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A mismatch index based on the difference between measured left ventricular ejection fraction and that estimated by infarct size at three months following reperfused acute myocardial infarction

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Abstract

Background and Aim: The reduction of left ventricular ejection fraction (LVEF) following ST-segment elevation myocardial infarction (STEMI) is a result of infarcted myocardium and may involve dysfunctional but viable myocardium. An index that may quantitatively determine whether LVEF is reduced beyond the expected value when considering only infarct size (IS) has previously been presented based on cardiac magnetic resonance (CMR). The purpose of this study was to introduce the index based on the electrocardiogram (ECG) and compare indices based on ECG and CMR.

Method and Results: In 55 patients ECG and CMR were obtained 3 months after STEMI treated with primary percutaneous coronary intervention. Significant, however moderate inverse relationships were found between measured LVEF and IS. Based on IS and LVEF an IS estimated LVEF was derived and an MI–LVEF mismatch index was calculated as the difference between measured LVEF and IS estimated LVEF. In 41 (74.5%) of the patients there was agreement between the ECG and CMR indices in regards to categorizing indices as >10 or ≤ 10 and generally no significant difference was detected, mean difference of 1.26 percentage points ($p = 0.53$).

Conclusion: The study found an overall good agreement between MI–LVEF mismatch indices based on ECG and CMR. The MI–LVEF mismatch index may serve as a tool to identify patients with potentially reversible dysfunctional but viable myocardium, but future studies including both ECG and CMR are needed.

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Introduction

ST-segment elevation myocardial infarction (STEMI) is a major cause of mortality and morbidity [1], and the recommended treatment for STEMI is reperfusion therapy with primary percutaneous coronary intervention (pPCI) [2,3] to reduce infarct size (IS) and preserve left ventricular ejection fraction (LVEF), which are important predictors of prognosis [4,5]. Using various methods, including cardiovascular magnetic resonance (CMR) and electrocardiographic (ECG) scores, previous studies have demonstrated a moderate inverse linear relationship between IS and LVEF [6–8]. The reduction of LVEF following STEMI is a result of infarcted myocardium and may involve dysfunctional but viable myocardium. The latter represents both stunned and hibernating myocardium. While stunned myocardium recovers contractility in time without intervention, hibernating myocardium may regain contractility through revascularization [9,10]. It has been reported that from IS determined with CMR the "maximum possible LVEF" can be estimated and

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the absolute difference between this maximum possible LVEF and measured LVEF can be used to calculate a dysfunction index [7]. This index may quantitatively determine whether LVEF is reduced beyond the expected value when considering only IS. It has therefore been suggested that a potential for subsequent improvement in function following revascularization can be identified by assessing the relationship between LVEF and IS [7]. The clinical use of CMR is expanding, however it remains important to assess whether a similar index can be developed based on IS estimated with the widely available and low-cost ECG. Thus the purpose of this study was to compare indices based on ECG and CMR measured IS 3 months after a STEMI treated with pPCI.

Methods

Patients were recruited retrospectively from a study of 118 STEMI patients described in detail elsewhere [11]. In brief, consecutively patients enrolled for that study were ≥ 18 years of age, had ST-elevation in two contiguous ECG leads of > 0.1 mV in V4-V6, limb leads II, III and aVF or > 0.2 mV in leads V1-V3 and arrived < 12 h after onset of symptoms at the Department of Cardiology, Copenhagen University Hospital, Denmark. Patients were randomized to treatment with either pPCI alone or pPCI followed by ischemic post-conditioning treatment. Patients were excluded if: spontaneous reperfusion had occurred before pPCI; pPCI was unsuccessful in restoring perfusion; stent thrombosis occurred; any other significant stenosis (> 70% diameter stenosis) was present; cardiogenic shock; left bundle branch block; prior Q-wave MI; coronary bypass surgery; severe renal or liver failure.

