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Original article

Longitudinal Doppler strain measurement for assessment of damaged and/or hibernating myocardium by dobutamine stress echocardiography in patients with old myocardial infarction

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Stress echocardiography;
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Doppler ultrasound

Summary
Background: The ratio of systolic lengthening to combined late and postsystolic shortening (L/TS ratio) on longitudinal Doppler strain imaging (Doppler SI) may be an index of myocardial viability. We hypothesized that measuring the postsystolic index (PSI) and the L/TS ratio during dobutamine stress echocardiography (DSE) could quantitatively identify viable myocardium with the potential for regional functional recovery.
Methods: Thirty-eight patients with old myocardial infarction (OMI) underwent DSE with Doppler SI and coronary angiography (Group 1). To clarify the value of measuring the PSI and L/TS ratio by DSE with Doppler SI in patients with OMI, these Doppler parameters and visual analysis of wall motion abnormality (WMA) were compared on a segmental basis. To investigate the prediction of regional functional recovery, 10 patients with OMI (Group 2) and stenosis of the infarct-related coronary artery underwent DSE with Doppler SI before and after percutaneous coronary intervention.
Results: In Group 1, 143 out of 556 segments showed a biphasic WMA pattern during DSE. There were no segments with evidence of necrosis. The PSI at peak stress was $\geqq$0.25 in 114 out of 143 segments and the L/TS ratio at peak stress was >0 in 82 out of 114 segments. Regarding functional recovery, 42 of the 73 segments with WMA at rest showed improvement after reperfusion. The wall motion score (WMS) showed 86% sensitivity and 71% specificity for predicting regional recovery, while PSI and L/TS ratio showed 61% vs. 84% sensitivity and 60% vs. 79% specificity, respectively. The AUC for the ROC curve of the L/TS ratio as a predictor of

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regional recovery was significantly larger compared with that of WMS (0.894 vs. 0.783, $p < 0.05$).
Conclusions: The peak stress L/TS ratio could be a specific and quantitative marker for identifying myocardial viability that has the potential for regional functional recovery.

Introduction

Currently, dobutamine stress echocardiography (DSE) is performed by visually interpreting the movements of the myocardium. Thus, DSE is a highly subjective examination. Doppler strain imaging (Doppler SI) has been suggested as a tool for quantification of regional myocardial function, assessing the timing of segmental deformation, prediction of functional recovery and improving the quantification of DSE [1—6]. However, visual analysis of wall motion and strain parameter analysis using low-dose dobutamine have a similar sensitivity and specificity for the prediction of segmental functional recovery [7].

A previous animal study revealed that the ratio of systolic lengthening to combined late and postsystolic shortening (L/TS ratio) could help to identify viable myocardium [8]. Myocardium that is able to generate force becomes shorter during systole when left ventricular (LV) pressure is rising, whereas myocardium with no activity lengthens passively and then recoils during late systole/early diastole when LV pressure is falling [9]. We hypothesized that myocardium with dobutamine-induced ischemia may also lengthen passively during early systole and recoil during late systole/early diastole, and that changes of the contractility pattern might be an optimal parameter for the prediction of regional myocardial functional recovery. The aims of the present study were: (1) to clarify the incidence of early systolic lengthening and postsystolic shortening during DSE in patients with old myocardial infarction (OMI) and (2) to investigate the usefulness of the postsystolic index (PSI) and the L/TS ratio for predicting regional myocardial functional recovery after successful percutaneous coronary intervention (PCI) in patients with OMI.

Subjects and methods

Study population

Data from 48 patients with OMI aged 70 ± 8 years (onset of previous myocardial infarction >6 months previously) were obtained at Nippon Medical School Hospital between September 2004 and August 2005 (Table 1). All 48 patients had received PCI at the onset of myocardial infarction and had a decrease in contractile myocardium, but no necrosis in the territory supplied by the stenosed infarct-related coronary artery.

Of these 48 patients, 38 patients (Group 1) aged 71 ± 8 years (28 men and 10 women) underwent DSE with simultaneous Doppler SI, as well as coronary angiography (CAG) to clarify the incidence of early systolic lengthening and postsystolic shortening during DSE. The other 10 patients (Group 2) aged 67 ± 8 years (6 men and 4 women) were studied to assess how improvement in myocardial function could be evaluated by performing DSE with simultaneous Doppler SI both before and after successful PCI (at a mean interval of 6 months). All patients gave informed consent. Exclusion criteria included acute myocardial infarction, unstable angina, tachyarrhythmia, second-or third-degree atrioventricular block, and use of β-blockers.

Coronary angiography

CAG was performed according to the standard procedure by the femoral approach within two weeks of the other studies. Coronary stenosis was assessed visually and expressed as the percent reduction of the luminal diameter.

Dobutamine stress echocardiography

A standard dobutamine-atropine stress protocol was performed starting at a dose of 5 $\mu g\,kg^{-1}\,min^{-1}$ and increasing to 10, 20, 30, and 40 $\mu g\,kg^{-1}\,min^{-1}$ at 3-min intervals. Atropine (0.5 mg) was infused in patients who did not achieve 85% of their age-predicted maximal heart rate [10—13]. A 12-lead electrocardiogram (ECG) and blood pressure measurements were recorded at baseline and at the end of each stage of the protocol. Images were obtained by using a commercially available echocardiography system (Vivid 7, GE Healthcare UK Ltd., Chalfont St Giles, UK) and were stored digitally and on tape. Segmental wall motion was assessed according to the 16-segment model of the American Society of Echocardiography [14]. Apical 4-, 3-, and 2-chamber views were employed to evaluate longitudinal deformation. Each wall was divided into 3 segments. The basal, middle, and apical inferior segments and the middle and basal septal segments were considered to be the territory of right coronary artery. The basal, middle, and apical lateral segments and the basal and middle posterior segments were considered to be the territory of the left circumflex artery. The basal, middle, and apical anterior segments and the basal, middle, and apical anteroseptal segments were considered to represent the territory of the left anterior descending artery. Two independent experienced readers scored each LV segment at baseline and during dobutamine stress as follows: −1 = hyperkinesis, 0 = normokinesis, 1 = mild hypokinesis, 2 = moderate to severe hypokinesis, 3 = akinesis, 4 = dyskinesis. Ischemia was defined as regional reduction or impairment of radial myocardial contraction in 2 segments. A viable response was defined as either a uniphasic (sustained improvement at peak stress) or biphasic pattern of wall motion abnormality (WMA).

In Group 2, reperfusion therapy was considered to have promoted regional myocardial functional recovery if resting wall motion demonstrated improvement by at least one grade in 2 segments. Images were analyzed by two independent experienced readers who were blinded to the clinical data, angiography findings, and other echocardiography data.