Preliminary Report

Reliability of the Evaluation for Left Ventricular Ejection Fraction by ECG-Gated Multi-Detector CT (MDCT): Comparison with Biplane Cine Left Ventriculography

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Objective: *To evaluate the reliability of measurement for left ventricular ejection fraction (LVEF) by ECG-gated multi-detector CT (MDCT) comparing with biplane cine left ventriculography that is current gold standard.*

Material and Method: *The authors reviewed the data from 15 patients who were referred for coronary CT angiography for clinical indications and underwent cardiac catheterization within 14 days. Coronary CTA studies were performed on MDCT Somatom Sensation 16, Siemens, Germany, Slice thickness 1 mm, Slice collimation 0.75 mm, and Pitch 0.3. LVEF were measured with MDCT by Simpson's method and compared with values measured by biplane area length method from cardiac catheterization. The LVEF from both techniques were compared using intraclass correlation power analysis (SPSS analysis software).*

Results: *The study population consisted with six men and nine women with a mean age of 54 $\pm$ 10 years. The LVEF measured from MDCT and cine ventriculography were 54.7 $\pm$ 10% and 56.3 $\pm$ 10%, respectively. LVEF measured with MDCT by interpreter 1 and interpreter 2 was significantly correlated with LVEF measured with biplane cine ventriculography (ICC= 0.99 and 0.98, respectively). The interobserver reliability was excellent with ICC = 0.9.*

Conclusion: *LVEF measurement with MDCT during coronary CT angiography can be performed easily, very accurately, and compare well with measures taken from biplane cine left ventriculography.*

Keywords: *Left ventricular ejection fraction, Ejection fraction, Cardiac CT, MDCT*

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The assessment of left ventricular function, especially left ventricular ejection fraction (LVEF) is an important basis for clinical diagnosis, management decisions and follow up of various cardiac diseases[1,2]. Various noninvasive imaging modalities, such as echocardiography, nuclear scintigraphy, magnetic resonance imaging, and multi-detector computed tomography (MDCT) are used to determine left ventricular function[3,4].

Ventricular function in patients with coronary artery disease who undergo coronary angiography is conventionally assessed on biplane cine ventriculography. Although this method is limited by the geometric assumptions made from projection images, it is currently serving as a clinically accepted standard[5,6].

Recent studies show good correlation between function parameters derived from MDCT and other methods such as cine ventriculography and cardiac MRI[7-9].

The combination of non-invasive coronary artery imaging and assessment of cardiac function with a single breath hold by cardiac MDCT might be an interesting approach to a conclusive cardiac workup that served as one stop service in coronary artery disease patients. Functional information is inherently available in retrospective ECG-gated MDCT acquisitions at no extra cost in terms of scan time, radiation

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exposure and contrast administration to the patients and should be used if additional diagnostic information can be obtained.

The authors have performed more than 100 cases of cardiac MDCT and measured LV volume since 2003 but the accuracy data of MDCT measured LV volume has never been assessed in the authors' institution. Therefore, the present study is to compare LVEF measured with MDCT and biplane cine left ventriculography at King Chulalongkorn Memorial Hospital.

Material and Method

The data was collected between March 2005 and January 2006. Among 43 patients, the 15 patients, who underwent both cardiac MDCT and conventional coronary angiography with biplane cine ventriculography within 14 days, were recruited to the present study. These patients had a high suspicion of coronary artery disease (CAD) such as positive stress tests or high likelihood of CAD by clinical information. Informed consents were obtained from all participants. The present study was approved by the ethics committee of the Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand. Patients with irregular heart rhythms such as atrial fibrillation or ventricular arrhythmias, contraindication of iodinated contrast material administration, contraindication of beta-blocker agent administration (if needed) such as asthma, COPD, severe pulmonary hypertension, or renal insufficiency or creatinine level above 1.5 mmol/L were excluded.

Cardiac CT imaging examinations were performed by multi-detector computed tomography Somatom Sensation 16, Siemens, Germany (detector collimation 16 x 0.75mm, 600 mAs, 120 kVp).

