Detection of Coronary Restenosis by Serial Doppler Echocardiographic Assessment of Coronary Flow Velocity Reserve after Percutaneous Intervention

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ABSTRACT

Background: A measurement of the coronary flow velocity reserve (CFVR) with transthoracic Doppler echocardiography (TDE) is a good noninvasive method for detecting a coronary stenosis. However, microcirculatory impairment is a major limitation in assessing the coronary stenosis by CFVR. The effect of microcirculatory impairment on the CFVR can be minimized, and the diagnostic accuracy for detecting a coronary restenosis can be improved using serial evaluations of the CFVR.

Methods: This study prospectively measured the CFVR in 36 consecutive patients (age: 57±11 years, 23 men), in whom a successful PCI of the left anterior descending artery (LAD) was performed. The coronary flow velocity in the distal LAD was measured by TDE, and the CFVR was calculated. The initial CFVR measurement (CFVR0) was performed the next day after the PCI, and a follow-up CFVR measurement (CFVR1) was obtained on the day before the 6-month follow-up CAG. A significant decrease in the CFVR1 was defined as (CFVR0-CFVR1)/CFVR0 >0.1, and a restenosis was defined as >50% of the stenosis diameter on a quantitative CAG.

Results: Adequate TDE studies for the CFVR were performed in all patients, and the follow-up CAG showed a restenosis in 9 (25%) patients. The sensitivity and specificity of the CFVR1 <2.0 were 5/9 (56%), 27/27 (100%), and those of the CFVR1 <2.5 were 8/9 (89%), 22/27 (81%) for predicting a LAD restenosis, respectively. The significant decrease in the CFVR had a sensitivity of 9/9 (100%) and a specificity of 25/27 (93%). In addition, in the 15 patients with either diabetes or LVH, the significant decrease in the CFVR was more accurate (15/15, 100%) than the CFVR1 <2.5 (11/15, 73%).

Conclusions: Regardless of the associated microvascular impairment, a serial noninvasive assessment of the CFVR by TDE can improve the diagnostic accuracy of CFVR for detecting a LAD restenosis.

KEY WORDS: Coronary disease; Restenosis; Blood flow velocity; Echocardiography; Doppler.

Introduction

After successful percutaneous coronary intervention (PCI), restenosis occurs in 25–40% of patients. This is recognized as a critical clinical impediment limiting PCI.1-3) The restenosis occurs primarily within 6 months of PCI.4) In the diagnosis of restenosis, treadmill test, stress echocardiography and thallium spect., which have been used for the non-invasive diagnosis of angina pectoris, can not accurately diagnose restenosis as its false positive and false negative rates are high.5-6) Coronary angiograms have thus been used as the standard method for the diagnosis of restenosis. However, a coronary angiogram is invasive and a morphological test that measures the coronary artery internal diameter. As the degree of morphological stenosis can not accurately show the degree of myocardial blood flow impairment...
due to coronary artery disease, the necessity of functional tests for assessing the blood flow impairment has been suggested.

In the mid 1990s, the direct intravascular measurement of the coronary flow velocity during a coronary angiogram by Doppler guide wire became available, and measurement of the coronary flow velocity reserve (CFVR) was calculated by the ratio of the coronary flow velocity under hyperemia and under baseline conditions. As the coronary flow velocity reserve is a crucial diagnostic indication of the overall coronary flow, including coronary restenosis and microvascular impairment, its possible application to the diagnosis of coronary stenosis and restenosis after coronary angioplasty has been reported.

Recently, the technical improvement in trans thoracic Doppler echocardiography allows the visualization of coronary flow in the distal left anterior descending coronary artery and the non-invasive assessment of the coronary flow velocity reserve, which is highly correlated to the coronary flow velocity reserve measured by invasive means. This permits the measurement of the coronary flow velocity reserve, which has previously been invasively measured by applying the Doppler guide wire in the catheterization laboratory, in the echocardiography laboratory simply without additional costs and thus its clinical application has become more convenient. However, as the coronary flow velocity reserve varies according to coronary stenosis and microvascular impairment, a single measurement may cause problems for the diagnosis of stenosis.

