Clinical Usefulness of Myocardial Contrast Echocardiography to Detect Stress-Induced Cardiomyopathy in the Emergency Department

Jung-Hyun Choi, MD; Jong-Ho Nam, MD; Jang-Won Son, MD; Sang-Hee Lee, MD; Ung Kim, MD, PhD; Jong-Seon Park, MD, PhD; Dong-Gu Shin, MD, PhD; Young-Jo Kim, MD, PhD; Geu-Ru Hong, MD, PhD

Background: The purpose of this study was to investigate the clinical usefulness of myocardial contrast echocardiography (MCE) to distinguish stress-induced cardiomyopathy (SCMP) from acute myocardial infarction (AMI) in the emergency department (ED).

Methods and Results: We investigated 51 patients (62±13 years, 29 women) who had suspected SCMP in the ED with acute chest pain and showed apical wall motion abnormality on 2-dimensional echocardiography. All patients were assessed by real-time MCE and the perfusion status and quantitative myocardial perfusion parameters were analyzed. After MCE, coronary angiography was performed within 24 h. Of 51 patients, 27 had significant perfusion defects (group A) and 24 had preserved perfusion at the apex (group B) by MCE. In group A, 25 patients showed significant luminal stenosis in the left anterior descending artery (LAD) and 2 patients showed no critical luminal stenosis. In group B, 20 patients showed no luminal stenosis and 4 patients showed moderate LAD stenosis. Sensitivity, specificity, positive and negative predictive values of MCE for detection of SCMP were 91%, 86.2%, 83%, and 93%, respectively. Quantitative MCE parameters were significantly decreased in group A compared with group B.

Conclusions: Myocardial perfusion measured by MCE is relatively preserved in patients with SCMP compared with those with AMI. Therefore, real-time MCE may be a useful noninvasive diagnostic tool to distinguish SCMP from AMI in the ED. (Circ J 2012; 76: 1393–1398)

Key Words: Contrast echocardiography; Stress-induced cardiomyopathy

Stress-induced cardiomyopathy (SCMP) is characterized by an acute onset of reversible left ventricular (LV) dysfunction in the absence of significant coronary artery disease (CAD).1 Patients typically present with cardiac chest pain, which can mimic acute coronary syndrome (ACS). Although the coronary arteries have no flow-limiting lesions, an ECG shows acute changes and cardiac enzymes are usually raised.2-3 Therefore, the signs and symptoms of most of these patients at the emergency department (ED) are often confused with those of acute myocardial infarction (AMI). Despite a similar clinical presentation to AMI, the treatment and prognosis of SCMP are different,2 so early and correct triaging of these patients to revascularization vs. medical, supportive therapy is mandatory to improve patient outcome and save medical costs.

Myocardial contrast echocardiography (MCE), which uses an intravenous contrast agent that traverses the microvasculature, has the potential to provide real-time, noninvasive assessment of myocardial perfusion at the bedside. It has been shown to be accurate in detecting flow-limiting CAD in patients with suspected CAD.4-8 Recent studies have shown that SCMP is associated with dysfunction of the microvascular perfusion rather than obstruction of an epicardial coronary artery.7 Therefore, we hypothesized that MCE may also be able to accurately distinguish SCMP from AMI. The aim of this study was to investigate the clinical usefulness of MCE for distinguishing SCMP from AMI in the ED setting.

Methods

Study Population and Design
From June 2009 to March 2011, we prospectively enrolled 51 patients (62±13 years, 29 women) who had suspected SCMP in the ED with acute chest pain and showed an apical wall...
motion (WM) abnormality on 2-dimensional (2D) echocardiography. Exclusion criteria were the presence of definite Q wave or ST-segment elevation on the ECG, a history of MI, history of myocardial revascularization, significant valvular heart disease, significant arrhythmias, hemodynamically unstable, and poor image quality for MCE. Informed consent was given by all enrolled patients, and the study protocol was approved by the Ethics Committee of Yeungnam University, Daegu, Korea.