The authors prepared the patients by recorded blood pressure, heart rate, and respiratory rate before performing cardiac CT. If the heart rate was > 65 bpm the authors reduced the heart rate by giving an oral beta-blocking agent (100 mg metoprolol 1 hour prior to the examination or adding 5 mg IV metoprolol to keep the heart rate below 65 bpm). If the heart rate was < 65 bpm, IV line with NSS was accessed by 18G or 20G needle, on the right arm. The patients were informed to practice breath holding for at least 25 seconds and assured for hot flush sensation of contrast medium during scanning.

Field of view (FOV) covered mid pulmonary trunk or carinal level to the level of 1 cm below the dome of the left hemidiaphragm during full inspiration. If the patient had bypass graft (s), the upper border of FOV must cover the subclavian artery (T2). The authors used 80 ml, 90 ml and 100 ml of 300 mg% I non-ionic contrast + 50 ml NSS chasing for the patients whose body weight was < 55 kilograms, > 55 kilograms, and by pass graft, respectively. The bolus tracking circle was placed at the ascending aorta in the axial plane at carina level.

Subsequently, the standard technique of cardiac catheterization and biplane cine ventriculography were performed within 14 days.

The available raw data cardiac MDCT and the recorded ECG tracing were transferred to a separate Wizard work station for retrospectively ECG-gated image reconstruction by means of a work-in-progress cardiac CT reconstruction software (Cardio recon, version 6, Siemens).

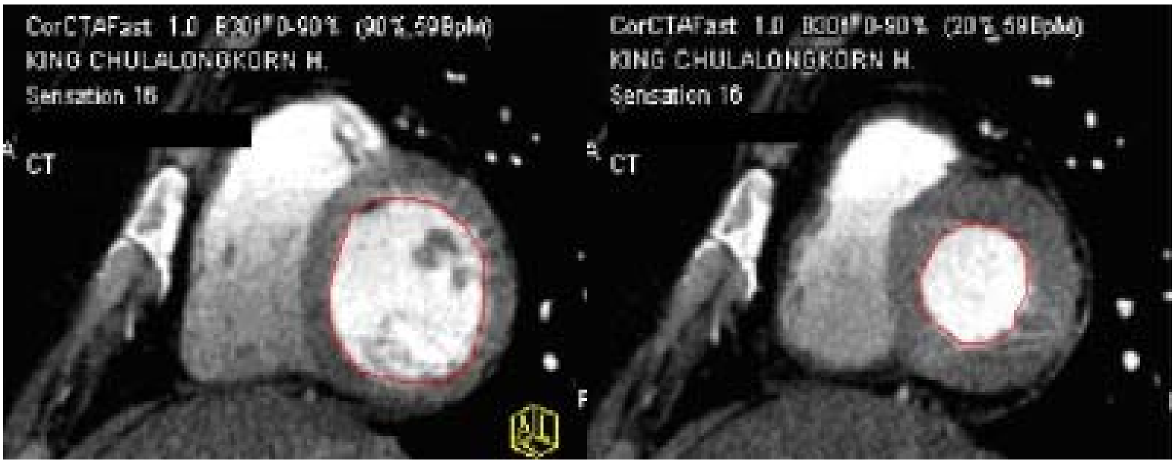
Using the workstation's standard three-dimensional software and the obtained multi-planar reformations according to the long and short axis of the left ventricle, a multi-planar reformation was obtained. It was done using the axial images in a long-axis orientation by using a plane parallel to the interventricular septum connecting the left ventricular apex and the middle level of mitral valve. This image was stored for further assessment. Then, the plane for creating multi-planar reformations was tilted perpendicular to the interventricular septum in the axial images. To obtain true short-axis images, the plane for image reformation was additionally adjusted parallel to the plane of the mitral valve in the long-axis view.

Using this geometry, multiple short-axis multi-planar reformations (10-12 slices) with a section thickness of 8 mm and no gap were produced to encompass the entire left ventricle from base to apex. Animated movies of these images can also be produced.

