J Cardiol 1997; 30: 197–203

Prediction of Wall Motion Improvement After Coronary Revascularization in Patients With Postmyocardial Infarction : Diagnostic Value of Dobutamine Stress Echocardiography and Myocardial Contrast Echocardiography

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Abstract

The diagnostic value of dobutamine stress echocardiography, myocardial contrast echocardiography and dipyridamole stress thallium-201 single photon emission computed tomography (SPECT) for predicting recovery of wall motion abnormality after revascularization was evaluated in 13 patients with postmyocardial infarction.

Seventeen segments showed severe wall motion abnormalities before revascularization. Nine segments which had relatively good Tl uptake on delayed SPECT images despite severely abnormal wall motion were opacified during myocardial contrast echocardiography, and showed improved wall motion after revascularization. In contrast, three segments which had poor Tl uptake and severely abnormal wall motion were not opacified during myocardial contrast echocardiography, and showed no improvement in wall motion during dobutamine stress echocardiography and after revascularization.

The following three findings were assumed to be signs of myocardial viability : 1) good Tl uptake on delayed SPECT images; 2) improved wall motion by dobutamine stress echocardiography; and 3) positive opacification of the myocardium by myocardial contrast echocardiography. Myocardial contrast echocardiography had the highest sensitivity (100%) and negative predictive value (100%). Delayed SPECT images had the highest specificity (100%) and positive predictive value (100%). Dobutamine stress echocardiography had a sensitivity of 83.0%, specificity of 80.0%, positive predictive value of 90.9 %, and negative predictive value of 66.7%, respectively. Myocardial contrast echocardiography showed the lowest specificity (60.0%).

The techniques of dobutamine stress echocardiography and SPECT, though noninvasive, may underestimate wall motion improvement after revascularization. Further examination by myocardial contrast echocardiography is recommended to assess myocardial viability for determining the indications for coronary revascularization in spite of its invasiveness.

J Cardiol 1997; 30 (4): 197–203

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Manuscript received May 24, 1996; revised May 19 and July 31, 1997; accepted August 1, 1997

Key Words
Myocardium (viability), Stress echocardiography (dobutamine), Radionuclide imaging (thallium myocardial scintigraphy), Revascularization, Contrast echocardiography

INTRODUCTION

Assessment of myocardial viability has become increasingly important due to recent advances in revascularization techniques such as percutaneous transluminal coronary angioplasty (PTCA). At present, revascularization is often performed even for infarct areas showing abnormal wall motion in patients with myocardial infarction which occurred several weeks or months earlier. Some patients show wall motion improvement after revascularization[1].

In recent years, two echocardiographic methods have been used to assess myocardial viability : low-dose dobutamine stress echocardiography, which elicits contractile improvement of wall motion abnormalities in response to an inotropic stimulus[2–6], and myocardial contrast echocardiography, which can be used to define the spatial distribution of microvascular perfusion[7]. Few studies have reported the usefulness of these two techniques in predicting wall motion improvement after revascularization in patients with postmyocardial infarction.

The present study compared the diagnostic value of dobutamine stress echocardiography, myocardial contrast echocardiography and dipyridamole stress thallium-201 (^{201}Tl) single photon emission computed tomography (SPECT) in predicting wall motion recovery after revascularization in the same patients with postmyocardial infarction and abnormal wall motion.

METHODS

Subjects

The study included 13 patients with postmyocardial infarction who fulfilled the following criteria : 1) chronic coronary artery disease with previous myocardial infarction which had occurred more than 1 month before, 2) severely reduced wall motion based on two-dimensional echocardiography, 3) more than 90% diameter stenosis of infarct-related coronary artery, 4) successful coronary revascularization, and 5) no evidence of coronary restenosis on the coronary angiogram performed 2–5 months after revascularization.

Twelve patients were male and one was female (mean age : 63±5 years). Twelve had undergone PTCA and one had undergone coronary artery bypass grafting (CABG) on the infarct-related coronary artery (left anterior descending coronary artery four cases, left circumflex coronary artery four cases and right coronary artery five cases).