The 51 patients underwent clinical evaluation, ECG, cardiac enzyme [troponin-I (Tn-I) and myocardial-bound creatine kinase (CK-MB)] measurement, and transthoracic echocardiography (TTE). They presented ischemic-like chest pain, ECG abnormalities such as T-wave inversion and ST depression, elevated cardiac enzyme levels, WM abnormality at apex by TTE and a particularly stressful incident preceding the onset of symptoms, such as a psychological, physical or disease-related trigger. Real-time MCE was performed in the ED for all patients immediately after TTE. The patients were divided into 2 groups according to their myocardial perfusion state. Group A included patients with a significant perfusion defect at the apex. Group B consisted of patients without a definite perfusion defect or preserved perfusion at the apex compared to other myocardial segments. After MCE, coronary angiography (CAG) was performed within 24 h (Figure 1). An increased cardiac enzyme level was defined as an initial Tn-I level >1.5 ng/ml and/or CK-MB more than twice the upper limit of normal (3.6 ng/ml). AMI was confirmed by documentation of significant coronary artery stenosis, presence of thrombus or plaque rupture requiring urgent revascularization.8,9

**2D Echocardiography and MCE**

2D echocardiography was performed in the standard apical and parasternal views using tissue harmonic imaging to assess regional WM abnormality (RWMA) and global left ventricular ejection fraction (LVEF). MCE was performed with the Sequoia CS12 (Acuson, Mountain View, CA, USA) platform using contrast pulse sequencing technology. All images were acquired in the apical 4-, 2-, and 3-chamber views using low-power continuous power modulation MCE at a mechanical index of 0.1–0.2. Tissue signal was minimized by reducing background gain and color gains, so that the Doppler signal was only seen at the mitral valve and proximal to the apex. Definity® (Perflutren Lipid Microsphere, Lantheus Imaging, North Billerica, MA, USA) was infused at a rate of 100–200 ml/h by infusion pump. The infusion rate was adjusted to maintain homogeneous contrast enhancement in the myocardium without attenuation. Destruction-replenishment imaging was used with a high-mechanical index (1.2) pulse to destroy microbubbles. The number of frames for a high-mechanical burst varied from 8 to 12 to achieve destruction of microbubbles within the myocardium. End-systolic frames were captured for a minimum of 15 s following microbubble destruction to record replenishment. MCE was performed in the mean time of 7.8±5.2 h and CAG was performed 14.8±8.5 h from ED visit. Follow-up 2D TTE was performed in all patients after 30 days.

**MCE Data Analysis**

All stored images were analyzed using a 17-segment model by 1 experienced investigator (for qualitative MCE) and 2 independent investigators (for quantitative MCE), all of whom were blinded to the clinical data. When a transmural or subendocardial perfusion defect was associated with a WM abnormality in the same area, or if the severity of the perfusion defects changed according to the adjusted triggering interval, perfusion defects were regarded as true myocardial perfusion defects as distinct from artifacts. If there was homogeneous contrast enhancement in the myocardium within 15 cardiac cycles it was regarded as preserved perfusion.

Axius ACQ auto-tracking contrast quantification software (Acuson, Mountain View, CA, USA) was used to quantify MCE. The region of interest was placed in the apical segments showing RWMA across the entire thickness of the myocardium, excluding the high-intensity endocardial and epicardial borders. A single value was obtained for the apical segment by averaging the results obtained. Segments with artifacts or attenuation were excluded. This quantification software automatically constructed background-subtracted plots of peak myocardial contrast intensity, representing capillary blood volume vs. pulsing intervals, from which the slope of the replenishment curve depicting mean microbubble velocity (β) was derived. Frames showing a wide variation in contrast intensity were discarded to minimize errors in the analysis. For the evaluation of myocardial blood flow (MBF), we measured β and A. Beta (s⁻¹) represents the mean red blood cell velocity and A (dB) represents myocardial blood volume; the product of the 2 is proportional to MBF (dB/s).10 10 randomly chosen studies were reanalyzed for intra- and interobserver variabilities.

