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Myocardial Salvage by CMR Correlates With LV Remodeling and Early ST-Segment Resolution in Acute Myocardial Infarction

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OBJECTIVES The purpose of this study was to assess the association of myocardial salvage by cardiac magnetic resonance (CMR) with left ventricular (LV) remodeling and early ST-segment resolution in patients with acute myocardial infarction (MI).

BACKGROUND Experimental studies revealed that MI size is strongly influenced by the extent of the area at risk (AAR), limiting its accuracy as a marker of reperfusion treatment efficacy in acute MI studies. Hence, an index correcting MI size for AAR extent is warranted. T2-weighted CMR and delayed-enhancement CMR, respectively, enable the determination of AAR and MI size, and the myocardial salvage index (MSI) is calculated by correcting MI size for AAR extent. Nevertheless, the clinical value of CMR-derived MSI has not been evaluated yet.

METHODS In a prospective cohort of 137 consecutive patients with acutely reperfused ST-segment elevation MI, CMR was performed at 1 week and 4 months. T2-weighted CMR was used to quantify AAR, whereas MI size was detected by delayed-enhancement imaging. MSI was defined as AAR extent minus MI size divided by AAR extent. Adverse LV remodeling was defined as an increase in LV end-systolic volume of ≥15%. The degree of ST-segment resolution 1 h after reperfusion was also calculated.

RESULTS AAR extent was consistently larger than MI size (32 ± 15% of LV vs. 18 ± 13% of LV, $p < 0.0001$), yielding an MSI of 0.46 ± 0.24. MI size was closely related to AAR extent ($r = 0.81$, $p < 0.0001$). After correction for the main baseline characteristics by multivariate analyses, MSI was a major and independent determinant of adverse LV remodeling (odds ratio: 0.64; 95% confidence interval: 0.49 to 0.84, $p = 0.001$) and was independently associated with early ST-segment resolution (B coefficient = 0.61, $p < 0.0001$).

CONCLUSIONS In patients with reperfused ST-segment elevation MI, CMR-derived MSI is independently associated with adverse LV remodeling and early ST-segment resolution, opening new perspectives on its use in studies testing novel reperfusion strategies. (J Am Coll Cardiol Img 2010;3:45–51) © 2010 by the American College of Cardiology Foundation

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Mortality is the best parameter for measuring the efficacy of reperfusion strategies in patients with acute myocardial infarction (MI) (1). Using this hard end point, a large sample is necessary to test novel treatments in combination with the existing reperfusion strategies that are already highly effective. Thus, other markers of reperfusion treatment efficacy are needed, and infarct size has often been used as a surrogate end point for mortality (2). This parameter, however, is influenced by several factors (3–6): 1) the size of the area at risk (AAR) (myocardium supplied by the culprit vessel); 2) residual flow to the ischemic territory (e.g., collateral flow); 3) myocardial metabolic demand; and 4) the duration of coronary occlusion. Small differences in the AAR may result in a significant variation of infarct size (5,6), underscoring the fact that most of the infarct size variability is due to the extent of the myocardium at risk. The myocardial salvage index (MSI) is calculated by correcting the amount of necrotic myocardium for the AAR extent, and it may be a better surrogate end point than infarct size (7–9).

ABBREVIATIONS AND ACRONYMS

AAR = area at risk
CMR = cardiac magnetic resonance
DE = delayed enhancement
ECG = electrocardiogram
FOV = field of view
LV = left ventricular
MI = myocardial infarction
MO = microvascular obstruction
MSI = myocardial salvage index
SI = signal intensity

In patients with MI, delayed-enhancement (DE) cardiac magnetic resonance (CMR) is a well-validated technique for the determination of the necrotic (acute phase) and scarred (chronic phase) myocardium (10). In experimental models, T2-weighted CMR enabled depiction of the myocardial edema in the salvageable AAR (11,12), and Friedrich et al. (13) reported promising data on myocardial salvage determination in acute MI patients. The purpose of this study was to investigate the clinical value of CMR-derived MSI by testing its association with 2 important clinical and prognostic parameters: left ventricular (LV) remodeling and early ST-segment resolution.

METHODS

Study population. Between May 2006 and September 2007, 137 consecutive acute MI patients (55 patients at the Monasterio Foundation, Pisa, Italy [Center A] and 82 patients at Gasthuisberg Hospital, Leuven, Belgium [Center B]), presenting with cumulative ST-segment elevation of ≥6 mm and treated with percutaneous coronary intervention within 12 h from symptom onset were prospectively studied by CMR at 1 week and 4 months. Exclusion criteria were critical stenosis (i.e., lumen narrowing of ≥75%) in vessels other than the infarct-related artery, previous MI or revascularization, atrial fibrillation, cardiogenic shock, or contraindication to CMR. The local ethics review boards approved the protocol, and written informed consent was obtained from each patient.

CMR protocol. Fifty-five patients were examined at Center A with a 1.5-T unit (CVi, GE Healthcare, Milwaukee, Wisconsin), and 82 patients at Center B with a 1.5-T unit (Intera CV, Philips Medical Systems, Best, the Netherlands). All studies were performed using dedicated cardiac software, phased-array surface receiver coil, and vectocardiogram triggering. LV volumes, mass, and function were assessed by breath-hold steady-state free-precession cine CMR. In the short-axis orientation, the left ventricle was completely encompassed by contiguous slices. The sequence parameters were field of view (FOV): 350 to 400 mm, repetition time (TR)/echo time (TE): 3.2/1.6 ms, flip angle: 60°, matrix: 224 × 192, slice thickness: 8 mm (CVi, GE Healthcare) and FOV: 350 to 400 mm, TR/TE: 3.6/1.8 ms; flip angle: 60°, matrix: 256 × 160, slice thickness: 8 mm (Intera CV, Philips Medical Systems).

AAR was determined using breath-hold T2-weighted short-TI inversion-recovery fast spin echo pulse sequence. In short-axis orientation, the left ventricle was entirely encompassed by contiguous slices. The sequence parameters were FOV: 380 to 400 mm; TR: 2 R-R intervals, TE: 100 ms, TI: 150 ms, matrix: 256 × 192, slice thickness: 8 mm (CVi, GE Healthcare) and FOV: 380 to 400 mm, TR: 2 R-R intervals, TE: 100 ms; TI: 150 ms, matrix: 256 × 256, slice thickness: 8 mm (Intera CV, Philips Medical Systems). After administration of 0.2 mmol/kg of gadolinium-tetraazacyclododecanetetraacetic acid, DE imaging was used to quantify infarct size and concomitant microvascular obstruction (MO) by breath-hold 3-dimensional (Intera CV, Philips) or 2-dimensional (CVi, GE Healthcare) segmented inversion-recovery gradient-echo pulse sequence. DE imaging was performed 8 to 20 min after contrast administration, and the inversion time was individually adapted to suppress the remote myocardium signal (typical range from 200 to 300 ms). Sequence parameters were FOV: 350 to 400 mm, TR/TE: 4.6/1.3 ms, flip angle: 20°, matrix: 256 × 192, slice thickness: 8 mm (CVi, GE Healthcare) and FOV: 350 to 400 mm TR/TE: 4.5/1.3 ms, flip angle: 15°, matrix: 256 × 128, slice thickness: 5 mm (Intera CV, Philips Medical Systems).

Image analysis. All CMR studies were analyzed offline using inhouse-developed cardiac software (CardioViewer, UZ Leuven, Belgium) by consensus of 2 experienced operators (J.B. and P.G.M.) who were