Methods

Segmentation of the left ventricle

The left ventricle on each image obtained from two-dimensional echocardiography, SPECT, dobutamine stress echocardiography and myocardial contrast echocardiography was divided into six segments in the mid-ventricular slices of the short-axis views as shown in **Fig. 1**.

Two-dimensional echocardiography and dobutamine stress echocardiography

All patients underwent baseline two-dimensional echocardiography and dobutamine stress echocardiography prior to revascularization. During dobutamine stress echocardiography, improvement in wall motion was assessed by two-dimensional echocardiography. Dobutamine was administered intravenously for 3 min at an initial dose of 5 μg/kg/min and was increased to 10 μg/kg/min during the subsequent 3 min period. Wall motion in each segment of the left ventricle was assessed visually and was semiquantified using the 4-grade system : 3 (normal), 2 (mildly hypokinetic), 1 (severely hypokinetic) or 0 (akinetic). Short-axis images of the left ventricle, taken at baseline echocardiographic examination, during low-dose dobutamine administration (10 μg/kg/min) and at the follow-up study after revascularization, were compared using a digital image analyzer (Freeland, CO, USA). In dobutamine stress echocardiography, improvement of contractile function was defined when the score improved by 1 grade or more.

Myocardial contrast echocardiography

Using a 20W, 20 kHz sonicator (Sonifier II, Branson, CT, USA), 5% human albumin was sonicated for 30 sec to obtain an ultrasonic contrast medium. Before revascularization, this contrast medium was infused manually into the right coronary artery (2 m*l*) and the left coronary artery (3 m*l*) at 1 m*l*/sec while simultaneously performing transtho-

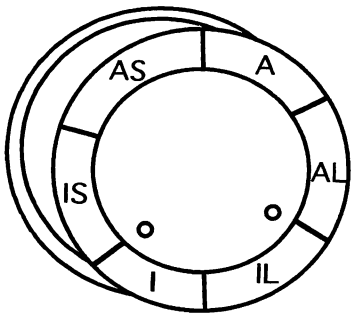

Fig. 1 Schematic representation of the six myocardial segments used for comparison of two-dimensional echocardiography and dipyridamole stress thallium-201 single photon emission computed tomography

A=anterior; AL=anterolateral; IL=inferolateral; I=inferior; IS=inferoseptal; AS=anteroseptal.

racic two-dimensional echocardiography. Segments with patchy or homogeneous opacification were defined as positive opacification.

Dipyridamole stress thallium-201 single photon emission computed tomography

Patients underwent SPECT (mean : 7.2 days) before revascularization. After dipyridamole (0.56 mg/kg) was injected intravenously for 4 min, ^{201}Tl (3 mCi) was injected intravenously. Tl images were acquired immediately after Tl injection (early image) and 3–4 hours after injection (delayed image). Short-axis, vertical long-axis and horizontal long-axis tomograms were displayed on transparency film for visual interpretation. On the mid-ventricular slices of the short-axis tomogram, Tl uptake was assessed visually using a 4-point scale : 3 (normal), 2 (mildly reduced), 1 (severely reduced) or 0 (absent). Segments of good Tl uptake (score 3 or 2) on delayed SPECT images were regarded as viable.

Follow-up study

At 2–5 months (mean : 3.6 months) after revascularization, the absence of restenosis was confirmed on the coronary angiogram, and subsequently follow-up resting two-dimensional echocardiography was performed. The definitive evidence of hibernating myocardium was provided by improvement of the wall motion score by 1 grade or more after revascularization.

The sensitivity, specificity, accuracy, and positive and negative predictive values of SPECT, dobutamine stress echocardiography and myocardial contrast echocardiography for predicting wall motion improvement after revascularization were calculated.