**Coronary Angiography**

CAG was performed in all patients by conventional methods. Significant CAD was defined as the presence of >50% luminal diameter narrowing in ≥1 major epicardial artery or the presence of thrombus. If there was no significant coronary artery stenosis, we performed the ergonovine provocation test to rule out coronary artery spasm. If there was significant coronary
artery stenosis (>70%), we performed a percutaneous coronary intervention. If there was abnormal haziness or filling defects on CAG, we performed intravascular ultrasound to confirm intracoronary thrombus or plaque rupture and embolization.

Statistical Analyses
Numerical variables are expressed as mean±SD (standard deviation). Frequencies and percentages are used to report categorical variables. Independent t-tests were used to compare continuous quantitative perfusion parameters between the 2 groups. Pearson’s chi-square test was used to compare the frequency ratio between groups. Sensitivity, specificity, positive predictive values, negative predictive values and accuracy for detecting significant CAD was also calculated. A P value <0.05 was considered statistically significant.

Results

Patients’ Demographics
Table 1 summarizes the characteristics of the study population. The patients were 22–87 years old (mean±SD, 62±13 years). Among the 51 patients, 29 (57%) were women and 23 (45%) had 2 or more CAD risk factors. In group A, 25 patients had significant stenosis in the left anterior descending artery (LAD) and 9 patients (36%) had multivessel disease. There were no significant differences in the distributions of age, coronary risk factors (hypertension, diabetes mellitus, hyperlipidemia, smoking and family history of CAD), WM score index and LVEF between the 2 groups. Tn-I (74.42±90.16 vs. 10.24±13.27, P<0.001) levels were significantly higher in group A than in group B. Group B patients were predominantly women (19 vs. 10 in group A; P<0.001). All patients showed severe hypokinesia or akinesia at the LV apex.

MCE Study
Qualitative According to the criteria used, all patients had analyzable images. The mean time for resting image acquisition for MCE was 8.7±2.3 min. There were no immediate or short-term (≤24 h) adverse events related to contrast infusion.

Of the 51 patients, qualitative MCE analysis was feasible in 225 of 255 apical segments (88%). In these 225 apical segments, 120 segments from 27 patients showed a WM abnormality with a perfusion defect (Group A, Movie S1) and 105 segments from 24 patients showed preserved perfusion with an apical WM abnormality (Group B, Movie S2). In group A, 25 patients (92.6%) showed significant coronary artery stenosis or thrombus and only 2 patients (7.4%) showed no significant luminal stenosis on CAG. In group B, 20 patients (83.3%) showed no significant luminal stenosis and 4 patients (16.7%) had significant coronary artery stenosis (ie, 50% stenosis at mid-LAD, 60% stenosis at distal LAD, 70% stenosis at distal LAD but small in size, diffuse irregular stenosis at distal LAD). There were no signs of plaque rupture or thrombus in group B (Figure 2). True-negative results accounted for 20 of 24 negative test results when MCE perfusion was considered. MCE perfusion imaging resulted in 25 true-positive findings out of 27 positive test results. Sensitivity and specificity of MCE to distinguish SCMP from AMI was 91% and 86.2%, respectively. Positive predictive values, negative predictive values and accuracy were 83%, 93% and 88.2%, respectively (Table 2).

Follow-up standard 2D TTE (mean follow-up, 58±31.0 days) showed complete recovery of both WM and systolic function or wall thickening in 20 patients (83%) and partial recovery in 4 patients (17%) in group B. In group A, 19 patients (70%) showed no WM improvement and 8 patients (30%) showed partial WM recovery.

Quantitative Quantitative MCE was feasible in 205 of 225 apical segments (91%). In group B, A (7.65±4.53 vs. 3.36±2.07, P<0.001, respectively), β (0.51±0.35 vs. 0.27±0.32, P<0.001, respectively), and Aβ (3.95±1.93 vs. 0.95±0.84, P<0.001, respectively) were significantly higher than in group A (Table 3). The intra- and interobserver agreements of qualitative MCE in our laboratory were 89% (k=0.64) and 85% (k=0.61) for myocardial perfusion. The intra- and interobserver variabilities for

