Coronary Recanalization in Anterior Myocardial Infarction
The Open Perforator Hypothesis

Paolo Voci, MD, PhD,* Enrica Mariano, MD,* Francesco Pizzuto, MD,* Paolo Emilio Puddu, MD, FESC, FACC,* Francesco Romeo, MD, FESC, FACC†
Rome, Italy

OBJECTIVES
Patent perforators, noninvasively imaged by transthoracic color-Doppler echocardiography, may reflect adequate reperfusion in anterior myocardial infarction (MI).

BACKGROUND
The Thrombolysis In Myocardial Infarction (TIMI) classification may not fully reflect adequate myocardial reperfusion in MI.

METHODS
We studied 61 patients with anterior MI undergoing thrombolysis (n = 28), primary stenting (n = 20), or neither one (n = 13). High-resolution color-Doppler ultrasound was used to image the left anterior descending coronary artery (LAD) and perforators in four segments of the anterior-apical wall and to build a new recanalization score (RS). The TIMI flow was assessed by angiography. Wall motion score index (WMSI), ejection fraction (EF), end-diastolic volume index, and end-systolic volume index (ESVI) were measured by echocardiography at baseline and at three-month follow-up. Linear regression equations, considering RS or TIMI flow as independent variables, were compared among these functional recovery parameters. A multivariate linear model, predicting percent changes of WMSI, EF, or ESVI, was used to investigate the contribution of several clinical covariates along with RS and TIMI flow.

RESULTS
Sensitivity, specificity, and diagnostic accuracy of color-Doppler ultrasound in detecting LAD patency were 86%, 98%, and 97%, respectively. Mean and peak flow velocities discriminated (0.004 < p < 0.008) TIMI flow but not RS. Regression equations showed that RS discriminated better than TIMI flow recovery of ventricular function (p < 0.012). The RS was the best single multivariate predictor (p < 0.0001) of percent changes in WMSI, EF, and ESVI.

CONCLUSIONS
Transthoracic color-Doppler ultrasound detects an open LAD after MI. Perforators reflect adequate myocardial reperfusion and are early noninvasive markers of myocardial viability. (J Am Coll Cardiol 2002;40:1205–13) © 2002 by the American College of Cardiology Foundation

Angiographic classification of the Thrombolysis In Myocardial Infarction (TIMI) study group (1,2) was a milestone in prognostic stratification after myocardial infarction (MI). However, subsequent studies suggested that TIMI classification may not fully reflect the adequacy of myocardial reperfusion after coronary recanalization (3). A significant proportion of patients, in fact, show a mismatch between epicardial flow and myocardial perfusion, known as “no reflow” phenomenon, which may be responsible for poor recovery of left ventricular (LV) function at follow-up. Microembolization of plaque debris, microvascular constriction, local inflammation, interstitial edema, and diffuse, irreversible myocardial damage may produce no-reflow at the tissue level despite preserved epicardial flow. Therefore, a new noninvasive method of detecting nutrient flow beyond the epicardial vessel is desirable (4).

Intracoronary Doppler ultrasound measurement of resting flow velocity has been recently proposed in acute MI to predict late functional recovery (5,6). However, resting velocity in a large epicardial vessel may not reflect intramural flow (7) and therefore may not differentiate vital from nonvital perfusion. Recent advances in color-Doppler technology allowed imaging of very small vessels such as the anterior spinal artery (8), peripheral retinal branches (9), and distal left anterior descending coronary artery (LAD) with its perforating branches (10–14). This simple, bedside method allows detection of LAD and perforator patency after MI because wall motion artifacts, which potentially affect color-Doppler echocardiography, are minimal.

