Late Intervention After Anterior Myocardial Infarction: Effects on Left Ventricular Size, Function, Quality of Life, and Exercise Tolerance

Results of the Open Artery Trial (TOAT Study)

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OBJECTIVE
We sought to conduct a randomized trial comparing late revascularization with conservative therapy in symptom-free patients after acute myocardial infarction (AMI).

BACKGROUND
In the absence of ischemia, the benefits of reperfusion late after AMI remain controversial. However, the possibility exists that an open infarct related artery benefits healing post AMI.

METHODS
Of 223 patients enrolled with Q-wave anterior AMI, 66 with isolated persistent occlusion of the left anterior descending coronary artery (LAD) were randomized to the following treatments: 1) medical therapy (closed artery group; n = 34) or 2) late intervention and stent to the LAD + medical therapy (open artery group; n = 32). The study was powered to compare left ventricular (LV) end-systolic volume between the two groups 12 months post AMI.

RESULTS
Late intervention 26 ± 18 days post AMI resulted in significantly greater LV end-systolic and end-diastolic volumes at 12 months than medical therapy alone (106.6 ± 37.5 ml vs. 79.7 ± 34.4 ml, p = 0.01 and 162.0 ± 51.4 ml vs. 130.1 ± 46.1 ml, p < 0.01, respectively). Exercise duration and peak workload significantly increased in both groups from 6 weeks to 12 months post AMI, although absolute values were greater in the open artery group. Quality of life scores tended to deteriorate during this time interval in the closed artery patients but remained unchanged in the open artery patients. Coronary angiography at 1 year documented a low incidence of intergroup cross-over (spontaneous recanalization in 19% and closure in 11%).

CONCLUSIONS
In the present study, recanalization of occluded infarct-related arteries in symptom-free patients approximately 1 month post AMI had an adverse effect on remodeling but tended to increase exercise tolerance and improve quality of life. (J Am Coll Cardiol 2002;40:869–76) © 2002 by the American College of Cardiology Foundation

The benefits of early reperfusion in acute myocardial infarction (MI) involve infarct size reduction, preservation of left ventricular (LV) function, and increased survival (1). By contrast, the role of late reperfusion, beyond the window for myocardial salvage, remains controversial. The potential mechanisms of benefit attributable to late reperfusion, which are largely hypothetical and/or poorly characterized, fall collectively under the umbrella of the “open artery hypothesis” (2). Despite a lack of consensus, late mechanical reperfusion after MI seems to be a common treatment strategy.

Clinical interest in the open artery hypothesis (3) stemmed from sub-group analyses demonstrating appreciable survival, compared with placebo-matched controls, in patients with MI receiving streptokinase >12 h after symptom onset (1,4). Subsequent thrombolytic studies powered specifically to address the role of late reperfusion, however, failed to confirm these initial observations (5). More recently, interest in the open artery hypothesis has resurfaced as safer and more effective mechanical revascularization practices have emerged. Although observational data suggest a role for late intervention (6), the results of randomized trials are inconclusive (7–9). One recent trial (10), however (albeit with incomplete follow-up and relatively high rates of restenosis), has shown long-term clinical benefits from balloon angioplasty late after MI and thus suggests that late-presenting patients, or those with failed thrombolysis, may still benefit from percutaneous coronary intervention (PCI) by mechanisms independent of myocardial salvage.

We therefore addressed this issue by conducting a prospective randomized trial comparing medical therapy with late PCI (including stents) in symptom-free patients with LV dysfunction after anterior MI associated with a proximal occlusion of the left anterior descending (LAD) coronary artery.

METHODS
The Open Artery Trial protocol is shown in Figure 1.
Patient selection. Patients presenting to a recruitment center between March 1997 and June 1999 with an acute transmural anterior wall MI were enrolled. Selection criteria included the following: 1) age ≥75 years; 2) an uncomplicated hospital course, including absence of post-infarction angina or cardiogenic shock; 3) sinus rhythm without bundle branch block; 4) echo-derived ejection fraction <50%, or ≥3 pathological Q waves in the precordial ECG leads; and 5) absence of chest pain, ECG change, or hemodynamic disturbance during modified Bruce treadmill exercise test. Written informed consent and subsequent procedures were approved by our Institute’s ethical committee.

Screening coronary angiography. Coronary angiography was performed between three days and four weeks of MI using standard Judkins technique. Patients with an occluded LAD coronary artery (Thrombolysis In Myocardial Infarction [TIMI] flow grades 0 or 1) (11) and non-significant disease elsewhere (≤50% stenosis) were randomized.

Randomization. Patients were assigned to either medical therapy alone (closed artery group) or PCI plus stent to the LAD artery in addition to medical therapy (open artery group). Randomization was performed with customized software (MINIM shareware; S.J. Evans et al; The London Hospital Medical School, London, UK) with matching for six pre-defined variables likely to influence remodeling: 1) age (≥50 or >50 years); 2) gender (male or female); 3) systolic blood pressure (≥100 or <100 mm Hg); 4) use of oral beta-adrenergic blocker therapy; 5) use of angiotensin-converting enzyme inhibitor (ACE-I) therapy; and 6) LV end-systolic volume (ESV) (≥60, 61 to 80, 81 to 100, or >101 ml).

