In some patients with chronic coronary artery disease, persistent left ventricular (LV) dysfunction can be restored by coronary revascularization. Thus, identifying potentially reversible dysfunction has important therapeutic and prognostic implications. Recently, it was reported that the cyclic variation (CV) of myocardial integrated backscatter (IBS), which reflects intrinsic contractile performance, can predict myocardial viability in patients with a reperfused acute myocardial infarction (MI). However, this method has not been validated for chronic LV dysfunction. The aim of this study was to examine whether myocardial IBS was useful for predicting LV functional recovery after coronary revascularization in patients with chronic LV dysfunction caused by a remote anterior MI.

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Key Words: Echocardiography; Myocardial infarction; Myocardial viability; Tissue characterization
At baseline, all patients underwent coronary and LV angiography. LV end-diastolic and end-systolic contours were traced in the frames with maximal and minimal volumes, respectively. LV volume was calculated with the area-length method, from which LVEF was derived (calculated by G.S. and M.T. who were without knowledge of the echocardiographic data). LV end-diastolic pressure was recorded with the fluid-filled method immediately before angiography. The degree of the culprit coronary artery was graded on a scale of 0 to 3, as proposed by the TIMI study group. The grade of collateral vessels was also assessed according to the scale proposed by Rentrop et al.

Echocardiography
Transthoracic echocardiography with IBS analysis was performed within 24h of the revascularization procedure using a 2.5-MHz phased-array probe attached to a commercially available echocardiographic apparatus (Hewlett Packard SONOS 2500, Andover, MA, USA). The IBS software allows the operator to acquire, store and retrieve a sequence of continuous 2-dimensional IBS images (62 frames), forming a continuous loop digital recording of a 2-s period. We performed off-line analysis of the acquired IBS images by retrieving the cineloop stored on an optical disk. A ROI, an ellipsoid figure of 21 pixels, was placed within the mid-myocardium of the anterior and posterior myocardium and traced during the cineloop. We constructed the IBS curve and obtained 2 parameters: the magnitude of CV, and normalized time delay. The former was the difference between the minimal and maximal values in a cardiac cycle averaged over at least 2 consecutive beats, irrespective of its synchronicity. The latter was determined by dividing the interval between the upstroke of the QRS complex and the nadir of the IBS curve by QT interval, as described. In our institution, the magnitude of CV in the anterior wall of normal healthy subjects was 8.3±2.4 dB. The normalized time delay in the normal area (posterior wall) was 1.1±0.1. If the normalized delay in the infarct area (anterior wall) was ≥1.3 (mean ±2SD of normal), we considered the IBS curve to have an asynchronized pattern (Fig 1).

We also analyzed LV wall motion at entry and the following scoring system was used: segments with normal motion were assigned a value of 1, hypokinesia 2, akinesia 3, and dyskinesia 4. A regional wall motion score index for the territory of the anterior descending artery was obtained by dividing the total scores by the number of segments analyzed.

Patient Groups
Patients were divided into 2 groups according to the patterns of the IBS curve; that is, IBS curve had a synchronized pattern (normalized time delay <1.3) with the magnitude of CV ≥3.5 (–2SD of that obtained from normal subjects) (group A); IBS curve had either an asynchronized pattern or the magnitude of CV was <3.5 even in the case of a synchronized pattern, or both (group B).

Follow-up Angiography
At 3 or 6 months after the revascularization procedure, we repeated the coronary and left ventricular angiography to ensure the patency of the left anterior descending artery and to assess LV function. In our institution, patients undergoing percutaneous transluminal coronary angioplasty undergo coronary angiography at 3 months after coronary intervention whereas those undergoing coronary stenting have repeat angiography at 6 months. LV volumes, LVEF, and end-diastolic pressure were measured.

Assessment of Reproducibility
The inter- and intraobserver variabilities for the magnitude of CV were assessed by 2 independent observers (S.M. and T.N.) without knowledge of the hemodynamic data. They were measured by tracing 10 myocardial regions on the same loop digital recordings.

