Assessment of left ventricular ejection fraction: comparison of two dimensional echocardiography, cardiac magnetic resonance imaging and 64-row multi-detector computed tomography

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Objectives To compare left ventricular ejection fraction (LVEF) determined from 64-row multi-detector computed tomography (64-row MDCT) with those determined from two dimensional echocardiography (2D echo) and cardiac magnetic resonance imaging (CMR). Methods Thirty-two patients with coronary artery disease underwent transthoracic 2D echo, CMR and contrast-enhanced 64-row MDCT for assessment of LVEF within 48 hours of each other. 64-row MDCT LVEF was derived using the Syngo Circulation software; CMR LVEF was by Area Length Ejection Fraction (ALEF) and Simpson method and 2D echo LVEF by Simpson method. Results The LVEF was 49.13 ± 15.91% by 2D echo, 50.72 ± 16.55% (ALEF method) and 47.65 ± 16.58% (Simpson method) by CMR and 50.00 ± 15.93% by 64-row MDCT. LVEF measurements by 64-row MDCT correlated well with LVEF measured with CMR using either the ALEF method (Pearson correlation r = 0.94, P < 0.01) or Simpson method (r = 0.92, P < 0.01). It also correlated well with LVEF measured using 2D echo (r = 0.80, P < 0.01). Conclusion LVEF measurements by 64-row MDCT correlated well with LVEF measured by CMR and 2D echo. The correlation between 64-row MDCT and CMR was better than the correlation between 2D echo with CMR. Standard data set from a 64-row MDCT coronary study can be reliably used to calculate the LVEF. (J Geriatr Cardiol 2006; 3(1): 2-8)

Key Words: ejection fraction; echocardiography; magnetic resonance imaging; computed tomography

Introduction

Left ventricular ejection fraction (LVEF) is an important piece of clinical information in the diagnosis and management of heart disease because of its prognostic significance. Patients with a low ejection fraction have a poorer outcome. Different methods have been used to determine left ventricular (LV) volumes, ejection fraction (EF) and regional wall motion abnormalities. The most commonly used method is the 2-dimensional echocardiography (2D echo). Ejection fraction determined by 2D echo can be calculated with either the Teichroiz or Simpson methods, depending on the preferred method by the individual institution. The accuracy of 2D echo, however, is dependent on the echocardiographic window which must be good enough to allow a sharp delineation of the endocardial border.

Recently, cardiac magnetic resonance imaging (CMR) has been used to measure LVEF and LV volumes, as it now has sufficient spatial resolution. Indeed both 2D echo and CMR assessments of LV function have been shown to correlate well with that obtained from invasive left ventriculography in the catheterization laboratory.

16-row multidetector computed tomography (16-row MDCT), when used to assess coronary arteries, can potentially provide information about LV function as well from the same data set acquired. However LVEF calculated using 16-row MDCT showed variable accuracies of correlation with 2D echo or CMR in the assessment of LV function.

The 64-row MDCT is an emerging cardiac imaging tool for the detection of coronary artery disease. Similar to the
16-row MDCT, data acquired during a coronary study can be used to determine LVEF and analyze regional wall motion but with an improved temporal and spatial resolution. So far, there has been no information on the accuracy of LVEF determined from 64-row MDCT as compared to CMR using solely left ventricular opacification values in a 3D CT data set.

Presently a newly developed software for the evaluation of the left ventricular volume and ejection fraction (Syngo Circulation® on Leonardo Workstations, Siemens Medical Solution, Germany) is available which highlights the left ventricle based on intra-ventricular contrast opacification. This method of LVEF measurement is different from the previous published reports of left ventricular function assessment by 16-row MDCT in which the left ventricle endocardial borders were manually traced.10

The objective of this study was to compare the accuracy of LVEF measurement by 64-row MDCT using the Syngo Circulation® with those measured by 2D echo and CMR.

Patients and method

Patients
Thirty-two (31 male and 1 female) patients from the outpatient cardiac clinic, aged 56.5 ± 9.7 years, with known coronary artery disease underwent 64-row MDCT scanning. Eight patients had a past history of myocardial infarction, 6 had undergone percutaneous coronary intervention and 9 had undergone coronary artery bypass graft (CABG) surgery. Five patients had diabetes mellitus and 9 had hypertension. Indications for cardiac MDCT study was angina or suspected graft disease. Both 2D echo and CMR were performed within 48 hours of the 64-row MDCT examinations. All patients gave written informed consent and the study protocol was approved by the local ethics committee.

64-row MDCT scan
All patients were scanned on a 64 MDCT scanner (Somatom Sensation 64 Cardiac, Siemens, Germany). A CT volume data set was acquired covering the region from the pulmonary hilum (for native vessels) or aortic arch (for grafts) to the diaphragmatic surface of the heart. CT gantry rotation time was 330 ms. Tube voltage and effective tube current-time product were 120 kV and 900 mA, respectively.

