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Technical report

Left ventricular ejection fraction measurement using cardiovascular magnetic resonance imaging in patients with post-myocardial infarction: assessment of reproducibility by a cardiovascular radiologist and a trained technologist

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Background: Cardiovascular magnetic resonance imaging (CMR) has recently been accepted as a preferential method for evaluation left ventricular ejection fraction (LVEF). The LVEF analysis by CMR is usually performed by trained technologists in many institutions of Thailand.

Objective: Assess the reproducibility of LVEF measured by a cardiovascular radiologist and a trained technologist using CMR in patients with post-myocardial infarction (MI).

Methods: Twenty-one MI patients (18 men and 3 women) were recruited, where nine patients underwent CMR and left ventriculography to follow-up LVEF two times in six months. Both CMR and left ventriculography were examined within two weeks. LVEF from CMR were measured by a cardiovascular radiologist and a trained technologist and the correlation between the left ventriculography and CMR was determined.

Results: In 30 CMR studies, interobserver reliability (intraclass correlation coefficient ICC=0.94) and intraobserver reliability (ICC=0.96) was excellent. LVEF measured by left ventriculography was higher compared with that by CMR, and their correlation was moderate (ICC=0.56).

Conclusion: The LVEF measurement by a cardiovascular radiologist and a trained technologist using CMR was very reproducible, but the correlation between CMR and left ventriculography was moderate.

Keywords: Cardiovascular magnetic resonance imaging (CMR), cardiovascular radiologist, left ventricular ejection fraction, left ventriculography, myocardial infarction, trained technologist

Left ventricular ejection fraction (LVEF) calculation is an important indicator for determination of cardiac prognosis in patients with myocardial infarction (MI) [1, 2]. In MI patients, left ventriculography is usually performed during diagnostic coronary angiography for the LVEF measurement [3-5].

Cardiovascular magnetic resonance imaging (CMR) is one of initial investigations for assessment of LVEF and myocardial viability in MI patients. CMR provides a good-quality image owing to its high spatial resolution and an accurate determination of left ventricular (LV) volume owing to its complete volumetric data [1, 5].

In practice, the LV volume measurement is assessed by drawing of the endocardial border on the CMR image at end-systolic and end-diastolic phases. This method LVEF measurement by CMR is time-consuming. In addition, this procedure is complicated in MI patients with abnormal LV contraction due to the regional wall motion abnormality.

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The LV volume analysis is usually performed by trained technologists in many institutions of Thailand. In this study, we assessed the reproducibility of LVEF measurement by a cardiovascular radiologist and a trained technologist using CMR in MI patients, and examined the correlation between CMR and left ventriculography.

Material and method

The study was approved by the Ethics Committee of Faculty of Medicine, Chulalongkorn University.

Twenty-one MI patients were recruited at King Chulalongkorn Memorial Hospital. All patients gave written informed consent. The patient underwent both left ventriculography and CMR within two weeks. We excluded patients who had severe arrhythmia and contraindication for MRI examination such as aneurysm clips, pacemaker, severe claustrophobia, and new event of acute coronary syndrome between the period of left ventriculography and CMR.

CMR imaging

Patients were examined by 1.5 Tesla MR scanner (MR Signa Excite HD, GE, USA) with eight-channel cardiac coil placed over their chest. After survey scout images, ECG-gated, breath-holding steady-state free precession (SSFP) cine imaging (repetition time: 3.9 millisecond, echo time: 1.7 millisecond, flip angle: 45°, matrix: 224x224, field of view: 360x288 mm, and section thickness: 8 mm without intersection gap) was performed in the multislice short axis view throughout the entire left ventricle. The raw data available for CMR was transferred to a workstation with the conventional software.