Here, assuming that the decrease in the coronary flow velocity reserve, within the relatively short 6-month follow-up period, is due to coronary restenosis rather than the exacerbation of microvascular impairment, efforts were made to improve the accuracy of the diagnosis of restenosis by repeatedly measuring the coronary flow velocity reserve in patients having undergone coronary angioplasty and thus minimize the effect of microvascular impairment.

**Methods**

**The study population**

The study population was comprised of 36 patients who successfully underwent coronary angioplasty in the left anterior descending coronary artery between March and August 2002. Patients without sinus rhythm, those with a previous history of acute myocardial infarct or bronchospasm, over 30% residual stenosis after coronary angioplasty or who refused to undergo the follow-up coronary angiogram were excluded from the study.

**The measurement of coronary flow reserve by transthoracic Doppler echocardiography**

Echocardiography was performed by applying a high frequency transducer (5 MHz) using Acuson Sequoia 512 digital ultrasound system (Acuson, California). In color Doppler, the velocity range was adjusted to between 12–24 cm/second. With correct filtering, the artifact of low frequency wall movement was minimized. Echocardiographic images from the 4th or 5th intercostal space in midclavicular line of the left decubitus were obtained. After obtaining the longitudinal cross-section of the lower interventricular sulcus, the transducer was turned to the left, and the distal left anterior descending coronary artery visualized under the guide of color flow mapping. After focusing the sample volume on the colored region of the distal left anterior descending coronary artery, the coronary blood flow velocity was measured by a 5 MHz pulsed Doppler wave. Efforts have been made to align the direction of the beam of ultrasound and the color signal of the distal left anterior artery as parallel as possible. After recording the baseline spectral Doppler signals, while infusing adenosine for over 2–3 minutes (140 μg/kg/min), the spectral Doppler signals during the hyperemia were recorded. The Doppler signal of the baseline and the hyperemia period in the left anterior descending coronary artery were recorded continuously for three beats. Attention was paid not to dislodge the transducer during the adenosine infusion. The maximum and average diastolic coronary flow velocities during the baseline and...
maximum hyperemia periods were measured. Coronary flow velocity reserve was defined as the value of the average diastolic coronary flow velocity during the maximum hyperemia period divided by the baseline period. Here, as the value may become smaller if the baseline coronary flow velocity reserve was measured after coronary angioplasty, due to the increase of the baseline coronary flow volume, to minimize such an effect, the baseline coronary flow velocity reserve was measured 24 hours after coronary angioplasty. The follow-up coronary flow reserve was measured one day prior to the coronary angiogram on the in-patients admitted for coronary angiograms. All patients received drugs for angina pectoris during a transthoracic Doppler echocardiogram. After signing a consent form, the coronary flow velocity reserve was measured by thoracic Doppler echocardiogram.

Quantitative coronary angiogram

In all patients, the coronary angiogram was performed by conventional methods. The quantitative analysis of the coronary angiography was performed blindly by experienced investigators. The calibration was performed by applying the diameter of the guide catheter or the diagnostic catheter. After administration of nitroglycerin, the coronary angiogram was performed.

The coronary angiographic pictures were analyzed by a quantitative analyzer (Ancor 2.0, Siemens, Erlangen, Germany). The internal diameter of the reference vessel, the internal diameter of lesions, and the diameter of stenosis were measured. The length of a lesion was determined on a coronary angiographic picture that had the least foreshortening by measuring the distance from the proximal shoulder to the distal shoulder. Over 50% restenosis of the internal diameter was defined as significant restenosis.

Statistical analysis

Continuous variables were presented as the mean ± standard deviation. In the comparison of groups, the continuous variables were analyzed using the Student t-test and nominal variables by the $\chi^2$ test. In each group, the analysis of variable values of the continuous variables was performed by paired t-tests. To assess the standard error among the investigators, two specialists analyzed the baseline coronary flow velocity reserve value. The correlation of the stenosis of the internal diameter on the angiogram to the follow-up coronary flow velocity reserve and the variable value of coronary flow velocity reserve was analyzed by Pearson’s correlation. The statistical analyses were performed using the software Windows™ SPSS® 11.0. A p-value less than 0.05 were considered statistically significant in all statistical analyses.

