Multimodality imaging in chronic coronary artery disease

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Chapter 3

Assessment of global and regional left ventricular function and volumes with 64-slice multi-slice computed tomography: a comparison with 2D echocardiography

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Abstract

Introduction: In patients with coronary artery disease (CAD), LV function and volumes are important parameters for long-term prognosis. 64-slice MSCT allows non-invasive assessment of the coronary arteries, but the accuracy of 64-slice MSCT for assessment of LV volumes and function is unknown.

Methods: A head-to-head comparison between 64-slice MSCT and 2D echocardiography was performed in 40 patients with known or suspected CAD. The LV end-diastolic (LVEDV) and LV end-systolic volume (LVESV) were determined and LV ejection fraction (LVEF) was derived. Regional wall motion was assessed visually using a 17-segment model. A 3-point scoring system was used to assign to each segment a wall motion score: 1=normokinesia, 2=hypokinesia, 3=a- or dyskinesia. 2D echocardiography served as gold standard.

Results: MSCT agreed well with 2D echocardiography for assessment of LVEDV ($r=0.97$; $P<0.0001$) and LVESV ($r=0.98$; $P<0.0001$). An excellent correlation between MSCT and 2D echocardiography was shown for evaluation of LVEF ($r=0.91$; $P<0.0001$). Agreement for assessment of regional wall motion was excellent (96%, $\kappa=0.82$).

Conclusions: Accurate assessment of global and regional LV function and volumes is feasible with 64-slice MSCT.

Introduction

Assessment of global and regional left ventricular (LV) function and volumes provides valuable information in patients with ischemic heart disease. Furthermore, LV ejection fraction (LVEF) is an important prognostic marker in coronary artery disease.[1] Non-invasive imaging modalities for the evaluation of global and regional LV function and volumes include single photon emission computed tomography (SPECT)[2], cardiac magnetic resonance imaging (CMR)[3] and two-dimensional (2D) echocardiography[4]. Over the past years, multi-slice computed tomography (MSCT) has proven to allow accurate non-invasive assessment of coronary artery disease.[5-7] In addition, since MSCT data acquisition is gated to the electrocardiogram (ECG), global and regional LV function and LV volumes can be derived from the same dataset. The feasibility of MSCT for the evaluation of LV function has been investigated for 4-slice and 16-slice MSCT.[8-11] However, the accuracy of 64-slice MSCT for the evaluation of global and regional LV function and volumes has not yet been investigated. The recently introduced 64-slice systems have even higher temporal and spatial resolution and allow the acquisition of high-resolution 3D images of the entire heart in less than 10 seconds. Assessment of global and regional LV function and LV volumes with MSCT, in addition to non-invasive evaluation of the coronary arteries in patients with known or suspected CAD, will optimize evaluation of patients with CAD.

The purpose of the present study was to validate the assessment of global and regional LV function and LV volumes with 64-slice MSCT, using 2D echocardiography as the reference standard for these parameters.

Methods

Patients and study protocol

Forty patients with known or suspected CAD underwent 64-slice MSCT to assess potential coronary artery stenoses. The study population consisted of 28 men and 12 women, with a mean age of 60±12 years. Fourteen patients had a history of previous myocardial infarction. A total of 26 (65%) patients used beta-blocking agents. Clinical characteristics of the study population are summarized in **Table 1**.

From the same dataset as used for the evaluation of the coronary arteries, regional LV function, LV ejection fraction and LV volumes were assessed and compared with 2D echocardiography. 2D echocardiography and MSCT were performed within one month of each other. Patients with (supra-) ventricular arrhythmias were excluded, as well as patients with renal insufficiency (serum creatinine >120 mmol/l) and known allergy to iodine contrast media. All patients provided informed consent to the study protocol, which was approved by the local ethics committee.

Table 1. Clinical characteristics of the study population (n=40).