### Table 1. Baseline Clinical, Echocardiographic and Coronary Angiographic Characteristics of the Patients

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=27)</th>
<th>Group B (n=24)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>62±14</td>
<td>63±13</td>
<td>NS</td>
</tr>
<tr>
<td>Women, n (%)</td>
<td>10 (37)</td>
<td>19 (79)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>7 (26)</td>
<td>6 (25)</td>
<td>NS</td>
</tr>
<tr>
<td>Diabetes mellitus, n (%)</td>
<td>7 (26)</td>
<td>3 (13)</td>
<td>NS</td>
</tr>
<tr>
<td>Hyperlipidemia, n (%)</td>
<td>5 (19)</td>
<td>4 (17)</td>
<td>NS</td>
</tr>
<tr>
<td>Smoking history, n (%)</td>
<td>7 (26)</td>
<td>4 (17)</td>
<td>NS</td>
</tr>
<tr>
<td>Family history of CAD, n (%)</td>
<td>0 (0)</td>
<td>1 (4)</td>
<td>NS</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>40.38±6.08</td>
<td>44.81±12.54</td>
<td>NS</td>
</tr>
<tr>
<td>WMSI</td>
<td>1.85±0.57</td>
<td>1.77±0.48</td>
<td>NS</td>
</tr>
<tr>
<td>TnI, ng/ml</td>
<td>74.42±90.16</td>
<td>3.60±4.17</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>CK-MB, ng/ml</td>
<td>162.86±170.16</td>
<td>10.24±13.27</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Coronary angiography, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-vessel disease</td>
<td>16 (59)</td>
<td>4 (17)</td>
<td>–</td>
</tr>
<tr>
<td>2-vessel disease</td>
<td>6 (22)</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>3-vessel disease</td>
<td>3 (11)</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>LAD disease</td>
<td>25 (93)</td>
<td>4 (17)</td>
<td>–</td>
</tr>
<tr>
<td>Multivessel disease</td>
<td>9 (33)</td>
<td>0</td>
<td>–</td>
</tr>
</tbody>
</table>

Data are presented as number (%) or mean±standard deviation. P value corresponds to comparison between 2 groups. Group A, perfusion defect at apex; Group B, preserved perfusion at apex; CAD, coronary artery disease; LVEF, left ventricular ejection fraction; CK, creatine kinase; LAD, left anterior descending artery; RCA, right coronary artery; LCX, left circumflex artery; NS, not significant.

### Table 2

<table>
<thead>
<tr>
<th>Coronary Angiographic Characteristics</th>
<th>Group A</th>
<th>Group B</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-vessel disease</td>
<td>16 (59)</td>
<td>4 (17)</td>
<td>–</td>
</tr>
<tr>
<td>2-vessel disease</td>
<td>6 (22)</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>3-vessel disease</td>
<td>3 (11)</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>LAD disease</td>
<td>25 (93)</td>
<td>4 (17)</td>
<td>–</td>
</tr>
<tr>
<td>Multivessel disease</td>
<td>9 (33)</td>
<td>0</td>
<td>–</td>
</tr>
</tbody>
</table>
Figure 2. Example of MCE and CAG in patients with AMI or SCMP. (A) In a MI patient, a myocardial perfusion defect at the apex and LAD stenosis were observed using MCE and CAG, respectively (white arrow). (B) Otherwise, preserved myocardial perfusion at the apex and no significant coronary stenosis were noted in a SCMP patient. MCE, myocardial contrast echocardiography; CAG, coronary angiography; AMI, acute myocardial infarction; SCMP, stress-induced cardiomyopathy; LAD, left anterior descending artery.

Table 2. Diagnostic Accuracy of MCE for Detecting SCMP

<table>
<thead>
<tr>
<th></th>
<th>CAD (–)</th>
<th>CAD (+)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>2</td>
<td>25</td>
<td>27</td>
</tr>
<tr>
<td>Group B</td>
<td>20</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>29</td>
<td>51</td>
</tr>
</tbody>
</table>

Data are presented as number. Sensitivity: 91%, specificity: 86.2%. Positive predictive value: 83%, negative predictive value: 93%.

MCE, myocardial contrast echocardiography; SCMP, stress-induced cardiomyopathy; CAD, coronary artery disease; Group A, perfusion defect at apex; Group B, no definite perfusion defect at apex.