We hypothesized that recanalization of perforators emerging from the LAD reflects adequate reperfusion in acute MI and has a positive impact on LV function at follow-up. On this basis, a comparative study with TIMI flow was undertaken to determine whether reperfusion can be assessed more accurately, yet noninvasively.
Abbreviations and Acronyms

CK = creatine kinase
EDVI = end-diastolic volume index
EF = ejection fraction
ESVI = end-systolic volume index
LAD = left anterior descending
LV = left ventricle/ventricular
MB-CK = myocardial creatine kinase fraction
MI = myocardial infarction
RS = recanalization score
TIMI = Thrombolysis In Myocardial Infarction
WMSI = wall motion score index

METHODS

Patients. We studied 61 consecutive patients with first acute anterior MI (47 males, 14 females, age 63 ± 13 years, weight 77 ± 14 kg, height 170 ± 9 cm, body surface area 1.89 ± 0.19 m², heart rate 83 ± 11 beats/min, systolic blood pressure 131 ± 13 mm Hg, diastolic blood pressure 77 ± 8 mm Hg). Inclusion criteria were typical chest pain of <12 h of onset and lasting >30 min, and ST segment elevation >0.2 mV in two or more contiguous anterior leads. Patients with prior MI and cardiogenic shock were excluded. Twenty-eight patients underwent intravenous thrombolysis (accelerated recombinant tissue-type plasminogen activator protocol), 20 underwent primary stenting, thrombolysis, or symptom onset, and 13 underwent neither, owing to contraindications to thrombolysis and unavailability of the catheterization laboratory. Coronary angiography was performed in 60 patients and LAD flow was graded according to the TIMI classification (1,2).

Echocardiography. Echocardiography, including coronary flow imaging, was performed within 24 h of coronary stenting, thrombolysis, or symptom onset, and at three months. Time between echocardiography and angiography was 1 to 6 h in 49 patients, 6 to 24 h in 7 patients, and 1 to 7 days in 4 patients. The end-diastolic volume index (EDVI), end-systolic volume index (ESVI), and ejection fraction (EF) were measured by the biplane method of discs. Wall motion score index (WMSI) was calculated using the 16-segment model proposed by the American Society of Echocardiography (15), with code 1 = normal, 2 = hypokinetic, 3 = akinetic, and 4 = dyskinetic.

Imaging of LAD and perforators. Imaging of the distal LAD and perforators was performed at the bedside by a dedicated multihertz transducer, which can be easily placed and tilted between the ribs, connected to an ultrasound system (Sequoia C256, Siemens-Acuson, Mountain View, California). The transducer was placed at the cardiac apex or one intercostal space above and focused on the interventricular groove, imaged in short-axis. To image the perforating branches, the classical or modified two- and four-chamber views were used. Based on our previous experience (10), four segments of the anterior–septal wall were considered: mid-anterior, apical anterior, apical lateral, and apical septal.

These segments are cardinal determinants of LV function and provide the best imaging of perforators. Color Doppler images of the LAD and perforators were obtained by reducing the Nyquist limit to 110 to 170 mm/s for 3.5 MHz, to 120 to 190 mm/s for 5 MHz, and to 130 to 200 mm/s for 6 MHz. Low-frequency wall motion artifacts were minimized by adequate filtering. Coronary flow velocity was measured by pulsed Doppler under color coding guide. The best long-axis view in color flow was obtained to optimize the angle between flow and Doppler beam. Coronary flow velocity was measured in the periapical tract of the LAD because, at this level, the epicardial flow more closely reflects intramural flow (7). The LAD was differentiated from the small layer of pericardial effusion that often accompanies infarction and may produce a color-Doppler signal, because of its characteristic decrescendo diastolic flow velocity, which is very different from the chaotic signal of pericardial effusion.

Doppler analysis. Left anterior descending coronary artery patency was assessed by the consensus of three experienced observers blinded to angiography. The sensitivity, specific-
ity, and diagnostic accuracy to detect an open LAD by color-Doppler ultrasound were calculated considering coronary angiography as the gold standard. Peak and mean diastolic flow velocity, deceleration time, and pressure halftime were measured on the assessments of two independent, server variability of color-Doppler recanalization imaging. Perforators were defined as vascular branches emerging perpendicularly every 4 to 5 mm from the epicardial LAD and penetrating the myocardium (Fig. 1), with flow velocity directed away from the transducer. A myocardial segment (2 to 2.5 cm in length) was considered reperfused when at least two of the predicted four to five perforators could be visualized. A recanalization score (RS) of 1 to 4—where 1 = LAD closed, no perforators; 2 = LAD open, no perforators; 3 = LAD open, 1 to 2 segments with perforators; 4 = LAD open, 3 to 4 segments with perforators—was adopted. The relationships between baseline RS and follow-up parameters of LV function (WMSI, EF, EDVI, ESVI) have been assessed. Intra- and interobserver variability of color-Doppler recanalization imaging were calculated on the assessments of two independent, experienced observers. Separate analysis was performed on epicardial LAD and all four myocardial segments in 61 patients. The absolute intra- and interobserver differences in measurements of flow were expressed as proportions of the total measurements. Statistical analysis. Data in tables, figures, and text are expressed as means ± standard deviation and ± standard error of the mean. Variables were compared (16) by analysis of variance and unpaired t tests with Bonferroni’s correction and by linear regression. To test significance between baseline and follow-up correlation lines, slopes (± asymptotic standard error) were compared, and analysis of variance was used. A linear model was used to predict multivariately (17) three different dependent variables (as percent of basal values) based on several covariates. A p value <0.05 was considered significant.