Results

In all 36 patients, the coronary flow velocity reserve was measured 1 day and 6 months after the coronary angioplasty. The coronary flow velocity reserve, the change in coronary flow velocity and coronary angiography were compared.

The clinical characteristic of patients

The mean age of the study population was $57 \pm 11$ years (ranged from 30 to 75 years), with 23 males (64%). In regard to the risk factors of coronary diseases, 12 (33%), 20 (56%), 13 (36%) and 12 cases (33%) had diabetes, high blood pressure, smoking and high serum cholesterol, respectively. On electrocardiogram, left ventricular hypertrophy was detected in 7 cases (21%).

During coronary angioplasty, coronary intervention was limited to the left anterior descending coronary artery in 30 patients, and on multiple vessels in 6 patients. At the follow-up coronary angiogram, significant restenosis, over 50% of the internal diameter of the left anterior descending coronary artery, was detected in 9 patients (25%). Comparing the value of blood pressure, the serum cholesterol level or the blood sugar level, measured at the baseline and 6 months later, no statistically significant differences were detected in these two groups (Table 1).
the baseline value of the maximum diastolic velocity in patients without restenosis (n=27), as assessed by thoracic Doppler echocardiogram on the next day after coronary angioplasty, the coronary flow velocity under the maximum hyperemia and the value of coronary flow velocity reserve were 49.0±44.6 cm/sec, 101.8±56.0 cm/sec and 2.9±1.1, respectively. These values were not significantly different from patients with restenosis, where these values were 60.7±20.0 cm/sec, 116.5±48.0 cm/sec and 3.3±0.7, respectively.

However, in the follow-up transthoracic Doppler echocardiogram, the diastolic coronary flow velocity values at the baseline in patients without and with restenosis were 32.9±13.2 cm/sec and 47.4±18.8 cm/sec, respectively, and the difference was statistically significant (p<0.05). The follow-up coronary flow velocity reserves in patients without and with restenosis were 3.3±0.9 and 2.0±0.7, respectively, and the difference was significant (p<0.001, Table 2). To obtain the standard error among the investigators, the baseline coronary flow velocity reserve was obtained by two specialists. The standard error of investigators was estimated to be 3.2%.

Applying a follow-up coronary flow velocity reserve of less than 2.0 as the criteria, the sensitivity and specificity of the diagnosis of restenosis in the left anterior descending coronary artery lesion were 56 (5/9) and 100% (27/27), respectively. The positive and negative predictive values were 100 (5/5) and 68% (27/31), respectively.

### Table 1. Patient baseline characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Baseline</th>
<th>Follow up</th>
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<tbody>
<tr>
<td>Age</td>
<td>57±11 (30–75)</td>
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<tr>
<td>Male sex (%)</td>
<td>23 (64%)</td>
<td></td>
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<tr>
<td>Risk factors for coronary artery disease</td>
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<td></td>
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<tr>
<td>Diabetes</td>
<td>12 (33%)</td>
<td></td>
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<tr>
<td>Hypertension</td>
<td>20 (56%)</td>
<td></td>
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<tr>
<td>Smoking</td>
<td>13 (36%)</td>
<td></td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>12 (33%)</td>
<td></td>
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<tr>
<td>LVH by ECG criteria</td>
<td>7 (27%)</td>
<td></td>
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<tr>
<td>Site of PCI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAD/multivessel</td>
<td>20/6</td>
<td></td>
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<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>125.6±11.5</td>
<td>127.0±15.3</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>78.4±11.9</td>
<td>78.0±10.8</td>
</tr>
<tr>
<td>Heart rate (/min)*</td>
<td>72.4±17.6</td>
<td>63.2±11.9</td>
</tr>
<tr>
<td>Serum glucose level (mg/dl)</td>
<td>134.9±45.2</td>
<td>127.0±40.5</td>
</tr>
<tr>
<td>Serum total cholesterol level (mg/dl)</td>
<td>167.0±38.9</td>
<td>167.9±33.8</td>
</tr>
</tbody>
</table>

Values are mean ± SD. *: p<0.05 vs. baseline and follow-up values. LVH: left ventricular hypertrophy, PCI: percutaneous coronary intervention, LAD: left anterior descending coronary artery, ECG: electrocardiography.

