ($p = 0.11$), but basal estimates were significantly different ($p < 0.05$). The precision of 4DCT-derived endocardial rotation can be characterized by the SD of the Bland-Altman plot, which was ±3.4°.

There was moderate correlation ($R = 0.48$; $p = 0.07$) between CMR and 4DCT-derived LV torsion. A 2-sided Student's *t*-test revealed no significant difference ($p = 0.14$) between the torsion estimates. The Bland-Altman plot indicated a small bias of 0.65°/cm for the CT estimates (**Figure 1B**). The precision of 4DCT-derived torsion (given CMR as the reference standard) was ±1.2°/cm.

To the best of our knowledge, this study is the first comparison between 4DCT- and CMR tagging-derived endocardial LV rotation and torsion in human subjects. Overall, there was moderate correlation between the 2 methods for measuring torsion and no significant difference between the measurements. The precision of the torsion estimate from CT imaging was estimated to be ±1.2°/cm. Given that the normal value of LV torsion at end-systole is 3.9°/cm ± 1.3°/cm, these results show the potential for 4DCT imaging to provide prognostic functional information about LV torsion in addition to high-quality anatomic data (1). In addition, this technique for deriving three-dimensional deformations from 4DCT imaging can be extended to measure endocardial strain.

FIGURE 1 Endocardial Torsion Derived From a 4DCT Method Compared With CMR Tagging



(A) Four-dimensional computed tomography (4DCT) method: in **red** are apical and basal slices matching the cardiac magnetic resonance (CMR)-derived locations at end-systole. Corresponding slices are in **green** at end-diastole. Rotation angles of adjacent slices are averaged together to match the thickness of the CMR data. **(B)** Bland-Altman plot comparing CMR and CT-derived torsion.

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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Multiplanar "En Face" Reconstruction of the Aortic Valve

Impact on Aortic Valve Calcium Scoring

Aortic valve calcification (AVC) is central in the pathophysiology and progression of aortic stenosis (AS). Quantification of AVC by using noncontrast multidetector computed tomography (MDCT) via the Agatston method (analogous to coronary calcium scoring) has shown an excellent correlation with aortic valve weight, hemodynamic severity (1), and clinical outcomes (2,3) in patients with AS. Although some authors have advocated alternative quantification techniques using contrast-enhanced MDCT scans, the Agatston method until now has been the only MDCT technique with a proven impact on clinical outcomes.