RESULTS

Of the 61 patients, 43 had hypertension, 13 had type II diabetes, 41 had cholesterol levels over 240 mg/dl, and 43 were smokers. Time from symptom onset to treatment was 5.36 ± 3.32 h. Total peak creatine kinase (CK) was 2,523 ± 1,179 IU, and myocardial creatine kinase fraction (MB-CK) was 275 ± 151 IU. Of the 60 patients submitted to coronary angiography, 25 had three-vessel disease, 22 had two-vessel disease, and 13 had one-vessel disease (mean 2.2 ± 0.78). Seven patients had TIMI 0, 8 TIMI 1, 11 TIMI 2, and 34 TIMI 3 flow grade. Nineteen patients (31%) underwent coronary bypass within two weeks of admission.

Echocardiography. Echocardiographic follow-up was completed at three months in 58/61 patients (three deaths). At baseline and follow-up, respectively, WMSI was 1.71 ± 0.23 and 1.56 ± 0.43, EF was 45 ± 10% and 48 ± 12%, EDVI was 59 ± 19 ml/m² and 63 ± 24 ml/m², and ESVI was 33 ± 16 ml/m² and 34 ± 21 ml/m². Detection of open artery. At coronary angiography (60 patients), the LAD was open in 53 patients and occluded in 8 patients; there was one false positive and one false negative assess-

Table 1. Relationship Between Pulsed Doppler Parameters Adequately Recorded in 52 Patients Distributed According to Recanalization or TIMI Flow Scores

<table>
<thead>
<tr>
<th>Recanalization score</th>
<th>MFV</th>
<th>PFV</th>
<th>P1/2</th>
<th>DT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (n = 0)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>2 (n = 17)</td>
<td>19 ± 10 (2)</td>
<td>24 ± 14 (3)</td>
<td>387 ± 238 (58)</td>
<td>1,310 ± 844 (205)</td>
</tr>
<tr>
<td></td>
<td>[10–43]</td>
<td>[12–59]</td>
<td>[145–1,090]</td>
<td>[118–3,722]</td>
</tr>
<tr>
<td>3 (n = 9)</td>
<td>22 ± 8 (3)</td>
<td>28 ± 12 (4)</td>
<td>305 ± 161 (54)</td>
<td>1,043 ± 551 (184)</td>
</tr>
<tr>
<td></td>
<td>[14–37]</td>
<td>[17–55]</td>
<td>[70–559]</td>
<td>[218–1,908]</td>
</tr>
<tr>
<td>4 (n = 26)</td>
<td>24 ± 10 (2)</td>
<td>33 ± 15 (3)</td>
<td>333 ± 161 (31)</td>
<td>1,148 ± 540 (105)</td>
</tr>
<tr>
<td></td>
<td>[8–44]</td>
<td>[11–63]</td>
<td>[127–838]</td>
<td>[432–2,860]</td>
</tr>
<tr>
<td>F</td>
<td>1.37</td>
<td>1.78</td>
<td>0.67</td>
<td>0.56</td>
</tr>
<tr>
<td>p</td>
<td>0.2645</td>
<td>0.1788</td>
<td>0.5141</td>
<td>0.5762</td>
</tr>
</tbody>
</table>

Mean ± SD (SEM) [range] by pulsed Doppler compared with Thrombolysis In Myocardial Infarction (TIMI) flow, there was 1 false positive patient (*) and 1 false negative (†) patient. F and p refer to standard one-way analysis of variance statistics and probability values on respective columns.

