Impact of Intramyocardial Hemorrhage and Microvascular Obstruction on Cardiac Mechanics in Reperfusion Injury: A Speckle-Tracking Echocardiographic Study

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Background: Intramyocardial hemorrhage (IMH) and microvascular obstruction (MVO) are two major mechanisms of reperfusion injury of the left ventricle after acute ST-segment elevation myocardial infarction (STEMI). The aim of this study was to assess the impact of IMH and MVO on left ventricular (LV) cardiac mechanics using two-dimensional speckle-tracking echocardiography during the acute phase of STEMI and on LV functional recovery.

Methods: Eighty-one patients with STEMI who received primary reperfusion therapy were prospectively studied. Infarct segments were classified by cardiac magnetic resonance according to infarct transmurality and the presence or absence of IMH and/or MVO. Segmental systolic longitudinal strain, circumferential strain (CS), and radial strain were measured by two-dimensional speckle-tracking echocardiography. Adverse LV remodeling and major adverse cardiovascular events were assessed at 1 year.

Results: MVO without IMH was much less frequent in nontransmural infarct segments than in transmural infarct segments (6.0% vs 19.1%, $P = .000$), while IMH was present only in transmural infarct segments. In nontransmural infarct segments, MVO was not associated with any significant changes in strain ($P > .5$). In transmural infarct segments, there were no differences in all types of strain between segments without reperfusion injury and those with MVO alone ($P > .20$). IMH was evident in the midmyocardial layer within the infarct zone in 196 segments (46.1%). The presence of IMH in addition to MVO decreased CS significantly ($P = .004$), but not longitudinal and radial strain ($P > .5$). A receiver operating characteristic curve analysis with cross-validation by k-folding showed that the sensitivity and specificity of CS using a cutoff of >−11.66% to diagnose IMH were 78.00% and 79.45%, respectively (area under the curve = 0.86; $P = .0001$). At 1 year, patients with major adverse cardiovascular events and LV remodeling had significantly lower baseline measurements of all types of global strain ($P < .05$).

Conclusions: In the acute phase of STEMI, reperfusion MVO and IMH injury have differential effects on cardiac mechanics. IMH preferentially affects CS, presumably related to its location in the midmyocardial layer. (J Am Soc Echocardiogr 2016;■:■-■.)

Keywords: Microvascular obstruction (MVO), Intramyocardial hemorrhage (IMH), 2D speckle tracking echocardiography, ST-segment elevation myocardial infarction, Cardiac magnetic resonance (CMR)

Intramyocardial hemorrhage (IMH) is an important mechanism of reperfusion injury after acute ST-segment elevation myocardial infarction (STEMI). It is closely related to the phenomenon of microvascular obstruction (MVO).[1,2] Both MVO and IMH are associated with adverse left ventricular (LV) remodeling, diminished recovery of LV function, and poor long-term prognosis after revascularization

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Abbreviations

CMR = Cardiac magnetic resonance

CS = Circumferential strain

ICC = Intraclass correlation coefficient

IMH = Intramyocardial hemorrhage

LS = Longitudinal strain

LV = Left ventricular

LVEF = Left ventricular ejection fraction

MACE = Major adverse cardiovascular events

MI = Myocardial infarction

MVO = Microvascular obstruction

NTI = Nontransmural infarct

RS = Radial strain

STE = Speckle-tracking echocardiography

STEMI = ST-segment elevation myocardial infarction

TI = Transmural infarct

2D = Two-dimensional

treatment for acute STEMI.[1,3-5] However, the interaction of IMH and MVO on contractile function and recovery of the infarct segments with reperfusion injury has not been clearly defined.

Both IMH and MVO can be detected by cardiac magnetic resonance (CMR).[2,6] Two-dimensional (2D) speckle-tracking echocardiography (STE) is a novel imaging technique that detects and tracks acoustic markers frame by frame on grayscale 2D images, allowing relatively angle-independent analysis of myocardial deformation in multiple directions, including longitudinal strain (LS), circumferential strain (CS), and radial strain (RS), both globally and of individual myocardial segments.[7-10] Previous studies using CMR assessment showed that global CS and LS in the acute phase of STEMI are closely related to infarct size.[11,12] More recent studies have demonstrated that 2D speckle-tracking echocardiographic assessment of CS is useful in distinguishing transmural from subendocardial infarction.[13] Moreover, 2D speckle-tracking echocardiographic evaluation of the presence of MVO and its impact on myocardial function was feasible.[14,15] Despite the prognostic significance of IMH and MVO after reperfusion injury, their interactions in relation to their impact on LV mechanics have not been systematically evaluated. We hypothesized that in the acute phase of STEMI, (1) reperfusion injury, which was defined as MVO or IMH in this study, is associated with altered segmental and global strains, in addition to myocardial infarction (MI) transmurality; (2) MVO and IMH have different influences on various strain components; and (3) reduced strain at baseline is associated with adverse myocardial functional recovery and outcome.

