OBJECTIVES
This study was performed to assess the prognostic implications of myocardial contractile reserve (MCR) in patients with coronary artery disease (CAD) and left ventricular (LV) dysfunction.

BACKGROUND
MCR during dobutamine stress echocardiography (DSE) identifies viable myocardium that may improve in function after revascularization. Whether revascularization influences prognosis of patients with MCR has not been determined.

METHODS
We performed DSE in 80 patients with CAD and LV dysfunction (ejection fraction ≤40%). Viable myocardium was defined in dysfunctional myocardial segments as enhanced thickening and contraction during low-dose dobutamine (5 to 10 mcg/kg/min). Serial prospective follow-up was obtained in all patients (mean follow-up 2.2 ± 1.1 years).

RESULTS
Among 52 patients treated medically, there were 20 cardiac deaths. By multivariate analysis, the number of dysfunctional segments demonstrating MCR was the strongest predictor of survival (p < 0.03). Patients with MCR had better initial survival during medical therapy than did those without MCR, but this survival advantage was not maintained beyond three years. In contrast, survival was excellent in patients with MCR who underwent myocardial revascularization. Among 58 patients with MCR in ≥5 myocardial segments, survival at three years was 93 ± 6% in the 24 patients who were revascularized but only 49 ± 15% in the 34 treated medically (p < 0.02).

CONCLUSIONS
Myocardial contractile reserve is a significant predictor of survival in patients with CAD and LV dysfunction undergoing medical therapy. Although patients with MCR have an initial survival advantage, this advantage is lost over the course of three years. In contrast, survival in patients with significant MCR is enhanced by revascularization. (J Am Coll Cardiol 1999; 34:730–8) © 1999 by the American College of Cardiology

In patients with coronary artery disease (CAD), left ventricular (LV) systolic function is among the most important determinants of long-term outcome. It is well established that patients with severe LV dysfunction have a poor prognosis (1–5). However, LV dysfunction is not always an irreversible process, because LV function may improve substantially in a subset of patients after myocardial revascularization (6–11). Data obtained using positron emission tomography (PET) suggest that this improvement in LV function may translate into improved functional status and long-term survival (12–14). Hence, the identification of patients with dysfunctional myocardium that is viable and has the potential for recovery of function has important implications regarding the selection of patients for myocardial revascularization.

Dobutamine stress echocardiography (DSE) is an inexpensive, readily available and accurate method of identifying contractile reserve in myocardial regions with resting wall-motion abnormalities (15–35). The demonstration of contractile reserve by this technique has been shown to predict functional improvement after revascularization, indicating that DSE may be used to identify dysfunctional but viable myocardium (17–20,22,24–28,30–32,34). However, whether the presence of contractile reserve also provides prognostic information in patients with LV dysfunction has not been determined. In the current study, we assessed the prognostic implications of contractile reserve as a marker of myocardial viability in patients with CAD and impaired LV function.

METHODS
Patient selection. We studied 80 patients with CAD and chronic LV dysfunction (ejection fraction ≤40%), who underwent DSE at Northwestern Memorial Hospital or the
Veterans Administration Lakeside Medical Center in Chicago, Illinois between January 1992 and July 1994. This represents a consecutive series of patients with LV dysfunction undergoing DSE at our institutions during this time period. Coronary artery disease was documented by previous myocardial infarction, coronary arteriography, or both. There were 64 men and 16 women, ranging in age from 28 to 85 years (mean 64 ± 12 years). Sixty-eight of the 80 patients had a history or electrocardiographic (ECG) evidence of previous myocardial infarction. The LV ejection fraction ranged from 12% to 40% (mean 27 ± 7%). All patients gave informed written consent for the DSE study.