DT = deceleration time; MFV = mean flow velocity (cm/s); PFV = peak flow velocity (cm/s); P1/2 = pressure half-time (ms).

The Open Perforator Hypothesis
October 2, 2002:1205-13
The sensitivity of color-Doppler ultrasound for detection of a closed LAD was 87%, specificity was 98%, and diagnostic accuracy was 97%.

**Pulsed Doppler versus function.** None of the resting pulsed Doppler parameters considered in this study (peak and mean diastolic flow velocity, deceleration time, and pressure half-time) correlated with the echocardiographic parameters of functional recovery at follow-up (WMSI, EF, EDVI, ESVI: data not shown).

**Pulsed Doppler versus TIMI and RS.** Of the 53 patients with open LADs at color-Doppler, adequate pulsed Doppler tracings of coronary flow, allowing reliable velocity measurements, were recorded in 52 patients. There was a significant discrimination between mean (F = 5.01; p < 0.05) and peak (F = 5.16; p < 0.01) diastolic flow velocities and TIMI flow (Table 1), but the wide overlap among velocities distributed according to TIMI flow (Table 1), but the wide overlap among velocities distributed according to TIMI flow prevented any generalization. Nevertheless, flow velocity <15 cm/s was exclusive of TIMI 1 and 2, whereas TIMI 3 was always, but not exclusively, characterized by a velocity of ≥15 cm/s. Figure 2 shows examples of the wide variability of resting coronary flow velocity patterns. Pressure half-time and deceleration time were highly variable parameters and did not correlate with TIMI flow (Table 1). Table 1 also shows Doppler parameters distributed according to RS. None provided discrimination among RS groups.

**RS versus function.** At color Doppler, eight patients were classified as RS 1, 18 as RS 2, 9 as RS 3, and 26 as RS 4. Both RS and TIMI scores correlated (0.0001 < p < 0.0025) at baseline with WMSI and EF (Fig. 3); however, only RS correlated (p < 0.0046) with ESVI (Fig. 4). At follow-up, slopes increased in all cases; however, the difference was significant between baseline and follow-up parameters of function related to RS as an independent variable, and although TIMI flow discriminated WMSI, it did not discriminate EF (Fig. 3), EDVI, or ESVI (Fig. 4).

---

**Figure 2.** Transthoracic Doppler shows a wide variability of diastolic flow velocity, ranging from 15 to 40 cm/s, and flow in opposite direction in a perforating branch (right lower panel). LAD = left anterior descending.
Table 2 shows the results of the multivariate models, whereby the dependent variables were percent changes (from baseline to follow-up) of WMSI, EF, or ESVI. Table 2 also provides univariate correlates (r) between those y variables and a series of x independent variables investigated in this study. There was a fair correlation between RS and WMSI (r = 0.674; p < 0.001), EF (r = 0.482; p < 0.001), and ESVI (r = 0.587; p < 0.001). The TIMI flow also correlated with WMSI (r = -0.366; p < 0.001) and ESVI (r = -0.349; p < 0.01), whereas correlation with EF was poor (r = 0.276; p < 0.05). These results relate (by default) to 58 patients with both basal and follow-up data and substantially confirm the evidence and analysis presented in Figures 3 and 4. More importantly, Table 2 shows the results of the multivariate analysis, comparing the overall predictive impact of baseline clinical, laboratory, angiographic, and echocardiographic covariates: it indicates that RS best predicted ΔWMSI, ΔEF, and ΔESVI (all p = 0.0001 with t > [5.73]). On the other hand, other predictors were peak CK for ΔWMSI (p = 0.059) and MB-CK for ΔESVI (p = 0.007), whereas baseline ESVI (p = 0.07) and EF (p = 0.012) predicted ΔWMSI, and baseline WMSI predicted both ΔEF and ΔESVI (both p = 0.0001). Models were robust enough based on r². The TIMI flow was not considered to be a significant independent covariate in any model.