Table 1 Relationship between myocardial contrast echocardiography (MCE) and dobutamine stress echocardiography (DSE) findings

		Group A			Group B		
		MCE			MCE	
		+	−		+	−
DSE	+	○○○ ○○○ ○○		DSE +	○○●	
	−	○		−	○●	●●●

MCE+ : myocardial opacification (+), MCE− : myocardial opacification (−), DSE+ : wall motion improved with DSE, DSE− : wall motion not improved with DSE, ○ : segments with recovery of wall motion abnormality after revascularization, ● : segments with no recovery of wall motion abnormality after revascularization.

RESULTS

Seventy-eight segments of the 13 patients were examined. Seventeen segments showed severely reduced or akinetic wall motion (score 1 or 0) before revascularization. These 17 segments were classified into two groups by the Tl uptake on delayed SPECT images, and compared to findings from myocardial contrast echocardiography and dobutamine stress echocardiography, as shown in **Table 1**.

Usefulness of myocardial contrast echocardiography in assessment of myocardial viability

In group A (nine segments with Tl uptake score 3 or 2, that is, segments which had relatively good Tl uptake despite severely abnormal wall motion), all segments were opacified during myocardial contrast echocardiography, and showed improved wall motion after revascularization.

In group B (eight segments with Tl uptake score 1 or 0, that is, segments with poor Tl uptake and severely abnormal wall motion), five segments were opacified during myocardial contrast echocardiography and three were not. The latter three segments showed no improvement in wall motion during dobutamine stress echocardiography and after revascularization. Of the five segments opacified during myocardial contrast echocardiography, three showed improved wall motion after revascularization and two showed no improvement.

Table 2 Comparison of SPECT, dobutamine stress echocardiography and myocardial contrast echocardiography for prediction of wall motion recovery after revascularization

	Sensitivity (%)	Specificity (%)	Accuracy (%)	Predictive value	
				Positive (%)	Negative (%)
SPECT	75.0	100.0	82.0	100.0	62.5
DSE	83.3	80.0	82.4	90.9	66.7
MCE	100.0	60.0	88.2	85.7	100.0

SPECT=dipyridamole stress thallium-201 single photon emission computed tomography. Other abbreviations as in Table 1.

Predictive values of SPECT, dobutamine stress echocardiography and myocardial contrast echocardiography

The sensitivity, specificity, accuracy, and positive and negative predictive values of each imaging technique for predicting wall motion improvement after revascularization were analyzed in the 17 segments showing severely reduced wall motion (**Table 2**). The following three findings were assumed to be signs of myocardial viability : 1) good Tl uptake (score 3 or 2) on delayed SPECT images, 2) improved wall motion by dobutamine stress echocardiography, and 3) positive opacification of the myocardium by myocardial contrast echocardiography. Myocardial contrast echocardiography had the highest sensitivity (100%) and negative predictive value (100%). Delayed SPECT images had the highest specificity (100%) and positive predictive value (100%). Myocardial contrast echocardiography had the lowest specificity (60%).

DISCUSSION

Reduced wall motion was previously thought to represent necrotic myocardium. However, patients with no history of myocardial infarction but with severe stenosis of the coronary artery showed reduced wall motion after revascularization[8,9], and even patients with postmyocardial infarction showed recovery of wall motion after coronary revascularization[1]. The myocardium in such cases is called "hibernating myocardium"[10]. Reduced wall motion is not always irreversible but can sometimes be recovered when adequate blood flow is restored.

In recent years, low-dose dobutamine stress echocardiography has been used to evaluate hibernating myocardium. The sensitivity, specificity, accuracy, and positive and negative predictive values of dobutamine stress echocardiography-based detection of hibernating myocardium were 75.0, 77.8, 76.2, 81.8 and 70.0%, respectively[11].