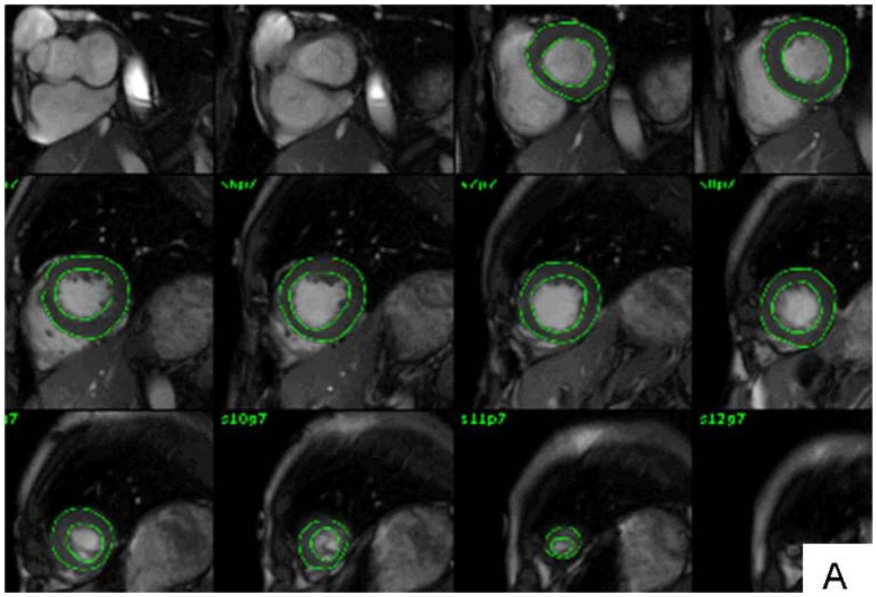
A cardiovascular radiologist and a trained technologist independently reviewed the images. The endocardial borders of the left ventricle in the standard short axis images were traced manually from below the level of mitral valve opening down to LV apex in end-systolic and end-diastolic phases as shown in **Figure 1**.

The papillary muscles were included in the LV cavity [6, 7]. End-diastolic and end-systolic phases were defined visually as the phases of largest LV volume and smallest LV volume, respectively [2]. Left ventricular end diastolic volume (LVEDV) and left ventricular end systolic volume (LVESV) were determined by integrating these areas and multiplying by slice thickness. Left ventricular ejection fraction (LVEF) was automatically calculated from the formula as follows:

$$\text{LVEF (\%)} = \frac{\text{(LVEDV – LVESV)}}{\text{LVEDV}} \times 100\%$$

Left ventriculography

Left ventriculography was performed with a pigtail catheter (6 Fr) in standardized 30° right anterior oblique projection. LVEF measurement was calculated with area-length method by a cardiologist who was unaware of the CMR results. **Figure 2** shows left ventriculography at the systolic and diastolic phases.



