Analysis of microvascularity after reperfused acute myocardial infarction using the maximum slope method of contrast-enhanced magnetic resonance imaging

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Abstract

Purpose. The aim of this study was to analyze microvascularity after reperfused acute myocardial infarction (AMI) using the maximum slope method of contrast-enhanced cardiac magnetic resonance imaging (CMR).

Materials and methods. CMR and resting $^{201}$Tl single photon emission computed tomography (SPECT) images were obtained in 30 consecutive patients after reperfused AMI and 10 controls. After bolus injection of gadolinium diethylenetriamine pentaacetic acid, first-pass CMR images were obtained using the True-FISP sequence. Time–intensity curves were generated by measuring the signal intensity in the myocardium and left ventricle. The arterial input function was obtained from the left ventricular time–intensity curve. On the basis of the maximum slope method, the microvascular index (MVI) was calculated by dividing the maximum initial upslope of the myocardium by the initial upslope of the left ventricle.

Results. The MVI was significantly lower in the segments related to the occluded coronary artery. MVIs in segments with $^{201}$Tl uptake of 50%–59% of peak were significantly lower than in those with $^{201}$Tl uptake of 60%–69%. MVIs in segments with $^{201}$Tl uptake of <50% of peak were significantly lower than in those with $^{201}$Tl uptake of 50%–59%.

Conclusion. This study presents a method that directly assesses microvascularity after reperfused AMI.

Key words Contrast-enhanced MRI · Myocardial infarction · Maximum slope method

Introduction

Patient prognosis after acute myocardial infarction (AMI) relates directly to the extent of myocardial injury produced during coronary occlusion. The phenomenon of microvascular obstruction frequently occurs during the first few days after AMI, despite successful revascularization of the infarct-related artery. Microvascular obstruction correlates with poorer global left ventricular (LV) function and more frequent post-MI complications. Thus, the magnitude of microvascular obstruction sustained during acute infarction has been related to clinical outcome.

Contrast-enhanced cardiovascular magnetic resonance (CMR) techniques allow in vivo visualization of regions of profound microvascular obstruction in patients with AMI. They appear as dark, subendocardial zones surrounded by hyperenhanced infarcted or injured myocardium and correspond to experimentally produced no-flow regions. Although myocardial perfusion CMR is available and offers a sensitive diagnostic
tool for the assessment of regional myocardial perfusion in coronary artery disease, the ability to recognize regional perfusion reduction by visual interpretation is highly dependent on the quality of the CMR images and the observer’s level of experience. Myocardial perfusion CMR has been shown to have the potential to provide insights into myocardial microcirculation semiquantitatively and quantitatively. Myocardial perfusion imaging with pharmacological stress CMR has recently been used to evaluate ischemic heart disease; however, assessment of hemodynamic change on myocardial ischemia at rest using CMR has not yet been elucidated. In this study, we introduced a semiquantitative analysis for myocardial perfusion at rest using the maximum slope method of first-pass contrast-enhanced CMR and evaluated microvascularity during the acute phase of a reperfused myocardial infarction.

Materials and methods

Study patients

The study protocol was approved by the institutional review board, and all patients gave informed consent. A total of 30 consecutive patients (18 men, 12 women; age range 44–83 years) admitted to the coronary care unit in our hospital were prospectively enrolled; they had myocardial infarction, defined as typical chest pain, characteristic abnormal findings from electrocardiography, creatine phosphokinase (CPK) elevation of more than twice the upper limit of normal, and >5% myocardium-specific bands. The patients were included if they had no history of MI, had undergone successful percutaneous transluminal coronary angioplasty with <50% residual stenosis, and were clinically stable. Exclusion criteria consisted of the following: (1) renal failure (serum creatinine level >1.5 mg/dl and/or blood urea nitrogen level >21 mg/dl); (2) atrial fibrillation. No patient was excluded because of technical failure or poor image quality.

Coronary angiography revealed that the infarct-related artery was the left anterior descending coronary arterial (LAD) territory in 11 patients, the right coronary arterial (RCA) territory in 18, and the left circumflex coronary arterial (LCX) territory in 1.

Control subjects

Ten control subjects (six men, four women; age range 40–65 years) who did not have documented cardiac or other chronic heart diseases and were not taking any kind of medication were recruited. All control subjects underwent clinical evaluation by cardiologists for blood pressure measurement, electrocardiography (ECG), and cardiac echocardiography. If no findings of disease were observed, the person was accepted as a control subject.

Data acquisition

CMR imaging

All measurements were carried out on a clinical 1.5 T whole-body scanner (Magnetom Symphony; Siemens Medical Solutions, Erlangen, Germany) using a 12-element body-phased array coil within 7 days after the onset of the MI. Three short-axis sections at midventricle were chosen for first-pass perfusion imaging with an ECG-triggered T1-weighted saturation recovery Turbo-FLASH sequence (repetition time 1.8 ms, echo time 1.2 ms, recovery time after saturation pulse 58 ms, flip angle 8°, field of view (FOV) 285 × 300 mm², matrix 80 × 128, slice thickness 8 mm, three images per two heartbeats). During an inspiratory breath hold, a bolus of gadopentetate dimeglumine (Gd-DPTA) (Magnevist; Schering, Berlin, Germany), 0.05 mmol/kg body weight, was injected into the right antecubital vein at 3 ml/s and flushed with 20 ml of normal saline using a power injector. A total of 60 to 80 dynamic images were acquired simultaneously during the first and second passes of the contrast agent. The patients were instructed to hold their breath as long as possible and to breathe quietly and slowly when necessary (Fig. 1).

Maximum slope method of first-pass CMR

The maximum slope method characterizes the relation between the perfusion and the time–intensity curves of the tissue and arterial input function (AIF). Assuming that extravasation of the contrast medium can be neglected during the measurement period, perfusion was estimated according to the following relation presented by Miles et al.

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\text{Perfusion} = \frac{\text{maximum initial slope of tissue curve}}{\text{maximum density of the AIF}}
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Time–intensity curves after Gd-DPTA inflow were generated by measuring the signal intensity in square regions of interest (ROIs) defined in the LV cavity and 12 myocardial sections (Fig. 2). We defined the anterior and septal segments as LAD territory, inferior segments as RCA territory, and lateral segments as LCX territory. Therefore, the infarct area was the segment corresponding to the coronary artery’s territory; for example, LAD-related infarct areas were A1–3 and S1–3. In all images an examiner who was blinded to the angiographic results