Dobutamine stress echocardiography. Transthoracic echocardiographic images were obtained with the patient in the left lateral decubitus position using commercially available ultrasound equipment (Sonos 1000 or Sonos 1500 with a 2.0–3.5-MHz transducer, Hewlett-Packard, Andover, Massachusetts). Four standard echocardiographic views were obtained with each acquisition: parasternal long axis, parasternal short axis, apical 4-chamber and apical 2-chamber views. The left ventricle was divided into 16 segments as recommended by the American Society of Echocardiography (36), and a score was assigned to each segment at baseline, low dose and peak dose of dobutamine infusion. Each segment was scored as follows: 1 = normal; 2 = mild to moderate hypokinesis (reduced wall thickening and excursion); 3 = severe hypokinesis (markedly reduced wall thickening and excursion); 4 = akinesis (no wall thickening or excursion); 5 = dyskinesis (paradoxical wall motion away from the center of the left ventricle during systole). All echocardiograms were interpreted by an experienced echocardiographer who was unaware of the patient’s treatment and outcome.

Dobutamine was administered intravenously beginning at a dose of 2.5 to 5 μg/kg/min and increased by 5 to 10 μg/kg/min every 3 min up to a maximum of 50 μg/kg/min, or until a study end point was achieved. The end points for termination of the dobutamine infusion included development of new segmental wall-motion abnormalities, attainment of 85% of age-predicted maximum heart rate or the development of significant adverse effects related to the dobutamine infusion. Atropine was administered intravenously in 0.25-mg increments every 3 min up to a maximum of 2.0 mg if a study end point was not achieved at the maximum dobutamine dose. Cardiac rhythm was monitored throughout the dobutamine infusion protocol, and 12-lead ECGs and blood pressure measurements were obtained at baseline, at each stage of the infusion protocol and during the recovery phase.

Echocardiographic images were acquired at baseline, with each increment of dobutamine infusion (after 2 min of infusion) and during the recovery phase. A normal response to dobutamine was defined as normal wall motion at rest with progressive increase in wall thickening and excursion during dobutamine infusion. The scoring system for abnormal wall-motion responses to dobutamine was the same as that used to assess regional wall motion at rest. Contractile reserve, indicating myocardial viability in a segment with a baseline wall-motion abnormality, was defined as an improvement in wall motion with a decrease in wall-motion score of ≥1 grade during dobutamine infusion. Myocardial ischemia was defined as a deterioration in segmental function during dobutamine with an increase in wall-motion score of ≥1 grade. Using these definitions, a myocardial segment with baseline dysfunction could demonstrate both viability at low doses of dobutamine and ischemia with the increased oxygen demands induced by higher doses of dobutamine (biphasic response) (22,37).

Echocardiographic LV ejection fractions were determined at baseline, low dose and peak dose of dobutamine. The images were digitized using a commercially available software package (Tomtec Imaging Systems, Boulder, Colorado). Definition of the LV endocardial surface was performed by an experienced echocardiographer at end-diastole and end-systole for the apical 2-chamber and apical 4-chamber views using the Tomtec Left Ventricular Function Analysis Program (Tomtec Imaging Systems, Boulder, Colorado). Left ventricular volumes were calculated by the modified Simpson biplane method using the apical 2-chamber and apical 4-chamber views as previously described (38). Ejection fraction was calculated as 100% × (end diastolic volume − end systolic volume)/end diastolic volume.

Global systolic function was assessed further by deriving a regional wall-motion score for each patient, which was calculated as the average of the scores of all 16 segments (16,19,36). The regional wall-motion score was computed at rest, during low-dose dobutamine and at the peak dose of dobutamine.

Follow-up evaluation. Serial prospective follow-up was obtained in all patients. After the DSE study, 52 patients were treated medically and 28 patients underwent myocardial revascularization by percutaneous transluminal angioplasty (7 patients), coronary artery bypass surgery (20 patients) or both (1 patient). The decision for myocardial revascularization was at the discretion of the referring cardiologist.

A computerized database consisting of demographic,
Clinical, angiographic and echocardiographic data was established for the study population. Prospective follow-up was serially obtained by means of a physician-directed telephone interview using a standardized questionnaire. If the patient died after the DSE study, the closest surviving relative and the patient’s physician were interviewed to determine the cause of death. Autopsy records were reviewed when available. All patients or relatives were interviewed at least twice during the follow-up period (except for those who were dead at the initial contact).