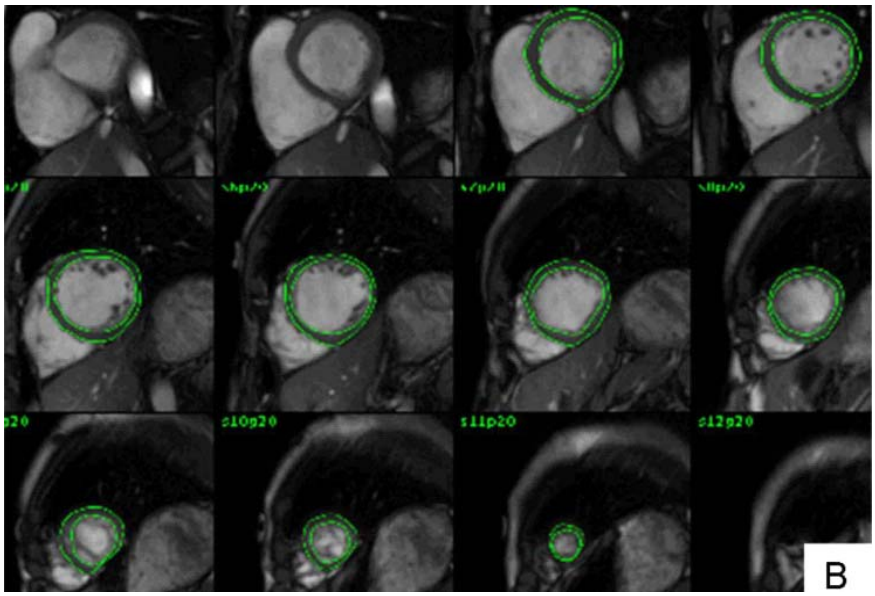


Figure 1. A multislice short axis view CMR of the left ventricle in 47-year-old male MI patient. Endocardial contour delineation in end-systolic phase (A) and end-diastolic phase (B) by inclusion of the papillary muscles in the left ventricular cavity. The endocardial borders of the left ventricle were traced manually. The left ventricular ejection fraction (LVEF) was 47.5%.

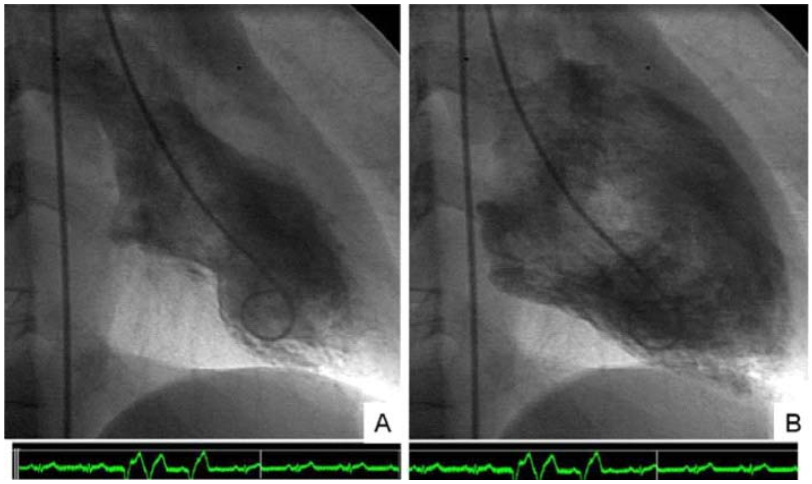


Figure 2. Left ventriculography at the end systolic and end diastolic phases in the same patient. The left ventriculography was displayed in 30 degree right anterior oblique view on systolic phase (A) and diastolic phases (B). The left ventricular ejection fraction (LVEF) determined by area-length method was 56%.

Statistic analysis

The interobserver reliability was assessed by comparing the LVEF measured by a cardiovascular radiologist and a trained technologist. Intraobserver reliability was performed by re-evaluation of 15 CMR images three months later by the trained technologist. The 15 CMR images were chosen by means of a simple random technique.

For the Intraclass correlation coefficient (ICC), SPSS analysis software (version 16.0; Statistical Package for Social Sciences) was used to assess the interobserver and intraobserver reliabilities of LVEF measurement of CMR. The intraclass correlation closed to 1.0 was considered as good correlation, and 95% confidence interval (CI) was considered.

Results

Twenty-one patients (18 men and 3 women) were enrolled, where nine patients underwent the CMR and left ventriculography to follow-up LVEF two times after intracoronary bone marrow monocular cell transplantation six months apart. Thirty CMR studies were assessed in this study. The patient characteristics are shown in **Table 1**.

Mean time interval between CMR and cine ventriculography were 1.3±1.7 days. Most patients had regional wall motion abnormality at the anterior wall, septal wall, and LV apex.

Short-axis plane of left ventricle allowed clear delineation of endocardial contours in all cases. LV volume measurement by left ventriculography and CMR were shown in **Table 2**.

Figure 3 shows relations of LVEF measurement with CMR between a cardiovascular radiologist and a trained technologist. Interestingly, there were excellent interobserver reliability between the cardiovascular radiologist and trained technologist (ICC=0.94, 95%CI=0.88-0.97) and intraobserver reliability between the first and second evaluations by trained technologist (ICC=0.96, 95%CI=0.88-0.99).

