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Original Research Article

Automated assessment of heart chamber volumes and function in patients with previous myocardial infarction using multidetector computed tomography

Andreas Fuchs, MD[a,*], Jørgen Tobias Kühl, MD[a], Jacob Lønborg, MD[a], Thomas Engstrøm, MD, DMSc[a], Niels Vejlstrup, MD, PhD[a], Lars Køber, MD, DMSc[a], Klaus F. Kofoed, MD, DMSc[a,b]

[a]*Department of Cardiology 2012, The Heart Centre, University of Copenhagen, Blegdamsvej 9, Copenhagen East DK-2100, Denmark and* [b]*Department of Radiology, Diagnostic Center, Rigshospitalet, University of Copenhagen, Copenhagen East, Denmark*

KEYWORDS:
Cardiac chambers;
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Ventricular mass

BACKGROUND: Left ventricular (LV), right ventricular (RV), and left atrial (LA) volumes and functions contain important prognostic information in ischemic heart disease. Because multidetector computed tomography (MDCT) has high spatial resolution, this method may be optimal to obtain this information.

OBJECTIVE: We evaluated automated assessment for MDCT, by comparing it with cardiac magnetic resonance (CMR).

METHODS: Fifty-three patients with previous myocardial infarction were scanned with 1.5 Tesla CMR and 64-slice MDCT. End-diastolic volume, end-systolic volume, stroke volume, and ejection fraction (EF) were assessed for the left and right ventricle with automatic MDCT software and manual CMR software. LV myocardial mass and cyclic changes in LA volume were derived.

RESULTS: The mean age of patients was 61 ± 10 years, 40 (75%) were men. Automated MDCT segmentation was possible in all but 2 patients. The average duration of image processing was 21 ± 4 minutes by CMR and 11 ± 4 minutes by MDCT. Bland-Altman plots showed good agreement between MDCT and CMR with only small bias. LVEF by CMR was 56% ± 10% and by MDCT 61% ± 11%, mean difference of −5% (limits of agreement, −18% to 8%), and $P < 0.001$. RVEF by CMR was 60% ± 5% and by MDCT 56% ± 8%, mean difference of 5% (limits of agreement, −10% to 20%), and $P < 0.001$. LA fractional change by CMR was 49% ± 9% and by MDCT 45% ± 9%, mean difference of 4% (limits of agreement, −12% to 20%), and $P \leq 0.001$.

CONCLUSION: LV, RV, and LA volumes and functions may be evaluated fast and reliably with the use of automated assessment and cardiac MDCT, with good agreement to CMR. Accurate assessment of cardiac chambers with MDCT appears possible in clinical practice.

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* Corresponding author.

E-mail address: mck601@alumni.ku.dk

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Introduction

Cardiac volumes, mass, and function contain important diagnostic and prognostic information for treatment and risk stratification in patients after myocardial infarction.[1–9] Technical improvements in multidetector computed tomography scanners (MDCT) have enabled cardiac functional analysis. Because contemporary MDCT imaging provides full 3-dimensional volume datasets with high spatial resolution, a highly flexible image procession approach is possible, potentially providing simultaneous accurate assessment of cardiac volumes, mass, and function. Cardiac functional analysis has been performed with MDCT, but, because of the lack of ability to extract this data in a short time, this type of analysis has not been applied routinely in clinical practice. Software approaches now have enabled automated segmentation of left ventricular (LV), right ventricular (RV), and left atrial (LA) volumes and derived functions in addition to LV myocardial mass.

Currently cardiac magnetic resonance (CMR) provides a highly accurate reference standard for assessing cardiac chamber volume, function, and mass,[10–12] but clinical limitations include contraindications (eg, metal implants) and availability of the technology. Recent studies have suggested that MDCT is clinically useful for evaluation of coronary artery disease and that it has the potential to provide simultaneous measures of cardiac chamber volumes and functions.[12–17] It appears likely that if coronary examinations with MDCT also could provide cardiac chamber functional analysis, this would be clinically advantageous. Besides patients with myocardial infarction, functional analyses by MDCT could also be indicated in patients suspected with heart failure or cardiomyopathy.

We evaluated LV, RV, and LA volumes and functions with a new image processing automated assessment tool for MDCT that compared measurements with manual assessment by CMR in stable patients with previous myocardial infarction.

Methods

Patient group and study design

We prospectively included 53 clinically stable patients 90 days (range, 69–111 days) after having an ST segment myocardial infarction. All included patients had undergone successful primary percutaneous coronary intervention at Rigshospitalet, Copenhagen, Denmark. Patients with renal dysfunction (serum creatinine > 125 μmol/L) or atrial fibrillation were excluded. MDCT was performed on average 9 days (range, 0–19 days) after CMR. The study was performed according to the Helsinki declaration, and all patients were informed and gave written consent before inclusion. The Danish National Committee on Biomedical Research Ethics approved the research protocol (No.: H-KF-269475).

Cardiac magnetic resonance

CMR was performed on a 1.5-Tesla scanner (Avanto; Siemens, Erlangen, Germany). An electrocardiogram (ECG)–gated steady state free precession cine sequence (slice thickness, 8 mm; slice gap, 0 mm; echo time, 1.5 milliseconds; resolution matrix, 192×162; field of view, 300 mm; frames, 25) was used to assess cardiac chambers. The LV, RV, and LA were covered by applying multiple slices in the short-axis image plane. The time needed to acquire the image data with CMR was 15–20 minutes; a complete examination, including patient positioning and instructions, took 40–60 minutes.

Manual image analysis was performed with ARGUS image processing tool (Siemens). The diastolic and systolic frames of the ventricles were identified according to blood pool area. Left and right ventricular end-systolic (ESV) and end-diastolic volumes (EDV) were calculated by manually tracing the endocardial borders at end systole and end diastole for each short-axis slice and adding up the corresponding volumes from each slice. Papillary muscles were included in the volumes. The atrioventricular plane defined the border between the atriums and the ventricles and was identified in the 4-chamber image plane.[16,18] For the outflow tract of the right ventricle only the part surrounded by thick trabeculated wall was considered as part of the RV volume, a method that previously has been used.[19,20]

For the left atrium, the phases of interest were the minimum and maximal volume. The LA volumes were traced and calculated the same way as for the ventricles. The LA appendage was included in the LA volume.[17] The CMR analyses were made by an investigator unaware of the MDCT results, and the analyses of LV, RV, and LA volumes were done independently. LV myocardial mass was calculated as the region between the endocardial and epicardial contours in 3 dimensions, which detected all voxels included in the myocardium. In the end the volume was multiplied by the tissue factor (assuming a tissue density of 1.055 g/mL) to equal the mass.[21] Two independent observers assessed interobserver variability in 20 patients.

Multidetector computed tomography

A 64-slice MDCT scanner (Aquillion; Toshiba, Tokyo, Japan) with retrospective ECG gating was used for image acquisition. We infused 100 mL of contrast agent (Visipaque 320; GE Healthcare, Chalfont St Giles, United Kingdom) intravenously with a flow rate of 5 mL/s, followed by saline. Image acquisition was initiated automatically at a density threshold of 170 HU in the descending aorta, according to clinical routine procedure for coronary artery evaluation, providing contrast enhancement primarily in left-sided chambers and coronary arteries. The scan parameters included a detection collimation of 64×0.5 mm, tube voltage of 100–120 kV depending on body mass index, rotation time of 400–500 milliseconds, and

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