Myocardial contrast echocardiography is considered useful in evaluating the effects of early reperfusion therapy for occluded coronary arteries in cases of acute myocardial infarction. However, the myocardium in some patients was not opacified with contrast medium even when reperfusion therapy was successfully performed. This finding was called the "no-reflow phenomenon" in animal models of acute myocardial infarction[12]. The no-reflow phenomenon predicts the poor recovery of wall motion after reperfusion therapy in acute myocardial infarction[13]. However, the usefulness of myocardial contrast echocardiography to predict wall motion recovery after revascularization in postinfarction patients remains unclear.

The present study attempted to evaluate the diagnostic values of dobutamine stress echocardiography and myocardial contrast echocardiography in predicting wall motion improvement after revascularization comparing the values with data yielded from SPECT. This evaluation yielded the following results : segments showing good Tl uptake on delayed images remained viable to some extent, even when wall motion was severely reduced. However, since wall motion in some segments was improved by revascularization even when Tl uptake on delayed images of these segments was poor, the evaluation of myocardial viability solely based on redistribution is limited. All 12 segments which showed improved wall motion after revascularization had been opacified during preoperative myocardial contrast echocardiography, and three segments without myocardial opacification showed no improvement in wall motion after revascularization. Therefore, myocardial opacification during myocardial contrast echocardiography, that is, the preservation of myocardial microcirculation, is indispensable for wall motion to improve after revascularization in postinfarction patients. All but one of the ventricular segments with severely reduced wall motion and markedly reduced Tl uptake on delayed images, but which were opacified during myocardial contrast echocardiography and showed improved wall motion during dobutamine stress echocardiography, showed improved wall motion after revascularization, sug-

gesting that myocardial segments which show such features before revascularization are viable and indicate revascularization procedures.

Myocardial areas which are opacified during myocardial contrast echocardiography but show reduced wall motion may be : 1) areas with hibernating myocardium, 2) areas comprising a mixture of scar tissue and normal myocardium, with adequate perfusion at rest to sustain cellular viability, and 3) areas with islands of viable myocytes surrounded by predominantly fibrotic tissue or areas tethered to regions of extensive scar tissue[14–17]. In the first case, wall motion is likely to improve during dobutamine stress echocardiography and after revascularization. In the second case, wall motion is likely to improve during dobutamine stress echocardiography but unlikely to improve after revascularization. In the third case, wall motion is not likely to improve during dobutamine stress echocardiography or after revascularization. This is probably the reason why the specificity of myocardial contrast echocardiography-based prediction of wall motion improvement after revascularization was lower than that of dobutamine stress echocardiography- or SPECT-based predictions. However, the sensitivity of dobutamine stress echocardiography was lower than that of myocardial contrast echocardiography and was comparable to that of SPECT. This is probably related to factors such as : 1) the difficulty in detecting mild improvement of wall motion by visual assessment, and 2) the possibility that ischemia is induced even by low-dose dobutamine administration (5–10 μg/kg/min) to hibernating myocardium. Opacification of the myocardium during myocardial contrast echocardiography is indispensable for improvement of wall motion following revascularization, but does not guarantee wall motion improvement in late postoperative periods. The assessment of myocardial perfusion by myocardial contrast echocardiography gives fewer false negative results than dobutamine stress echocardiography and SPECT. The techniques of dobutamine stress echocardiography are noninvasive, but have the risk of underestimating wall motion improvement after revascularization. Further examination by myocardial contrast echocardiography for the assessment of myocardial viability is recommended for determining the indication of coronary revascularization in spite of its invasiveness.

In our institution, SPECT is performed before revascularization to identify ischemic myocardium. Recently, many studies have reported that some segments which showed persistent Tl defects on redistribution images demonstrated enhanced reversibility after reinjection of Tl and that these segments showed improved regional wall motion after coronary angioplasty[18,19]. We believe that some persistent defects in our patients would have been reversible after Tl reinjection. The usefulness of the myocardial contrast echocardiography and dobutamine stress echocardiography compared with reinjection Tl imaging protocol must be evaluated in further studies.