Table 1. Patient characteristics

Parameter	Data
Men	18 patients (24 studies)
Women	3 patients (6 studies)
Age (years)	Mean 54±13 (range: 29-76)
Body weight (kg)	Mean 66.4±12.3 (range: 41.5-92.0)
Height (cm)	Mean 165.4±9.7 (range: 149.0-190.0)
Time between CMR and left ventriculography (day)	Mean 1.3±1.7 (range: 0-6)

Table 2. Left ventricular volume measurement by left ventriculography and cardiovascular magnetic resonance (CMR) (mean±SD)

	Left ventriculography	CMR: Cardiovascular radiologist	CMR: Trained technologist
LVEF (%)	39.9±11.3	32.5±7.2	32.1±7.3
LVESV (mL)	-	117.4±48.9	110.1±28.9
LVEDV (mL)	-	166.1±51.5	159.2±31.9

LVEF: left ventricular ejection fraction, LVESV: left ventricular end-systolic volume, LVEDV: left ventricular end-diastolic volume

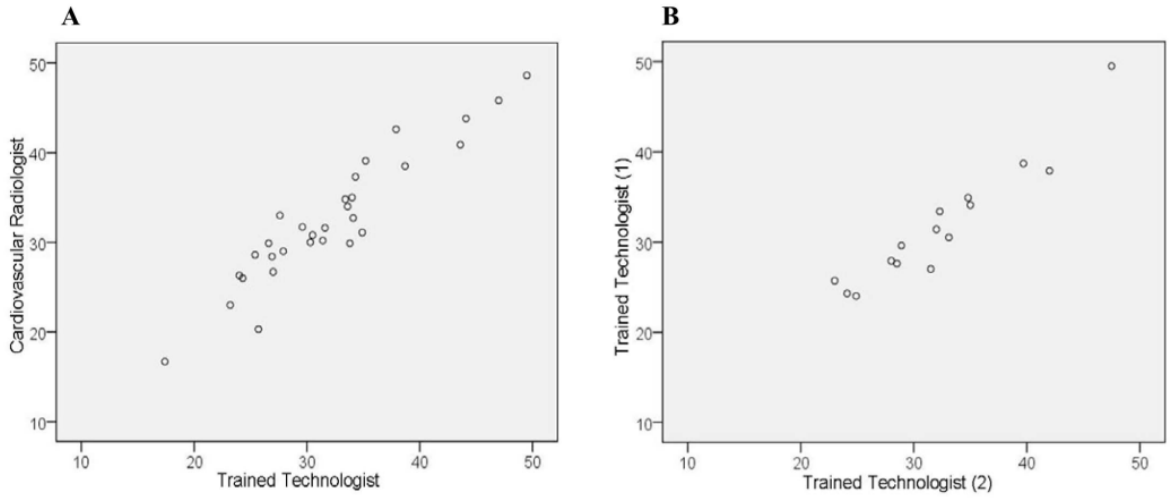


Figure 3. Plots of correlation of left ventricular ejection fraction (LVEF) determination by CMR. A: Interobserver reliability of cardiovascular radiologist and trained technologist. B: First and second evaluations by two trained technologists for intraobserver reliability

Figure 4 shows relations of LVEF measurement between CMR and left ventriculography. Correlation between left ventriculography and CMR was moderate. Left ventriculography correlated with CMR measurement by cardiovascular radiologist and trained technologist in ICC = 0.56 (95%CI=0.25-0.76) and 0.50 (95%CI=0.18-0.73), respectively. The LVEF measurement by left ventriculography was higher compared with CMR measurement.

Discussion

CMR is recently a preferential modality to LV volume measurement. Its accuracy is greatly dependent upon the skill of operator. Our study demonstrated excellent interobserver agreement of LVEF measured by a cardiovascular radiologist and a trained technologist. The intraobserver reliability for the trained technologist was also excellent, but the correlation of LVEF measurement between left ventriculography and CMR was not high but moderate. Our high inter- and intraobserver reliabilities of CMR indicate that CMR is a valid and reproducible method for the LVEF measurement in MI patients. In addition, the LVEF measurement by CMR could be performed by the trained technologist as well as the cardiovascular radiologist.