Characteristic	
Age (yrs)	60 ± 12
Men	28 (70%)
History of myocardial infarction	14 (35%)
Location	
Anterior	10 (71%)
Inferior	2 (14%)
Both*	2 (14%)
Q wave on electrocardiogram	9 (23%)
Multi-vessel CAD	8 (20%)
Angina pectoris	
CCS class I/II	38 (95%)
CCS class III/IV	2 (5%)
Heart failure	
NYHA class I/II	37 (93%)
NYHA class III/IV	3 (8%)

** Two patients had two previous myocardial infarctions.*
CAD = coronary artery disease; CCS = Canadian Cardiovascular Society; NYHA = New York Heart Association

MSCT

Data acquisition

MSCT examinations were performed with a 64-slice Toshiba Multi-slice Aquilion 64 system (Toshiba Medical Systems, Otawara, Japan). Collimation was 64x0.5 mm and rotation time was 400 or 450 ms, depending on heart rate. Tube current and voltage were 300 mA and 120 kV, respectively. Total amount of contrast (Iomeron 400, Altana, Konstanz, Germany) was 80 ml, followed by a saline flush of 40 ml. To time the scan, automated detection of peak enhancement in the aortic root was used. All images were acquired during an inspiratory breath hold, while the ECG was recorded simultaneously for retrospective gating of the data. To assess LV function and LV volumes, 5.0-mm slices were reconstructed in the short-axis orientation at 20 time points, starting at early systole (0% of cardiac cycle) to end-diastole (95% of cardiac cycle) in steps of 5%. Consequently, images were transferred to a remote workstation with dedicated cardiac function analysis software (CMR Analytical Software System, Medis, Leiden, The Netherlands).

Data analysis

To determine LV function, an independent observer outlined endocardial borders manually on the short-axis cine images. The papillary muscles were regarded as being part of the left ventricular cavity. The LV end-diastolic (LVEDV) and LV end-systolic (LVESV) volumes were calculated and the LV ejection fraction (LVEF) was derived by subtracting the end-systolic volume from the end-diastolic volume and dividing the result by the end-diastolic volume. The regional wall motion was assessed visually using the short-axis slices, by two observers blinded to all other data using a 17-segment model.[12] A 3-point scoring system was used to assign to each segment a wall motion score: 1=normokinesia, 2=hypokinesia, 3=a- or dyskinesia. For reconstruction of the scan in short

axis cineloops, subsequent delineation of the endocardial contours and analysis of LV volumes and regional function approximately 15 to 20 minutes was needed.

2D echocardiography

For comparison of LVEF and LV volumes, harmonic 2D echocardiography was performed. Patients were imaged in the left lateral decubitus position with a commercially available system (Vingmed Vivid-7, GE-Vingmed, Milwaukee, Wisconsin, USA). Images were acquired using 3.5-MHz transducer at a depth of 16 cm in the parasternal view and apical 2- and 4-chamber views. From the apical 2- and 4-chamber views, the LV volumes were derived and LVEF using the biplane Simpson's rule.[13] Regional wall motion was scored using the same 17-segment model and 3-point scoring system as described for MSCT. LV function was assessed by an experienced cardiologist, who was blinded to the results of MSCT.

Statistical analysis

Continuous data are expressed as mean±SD. Agreement for LV volumes and global LV function by MSCT and echocardiography was determined by Pearson's correlation coefficient and Bland-Altman analysis.[14] The 95% limits of agreement were defined as the range of values ±2 SDs from the mean value of differences. Agreement between findings on 2D echocardiography and MSCT for assessment of regional LV function was calculated and κ values were determined (<0.4 poor agreement, 0.4 to 0.75 fair to good, and >0.75 excellent).[15] A P-value <0.05 was considered statistically significant.