The primary end point of the study was cardiac mortality due to sudden cardiac death, fatal myocardial infarction or progressive congestive heart failure. Nonfatal myocardial infarction was evaluated as a secondary event. In addition, an assessment of New York Heart Association (NYHA) functional class and Canadian Cardiovascular Society anginal class was made before the DSE study and with each subsequent interview. In patients who died of a cardiac cause during the follow-up period, a NYHA functional class IV was substituted for the missing data points. The NYHA functional class before DSE was substituted for the missing data points for patients who died of a noncardiac cause during follow-up. Two patients initially treated medically who underwent revascularization greater than one year after DSE were considered medically treated and censored at the time of revascularization.

Statistical analysis. Continuous data are expressed as the mean ± SD. The effect of clinical, DSE results and revascularization time to cardiac death was initially assessed using univariate Cox regression analysis (39). Variables included in this analysis were age, gender, diabetes, history of hypertension, smoking history, hyperlipidemia, history of myocardial infarction, previous revascularization, number of stenotic coronary arteries, NYHA functional class, medication use, heart rate, blood pressure, dobutamine dose, number of dysfunctional myocardial segments with contractile reserve, number of myocardial segments with ischemic responses, ejection fraction and the regional wall-motion score. Variables with a significance level of $p < 0.2$ in the univariate analysis were considered for inclusion in a multivariate Cox regression model, and variables with a significance level of $p < 0.05$ were retained in the final model.

For purposes of constructing survival curves, patient subgroups were created using cutoff values of the number of segments with contractile reserve that optimized positive and negative predictive values. Differences in discrete variables among groups were assessed by chi-square analysis and in continuous variables by analysis of variance (ANOVA). For variables determined to be significant ($p < 0.05$) by ANOVA, comparisons between groups were made using the Bonferroni method of adjustment for multiple comparisons, where applicable. Life table analysis with the product-limit method of the Kaplan-Meier estimate was used to estimate rates of freedom from cardiac death (40); comparisons of survival between groups were made using the Cox-Mantel statistic (41).

RESULTS

Patient characteristics. All patients successfully completed the DSE protocol. The peak dobutamine dose achieved was $20.3 ± 11.8 \ \mu g/kg/min$. Four patients received atropine (mean dose $1.1 ± 0.6 \ \mu g$) to achieve a study end point. No patient developed significant adverse effects requiring premature termination of the dobutamine infusion protocol.

All patients manifested LV dysfunction, with multiple segmental wall-motion abnormalities under basal conditions (mean $15.6 ± 1.1$, range 10 to 16). During the dobutamine infusion, 71 patients (89%) demonstrated contractile reserve consistent with myocardial viability in at least one myocardial segment with abnormal baseline wall motion, 62 patients (78%) demonstrated contractile reserve in ≥3 myocardial segments and 58 patients (73%) demonstrated contractile reserve in ≥5 myocardial segments. Fifty-nine patients (74%) developed new reversible wall-motion abnormalities consistent with an ischemic response during dobutamine infusion.

Clinical course in medically treated patients. For the 52 patients receiving medical management, the mean duration of follow-up after DSE was 2.2 ± 1.0 years (range 0.3 to 3.8 years). During that time, there were a total of 20 cardiac deaths (38%), including 10 sudden deaths, 3 fatal myocardial infarctions and 7 deaths from chronic heart failure. The mean interval between the DSE study and cardiac death was $1.2 ± 1.0$ years (range 0.03 to 2.8 years). Noncardiac death occurred in four patients.

Univariate predictors of survival are shown in Table 1. Variables that were significantly associated with survival included the number of dysfunctional myocardial segments manifesting contractile reserve with low-dose dobutamine with or without ischemic responses (monophasic or biphasic responses) at higher dobutamine doses ($p = 0.011$), the number of myocardial segments with an ischemic response with dobutamine ($p = 0.015$), the number of dysfunctional segments with contractile reserve without ischemia (monophasic responses) ($p = 0.05$), the LV ejection fraction during low-dose ($p < 0.04$) and high-dose ($p < 0.05$) dobutamine and NYHA functional class ($p < 0.03$). The anatomic locations of segments with contractile reserve or ischemic responses were not related to survival. The number of segments with contractile reserve with low-dose dobutamine that had ischemic responses at higher dobutamine doses (biphasic responses) was not a significant predictor of mortality, nor was the regional wall-motion score at baseline or during DSE. Age was of borderline significance, and using angiotensin-converting enzyme (ACE) inhibitors and beta-blockers was not significantly associated with survival.