Our moderate correlation of LVEF measured by MRI and left ventriculography was similar to the study by Hoffmann et al. [5]. In our study, LVEF determined by CMR was less than those by left ventriculography. Hoffmann et al. [5] assessed the agreement of LVEF determination from unenhanced echocardiography, contrast-enhanced echocardiography, CMR, and left ventriculography as well as the interobserver agreement for each method. LVEF determined by CMR from their study was also less than those determined by left ventriculography with the mean difference of 5.8%.

There are several reasons for different LV volume measurement in each modality. First, the LV complex geometry may lead to difficult estimation of its outermost margin during contrast opacification in left ventriculography [8, 9]. Second, the LVEF measurement by left ventriculography was projected in a single 30° right anterior oblique plane and displayed only septal wall and inferolateral wall of the left ventricle. On the other hand, CMR was scanned in isolated tomographic short axis plane and available for the whole LV walls assessment [2, 10]. Most of our MI patients had regional wall motion abnormality in more than two myocardial walls. This may explain an over estimate of left ventriculography. Third, attention to catheter position and injection rate may produce ventricular ectopy during contrast media injection. This is important because analysis of extrasystolic and post-extrasystolic beat cannot be used for proper assessment of basal ventricular function [8, 9].

In conclusion, the present LVEF determination by a cardiovascular radiologist and a trained technologist showed excellent correlation between them. The trained technologist could perform LVEF measurement by CMR as well as the cardiovascular radiologist. The LVEF measurement with CMR and left ventriculography was in moderate agreement. The LVEF determination by CMR was lower than that by left ventriculography.

The authors have no conflict of interest to report.

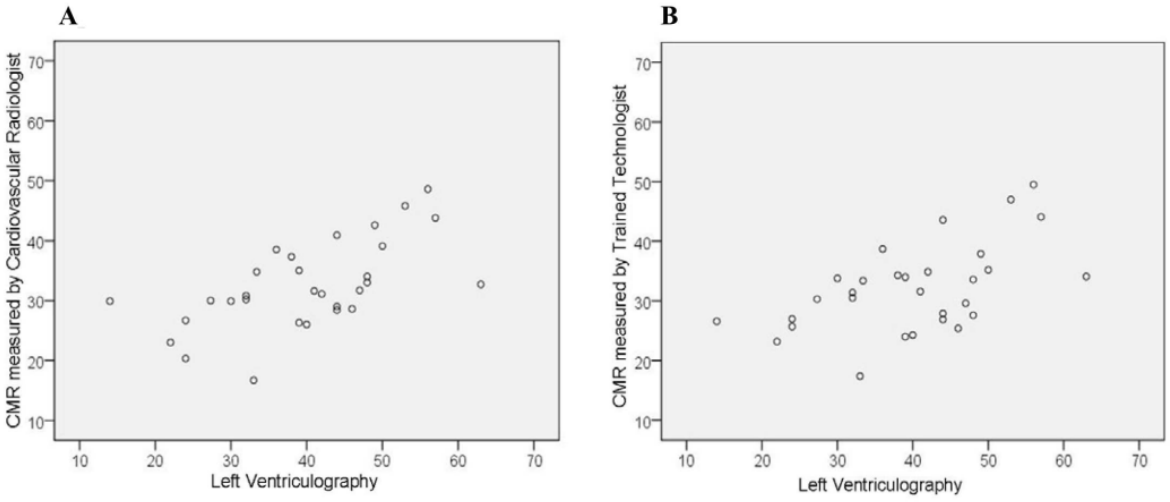


Figure 4. Plots of correlation between LVEF determined by CMR and left ventriculography. A: Correlation of LVEF measured by cardiovascular radiologist using CMR and left ventriculography. B: Correlation of LVEF measured by trained technologist using CMR and left ventriculography

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