Of the 118 patients 80 (67.7%) had ECG and CMR recorded at 3 months after pPCI and were thus eligible for the present study. However, 25 patients were excluded due to ECG score confounders: right bundle branch or left fasciculate block or hypertrophy (n = 15), prior MI (n = 7) and poor quality of the ECG (n = 3) leaving 55 (46.6%) patients to be included.

ECG acquisition and analysis

Standard 12-lead ECGs were recorded at hospital admission and 3 months after pPCI. The former ECG was used for diagnosis of STEMI, and the latter ECG was analyzed for IS with the 50-criteria/31-point Selvester QRS score [12]. This method awards points based on Q- and R wave durations, Q-, R- and S wave amplitudes, and R/Q and R/S ratios in leads: I, II, aVL, aVF and V1-V6. Each of the 31 points has been designed to represent 3% of LV [13]. Points were awarded when a specific criterion was fulfilled in more than half the QRS complexes in a lead. QRS scoring was performed manually by 2 independent experienced observers and blinded to the CMR results.

The interobserver difference was 0.2 percentage points (pp) (95% confidence interval [CI] of difference, −0.8 pp to 1.2 pp). Interobserver disagreements were discussed, and a consensus score was achieved in all patients, which was used for estimation of IS.

CMR acquisition and analysis

CMR was performed on a 1.5-T scanner (GE Healthcare Sigma HD, Milwaukee, WI) 3 months after pPCI.

Delayed enhancement CMR images were acquired during breath-hold, 10 min after injection of 0.2 mg/kg body weight of gadolinium-diethylenetriamine pentaacetic acid and using an ECG-triggered inversion-recovery gradient-echo sequence (echo time, 1.4 ms; repetition time, 4.0 ms; slice thickness, 8 mm). Semiautomatic quantification of IS was performed by 2 independent experienced observers using the freely available software, Segment v1.9 (http://segment.heiberg.se) [14], and blinded to the QRS score results. Endocardial and epicardial borders were manually delineated, and papillary muscles were considered as part of the left ventricle (LV) lumen. The algorithm automatically defines the area of infarction accounting for the effects of partial volume. Manual adjustments were performed only when the delineation was wrong. IS was calculated as a percentage of the LV mass. The interobserver difference was 0.8 pp (95% CI of difference, 0.4 pp to 1.3 pp) and the mean value for each patient was used in the data analysis.

Cine CMR was acquired during breath hold using an ECG-triggered steady-state imaging pulse sequence (echo time, 1.6 ms; slice thickness, 8 mm; 20 cardiac phases). The endocardial borders at end diastole and end systole were manually traced in each short axis slice for measurement of end diastolic and end systolic volume (EDV and ESV). LVEF (%) was then calculated by the formula: (EDV − ESV)/EDV × 100%. The interobserver difference was 1.2 pp (95% CI of difference, −0.1 pp to 2.5 pp) and the mean value for each patient was used in the data analysis.

IS estimated LVEF and MI–LVEF mismatch index

Generally an inverse relationship between IS and LVEF exists, however factors such as myocardial ischemia, cardiomyopathy, asynchrony may change this relationship by further decreasing LVEF. In the absence of these, since all of the LVEF reduction is caused by infarction, the measured value has previously been termed “maximum possible LVEF” [7]. However, in this paper the term IS estimated LVEF will be used instead to indicate the relationship with IS. The relationship between IS estimated LVEF and IS was described with a linear function ($y = ax + b$), where y is the IS estimated LVEF, a is the slope, x is the IS and b is the intercept with the y-axis [7]. The intercept and slope of the function were determined by the angle θ and distance CD that would minimize the area of triangle ABC whilst encompassing 95% of the data points as previously described by Ugander et al. [7], see Fig. 1. The 95% threshold was chosen to enable comparison of the formulas for IS estimated LVEF with the formula previously reported. In detail, the line CD was positioned at multiple angles and at each angle the length of CD that would encompass 95% of the data points was noted. Based on the angle and the length of CD, the positions of A and B and the area of the triangle ABC

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