Percutaneous coronary intervention. These procedures were performed using standard techniques, either at the time of or within two weeks of angiography (overall between three days and six weeks of MI). NIR stents (Boston Scientific Corporation; Quincy, Massachusetts) were recommended, although selection of guidewires, balloons, inflation pressures, stent sizes, and use of adjunctive therapies were left to the discretion of the operator. Angiographic success was defined as the restoration of TIMI flow grades 2 or 3 in the infarct artery together with <50% residual stenosis. Post-procedural quantitative coronary angiographic assessments were performed off-line with commercial software (Quantum systems, Quinton, Seattle).

Medical treatment after randomization. Optimal medical therapy for all patients included drugs known to carry prognostic benefits after MI: 1) aspirin; 2) beta-blockers; 3) ACE-I; and 4) lipid-lowering agents to maintain total cholesterol level <4.8 mmol/L. In addition, stented patients received clopidogrel and higher-dose aspirin for two weeks post procedure.

Patient follow-up. Patients presented at six weeks, three months, six months, and 12 months post MI for echocardiographic estimates of LV size and function and for assessments of exercise tolerance and quality of life (QoL). In addition, at the final 12-month visit, repeated coronary angiography was performed to re-assess coronary artery patency.

LEFT VENTRICULAR FUNCTION. Left ventricular function was assessed by echocardiography (Hewlett Packard sonos 2500 or Advanced Technology Ltd HDI 3000). Estimates of LV ESV, end-diastolic volume (EDV), and ejection fraction (EF) were obtained from the average of three consecutive cardiac cycles taken from apical four chamber views using the modified Simpson’s rule. Measurements were performed off-line (VingMed system 5 with in-built analysis pack) by two blinded echocardiographers after calibrating for each study. Final values for LV ESV, EDV, and EF represent the mean of the values of the two independent reporters.

EXERCISE TOLERANCE. Patients underwent maximal treadmill testing using the Bruce protocol. Tests were conducted by a blinded technician who recorded exercise duration (min) and maximal cardiac workload (peak rate pressure product; mm Hg/min).

QoL. A generic QoL tool, the Nottingham Health Profile (NHP), was self-administered (12).

Study end-points and sample size calculations. Left ventricular ESV is a sensitive measure of post-infarction LV remodeling and one of the most powerful predictors of long-term prognosis after MI (13). Furthermore, attenuation of post-infarction LV dilation is thought to be an important contributing mechanism to the open artery hypothesis (2). The Open Artery Trial was therefore designed to compare LV ESV between the two study groups of patients at highest risk of adverse LV remodeling (transmural anterior MI).

To date, two prospective randomized trials examining the open artery hypothesis have reported serial changes in LV ESV (9,10). Data from the former study were available for the present power calculations. In addition, a Medline search identified eight observational studies reporting relationships between infarct artery patency and subsequent LV ESV (14–21). Using the formula for the comparison of two...
means (unpaired data), sample sizes were calculated on the basis of: 1) an anticipated 30% reduction of LV ESV at 12 months in the open artery group; 2) the statistical significance of 0.05; and 3) a power of 80%. Sample size estimates of 58 patients (weighted mean of observational studies) and 54 patients (randomized study) were calculated. The larger estimate was used in the design of the present study.

Statistical analysis. Data (mean ± SD) were analyzed on an intention-to-treat basis using SigmaStat v2.03 (incorporating SPSS). After data passed normality and equal variance tests, two-way repeated measures analyses of variance were applied to determine differences in end points by time post MI and study group allocation. Post hoc Tukey tests were used to compare between-group differences at six weeks and 12 months post MI. Non-parametric data were compared with the Fisher exact test. A p value <0.05 was considered statistically significant.

RESULTS

Patient recruitment and baseline characteristics. Over the 28-month recruitment period, 223 patients meeting the selection criteria were referred for angiography (Fig. 1). Baseline characteristics (Table 1) of randomized patients

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Figure 1. The open artery trial protocol. *Two patients meeting the angiographic criteria were excluded on account of distal left anterior descending (LAD) occlusion with target vessel diameter <2.5 mm. †Randomization was based on the principle of minimization of confounding baseline variables (see text). MI = myocardial infarction; PCI = percutaneous coronary intervention; TOAT = Open Artery Trial.
were similar apart from a trend toward a higher prevalence of diabetes in the open artery group.

All patients enrolled in the study received, and tolerated, lisinopril, 10 mg/day. Twenty-six patients in the open group and 29 in the closed group were given beta-adrenoceptor blockers in the form of atenolol. At six weeks, the resting heart rate and systolic and diastolic blood pressures in the open and closed group were, respectively, 72.7 ± 13.3 versus 74.8 ± 10.2 beats/min, p = 0.5; 129.9 ± 18.5 versus 127.6 ± 16.5 mm Hg, p = 0.6; and 78.9 ± 11.9 versus 77.3 ± 9.0 mm Hg, p = 0.5.