METHODS

Study Population

We prospectively screened patients admitted to our hospital for acute STEMI from September 2012 to December 2013. STEMI was defined as (1) chest pain and (2) new ST-segment elevation at the J point in two anatomically contiguous leads using the following diagnostic thresholds: ≥0.1 mV (1 mm) in all leads other than V_2 and V_3, where the following diagnostic thresholds apply: ≥0.2 mV (2 mm) in men ≥40 years of age, ≥0.25 mV (2.5 mm) in men <40 years of age, and ≥0.15 mV (1.5 mm) in women. A total of 260 patients were screened. The inclusion criteria were as follows: (1) symptom onset < 12 hours and (2) eligibility for primary reperfusion therapy. The exclusion criteria were as follows: (1) age > 75 years, (2) left bundle branch block and/or atrial fibrillation, (3) cardiomyopathy, (4) significant valvular heart disease, (5) prior MI, (6) contraindication to reperfusion therapy or CMR, (7) poor echocardiographic image quality, and (8) refusal to participate in the study. A total of 81 patients were included in the final analysis for this study. Selection for our study population is presented in the flowchart shown in Figure 1. At 1 year after the index STEMI, occurrences of major adverse cardiovascular events (MACEs), including death, resuscitated cardiac arrest, and acute heart failure (with typical manifestations of pulmonary edema), were followed and recorded. Written informed consent was obtained from all patients. The study was approved by the ethics committee of the institution.

CMR Imaging and Analysis

All patients underwent CMR within 8 days (median, 4.9 days) after reperfusion therapy. Electrocardiographically gated CMR imaging was performed using a 3.0-T scanner (Achieva TX; Philips Healthcare, Best, The Netherlands). All sequences were acquired in breath-hold, with a field of view of 350 × 350 mm^2.

Cine CMR was performed using a balanced steady-state free precession sequence in the short-axis view to cover the whole left ventricle without gap (repetition time, 3.2 msec; echo time, 1.6 msec; 30 phases; voxel size, 2.0 × 1.6 × 8 mm^3).

Three black-blood T2 short-tau inversion-recovery images were acquired at the apical, mid, and basal levels (repetition time, two R-R intervals; echo time, 75 msec; voxel size, 2.0 × 1.6 × 8 mm^3). Myocardial edema was defined as high-signal myocardium within the territory of the culprit vessel (signal intensity > 2 SDs above the mean signal in remote noninfarcted myocardium), and the hyposignal area within the edema area was recognized as IMH (Figures 2A–2C).[3,6]

Immediately after a bolus intravenous administration of contrast agent (0.2 mmol/kg) (Magnevist; Bayer HealthCare Pharmaceuticals, Munich, Germany), first-pass perfusion was performed in the same slice locations and planes. Myocardial defect within the territory of the culprit vessel was defined as first-pass perfusion defect.

Late gadolinium enhancement using a three-dimensional inversion recovery segmented gradient echo sequence was performed 10 min after contrast injection in short-axis and two- and four-chamber views covering the whole left ventricle (repetition time, 3.5 msec; echo time, 1.7 msec; temporal resolution, 190 msec; voxel size, 1.5 × 1.7 × 10 mm^3 interpolated into 0.74 × 0.74 × 5 mm^3). Infarction was defined as hyperenhanced myocardium (signal intensity > 5 SDs of normal myocardium). An experienced reader who was blinded to the clinical data analyzed the CMR data using customized software (QMass MR version 7.5; Medis Medical Imaging, Leiden, The Netherlands). Infarct size was expressed as percentage necrosis of segmental volume for each of the LV segments. Nontransmural infarct (NTI) was defined as 1% to 50% extent of infarction in the radial direction at the segmental level, and transmural infarct (TI) was defined as 51% to 100% infarct extent.[13] The total scar percentage was reported as the percentage of infarction to the total LV mass. MVO was defined as a hypoenhanced region in the infarct-related myocardium (Figures 2D–2F).

Myocardial segments were divided into six groups on the basis of CMR findings: (1) normal segments without infarction, (2) segments with NTI but no CMR evidence of reperfusion injury (NTI MVO−/IMH−), (3) NTI segments with MVO but no IMH (NTI MVO+/IMH−), (4) segments with TI but no reperfusion