In the multivariate Cox regression analysis, the number of dysfunctional segments with contractile reserve during dobutamine ($p < 0.03$) and NYHA functional class ($p < 0.05$)
were the only significant independent predictors of freedom from cardiac death. In contrast, the number of myocardial segments demonstrating inducible ischemia with deterioration in wall motion during dobutamine and ejection fraction with dobutamine were not independent predictors of survival.

On the basis of the results of the Cox regression model, patients were put into subgroups on the basis of the number of dysfunctional segments manifesting contractile reserve. Among the 52 patients treated medically, 34 manifested contractile reserve in 5 myocardial segments and 18 had contractile reserve in 5 segments. These two patient groups did not differ in terms of age, gender, coronary anatomy, prior revascularization, previous myocardial infarction, severity of symptoms or baseline ejection fraction and regional wall-motion score (Table 2). The groups also did not differ with respect to therapy with ACE inhibitors, beta-blockers, calcium blockers or nitrates. The ejection fraction was higher and regional wall-motion score lower during both low-dose and high-dose dobutamine in patients with contractile reserve in 5 segments (Table 2). The influence of contractile reserve on subsequent survival during medical therapy is shown in Figure 1. Initial survival in patients with contractile reserve in 5 myocardial segments declined thereafter, resulting in survival rates at three years of medical therapy that were equivalent between the two groups (Fig. 1).

Outcome with medical therapy compared to myocardial revascularization. Among the 58 patients with evidence of contractile reserve in 5 dysfunctional segments, there was no difference in the number of viable segments between the 24 patients who underwent revascularization (10.1 \(\pm\) 3.0 segments/patient) compared to the 34 patients who were treated medically (9.3 \(\pm\) 2.8 segments/patient). These groups did not differ with respect to age, NYHA functional class, previous myocardial infarction, or revascularization. The ejection fraction and regional wall-motion score also did not differ between these two groups at baseline or during low-dose and high-dose dobutamine. However, patients who underwent revascularization demonstrated a greater number of ischemic segments during DSE than did patients

### Table 1. Univariate Predictors of Cardiac Mortality in Medically Treated Patients

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Relative Risk</th>
<th>Mean</th>
<th>95% CI</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>0.970</td>
<td>0.938, 1.002</td>
<td>0.074</td>
<td></td>
</tr>
<tr>
<td>NYHA functional class</td>
<td>1.809</td>
<td>1.082, 3.027</td>
<td>0.028</td>
<td></td>
</tr>
<tr>
<td>Drug therapy—ACE inhibitors</td>
<td>1.185</td>
<td>0.471, 2.981</td>
<td>0.721</td>
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<tr>
<td>Beta-blockers</td>
<td>0.850</td>
<td>0.281, 2.568</td>
<td>0.770</td>
<td></td>
</tr>
<tr>
<td>Calcium channel blockers</td>
<td>0.851</td>
<td>0.284, 2.550</td>
<td>0.773</td>
<td></td>
</tr>
<tr>
<td>Nitrates</td>
<td>1.562</td>
<td>0.516, 4.725</td>
<td>0.433</td>
<td></td>
</tr>
<tr>
<td>Dobutamine—peak dose</td>
<td>0.952</td>
<td>0.907, 0.998</td>
<td>0.046</td>
<td></td>
</tr>
<tr>
<td>Regional wall-motion score—baseline</td>
<td>1.349</td>
<td>0.464, 4.000</td>
<td>0.612</td>
<td></td>
</tr>
<tr>
<td>Low-dose dobutamine</td>
<td>2.355</td>
<td>0.903, 6.138</td>
<td>0.086</td>
<td></td>
</tr>
<tr>
<td>Peak-dose dobutamine</td>
<td>2.074</td>
<td>0.935, 4.600</td>
<td>0.079</td>
<td></td>
</tr>
<tr>
<td>Ejection fraction—baseline</td>
<td>0.943</td>
<td>0.876, 1.014</td>
<td>0.119</td>
<td></td>
</tr>
<tr>
<td>Low-dose dobutamine</td>
<td>0.941</td>
<td>0.889, 0.996</td>
<td>0.039</td>
<td></td>
</tr>
<tr>
<td>Peak-dose dobutamine</td>
<td>0.945</td>
<td>0.896, 0.997</td>
<td>0.045</td>
<td></td>
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<tr>
<td>No. segments with ischemia only</td>
<td>1.266</td>
<td>1.054, 1.521</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>No. segments with CR</td>
<td>0.856</td>
<td>0.761, 0.962</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>No. segments with CR only</td>
<td>0.875</td>
<td>0.768, 0.997</td>
<td>0.050</td>
<td></td>
</tr>
<tr>
<td>No. segments with CR and ischemia</td>
<td>0.842</td>
<td>0.640, 1.110</td>
<td>0.228</td>
<td></td>
</tr>
<tr>
<td>No. segments with CR or ischemia</td>
<td>0.898</td>
<td>0.795, 1.009</td>
<td>0.077</td>
<td></td>
</tr>
<tr>
<td>No. segments with fixed abnormality</td>
<td>1.119</td>
<td>0.996, 1.256</td>
<td>0.063</td>
<td></td>
</tr>
</tbody>
</table>