Statistical Analysis
Differences between 2 groups were assessed by using the unpaired t-test or chi-square test. Changes in hemodynamic parameters in each patient group were assessed by the paired t-test. Data are expressed by mean ± SD and p<0.05.
was considered significant.

**Results**

**Patient Groups (Fig 2)**

Group A consisted of 8 patients and group B had 9 patients. Table 1 compares the clinical and echocardiographic data at baseline. There was no significant difference with regard to age or gender distribution between the groups. The proportion of patients who had had a non-Q-wave MI and the mode of coronary intervention were similar. The incidence of poor anterograde perfusion with TIMI grade 1 or 2 and the incidence of well-developed collateral vessels (Rentrop grade 3) were comparable. The wall motion score index for the territory of the anterior descending artery was also similar between the groups (2.6±0.4 to 2.7±0.4, p=0.668). For the IBS data, the normalized time delay was significantly increased in group B compared with group A, although no difference was observed in the magnitude of CV.

**Follow-up Angiography (Fig 3)**

In both groups, the LV end-diastolic volume did not alter significantly (115±18 ml to 110±15 ml, p=0.428 for group A and 109±24 ml to 111±22 ml, p=0.478 for group B), but in group A, however, the LV end-systolic volume decreased (75±21 ml to 56±20 ml, p=0.05), LVEF increased (35±12% to 50±14%, p=0.014), and LV end-diastolic pressure (19±10 mmHg to 13±6 mmHg, p=0.02) decreased. In group B, only the LVEF (34±9% to 40±11%, p=0.03) improved significantly; LV end-systolic volume (72±19 ml to 66±16 ml, p=0.126) and LV end-diastolic pressure (18±12 mmHg to 14±8 mmHg, p=0.184) showed no significant changes.

**Reproducibility**

The inter- and intraobserver variabilities for the magnitude of CV were 0.6±0.4 dB and 0.5±0.4 dB (absolute differences), respectively, without significant differences between observations.

### Table 1 Clinical and Echocardiographic Data of the 2 Patients Groups

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=8)</th>
<th>Group B (n=9)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>56±6</td>
<td>59±11</td>
<td>0.406</td>
</tr>
<tr>
<td>Female gender</td>
<td>1 (13%)</td>
<td>1 (11%)</td>
<td>0.929</td>
</tr>
<tr>
<td>Non Q-wave MI</td>
<td>1 (13%)</td>
<td>3 (33%)</td>
<td>0.321</td>
</tr>
<tr>
<td>Coronary intervention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stenting</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>PTCA</td>
<td>1</td>
<td>2</td>
<td>0.6</td>
</tr>
<tr>
<td>Coronary angiographic findings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIMI grade 1 or 2</td>
<td>2 (25%)</td>
<td>3 (33%)</td>
<td>0.781</td>
</tr>
<tr>
<td>Collateral vessels grade 3</td>
<td>1 (13%)</td>
<td>0 (0%)</td>
<td>0.304</td>
</tr>
<tr>
<td>IBS date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnitude of CV in the anterior wall (dB)</td>
<td>5.3±1.3</td>
<td>5.3±1.7</td>
<td>0.977</td>
</tr>
<tr>
<td>Magnitude of CV in the posterior wall (dB)</td>
<td>7.5±1.5</td>
<td>6.6±1.8</td>
<td>0.285</td>
</tr>
<tr>
<td>Normalized time-delay in the anterior wall</td>
<td>1.13±0.10</td>
<td>1.63±0.33</td>
<td>0.001</td>
</tr>
<tr>
<td>Normalized time-delay in the posterior wall</td>
<td>1.08±0.12</td>
<td>1.08±0.07</td>
<td>0.993</td>
</tr>
</tbody>
</table>

*Values expressed as mean±SD. MI, myocardial infarction; PTCA, percutaneous transluminal coronary angioplasty; IBS, integrated backscatter; CV, cyclic variation.*

**Discussion**

**Role of IBS in the Assessment of Myocardial Viability**

It is well established that impaired LV dysfunction caused by myocardial ischemia is not always irreversible, because LV function may improve after myocardial revascularization procedures. To date, noninvasive methods to identify viable but dysfunctional myocardium include positron emission tomography to assess myocardial metabolic activity and 201Tl imaging to assess myocardial perfusion and dobutamine echocardiography to assess myocardial contractile reserve. However, all three methods are somewhat expensive and time-consuming, and therefore an easy and cost-effective method is required.