The maximal systolic contraction phase and diastolic phase as the images showing the smallest and the largest left ventricular cavity area, respectively were identified (Fig. 1). Diastolic and systolic left ventricular volumes were calculated by the Simpson's method applied to contiguous short-axis reformations of endocardial contours showing the left ventricular cavity[8,9]. Left ventricular volumes (V_L) were calculated by adding all measured cross-sectional areas (A_N) multiplied by the intersection thickness (S)

$$V_L = S\, A_N \times S$$

Interpretation of MDCT ventriculography was made by two interpreters who were unaware of the results from cine ventriculography. They independently performed MDCT data analysis. Biplane cine ventriculography was performed in standardized 60° left anterior oblique and 30° right anterior oblique pro-



A B

Fig. 1 Cardiac MDCT short axis: The diastolic phase (A) and systolic phase (B) are displayed. The LVEF was calculated to be 70%. Endocardial contours were manually traced (black-line circle) using planimetric software. Papillary muscles were included in the left ventricular cavity

jections[10] (Fig. 2). A cardiologist who was unaware of the MDCT results used the area-length method to analyze the cine ventriculograms.

The mean left ventricular ejection fraction as assessed from MDCT was compared with that found on biplane cine ventriculography using intraclass correlation power analysis, SPSS analysis software (version 10; Statistical Package for the Social Sciences, Chicago, IL). The intraclass correlation (ICC) close to 1.0 was considered good correlation and *p* value of less than 0.05 was considered significant.

Results

Short-axis reformation allowed clear delineation of endocardial contours in all cases. The study population consisted of six men and nine women with a mean age of 54 $\pm$ 10 years, mean body weight 68.4 $\pm$ 8.2 kilograms, and mean height 158 $\pm$ 6.5 cm (Table 1). The median time interval between cardiac MDCT and cine ventriculography was 12 days (3-14 days). Six patients received a beta-blocking agent prior to perform cardiac MDCT and nine patients did not receive it. Mean heart rate during MDCT scan in all patients was about 55-65 beats per minute. The LVEF measured by MDCT in both groups showed excellent correlation with cine ventriculography. (ICC = 0.99 and 0.98, respectively, $p < 0.05$) (Table 2).

LVEF measured with MDCT by interpreter 1 and interpreter 2 was significantly correlated with LVEF measured with biplane cine ventriculography (ICC = 0.99 and 0.98, respectively, $p < 0.05$), Fig. 3A and 3B. The interobserver reliability was minimal with ICC = 0.9, $p < 0.05$, Fig. 3C.

Table 1. Basic characteristics of 15 patients

	Mean $\pm$ SD (range)
Gender M:F	6:9 (40% : 60%)
Age (year)	59.0 $\pm$ 6.7 (47-69)
Body weight (kg)	69.4 $\pm$ 9.2 (58-95)
Height (cm)	159.9 $\pm$ 6.6 (144-172)

Table 2. LVEF measured with MDCT and biplane cine ventriculography

	MDCT	Cine ventriculography
Received Beta-blocker (n = 6)	54.6 $\pm$ 10%	57.5 $\pm$ 10%
Not received Beta-blocker	53.4 $\pm$ 10%	55.1 $\pm$ 10%
All patients	54.7 $\pm$ 10%	56.3 $\pm$ 10%