Contrast ( Ultravist 370, Schering, Germany) was continuously injected at a rate of 5ml/sec followed by a saline injection of 50 ml at a flow rate of 5 ml/sec. As soon as the signal density in the ascending aorta reached a predefined threshold of 100 Hounsfield units (HU), the patient was instructed to maintain an end-inspiratory breath hold during which the CT volume data set and ECG trace were acquired.

For this study, an effective slice thickness of 3 mm and a reconstruction increment of 3 mm were applied for axial image reconstruction using an ECG-gated half-scan reconstruction algorithm. The data set reconstruction was performed at every 10% from 0-90% of the cardiac cycle resulting subsequeently in 10 image stacks of the cardiac cycle for the use of 4D visualization and evaluation. The data was then analyzed using the Syngo Circulation® software. The end-diastolic and end-systolic phases were determined by finding the R-R intervals which showed the largest and smallest LV dimensions respectively. The end-diastolic and end-systolic phase was confirmed by reviewing the entire R-R interval in increment of 10%. Four and two-chamber views as well as short axis views of the heart were created by using the 3D reference lines of the program. A reference plane was fixed at the mitral valve annulus. Based on intra-ventricular contrast opacification, the end-systolic volume (ESV) and end-diastolic volume (EDV) as well as the ejection fraction were automatically computed by this software and displayed graphically as well as stored in a report format (Fig.1 and Fig.2). The LVEF measurements using the Syngo Circulation® software were done by a cardiologist blinded to the results of the 2D echo and CMR.

Cardiac magnetic resonance imaging
A 1.5T Intera Release 9 MR scanner (Philips Medical Systems, Best, Netherlands) with a 5 element cardiac synergy
coil was used for CMR imaging. The cardiac imaging started with the survey scan followed by reference scan with SENSE. Subsequent scans were done with ECG-triggering, breath-hold and steady state free precision (SSFP) sequences. For the purpose of angulation a pseudo right anterior oblique view was scanned using the transversal survey view for planning. The second angulation was done by obtaining the pseudo 4 chamber view using the pseudo right anterior oblique view for the planning. The short axis view was scanned using the pseudo 4 chamber for the planning and the 4 chamber view was scanned using the mid short axis view. This was followed by scanning of the 2 chamber view using the 4 chamber view for planning. Multiple short axis views were taken to cover the entire LV cavity with 6 mm thickness without gap. This allowed the assessment of the LV cavity and LVEF with the Simpson method. The 4 chamber view allowed the assessment of the LV cavity and LVEF with the area length ejection fraction method (ALEF) (Fig. 3 and Fig. 4).

**2D Echocardiography**

2D echo was performed with the Agilent SONOS 5500 M2424A ultrasound system. The patients were examined with the ultrasound system while lying in the left lateral position. Image loops from 2-3 consecutive cardiac cycles were acquired and stored. Standard para-sternal long and short axis views as well as apical four and two chamber views were acquired. After manual tracing of the end-diastolic and end-systolic endocardial borders in the apical four chamber view, the end-diastolic and end-systolic left ventricular volumes and EF were determined automatically with the in-built software in the ultrasound system. The 2D echo was read by a cardiologist blinded to the results from the 64-row MDCT and CMR (Fig. 5).

![Fig. 2. 64-row multidetector computed tomography (MDCT) – 2-chamber view in systolic (left) and diastolic (right) phase used in the assessment of left ventricular ejection fraction with opacification of the intra-ventricular contrast](image)

![Fig. 3. Cardiac magnetic resonance imaging – four chamber view in systolic (left) and diastolic (right) phase used in the calculation of left ventricular ejection fraction (Area Length Ejection fraction, ALEF)](image)
Fig. 4. Cardiac magnetic resonance imaging (CMR) – multiple short axis view of systolic and diastolic phase used in the calculation of ejection fraction (Simpson method)

Fig. 5. 2D echo – four chamber view used in the assessment of left ventricular ejection fraction (Simpson method)
Statistical analysis

Statistical analysis was performed using the SPSS software package version 12.2. The baseline data, continuous data and difference in various parameters using various modalities are presented as mean ± standard deviation. Agreements between different modalities were made using Pearson correlation coefficients (r) and Bland Altman method.

Results

The mean ejection fraction was 49.13 ± 15.91% by 2D echo, 50.72 ± 16.55% by CMR (ALEF method), 47.65 ± 16.58% by CMR (Simpson method) and 50.00 ± 15.93% by 64-row MDCT.