There are several potential limitations of this study. First, we obtained only one short-axis slice at the mid-ventricular level because of the difficulty in obtaining multiple echocardiographic images during the short period of injection of contrast material. One short-axis slice obviously does not depict the entire infarct area, so assessment by integrating information from multiple images is necessary for precise analysis of wall motion and myocardial perfusion. Second, the short-axis slice may not have been precisely the same in myocardial contrast echocardiography and SPECT. We used the right to left ventricular junction as the anatomic landmark and obtained the short-axis slice at the mid-ventricular level to minimize discrepancies in the tomography studied in myocardial contrast echocardiography and SPECT.

This preliminary report includes a relatively small number of patients. Further studies in a larger population are necessary to assess precisely the advantage and limitation of myocardial contrast echocardiography, dobutamine stress echocardiography and SPECT for the prediction of wall motion improvement after coronary revascularization.

CONCLUSIONS

SPECT, dobutamine stress echocardiography and myocardial contrast echocardiography were carried out in patients with postmyocardial infarction who had abnormal wall motion. The following results were obtained:

1) The myocardium can be regarded as viable if Tl uptake on delayed SPECT images is adequate, even when severe wall motion abnormalities are visible.

2) The absence of myocardial opacification by myocardial contrast echocardiography indicates the

loss of myocardial viability.

3) The myocardium is regarded as viable and revascularization is indicated when the myocardium is opacified by myocardial contrast echocardiography and shows improved wall motion by dobutamine stress echocardiography despite the presence of severe wall motion abnormalities and marked reduction in Tl uptake.

4) Myocardial contrast echocardiography is superior to dobutamine stress echocardiography and SPECT in sensitivity, accuracy, and negative predictive value, but inferior in specificity and positive predictive value.

These findings indicate that even when wall motion is severely abnormal and Tl uptake is markedly reduced, the additional information yielded from myocardial contrast echocardiography and dobutamine stress echocardiography will allow a more detailed assessment of myocardial viability and thus help clinicians to determine the indications for revascularization in an individual patient.

要　約

陳旧性心筋梗塞症における血行再建術後の壁運動改善の予測：Dobutamine 負荷心エコーと心筋コントラストエコー図法の有用性と問題点

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壁運動異常を有する陳旧性心筋梗塞症例 13 例に，dobutamine 負荷心エコー図法，心筋コントラストエコー図法および dipyridamole 負荷 thallium (Tl)-201 SPECT を施行し，血行再建術後の壁運動改善を予測する際の各検査の診断的価値を比較検討した．

血行再建術前に高度壁運動異常を示した左室 17 分画のうち，SPECT の遅延像 (delayed image) で Tl の取り込みが比較的良好な 9 分画は，全て心筋コントラストエコー図法で染影され，血行再建術後壁運動は改善した．一方，心筋コントラストエコー図法で染影のなかった 3 分画は，全て dobutamine 負荷心エコー図法で壁運動改善を認めず，また血行再建術後にも壁運動改善はなかった．

1) SPECT の遅延像での Tl の良好な取り込み，2) dobutamine 負荷心エコー図法での負荷時壁運動改善，3) 心筋コントラストエコー図法での心筋染影の存在の 3 所見を心筋の生存可能性 (viability) の存在を示す所見と仮定すると，感度と陰性反応適中度は心筋コントラストエコー図法が 100% で最も高く，特異度と陽性反応適中度は SPECT の遅延像が 100% で最も高かった．Dobutamine 負荷心エコー図法は，感度 83.0%，特異度 80.0%，陽性反応適中度 90.9%，陰性反応適中度 66.7% であった．また心筋コントラストエコー図法の特異度は 60.0% で最も低かった．

Dobutamine 負荷心エコー図法や SPECT は非観血的方法であるが，術後の壁運動改善を過小評価する可能性がある．したがって，観血的方法ではあるが，心筋コントラストエコー図法を追加検討することで，より詳細に心筋 viability の推察が可能となると思われた．

J Cardiol 1997; 30 (4): 197–203

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