Results

Left ventricular end-diastolic volume

The mean LVEDV was 159±54 ml (range 97 to 343 ml) on 2D echocardiography, as compared to157±59 ml (range 73 to 336 ml) on MSCT. An excellent correlation was demonstrated using linear regression analysis (r=0.97, P <0.0001) (**Figure 1A**). At Bland-Altman analysis, the mean value of differences for MSCT was 1.8 ml, with 95% limits of agreement ranging from –28.2 to 31.8 ml (**Figure 1B**). The intra-observer variability (mean difference±SD) for LVEDV was 1.7±7.6 ml.

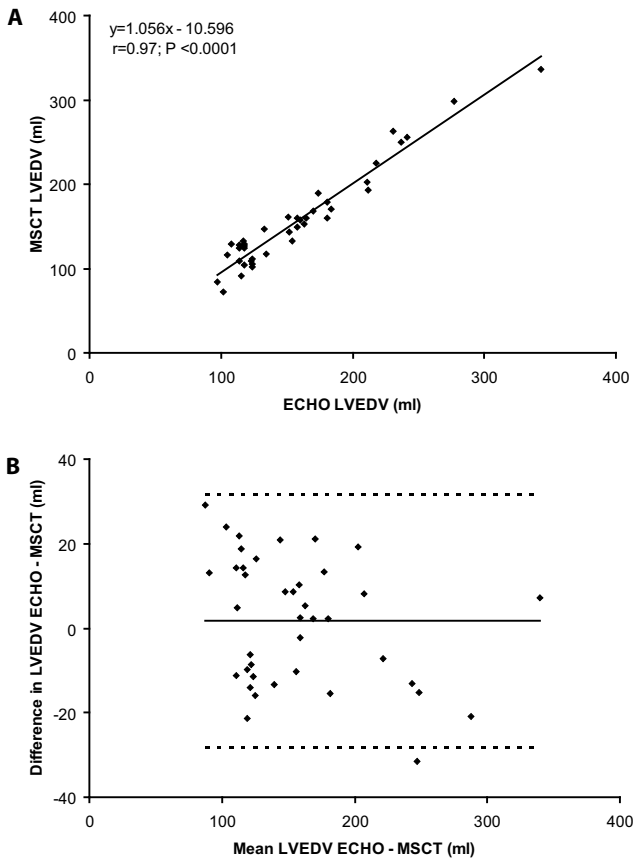

Figure 1. (A)Linear regression plot shows correlation between left ventricular end-diastolic volume (LVEDV) as measured by MSCT and 2D echocardiography. (B) Bland-Altman plot of LVEDV shows the difference between each pair plotted against the average value of the same pair, i.e. mean value of differences (solid line) and mean value of differences±2 SDs (dotted lines).

Left ventricular end-systolic volume

The mean LVESV was 78±46 ml (range 33 to 229 ml) on 2D echocardiography, as compared to 74±47 ml (range 18 to 224 ml) on MSCT. The correlation coefficient for this parameter was excellent, r=0.98, P <0.0001 (**Figure 2A**) . Bland-Altman analysis demonstrated a mean value of differences for MSCT of 4.2 ml, with 95% limits of agreement ranging from –13.9 to 22.3 ml (**Figure 2B**). The intra-observer variability (mean difference±SD) for LVESV was 1.0±6.2 ml.