**RS versus TIMI.** The absence of perforators in all segments was exclusive of TIMI 0. The presence of perforators in the apical septal segment was exclusive of TIMI 3, but, occurring in only 41% of the cases, it was a high specific but low sensitive marker of TIMI 3 flow. When RS was taken into account concomitantly with TIMI score, only the former was a significant multivariate predictor of changes in functional parameters seen at follow-up (Table 2) independent of WMSI, which also contributed statistically.

**Reproducibility.** Reproducibility ranged from 93% to 98%, and it was expectedly higher intraobserver than interobserver. The maximal and minimal measurement error was in the assessment of mid-anterior segment perforators (7% intra- and interobserver) and in the epicardial LAD patency, respectively (2% intra- and 3% interobserver).

**DISCUSSION**

The TIMI study (1,2) paved the way for our understanding of the pathophysiology of coronary reflow. Starting from these seminal observations, we propose a more practical, noninvasive, bedside method to assess not only coronary recanalization and flow velocity in the epicardial artery but
also the presence of perforating branches, which may represent vital myocardial perfusion and could have a positive prognostic impact in acute MI.

**Detection of LAD patency.** In our hands, transthoracic color-Doppler ultrasound is a good method to detect LAD patency in acute anterior MI, with potential impact on prognosis (18) and clinical decision making, that is, primarily to refer to angioplasty patients with failed thrombolysis.

**Beyond the LAD: detection of perforators.** In 1963, Gregg and Fisher (19) speculated that blood flow in epicardial arteries is "a combination of intramural and extramural flow, and does not necessarily indicate correctly the intramural flow at all times." One year later, Eckstein et al. (20) theorized that "the capacitance of epicardial arteries may distort the actual myocardial perfusion." In acute MI, the mismatch between epicardial and intramural flow is even more striking than in normal conditions because: 1) myocardial reflow is a combination of local hyperemia, low-reflow, and no-reflow, depending on local metabolic and microvascular conditions (21–23); and 2) epicardial flow may be drained by collaterals to perfuse remote, noninfarcted tissue.

Accordingly, TIMI flow is an imperfect indicator of successful reperfusion: up to 30% of TIMI 3 patients have permanent perfusion defects and wall motion abnormalities, as demonstrated by myocardial contrast echocardiography (24–27). Perforators bridge the large epicardial artery and the microcirculation and may yield the same information as myocardial contrast echo about the status of local nutrient perfusion. A 50% increase in perfusion in the risk area has been proposed as a cut-off indicator of successful reperfusion assessed by contrast echocardiography (27). Similarly, in our study a cut-off value of 50% of perforators predicted good recovery of ventricular function. The two techniques may be complementary because color-Doppler provides quantitative flow velocity data, whereas contrast echocardiography directly depicts microvascular flow and provides better spatial resolution of the reperfused area (28).

**The velocity paradox.** Resting flow velocity, measured by intracoronary Doppler ultrasound, has been recently proposed to predict TIMI flow and functional recovery (5,29,30). Our data confirm a relationship between TIMI score and LAD Doppler flow velocity (in fact, both deal with velocity); nevertheless, epicardial flow does not necessarily reflect intramural flow. High velocity is not synonymous with good flow, because residual stenosis or coronary spasm may produce acceleration to compensate for lumen loss. Conversely, low velocity is not synonymous with

---

**Figure 4.** Regression lines show good correlation between recanalization score and end-diastolic volume index (EDVI) and end-systolic volume index (ESVI) at follow-up, indicating a positive impact on left ventricular remodeling, whereas with Thrombolysis in Myocardial Infarction (TIMI) flow there was no difference between the regression lines of baseline versus follow-up of EDVI and ESVI.
Table 2. Predictive Covariates of Changes of Contractile Function Investigated by Echocardiography at Both Segmental-Wall and Chamber Levels in 58 Patients (with Complete Data Sets) Followed Up for 3 Months After Anterior Myocardial Infarction