Table 3. Differences in Quantitative MCE Parameters Between the 2 Groups

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=27)</th>
<th>Group B (n=24)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(dB)</td>
<td>3.36±2.07</td>
<td>7.65±4.53</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>β(s⁻¹)</td>
<td>0.27±0.32</td>
<td>0.51±0.35</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Aβ(dB/s)</td>
<td>0.95±0.84</td>
<td>3.95±1.93</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Data are presented as mean±standard deviation. P value corresponds to comparison between 2 groups.

MCE, myocardial contrast echocardiography; Group A, perfusion defect at apex; Group B, no definite perfusion defect at apex; A(dB), myocardial blood volume; β(s⁻¹), mean microbubble velocity; Aβ(dB/s), myocardial blood flow.
quantitative MCE were assessed by determining the correlation coefficients. There was no significant difference between 2 observers or within an observer for quantitative MCE analysis (2-sided P value of 0.05).

Discussion

This is the first clinical study demonstrating the value of MCE in distinguishing SCMP from AMI in the ED setting.

SCMP is found in 1.7–2.2% of patients with ACS.1 The pathogenesis of the SCMP is not well understood and postulated mechanisms include catecholamine excess, coronary artery spasm, and microvascular dysfunction.12,13 Despite advances in clinical, ECG, serological and 2D TTE assessments, the differential diagnosis of SCMP from AMI in the ED remains problematic.14–16 Because of the similar clinical presentation to AMI, such as acute onset of chest pain or dyspnea, apical RWMA, modest elevations of cardiac enzyme levels, ST-segment changes and evolutionary T-wave inversions on ECG,12,17 it is expected that most patients with SCMP will undergo emergency CAG. In this study, almost all of the demographic and clinical features were not useful in the early triage of these patients. Although cardiac enzyme (Tn-I, CK-MB) levels were significantly higher in group A, there was no clear cut-off value for diagnosing SCMP from AMI. The patients with SCMP were predominantly women (19 vs. 10, P<0.001), which is similar to findings in previous studies.11,17–19 However, this does not seem to play a pivotal role in confirming SCMP in the ED.

The final diagnosis of SCMP is made by the patient’s history, ECG abnormalities, elevation of cardiac biomarkers, pathognomonic RWMA on echocardiography, and CAG, which typically demonstrates either normal vessels or mild to moderate coronary atherosclerosis. However, obstructive CAD may rarely coexist20 and CAG is invasive and not cost-effective considering the characteristics of SCMP. Cardiovascular magnetic resonance imaging (CMR) may be helpful in differentiating SCMP, which is characterized by reversible perfusion abnormalities without delayed gadolinium enhancement in the LV apex, from AMI.21–25 However, accessibility, complexity, long scan time and cost are critical limitations for the use of CMR as an initial diagnostic modality to confirm SCMP in the ED setting.

Recent developments in microbubble technology and ultrasound imaging techniques have made it possible to achieve real-time assessment of myocardial perfusion.4,6,24,25 Hayat et al25 reported that MCE entails the use of microbubbles during echocardiography that remain within the intravascular space, and their presence within any myocardial territory denotes the microvascular perfusion status within that region.25 The clinical benefit of MCE for detecting myocardial ischemia has been demonstrated.25 Moreover, quantitative assessment of myocardial perfusion is possible by using ultrasound-induced destruction of microbubbles and assessment of their replenishment.20 Therefore, we hypothesized that myocardial perfusion as assessed by MCE might be relatively preserved in patients with SCMP compared with patients with AMI.

In this study, MCE was a useful tool for distinguishing SCMP from AMI with high sensitivity (91%) and specificity (86.2%). Furthermore, qualitative assessment demonstrated high accuracy for the detection of SCMP from AMI with good positive predictive value (83%) and negative predictive value (93%). Four patients showed negative MCE with significant coronary stenosis (false negative), but the degree of stenosis was modest, distally located, or small in size and only 2 patients showing positive MCE had no significant coronary stenosis (false positive).