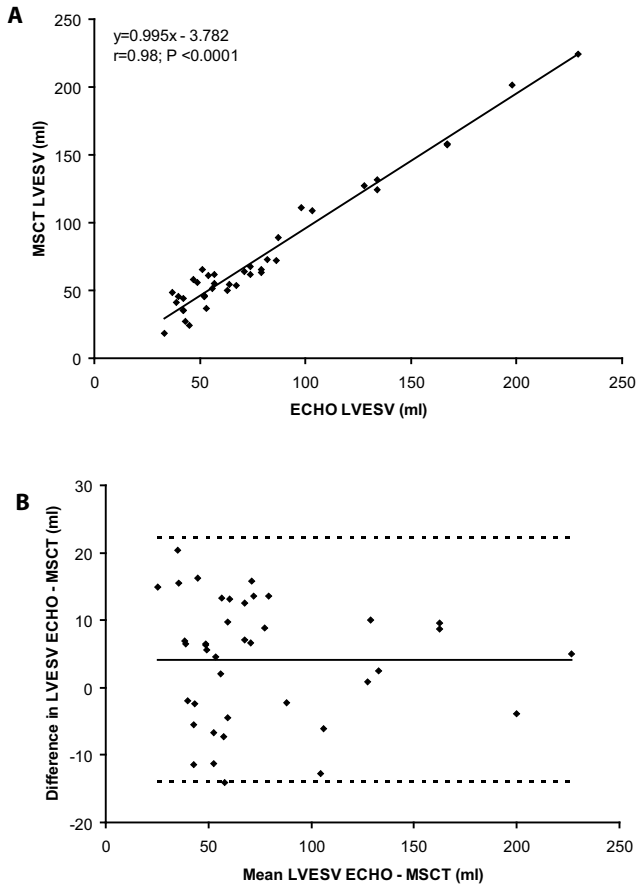

Figure 2. (A) Linear regression plot shows correlation between left ventricular end-systolic volume (LVESV) as measured by MSCT and 2D echocardiography. (B) Bland-Altman plot of LVESV shows the difference between each pair plotted against the average value of the same pair, i.e. mean value of differences (solid line) and mean value of differences±2 SDs (dotted lines).

Left ventricular ejection fraction

The mean LVEF was 53±11% (range 16 to 73%) on 2D echocardiography, as compared to 56±12% (range 19 to 79%) on MSCT. Pearson's regression analysis demonstrated an excellent correlation, with a correlation coefficient of 0.91, P <0.0001 (**Figure 3A**) . Bland-Altman analysis showed a mean value of differences of -2.5%, and the 95% limits of agreement ranged from –12.2 to 7.3% (**Figure 3B**). The intra-observer variability (mean difference±SD) for LV ejection fraction was -0.93±3.2%.

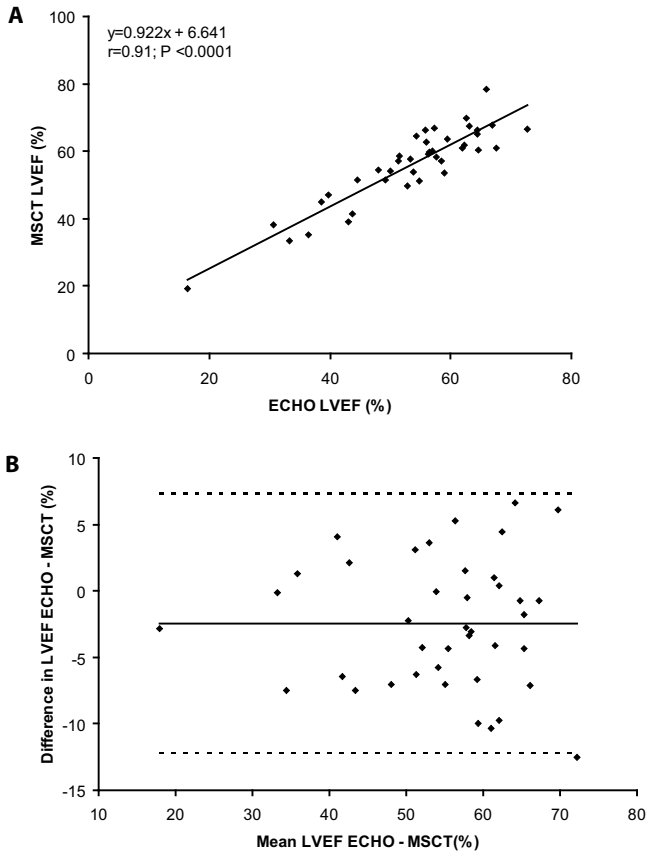

Figure 3. (A) Linear regression plot shows correlation between left ventricular ejection fraction (LVEF) as measured by MSCT and 2D echocardiography. (B) Bland-Altman plot of LVEF shows the difference between each pair plotted against the average value of the same pair, i.e. mean value of differences (solid line) and mean value of differences±2 SDs (dotted lines).