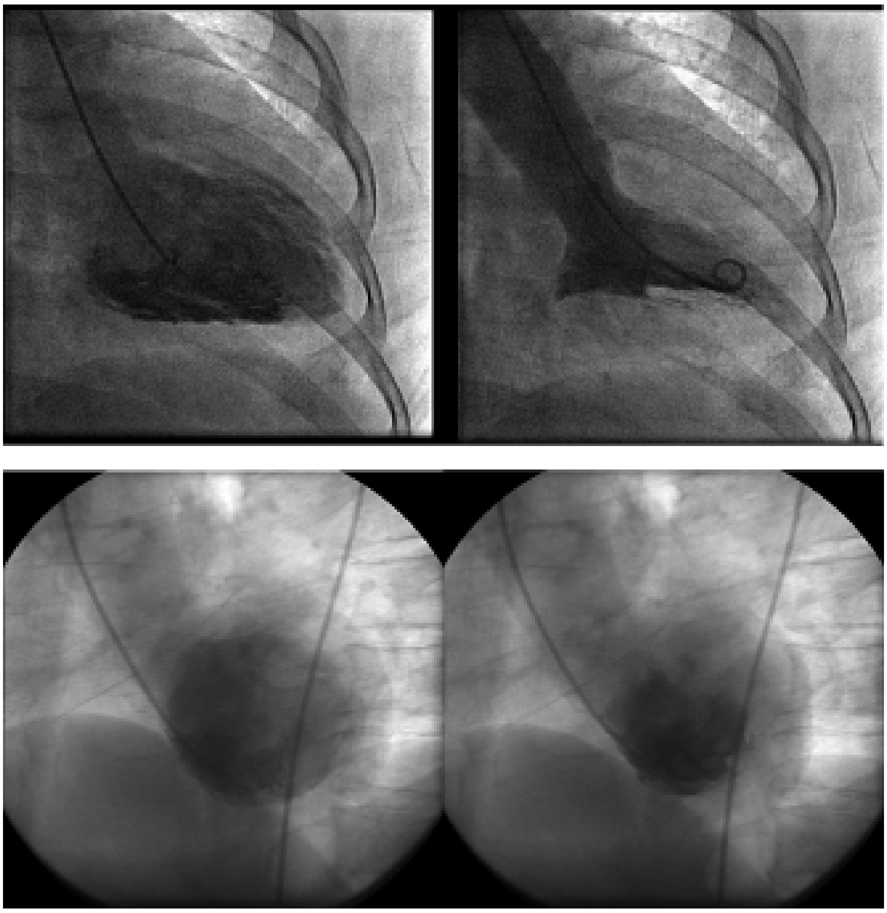


Fig. 2 (In the same patient in Fig. 1) Biplane cine left ventriculography is displayed in RAO 30 view (upper row) and LAO view 60 view (lower row). The diastolic and systolic phases are displayed in left and right columns, respectively. The LVEF was calculated to be 71%

Discussion

Recently introduced MDCT with subsecond rotation times and dedicated cardiac reconstruction algorithms have shown their capability to perform high resolution helical coronary CTA. The present results show that functional and temporal information contained in a cardiac MDCT study intended for cardiac imaging can be used to assess left ventricular volume, and ejection fraction with an excellent correlation with those from cine biplane left ventriculography.

Because of the radiation exposure and contrast administration, cardiac MDCT does not appear to be reasonable solely for analysis of cardiac function parameters. The combination of non invasive coronary artery imaging and assessment of cardiac function with a single breath-hold MDCT study, however, might be an interesting approach to a conclusive cardiac workup in patients with suspected coronary artery disease. Functional information is available in retrospective ECG-gated MDCT acquisitions at no extra cost in terms of scan time, radiation exposure, or contrast administration to the patients.

As previously shown, left ventricular function has correlated with cardiovascular outcomes and determined the treatments in coronary artery disease patients[1,2]. Therefore, the data on LV function will be complimentary to the data on coronary arterial luminal narrowing. This information can be obtained very fast with the current state-of-the-art analysis software. A previous study revealed that limitation of this CT technique to evaluate LVEF is a tendency of CT ventriculography to underestimate LVEF in patients with a higher heart rate. Theoretically, an insufficient time resolution underestimates end-diastolic volume, over-