Analysis by Cox proportional hazards model.  
ACE = angiotensin-converting enzyme; CR = contractile reserve; NYHA = New York Heart Association.
treated medically (4.7 ± 3.1 vs. 2.7 ± 2.8 segments/patient, respectively; p < 0.02). In the patients with ≥5 segments manifesting contractile reserve, survival was significantly better in patients who underwent revascularization (93 ± 6% at 3 years) compared to those who were treated medically (49 ± 15%, p < 0.02) as shown in Figure 2. In addition, 63% of revascularized patients were asymptomatic at the last follow-up contact compared to 32% of those treated medically (p < 0.03).

In the 22 patients with either no evidence of contractile reserve in dysfunctional segments or with only 4 or fewer segments with contractile reserve, 4 patients (18%) underwent myocardial revascularization (all with coronary artery bypass surgery). All four of these patients died, and three died within one month of revascularization, as shown in Figure 3. Survival was significantly greater in the 18 patients who were managed medically compared to the 4 patients who underwent myocardial revascularization (p < 0.007).

Table 2. Patient Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Medical Therapy</th>
<th>Revascularization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≥5</td>
<td>&lt;5</td>
</tr>
<tr>
<td>No. of patients</td>
<td>34</td>
<td>18</td>
</tr>
<tr>
<td>Male (♀)</td>
<td>29 (85%)</td>
<td>12 (67%)</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>65 ± 12</td>
<td>65 ± 11</td>
</tr>
<tr>
<td>History of MI</td>
<td>26 (76%)</td>
<td>14 (78%)</td>
</tr>
<tr>
<td>Previous PTCA</td>
<td>7 (21%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Previous CABG</td>
<td>11 (32%)</td>
<td>6 (33%)</td>
</tr>
<tr>
<td>NYHA functional class</td>
<td>2.9 ± 1.2</td>
<td>3.0 ± 1.0</td>
</tr>
<tr>
<td>CAD (no. of vessels ≥50%)</td>
<td>2.0 ± 0.8</td>
<td>2.4 ± 0.7</td>
</tr>
<tr>
<td>Heart rate—baseline</td>
<td>76 ± 13</td>
<td>85 ± 16</td>
</tr>
<tr>
<td>Low-dose dobutamine</td>
<td>80 ± 17</td>
<td>90 ± 18</td>
</tr>
<tr>
<td>Peak-dose dobutamine</td>
<td>117 ± 21</td>
<td>122 ± 17</td>
</tr>
<tr>
<td>Regional wall-motion score—baseline</td>
<td>3.2 ± 0.4</td>
<td>3.2 ± 0.5</td>
</tr>
<tr>
<td>Low-dose dobutamine</td>
<td>2.8 ± 0.5</td>
<td>3.2 ± 0.5*</td>
</tr>
<tr>
<td>Peak-dose dobutamine</td>
<td>2.7 ± 0.6</td>
<td>3.4 ± 0.5*</td>
</tr>
<tr>
<td>Ejection fraction—baseline (%)</td>
<td>28 ± 7</td>
<td>24 ± 7</td>
</tr>
<tr>
<td>Low-dose dobutamine (%)</td>
<td>35 ± 9</td>
<td>27 ± 11*</td>
</tr>
<tr>
<td>Peak-dose dobutamine (%)</td>
<td>39 ± 10</td>
<td>30 ± 8*</td>
</tr>
<tr>
<td>No. segments with contractile reserve</td>
<td>9.3 ± 2.8</td>
<td>1.2 ± 1.2</td>
</tr>
<tr>
<td>No. segments with ischemia</td>
<td>2.7 ± 2.8</td>
<td>2.8 ± 2.8</td>
</tr>
</tbody>
</table>