Regional wall motion

At 2D echocardiography, regional wall motion abnormalities were detected in 88 (13%) of 680 segments, with 47 segments showing hypokinesia and 41 segments a- or dyskinesia. In 74 (84%) segments decreased wall motion was also observed on the MSCT images (**Table 2**). An excellent agreement was shown between the 2 techniques, with 96% of the segments scored identically on both modalities (κ=0.82). Agreements for the individual gradings for the regional wall motion (normokinesia, hypokinesia, and a -or dyskinesia) were 99%, 70%, and 78%, respectively. An example of a patient with normal LV function, without wall motion abnormalities is shown in **Figure 4.** An example of a patient with abnormal wall motion is provided in **Figure 5.**

Table 2. Agreement between 2D echocardiography and MSCT in the evaluation of wall motion abnormalities (96%, κ=0.82).

	MSCT			
2D echo	**1**	**2**	**3**	**Total**
1	**587**	5	0	592
2	13	**33**	1	47
3	1	8	**32**	41
Total	601	46	33	680

1=normokinesia; 2=hypokinesia; 3=a- or dyskinesia

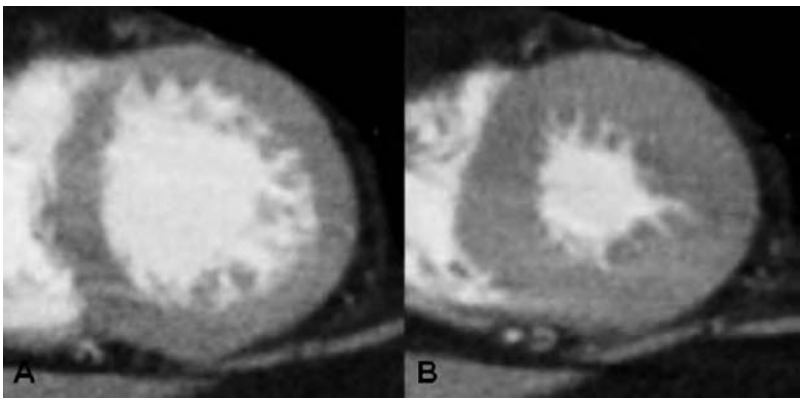

Figure 4. Short-axis MSCT images of a patient with normal wall motion, (A) diastole and (B) systole.

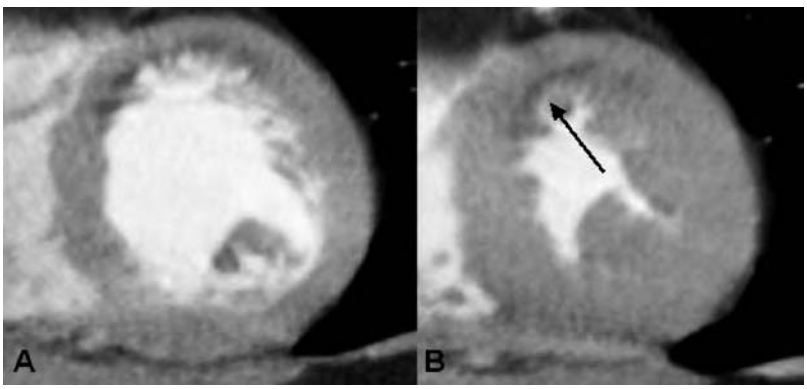

Figure 5. Short-axis MSCT images of a patient with abnormal wall motion, (A) diastole and (B) systole. Reduced wall thickening is shown in the anteroseptal region (black arrow).