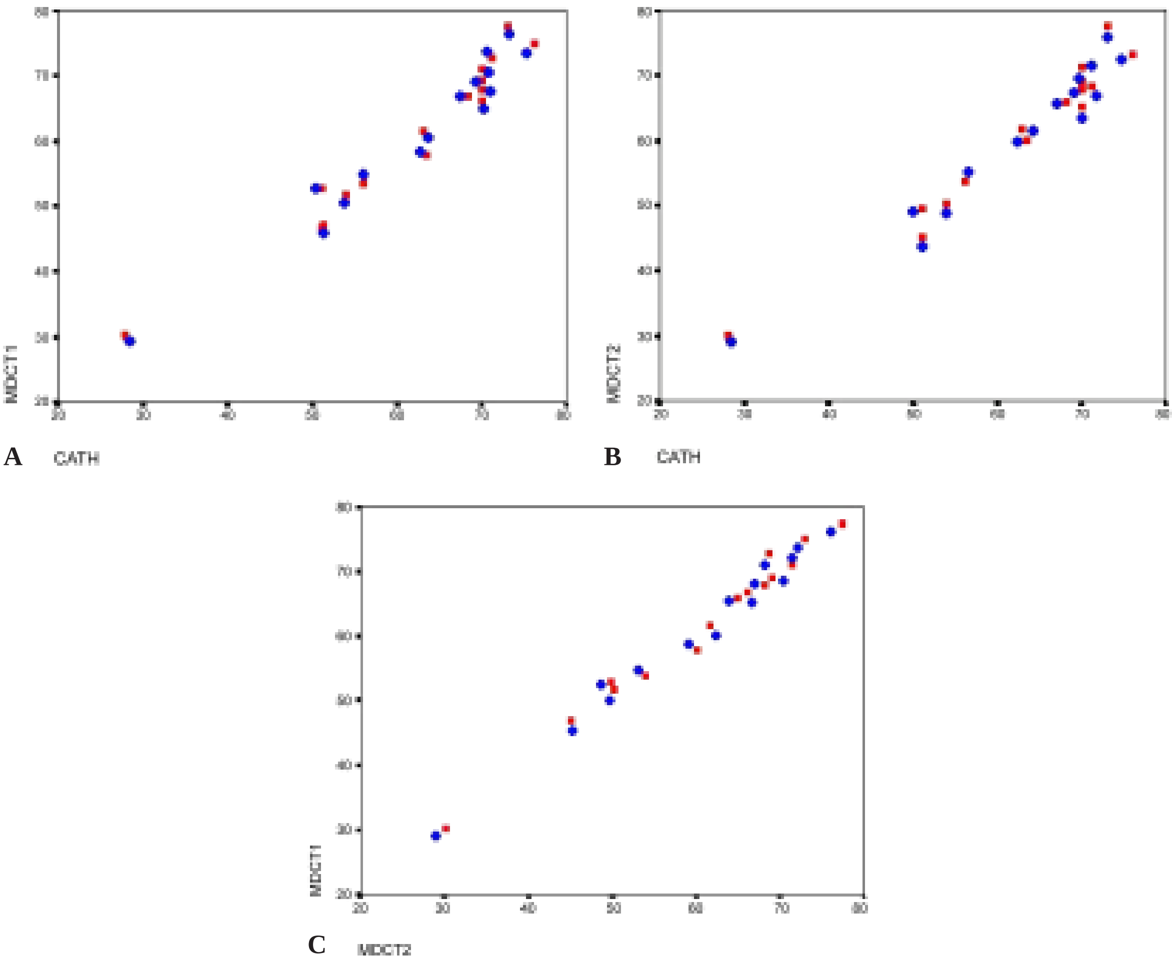


Fig. 3 Scatter diagrams show LVEF determined from cardiac MDCT and cine ventriculography by using intraclass correlation power analysis, SPSS analysis software (version 10; Statistical Package for the Social Sciences, Chicago, IL) LVEF measured with MDCT (squares) by interpreter 1 (A) and interpreter 2 (B) were significantly correlated with LVEF measured with biplane cine ventriculography (circles) (ICC = 0.99 and 0.98, respectively, $p < 0.05$). The interobserver reliability is excellent (C) with ICC = 0.9, $p < 0.05$. (interobserver 1: squares and interpretator 2: circles)

estimates end-systolic volume, and underestimates LVEF[11]. However, this problem was not found in the present study because the heart rate of all patients was below 65 beats per minute during the scan.