Quantitative MCE analysis further supported these findings. In this study, the presence of severe coronary stenosis in group A patients resulted in a significant decrease in MBF compared with that of group B, because of occlusion of the epicardial coronary artery. Several diagnostic methods have been used to evaluate microvascular perfusion in patients with SCMP, including Doppler guidewire recording,27 single-photon-emission computed tomography (SPECT),28,29 and MCE.7 Abdelmoneim et al reported that myocardial perfusion by contrast echocardiography was significantly decreased at the abnormal WM area compared with normal segment in patients with SCMP.7 However, their studies were conducted in a small number of patients and compared myocardial perfusion states with normal segments in the same population. In our study, in agreement with other studies,7,28–30 quantitative MCE parameters were also significantly decreased in the abnormal WM area compared with normal segments for A (7.65±2.53 vs. 10.58±5.12, P<0.05), β (0.51±0.35 vs. 0.69±0.48, P<0.05) and Ap (3.95±1.93 vs. 7.45±6.89, P<0.001) respectively. This finding supports that transient coronary microvascular dysfunction is a key feature of SCMP. Notwithstanding this finding, the perfusion defect in AMI is more definitive than that of SCMP (Table 3). AMI caused by epicardial coronary artery occlusion may show more severe perfusion defects than that of the microvascular perfusion dysfunction of SCMP.

Unlike previous attempts, the current study is unique in reporting the clinical usefulness of qualitative and quantitative MCE analysis to triage SCMP from AMI in the setting of ED. Our results show that imaging of myocardial perfusion by MCE provides valuable diagnostic information during ED presentation. Relatively preserved myocardial perfusion by MCE virtually rules out AMI in patients with suspected SCMP. This information can be used for either further evaluation or rapid treatment of patients with suspected SCMP.

Study Limitations

This study was limited by the small number of patients. We excluded patients with an obvious suspicion of AMI, in unstable condition or with poor image quality. We wanted to identify SCMP using bedside MCE when the differential diagnosis of SCMP from AMI is difficult by conventional imaging modalities. That is one of the reasons why the total study population was small, despite the relatively large number of SCMP patients. Another limitation was the absence of a comparison group, such as CMR or SPECT, which could have provided the validity of the findings. This study was designed to evaluate the clinical usefulness of MCE in triaging SCMP from AMI in the ED setting. Therefore, after TTE and MCE evaluation in the ED, CAG was performed as soon as possible. Also, we did not include cases of atypical SCMP or non-LAD MI. Perfusion analysis by MCE has limitations of analysis of the inferior and lateral wall because of the frequent artifacts and attenuation. Therefore, we wanted to focus on differentiating typical SCMP from acute anterior wall MI. If early spontaneous reperfusion occurs in patients with AMI, this may result in the presence of MCE perfusion and it is difficult to definitely differentiate this phenomenon from SCMP using MCE alone. For the differential diagnosis, additional information, including clinical history, ECG abnormalities, and cardiac enzyme levels, may be needed to confirm the diagnosis. Lastly, qualitative and quantitative analyses of MCE images were used in this study. Digital acquisition and quantitative analysis might allow for more objective interpretation.
However, quantitative analysis of MCE images may be a time-consuming procedure in the ED setting, where rapid and timely interpretation is needed. Nevertheless, our findings (i.e., usefulness of MCE for detecting SCMP in the ED setting) warrant further confirmatory large prospective studies.

**Conclusions**

Myocardial perfusion measured by MCE is relatively preserved in patients with SCMP than in those with AMI. Therefore, real-time MCE may be a useful noninvasive diagnostic tool to distinguish SCMP from AMI in the ED.

**Acknowledgment**

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (No. 2011-0006184).

**References**


**Supplemental Files**

**Supplemental File 1**

**Movie S1.** Myocardial contrast echocardiography image in a patient with acute anterior wall myocardial infarction. A myocardial perfusion defect is clearly seen in the apex.

**Supplemental File 2**

**Movie S2.** Myocardial contrast echocardiography image in a patient with stress-induced cardiomyopathy. Despite a regional wall motion abnormality, myocardial perfusion is well preserved in the apex.

Please find supplemental file(s); https://dx.doi.org/10.1253/circj.CJ-11-1512