Discussion

Assessment of global and regional LV function and LV volumes is essential in the evaluation of patients with CAD. These parameters provide important information for clinical diagnosis, risk stratification, therapeutic strategy and prognosis, as has been shown previously in numerous scintigraphic studies.[16 17] In the present study the purpose was to validate the assessment of global and regional LV function and LV volumes with 64-slice MSCT in patients with known or suspected CAD, using 2D echocardiography served as reference standard for these parameters.

Our results show excellent correlations between MSCT and 2D echocardiography for LVEDV, LVESV and LVEF. The overall agreement of regional wall motion was excellent, with 96% of the segments scored identically on both imaging modalities (κ=0.82). The agreements for the individual gradings of regional wall motion (normokinesia, hypokinesia, and a- or dyskinesia) were 99%, 70%, and 78%, respectively. It should be noted however, that LV ejection fraction was well preserved in the majority of our study population, and limited wall motion abnormalities were present. This could reduce the correlation between the 2 techniques in general practice. To our knowledge, this is the first study to compare 64-slice MSCT with 2D echocardiography for the evaluation of LV function and LV volumes.

In a previous study from our institution, Dirksen et al.[8] demonstrated an excellent correlation for the LVEF as assessed by 4-slice MSCT and 2D echocardiography (r=0.93; P <0.001), and an excellent agreement for regional function (88%, κ=0.84). Juergens et al.[10] compared 4-slice MSCT with CMR for the evaluation of LV function. Both for LVEDV and LVESV, the correlation between both imaging modalities was excellent (r=0.93; P <0.001 and r=0.94; P <0.001 respectively). In addition, the correlation coefficient for LVEF was good (r=0.89, P <0.001). More recently, global LV function and LV volumes were investigated by Heuschmid et al.[18] using 16-slice MSCT and compared with CMR. The authors demonstrated a good agreement between the two techniques for assessing these LV parameters. Similarly, Kim et al.[19] showed that LV function measurements as derived from 16-slice MSCT correlated well with 2D echocardiography. The findings in the current study with 64-slice MSCT technology extrapolate these earlier findings with 4- and 16-slice MSCT.

In the present study an underestimation of LVEDV by MSCT was observed compared to 2D echocardiography. Recent studies[20 21] suggested that low-power contrast echocardiography is more accurate than unenhanced harmonic echocardiography for the assessment of LVEDV and LVESV as compared to CMR as gold standard. In both studies, LV volumes were underestimated by contrast enhanced echocardiography compared with CMR. Extrapolating these observations to the present study would suggest a further underestimation of LV volumes. Nevertheless, Yamamuro et al.[22] showed a good correlation for the assessment of LV volumes and LV function between 8-slice MSCT and CMR. A direct comparison between 64-slice MSCT and CMR is needed to investigate the performance of 64-slice MSCT for the assessment of LV volumes and LV function.

Some limitations of the present study should also be addressed. Firstly, MSCT (a 3D technique) was compared to 2D echocardiography, and a comparison between MSCT and CMR (both 3D techniques) would have been more appropriate. Nevertheless, the agreement between MSCT

and 2D echocardiography was good for assessment of the different LV parameters. Also, 2D echocardiography is the most frequently applied technique in the clinical setting, but still direct comparison between 64-slice MSCT and CMR needs to be performed in future studies.
Secondly, general disadvantages of MSCT include the use of potentially nephrotoxic contrast and the relatively high radiation dose. The ongoing development of MSCT in order to improve spatial and temporal resolution, may lead to an increased radiation burden. Adjustments in imaging protocols are warranted to keep the radiation exposure within limits.

Conclusions

In summary, this study demonstrates the feasibility to assess global and regional LV function and LV volumes with 64-slice MSCT in patients with known or suspected CAD. This information can be derived from the same data acquisition as used for the non-invasive evaluation of the coronary arteries.

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