Correlation in LVEF between 64-row MDCT and CMR

LVEF determined by 64-row MDCT correlated well with LVEF determined by CMR, using either the ALEF method or Simpson method (r = 0.94 and 0.92 respectively, both P<0.01; Fig. 6a and Fig. 6b). The mean difference in LVEF between 64-row MDCT and CMR (ALEF) was 0.72 ± 5.90%. The mean difference in LVEF between 64-row MDCT and CMR (Simpson) was -2.34 ± 6.70%. In the Bland-Altman analysis all the data were within ± 2SD of the mean difference for 64-row MDCT versus CMR (ALEF) and 94% for 64-row MDCT versus CMR (Simpson) (Fig. 7a and Fig. 7b).

Correlation in LVEF between 64-row MDCT and 2D echocardiography

LVEF determined by 2D echo correlated well with LVEF determined by 64-MDCT (r = 0.80, P<0.01). The mean difference in LVEF between echo and 64-MDCT was 2.34 ± 12.36% In the Bland-Altman analysis, 97% of the data were within ± 2SD of the mean difference for 2D echo versus 64-row MDCT (Fig. 8a and Fig. 8b).

Correlation between 2D echocardiography and CMR

LVEF determined by 2D echo correlated well with LVEF determined by CMR using either the ALEF method or Simpson method (r = 0.73 and 0.76 respectively, both P<0.01)( Fig. 9a and Fig. 9b). The mean difference in LVEF between echo and CMR (ALEF) was 1.65 ± 11.8%. In the Bland-Altman analysis 100% of the data were within ± 2SD of the mean difference for 2D-echo versus CMR (ALEF) and 94% for 2D echo versus CMR (Simpson) (Fig. 10a and Fig. 10b). The mean difference in LVEF between 2D echo and CMR (Simpson) was -1.41 ± 11.14%.

Discussion

Our results have demonstrated a very good and close...
correlation between LVEF measurements by 64-row MDCT using the Syngo Circulation © on Leonardo Workstations, Siemens Medical Solution, Germany compared to CMR.

We regarded CMR to be the ‘gold standard’ for evaluation of LV function and LVEF based upon previous published reports of correlation with contrast ventriculography and 2D echo.6-10 Furthermore CMR is non-invasive and does not entail exposure to radiation or nephrotoxic contrast agent.10 However, CMR is less readily available, is contra-indicated in the presence of certain metal implants and is difficult to perform if the patient has an irregular heart rate. In addition, compared with MDCT, CMR needs a much longer total examination time for the patient.

Other methods of LV function analysis such as nuclear uptake scans were expensive to maintain and not free of risks.21,22 The most frequently used imaging tool in daily clinical work is 2D echo. It is fast, non-invasive, widely available and, like CMR, does not expose patients to radiation or contrast agents. However, certain factors may impair the quality of echo images, for example, obesity and chronic lung disease. Echocardiography may not be ideal in these circumstances due to poor acoustic windows. Thus, LVEF assessment by 2D echo is not accurate if it is not possible to define the endocardial borders clearly.

Both the 16-row and 64-row MDCT have been used to accurately detect coronary disease in native vessels and bypass grafts.17-20,23,34 As our results have shown, the same data from a coronary study by 64-row MDCT can be used to generate images for the assessment of overall LV function with dedicated software, without additional risks or inconvenience to the patient. Indeed, compared to previous reports using 16-row MDCT,10,11 our study showed that there were excellent correlations between the LVEF measurements of ‘gold standard’ CMR. Furthermore LVEF assessment from a 3D CT data set using a dedicated software like the one described, is a simple and accurate and fast procedure – it took less than 5 minutes to complete each post-processing LVEF calculation using the Syngo Circulation © software.

However, there are some limitation of a 3D CT data set in that several parts of the cardiac cycle (as expressed by percentage intervals) have to be calculated (in this study in 10% steps) which might result in minimal deviations of the true end-systole and end-diastole positions captured as compared to 2D echo and CMR which are real-time. The R-R interval representing the end-systolic and end-diastolic phase is chosen by the computer automatically but the software allows the operator to accept or edit the recommended phase. Problems can also arise when remaining contrast in the right ventricle cause the software to include these volumes as well, which might affect the accuracy of the result.

Importantly, MDCT exposes the patient to radiation and contrast agents. And because of the risks associated with these, MDCT should not be used solely for the purpose of LV function assessment. On the other hand, if the 64-row MDCT is performed to analyze at the coronary arteries, the same data from the coronary study can be used to provide accurate information about the global left ventricular function and to determine the ejection fraction with the use of dedicated software.

Study Limitations

This was a small-size study including only 32 patients. Most of the patients were on treatment for coronary artery disease. This study assumes that the ejection fraction was stable and not acutely affected by treatment even though the tests were performed within 48 hours of each other.

Conclusion

64-row MDCT can be used to accurately measure the left ventricular ejection fraction using available data set derived from a routine coronary MDCT scan. A dedicated software is of great importance to speed up the assessment under clinical conditions and to ensure a seamless workflow as well as to reduce user dependent results.

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References