### Table 2. Transthoracic Doppler parameters and coronary flow velocity reserve in the groups with and without restenosis

<table>
<thead>
<tr>
<th></th>
<th>Restenosis (−) (n=27)</th>
<th>Restenosis (+) (n=9)</th>
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<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Hyperemia</td>
</tr>
<tr>
<td>Baseline</td>
<td></td>
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</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>73.4±16.8</td>
<td>81.2±15.9</td>
</tr>
<tr>
<td>Vmaxsystole (cm/s)</td>
<td>21.0±13.8</td>
<td>52.4±33.5</td>
</tr>
<tr>
<td>Vmaxdiastole (cm/s)</td>
<td>49.0±44.6</td>
<td>101.8±56.0</td>
</tr>
<tr>
<td>CFVR0</td>
<td>2.9±1.1</td>
<td></td>
</tr>
<tr>
<td>Follow-up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>63.4±11.4</td>
<td>76.2±13.3</td>
</tr>
<tr>
<td>Vmaxsystole (cm/s)</td>
<td>19.1±8.8</td>
<td>61.5±25.9</td>
</tr>
<tr>
<td>Vmaxdiastole (cm/s)</td>
<td>32.9±13.2</td>
<td>105.9±38.6</td>
</tr>
<tr>
<td>CFVR†</td>
<td>3.3±0.9</td>
<td></td>
</tr>
<tr>
<td>Change of CFVR†</td>
<td>−0.30±0.46</td>
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</tr>
</tbody>
</table>

Values are mean ± SD. TVI: time velocity integral, CFVR: coronary flow velocity integral, Vmax: maximal velocity. *: p<0.05. †: p<0.001 vs. group with restenosis and without restenosis.
In such an assessment, the shortcoming was low sensitivity. Applying a follow-up coronary flow velocity reserve of less than 2.5 as the criteria, the sensitivity and specificity were 89% (8/9) and 81% (22/27), respectively. The positive and negative predictive values were 62% (8/13) and 96% (22/23), respectively. Although the sensitivity was increased, the shortcoming was the decreased specificity.

Figures 1 and 2 show the transthoracic Doppler and coronary angiogram results of a patient without and with restenosis, respectively.

Regarding the significant difference in the CFVR analyzed by the ROC curve, the best sensitivity and specificity were obtained when 10% was applied as the criterion of a significant decrease in the coronary flow velocity reserve (Figure 3).

When measured repeatedly, for the assessment of the significant reduction of coronary flow velocity reserve, the sensitivity and specificity of significant decrease of CFVR were 100% (9/9) and 93% (25/27), respectively.

Additionally, the follow-up coronary flow velocity reserve was significantly and inversely correlated to the degree of restenosis of the internal diameter shown on the coronary angiogram. The decrease in the CFVR was significantly correlated to the stenosis of the internal diameter shown on the coronary angiogram (Figure 4).

In 15 patients with diabetes or left ventricular hypertrophy, which are known to induce microvascular impairment, in the diagnosis of restenosis, the assessment of the significant reduction of coronary flow velocity reserve was more accurate than when a follow-up coronary flow velocity reserve of less than 2.5 was applied as the standard criteria (Table 4).
Here, after left anterior descending coronary artery angioplasty, it was confirmed that by reducing the effect of microvascular impairment with repeated measurements of the coronary flow reserve on applying transthoracic Doppler echocardiogram, the accuracy of the diagnosis of restenosis (diameter of stenosis was 77.5% by quantitative coronary angiographic analysis).

The coronary flow velocity reserve is known to represent the overall coronary flow velocity condition, including epicardial coronary stenosis and microvascular impairment. It has been measured by invasive coronary Doppler guide wire or non-invasive methods, such as echocardiogram, magnetic resonance imaging and positron emission tomogram, etc.\(^8\)\(^{20}\)\(^{21}\)