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean ± SD</th>
<th>Coefficient of Variation</th>
<th>Range</th>
<th>Statistics to Predict Changes at Follow-Up</th>
<th>Δ%WMSI</th>
<th>Δ%ESVI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Multivariate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WMSI</td>
<td>91 ± 23</td>
<td>0.2498</td>
<td>55</td>
<td>158</td>
<td>0.024</td>
<td>NS</td>
</tr>
<tr>
<td>EF</td>
<td>108 ± 20</td>
<td>0.1879</td>
<td>63</td>
<td>173</td>
<td>0.096</td>
<td>NS</td>
</tr>
<tr>
<td>ESVI</td>
<td>104 ± 39</td>
<td>0.3796</td>
<td>43</td>
<td>221</td>
<td>0.029</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Multivariate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td>t</td>
<td></td>
<td>p</td>
</tr>
<tr>
<td>p</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ%WMSI</td>
<td></td>
<td></td>
<td></td>
<td>Multivariate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td>t</td>
<td></td>
<td>p</td>
</tr>
<tr>
<td>p</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ%EF</td>
<td></td>
<td></td>
<td></td>
<td>Multivariate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td>t</td>
<td></td>
<td>p</td>
</tr>
<tr>
<td>p</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ%ESVI</td>
<td></td>
<td></td>
<td></td>
<td>Multivariate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td>t</td>
<td></td>
<td>p</td>
</tr>
<tr>
<td>p</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regression coefficient of intercept 70.1807, t = 3.11, p = 0.003, for Δ%WMSI (r² = 0.54, F = 15.19, p = 0.0000); 2.6697, t = 0.12, p = 0.904, for Δ%EF (r² = 0.39, F = 17.21, p = 0.0000); and 278.229, t = 7.19; p = 0.000, for Δ%ESVI (r² = 0.54, F = 20.71, p = 0.0000), respectively. Range expresses, respectively, minimal (left column) and maximal (right column) values of both dependent and independent variables. r = univariate regression coefficient (r > 0.2542 = p < 0.05); t = multivariate regression coefficient/SE; t > |3.96| = p < 0.05; the statistical software used, by default, calculates t values only when p < 0.10. *Absolute values not included in the models predicting respective changes in order to prevent errors due to collinearity.

CK = creatine kinase; EDVI = end-diastolic volume index; EF = ejection fraction; ESVI = end-systolic volume index; MB-CK = myocardial creatine kinase fraction; RS = recanalization score; TIMI = Thrombolysis In Myocardial Infarction study group classification; WMSI = wall motion score index.
hypoperfusion, because it can be produced by vasodilators, which are routinely used in acute infarction.

Systolic flow was not considered in this study, because its magnitude depends strictly on the sampling site: it is anterograde in the epicardial artery and retrograde in perforators, but in the watershed area, anterograde and retrograde flow may cancel each other. Nevertheless, inverted systolic flow patterns have been correlated with slow reflow (5,29).

**Invasive or noninvasive?** The study of no–reflow seems to confer to a noninvasive tool such as echocardiography (contrast or Doppler) a surprising supremacy over angiography (5,25,27,31) and intracoronary Doppler ultrasound. Angiography provides a “snapshot” view of the epicardial coronary arteries, whereas echocardiography allows continuous bedside imaging of epicardial and intramural flow, with potential additional information on intermittent reperfusion and microvascular stunning.

Noninvasive Doppler has some advantages over intracoronary Doppler ultrasound (32): it is an easy, safe, and repeatable technique; it does not require additional personnel or cost; it avoids contact with the coronary artery, which may be reactive during infarction; it allows one to measure velocities in regions inaccessible to intracoronary Doppler, such as the periapical LAD and perforators, which may contain more information on vital flow than the proximal LAD (7).

**Study limitations.** As for the state-of-the-art technology, only four segments of the LAD perfusion territory can be reliably imaged. Technical refinements of ultrasound systems and the use of contrast agents may expand the potentialities of this technique. Intermittent coronary patency and unstable microvascular flow may characterize the first days after MI, and therefore a continuous monitoring may better describe the recanalization pattern and/or detect microvascular stunning. This study focused on the LAD, but little information is available on other coronary arteries. We have recently shown that color–Doppler imaging of the posterior descending coronary artery is feasible (33–35) and may provide a means for the study of inferior MI.

Reprint requests and correspondence: Dr. Paolo Voci, Via San Giovanni Eudes, 27 00163 Rome, Italy. E-mail: voci@uniroma1.it.

REFERENCES

October 2, 2002:1205–13