*p < 0.05 vs. ≥5 segments with contractile reserve.

CABG = coronary artery bypass graft surgery; CAD = coronary artery disease; CR = contractile reserve; MI = myocardial infarction; NYHA = New York Heart Association; PTCA = percutaneous transluminal coronary angioplasty.
DISCUSSION

In patients with CAD, LV function is among the most important determinants of both short-term and long-term prognosis (1–5). It has become apparent recently that resting LV dysfunction does not always represent an irreversible process, as LV function may improve and even normalize after myocardial revascularization in a subset of patients (6–11). Moreover, data from recent studies suggest that the improvement in LV function after revascularization is associated with reduced heart failure symptoms (13,42) and enhanced long-term survival (12–14). However, patients with LV dysfunction undergo coronary artery bypass surgery or coronary angioplasty with an increased risk of procedure-related death, and not all patients manifest an improvement in LV function despite successful myocardial revascularization. Hence, the distinction between dysfunctional myocardium that is viable from that which is nonviable has important implications regarding the selection of patients in whom these risks associated with revascularization are justified. The current study indicates that assessment of the degree of myocardial viability, as assessed by myocardial contractile reserve, also has important prognostic implications.

Assessment of myocardial viability. Several noninvasive imaging techniques have evolved during the past decade for assessing myocardial viability (43). These include PET for evaluating myocardial perfusion and metabolism (12–14,44,45); thallium-201 or technetium-99m sestamibi perfusion imaging for evaluating myocardial perfusion and cell membrane integrity (18,46–50); and low-dose DSE for evaluating myocardial contractile reserve (15–35). Each of these methods has been used in several studies to predict which myocardial regions with contractile dysfunction will improve after revascularization, with excellent positive and negative predictive accuracies (51,52), but the relative diagnostic potential of these techniques has not been fully defined. The number of patients studied thus far by either of these methods is small, and the number of studies in which the relative diagnostic accuracies of these methods have been compared in the same cohort of patients undergoing revascularization is even more limited (18,24,25,27,28,30–32,48).

Myocardial viability and clinical outcome. These comparative diagnostic issues are clinically relevant only if both the presence and the extent of viable myocardium in patients with chronic LV dysfunction are related to subsequent outcome and if the identification of myocardial viability translates into management strategies that improve outcome. Our data using low-dose DSE support these concepts. Both the presence and the extent of contractile reserve in myocardial segments with resting contractile dysfunction were strong determinants of survival during medical therapy; the same was true for the presence and extent of inducible myocardial ischemia.

Our findings also indicate a significant improvement in survival with revascularization compared with medical therapy in patients with viable but dysfunctional myocardium. Survival in patients with contractile reserve in five or more segments was significantly greater in those who underwent revascularization compared with patients treated medically (Fig. 2). These data suggest that patients with substantial myocardial viability despite LV dysfunction are a group in whom survival may be enhanced with myocardial revascularization. The results of the current study are consistent with three recent studies using PET in which patients with evidence of viable but dysfunctional myocardium who underwent revascularization had better survival than did those who were treated medically (12–14).