Recently, by applying a high frequency transducer over 5 MHz in the assessment of coronary flow, the direct measurement of the coronary flow velocity has become possible. Especially, for the left anterior descending coronary artery, which runs through the cardiac interventricular sulcus, and its distal part that is separated from the thorax by 1–4 cm, a transducer with the frequency range 5–12 MHz placed between the 4th and 5th intercostal space in midelavicular line of the left decubitus, reveals the coronary blood flow moving forward in over 95% cases on reacting to the low speed range color Doppler program installed in the machine. The angle of the Doppler sample volume to the blood flow direction was adjusted as parallel as possible so that the coronary flow velocity, which is primarily diastolic by on pulsed Doppler, can be measured. However, in the right coronary

### Table 3. Diagnostic accuracy for detection of restenosis

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFVR &lt; 2.0</td>
<td>56% (5/9)</td>
<td>100% (27/27)</td>
<td>89% (32/36)</td>
</tr>
<tr>
<td>CFVR &lt; 2.5</td>
<td>89% (8/9)</td>
<td>81% (22/27)</td>
<td>83% (30/36)</td>
</tr>
<tr>
<td>Decrease of CFVR</td>
<td>100% (9/9)</td>
<td>93% (25/27)</td>
<td>94% (34/36)</td>
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</tbody>
</table>

CFVR: coronary flow velocity reserve

### Discussion

Figure 2. Transthoracic Doppler (A) and coronary angiogram (B) results after the procedure in another patient who had undergone stenting of the left anterior descending coronary artery. The baseline coronary flow velocity reserve was 3.87 (77.5/20.0). Follow up transthoracic Doppler (C) and coronary angiogram (D) results six months after the procedure. The follow up coronary flow velocity reserve was 1.31 (67.1/87.6) and the coronary angiogram showed significant restenosis (diameter of stenosis was 77.5% by quantitative coronary angiographic analysis).
artery and the left circumflex artery, measurement of blood flow velocity is difficult in many cases because the distal part is separated from the thorax and its running direction does not concur to the ultrasound beam in many cases. In comparison of the assessment of coronary flow velocity reserve in the distal left anterior descending artery by an intracoronary Doppler guide wire and trans-thoracic Doppler echocardiogram, the highly correlated relationship of these two tests has been confirmed in numerous studies, which has facilitated its clinical application.15)16)18) Such a test method is anticipated to be applicable for the assessment of angina pectoris patients showing normal coronary angiogram, in the evaluation following percutaneous coronary angioplasty, functional assessment prior to interventional procedures for angina pectoris that is difficult to accurately evaluate by coronary angiogram and the early diagnosis of the accelerated atherosclerosis after a heart transplant. In addition, the advantage of this procedure is its lower cost than assessment by magnetic resonance imaging or positron emission tomography.

Under normal physiological condition, 95% of coronary resistance is determined by the intra-myocardial resistant vessel; particularly, the 50−500 \(\mu\)m intra-myocardial resistant vessel plays an important role of controlling coronary flow velocity in response to the oxygen requirement of the myocardium. When the hyperemia of coronary flow velocity is induced by exercise, a vasodilator or other stresses, small vessels are dilated. If small vessels were already somewhat dilated, due to existing coronary arteriosclerosis, the increase in the coronary flow velocity reserve, which is the velocity value, in response to stress is limited. Hence, the flow velocity reserve is decreased in cases with over 50% stenosis. By applying this, stenosis over 50% can be diagnosed. Recently, such a procedure has been reported as non-invasive and accurate in predicting restenosis after coronary angioplasty. Ruscazio et al. reported that applying a coronary flow velocity

\[ \text{Figure 3. ROC curve for obtaining the optimal cut off value for the change of CFVR. ROC: receiver operating curve, CFVR: coronary flow velocity reserve.} \]

\[ \text{Figure 4. Relation between diameter of stenosis (\%) and follow up coronary flow velocity value (CFVR1) (A) and change of CFVR value (B). CFVR: coronary flow velocity reserve.} \]
reserve, as measured by transthoracic Doppler echocardiogram, of less than 2.0 as the standard, the sensitivity and specificity were 78 and 93%, respectively, in the diagnosis of significant restenosis. Our data are in agreement with this report. Our results showed that applying a coronary flow velocity reserve value of 2.0 as the standard, the sensitivity and specificity were 56 and 100%, respectively. Applying 2.5 as the standard, the sensitivity and specificity were 89 and 81%, respectively.

