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 ± 10 years. The LVEF measured from MDCT and cine ventriculography were 54.7 ± 10% and 56.3 ± 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

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.
exposure and contrast administration to the patients
and should be used if additional diagnostic informa-
tion 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’ insti-
tution. Therefore, the present study is to compare LVEF
measured with MDCT and biplane cine left ventricu-
lography 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 ventriculo-
graphy within 14 days, were recruited to the present
study. These patients had a high suspicion of coro-
nary 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 com-
mittee 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 per-
formed 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 car-
diac catheterization and biplane cine ventriculogra-
phy 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, ver-
sion 6, Siemens).

Using the workstation’s standard three-
dimensional software and the obtained multi-planar re-
formations 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 orien-
tation 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 en-
compass 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 ven-
tricular 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 (VL) were calculated
by adding all measured cross-sectional areas (A_n)
multiplied by the intersection thickness (S)

\[ V_L = \sum A_n \times S \]

Interpretation of MDCT ventriculography
was made by two interpreters who were unaware of
the results from cine ventriculography. They indepen-
dently performed MDCT data analysis. Biplane cine
ventriculography was performed in standardized 60°
left anterior oblique and 30° right anterior oblique pro-
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 ± 10 years, mean body weight 68.4 ± 8.2 kilograms, and mean height 158 ± 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.

![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.](image)

Table 1. Basic characteristics of 15 patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean ± SD (range)</th>
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<tbody>
<tr>
<td>Gender M:F</td>
<td>6:9 (40%:60%)</td>
</tr>
<tr>
<td>Age (year)</td>
<td>59.0 ± 6.7 (47-69)</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>69.4 ± 9.2 (58-95)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>159.9 ± 6.6 (144-172)</td>
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Table 2. LVEF measured with MDCT and biplane cine ventriculography

<table>
<thead>
<tr>
<th></th>
<th>MDCT</th>
<th>Cine ventriculography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Received Beta-blocker (n = 6)</td>
<td>54.6 ± 10%</td>
<td>57.5 ± 10%</td>
</tr>
<tr>
<td>Not received Beta-blocker</td>
<td>53.4 ± 10%</td>
<td>55.1 ± 10%</td>
</tr>
<tr>
<td>All patients</td>
<td>54.7 ± 10%</td>
<td>56.3 ± 10%</td>
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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\(^1\,\text{to}\,2\). 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-

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**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%
estimates end-systolic volume, and underestimates LVEF. 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 separate 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. 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.

**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.

**References**

1. Mochizuki T, Murase K, Higashino H, Koyama Y,


ความน่าเชื่อถือของการวัดค่าการปั๊มตัวของหัวใจห้องล่างซ้ายจากการตรวจหัวใจโดยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด multidetector computed tomography ร่วมกับคลื่นไฟฟ้าหัวใจ เปรียบเทียบกับผลที่ได้จากการจิตสารที่บริวารสันดานพื้นเพื่อประเมินการปั๊มตัวของหัวใจห้องล่างซ้าย

นฤมล เขาวัตร, สุพจน์ ศรีมหาโชติ, กมล สุภัตร, ไพโรจน์ ฤกษ์พัฒน์, สมใจ หวังศุภชาติ, ไพโรจน์ ฤกษ์พัฒน์, สมจPremium สรุป

วัตถุประสงค์: เพื่อประเมินความน่าเชื่อถือของการวัดค่าการปั๊มตัวของหัวใจห้องล่างซ้าย (LVEF)จากการตรวจหัวใจโดยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด multidetector computed tomography (MDCT)ร่วมกับคลื่นไฟฟ้าหัวใจ (ECG) เปรียบเทียบกับผลที่ได้จากการจิตสารที่บริวารสันดานพื้นเพื่อประเมินการปั๊มตัวของหัวใจห้องล่างซ้าย (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 ± 10 ปี ค่าเฉลี่ย LVEF จาก cardiac MDCT และจาก ventriculogram เป็น 54.7 ± 10% และ 56.3 ± 10% ตามลำดับ ค่า LVEF จาก cardiac MDCT ซึ่งประเมินโดยผู้แปลผลคนแรกมีความสัมพันธ์กับค่า LVEF จาก cardiac MDCT ที่ได้จาก ventriculogram (ICC = 0.99 และ 0.98 ตามลำดับ) ความแตกต่างระหว่างค่า LVEF จาก cardiac MDCT ที่ได้จากผู้แปลผลคนแรกมีค่าแตกต่างกันน้อยมาก (ICC = 0.9)

สรุป: การวัดค่า LVEF จาก cardiac MDCT เป็นวิธีที่ทำได้ง่ายและแม่นยำสูงเมื่อเปรียบเทียบกับค่า LVEF ที่ได้จาก ventriculogram