Our results in patients treated medically, however, differ from several previous studies. Our finding of initial greater survival in patients with contractile reserve contrasts with two PET studies demonstrating worse survival during medical therapy in patients with myocardial viability (defined as preserved metabolic activity in regions of underperfused myocardium) than in patients without evidence of myocardial viability (12–13); these PET studies are supported by a third study using DSE (53). However, our results in medically treated patients are very similar to observations made two decades ago in a small number of patients in whom contractile reserve was evaluated using epinephrine infusion or postextrasystolic potentiation during left ventriculography, in whom the presence of viable myocardium manifesting contractile reserve was associated with enhanced long-term survival during medical therapy (54). Moreover, in a third PET study of patients with LV dysfunction (14) survival rates during medical therapy in patients with viable myocardium were not greater than in those with no evidence of viable myocardium (86% vs. 87% at 1.5 years), results comparable to the present study.

The apparent differences in the survival results during medical therapy that have been observed in patients with
viable myocardium in the setting of LV dysfunction (12–14,53,54) can be reconciled by the finding that the initial favorable survival trend in patients with contractile reserve in our series was not maintained over the course of two to three years (Fig. 1), suggesting that any survival advantage in patients with myocardial viability seems to be short-lived and time-dependent. Thus, the apparent discrepancies in survival among patients with LV dysfunction and viable myocardium reported in previous studies may be related to different time points along this continuum in which the patients were enrolled. This observation also supports the growing awareness that dysfunctional but viable myocardium represents jeopardized myocardium in which viability may not be maintained indefinitely (55,56).

Study limitations. Our data were obtained in patients in whom treatment decisions were not randomly assigned, and in some cases management strategies were based, in part, on the results of DSE. This represents an important limitation of our study. This limitation is also present in previous studies assessing the effect of medical therapy and revascularization in patients with viable myocardium assessed by PET (12–14), thallium imaging (57) and contrast left ventriculography (54). The lack of randomization could introduce potential biases into our results and contribute to the observed differences in outcome. However, there were no significant differences in age, symptoms, resting LV dysfunction or severity of CAD on coronary angiography between patients with and those without contractile reserve, or between patients with contractile reserve treated medically and those treated with myocardial revascularization (Table 2). The patients undergoing revascularization did have a greater extent of inducible myocardial ischemia (as assessed by DSE), which undoubtedly could have contributed to the decision in favor of revascularization in some patients, but this alone would not contribute to the better outcome observed in the revascularized patients, because patients with LV dysfunction and inducible ischemia would be expected to have a worse prognosis and a higher mortality than would those without ischemia (58,59). Thus, the greater extent of ischemic myocardium in the revascularization group did not bias that group toward better survival than the group treated medically.

Most patients had evidence of contractile reserve; 89% had contractile reserve in at least one segment, 78% in ≥3 segments and 73% in ≥5 segments. This prevalence is greater than in most previous investigations. In addition, our results were obtained in a relatively small number of patients in each subgroup and thus must be considered tentative until confirmed by other larger series.

Conclusions. Despite these limitations, our data indicate that LV contractile reserve and myocardial viability, as assessed by low-dose DSE, significantly influence prognosis in patients with CAD and chronic LV dysfunction. Although patients with contractile reserve may have an initial survival advantage compared to those with no evidence of viability, this advantage is temporary and is lost over the course of two years. In contrast, patients with contractile reserve who undergo myocardial revascularization have an excellent outcome. Hence, DSE may identify a subset of patients with impaired LV function who are candidates either for coronary artery bypass surgery or angioplasty. These data support the concepts that both the presence and the extent of viable myocardium are important determinants of prognosis in patients with CAD and LV dysfunction and that both survival and symptomatic status are enhanced by revascularization in patients with systolic dysfunction who manifest myocardial contractile reserve. These concepts warrant testing in larger-scale prospective randomized trials.

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patients with acute myocardial infarction identifies viable but not
contractile myocardium and predicts the magnitude of improvement in
wall motion abnormalities in response to coronary revascularization.
echocardiography identifies hibernating myocardium and predicts
recovery of left ventricular function after coronary revascularization.
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curacy in predicting recovery of ventricular function after coronary
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