Recently, IBS has emerged as a useful diagnostic tool.
for assessing myocardial viability. Takuchi et al used it to assess myocardial viability in patients with reperfused acute MI and found that the recovery of visually assessed regional contraction followed that of CV (for both magnitude of CV and normalized time delay). For patients with chronic LV ischemic dysfunction, on the other hand, Pasquet et al and later Homma et al showed the usefulness of IBS for assessing contractile reserve in combination with dobutamine echocardiography. Naito et al demonstrated that in patients with a remote MI, the magnitude of CV correlated with the percent $^{201}$Tl uptake on perfusion imaging. The results of the present study extend these earlier observations to patients with chronic LV dysfunction caused by an anterior MI. We measured LV functional indices in a longitudinal fashion with angiography, which is the gold standard for assessing LV function. The reasons for including only patients with anterior MI were: (1) narrowing or obstruction of the left anterior descending artery is the most common cause of LV dysfunction after MI, (2) The magnitude of CV basically differs between the anterior and posterior myocardium even in normal healthy subjects, and (3) the ultrasound beam is always perpendicular to the myocardial segments analyzed with IBS.

In the present study, patients with preserved CV showed better recovery of LV function than those with blunted or even absent CV. Numerous studies have shown that the magnitude of CV reflects intrinsic myocardial contraction in patients with cardiomyopathy or ischemic heart disease, and it is generally accepted that the greater magnitude of CV, the more viable myocardium exists. On the other hand, a decreased or delayed pattern of CV may indicate segmental viability of myocardium that has late systolic shortening and so does not always reflect irreversible ischemic injury. Indeed, the LVEF significantly improved in group B as well as in group A, which is not surprising given that even a dysskinetic myocardial segment may have a nontransmural MI or even normal myocardium histologically and in addition, patients with scar formation on 2-dimensional echocardiography were excluded from the present study. As mentioned before, the temporal relationship of CV with the cardiac cycle is also a useful marker of myocardial viability. In the present study, the normalized time delay was, though used as a cutoff point for grouping, significantly longer in group B than in group A, which supports the data of Pasquet et al and Homma et al in patients with chronic ischemic LV dysfunction as well as those with an acute MI.

**Study Limitations**

First, we did not compare IBS and other noninvasive imaging methods such as dobutamine echocardiography and $^{201}$Tl perfusion imaging. However, qualitative detection of changes in regional wall motion with dobutamine is often difficult and a dilated left ventricle may also mimic perfusion defects in normally perfused regions, thereby confounding viability assessment. Second, we measured the size of the perfusion bed only in a single short-axis view, which may not have represented the tomography of the entire infarct bed accurately. Although technical limitations involving the currently available echocardiographic system may be responsible for this, there is no doubt that the recovery of LV function in the patients resulted exclusively from coronary revascularization to the left anterior descending artery. Finally, presumably because of our stringent inclusion criteria, the present study consisted of a small number of patients and so we consider the results are tentative. Determining the sensitivity, specificity or predictive accuracy of IBS for assessing myocardial viability awaits a larger series of patients.

Despite these limitations, it is well known that revascularization procedures can provide clinical benefit by attenuating LV dilatation and remodeling, thus reducing ventricular arrhythmias and the risk of subsequent ischemic events. It would be encouraging if IBS emerged as a useful method for assessing myocardial viability in patients with a prior MI.

**References**