The authors concerned that the beta-blocker administration may cause lower LVEF in these patients. In the present study, six patients received a beta-blocking agent prior to the scan and nine patients did not. LVEF measured by MDCT in both seperate groups also showed excellent correlation with cine ventriculography. Similarly to previous studies, the present result showed either a minimal or no depressant effect of beta-blocker[11,12]. The present study did not examine the regional wall motion analysis, however, a few previous studies have shown that the regional wall motion determination has also good correlation with echocardiography and MRI[2-4].

Conclusion

LVEF measured with MDCT during coronary CT angiography can be performed easily and very accurately compared to that measured from biplane cine left ventriculography.

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ความน่าเชื่อถือของการวัดค่าการบีบตัวของหัวใจห้องล่างซ้าย จากการตรวจหัวใจโดยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด multidetector computed tomography ร่วมกับคลื่นไฟฟ้าหัวใจ เปรียบเทียบกับผลที่ได้จากการฉีดสารทึบรังสีผ่านสายสวนเพื่อประเมินการบีบตัวของหัวใจห้องล่างซ้าย

นฤมล เชาว์สุวรรณกิจ, ไพโรจน์ ฤกษ์พัฒนาพิพัฒน์, สมใจ หวังศุภชาติ, สุพจน์ ศรีมหาโชตะ

วัตถุประสงค์: *เพื่อประเมินความน่าเชื่อถือของการวัดค่าการบีบตัวของหัวใจห้องล่างซ้าย (LVEF)จากการตรวจหัวใจโดยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด multidetector computed tomography (MDCT)ร่วมกับคลื่นไฟฟ้าหัวใจ (ECG) เปรียบเทียบกับผลที่ได้จากการฉีดสารทึบรังสีผ่านสายสวนเพื่อประเมินการบีบตัวของหัวใจห้องล่างซ้าย (biplane cine left ventriculography) ซึ่งเป็นการตรวจมาตรฐานในปัจจุบัน*

วัสดุและวิธีการ: *รวบรวมข้อมูลผู้ป่วย 15 ราย ที่ได้รับการทำ cardiac MDCT และ ventriculogram ภายในระยะเวลาห่างกันไม่เกิน 14 วัน ค่า LVEF จาก cardiac MDCT วัดโดยวิธี Simpson เปรียบเทียบกับค่า LVEF ที่ได้จาก ventriculogram ซึ่งวัดโดยวิธี area length ประเมินโดย intraclass correlation (ICC) power analysis (SPSS analysis software)*

ผลการศึกษา: *ผู้ป่วย 15 ราย เพศชาย 6 ราย เพศหญิง 9 ราย อายุเฉลี่ย 54 $\pm$ 10 ปี ค่าเฉลี่ย LVEFจาก cardiac MDCT และจาก ventriculogram เท่ากับ 54.7 $\pm$ 10% และ 56.3 $\pm$ 10% ตามลำดับ ค่า LVEF จาก cardiac MDCT ซึ่งประเมินโดยผู้แปลผลคนแรกเปรียบเทียบกับค่าที่ได้จากผู้แปลผลคนที่สองมีค่าสัมพันธ์กันดีกับค่า LVEF ที่ได้จาก ventriculogram (ICC = 0.99 และ 0.98 ตามลำดับ) ความแตกต่างระหว่างค่า LVEF จาก cardiac MDCT ที่ได้จากผู้แปลผลทั้งสองมีค่าแตกต่างกันน้อยมาก (ICC = 0.9)*

สรุป: *การวัดค่า LVEF จาก cardiac MDCT เป็นวิธีที่ทำได้ง่ายและแม่นยำสูงเมื่อเปรียบเทียบกับค่า LVEF ที่ได้จาก ventriculogram*