In addition, Nagel et al. reported that in the diagnosis of restenosis, by measuring the coronary flow velocity reserve using magnetic resonance imaging (MRI), applying 1.2 as the standard, the sensitivity and specificity were 83 and 94%, respectively.

These studies predicted coronary restenosis by a single measurement during a coronary angiogram. The factors influencing the coronary flow velocity are the heart rate, the change in arterial pressure, left ventricular hypertrophy and microvascular angina. It has been reported that in patients with an increased heart rate or preload, myocardial hypertrophy or microvascular angina, even without coronary stenosis, the coronary flow velocity reserve can be decreased. Thus, the prediction of the degree of coronary stenosis by a single measurement may cause problems.

As the measurement of coronary flow velocity reserve by transthoracic Doppler echocardiogram has the advantages of lower cost and noninvasiveness, it can readily be repeatedly measured. The change in the coronary flow velocity reserve, when measured repeatedly within a short period, may be due to coronary restenosis rather than a change in the left ventricular hypertrophy or exacerbation of microvascular impairment. Thus, the coronary flow reserve value that is significantly lower than the baseline value may be helpful in the diagnosis of restenosis.

Our results have demonstrated that when the decrease in the coronary flow velocity reserve was significant, the sensitivity and specificity were 100 and 93%, respectively. Applying a follow-up coronary flow velocity reserve of less than 2.0 as the criteria, the sensitivity and specificity of the diagnosis of restenosis in the left anterior descending coronary artery lesion were 56 (5/9) and 100% (27/27), respectively. The positive and negative predictive values were 100 (5/5) and 68% (27/31), respectively. Using the standard 2.5, the diagnosis of restenosis could be more accurately made. In such an assessment, the sensitivity and specificity were 89 and 81%, respectively. Furthermore, in the diagnosis of restenosis in patients with left ventricular hypertrophy or diabetes that could cause microvascular impairment, the prediction was more accurate when a decrease in the coronary flow velocity reserve was applied as the standard.

In this study, 10% was considered as a significant decrease in the follow-up coronary flow velocity reserve value, as it must be larger than the 3.2% standard error of the investigators. In addition, when 10% was applied as the standard to the ROC curve analysis of the change in the coronary flow velocity reserve value, the sensitivity and the specificity were improved.

With regard to the heart rate and arterial pressure that may affect the coronary flow velocity reserve, their influence was ruled out, as a significant difference in patients with and without restenosis was not detected. Similarly, in comparison of the serum cholesterol or serum sugar levels of the baseline and follow-up periods, their differences were not statistically significant.

It is anticipated that the most suitable clinical indications of the coronary flow velocity reserve value obtained by transthoracic Doppler echocardiogram are: 1) the diagnosis of coronary restenosis, where the conventional non-invasive procedure has limitations. 2) the cases requiring Doppler guide wire, which are invasive and expensive; in other words, in cases requiring the evaluation of the

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<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFVR &lt;2.0</td>
<td>50% (2/4)</td>
<td>100% (11/11)</td>
<td>87% (13/15)</td>
</tr>
<tr>
<td>CFVR &lt;2.5</td>
<td>100% (4/4)</td>
<td>63% (7/11)</td>
<td>73% (11/15)</td>
</tr>
<tr>
<td>Decrease of CFVR</td>
<td>100% (4/4)</td>
<td>100% (11/11)</td>
<td>100% (15/15)</td>
</tr>
</tbody>
</table>

CFVR: coronary flow velocity reserve

Table 4. Diagnostic accuracy in patients with diabetes or left ventricular hypertrophy
Echo Diagnosis of Coronary Restenosis by CFVR

hemodynamic significance of the lesions as the degree of coronary stenosis and clinical conditions, disagree.

The limitation of our research is that, firstly, the measurement of coronary flow velocity reserve, by transthoracic Doppler echogram, is only anatomically suitable to the left anterior descending coronary artery. Its application to other coronary arteries is not suitable. However, the left anterior descending coronary artery is the vessel where most clinically important percutaneous coronary angioplasty is performed. Thus, the diagnosis of restenosis in the left anterior descending coronary artery may be clinically important. Secondly, it is desirable to analyze the significance by performing trials on a large number of patients, rather than the limited small number of patients in this study.

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