Results of intervention. Results of PCI are given in Table 2. The procedure was successful in 30 patients (94%). In one patient, the lesion could not be crossed, while in the other, a highly calcific lesion precluded stent implantation, although the angioplasty itself was successful. There was one procedural adverse event with re-infarction occurring 18 h after intervention. Repeated angiography confirmed stent thrombosis that was successfully treated with an infusion of a platelet GPIIb/IIIa receptor antagonist and repeated angioplasty to the occluded segment.

**Follow-up angiography.** Patients underwent follow-up angiography 52.9 ± 4.7 weeks post randomization. Recanalization (TIMI grades 0 or 1 flow) occurred in three (11.1%) and restenosis (>50% diameter stenosis) in five (18.5%) patients. In addition, spontaneous recanalization (≥TIMI 2 flow) occurred in six (18.6%) patients randomized to the closed artery group (Table 2).

**Left ventricular size and function.** Left ventricular ESV, EDV, and EF were similar in closed and open artery groups six weeks post MI (Fig. 2). No significant changes in ESV were observed in the closed artery group over 12 months (p = 0.46), while over the same period, LV ESV significantly increased in the open artery group (p < 0.01). Furthermore, at 12 months, LV ESV was significantly greater in the open artery group than in the closed artery group (p < 0.01).

**Exercise tolerance.** At six weeks, there were no significant differences in exercise duration between the closed and open artery groups (Fig. 3). Over the follow-up period, exercise duration significantly increased in both groups, but this was greatest in the open group.

**Quality of life.** No significant differences between the two groups were observed at six weeks (Fig. 4). The NHP part I scores (reflecting self-perceived QoL) significantly increased over time in the closed artery group (p < 0.01) and remained unchanged in the open artery group. The difference in the two groups at 12 months, however, was not significant. The NHP part II scores (reflecting impact on lifestyle) tended to increase (closed artery) and decrease (open artery) over time. At 12 months, late intervention was associated with significantly less functional impairment.

**Clinical events.** The clinical events are described in Table 3. The two deaths in the open artery group occurred between six and eight months post MI; both were sudden, with no definite underlying cause identified at post-mortem examination. The death in the closed artery group occurred three months post MI and was due to progressive arterial disease being immediately preceded by re-infarction, stroke, and circulatory failure. Of the three re-infarctions in the open artery group, one was related to the percutaneous transluminal coronary angioplasty procedure and the other two occurred six to eight weeks post procedure. Electrocardiographically, all were in the LAD territory, and repeated

### Table 1. Baseline Characteristics of Randomized Patients

<table>
<thead>
<tr>
<th></th>
<th>Closed Artery (n = 34)</th>
<th>Open Artery (n = 32)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ± SD, yrs)</td>
<td>57.6 ± 11.2</td>
<td>59.1 ± 9.7</td>
<td>0.6</td>
</tr>
<tr>
<td>% male</td>
<td>80%</td>
<td>81%</td>
<td>0.9</td>
</tr>
<tr>
<td>% thrombolysed</td>
<td>97%</td>
<td>97%</td>
<td>1.3</td>
</tr>
<tr>
<td>Peak CK</td>
<td>1.79%</td>
<td>1.97%</td>
<td>0.5</td>
</tr>
<tr>
<td>Risk factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>9%</td>
<td>19%</td>
<td>0.1</td>
</tr>
<tr>
<td>Hypertension</td>
<td>32%</td>
<td>28%</td>
<td>0.6</td>
</tr>
<tr>
<td>Prior dyslipidemia</td>
<td>18%</td>
<td>28%</td>
<td>0.1</td>
</tr>
<tr>
<td>Smoker at time of MI</td>
<td>47%</td>
<td>41%</td>
<td>0.5</td>
</tr>
<tr>
<td>Post-MI treatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta-blockers</td>
<td>82%</td>
<td>84%</td>
<td>0.9</td>
</tr>
<tr>
<td>ACE-I</td>
<td>100%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Post-MI LV ESV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(pre-intervention)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;60 ml</td>
<td>24%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>61–80 ml</td>
<td>29%</td>
<td>31%</td>
<td>0.8</td>
</tr>
<tr>
<td>&gt;81–100 ml</td>
<td>15%</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>&gt;101 ml</td>
<td>32%</td>
<td>31%</td>
<td></td>
</tr>
<tr>
<td>Screening angiogram</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MI angiogram (days)</td>
<td>29.1 ± 18.0</td>
<td>24.1 ± 17.6</td>
<td>0.3</td>
</tr>
<tr>
<td>TIMI 0 flow</td>
<td>77%</td>
<td>72%</td>
<td></td>
</tr>
<tr>
<td>TIMI 1 flow</td>
<td>23%</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>LV end-diastolic pressure (mm Hg)</td>
<td>26 ± 2.4</td>
<td>24 ± 2.0</td>
<td>0.4</td>
</tr>
</tbody>
</table>

ACE-I = angiotensin-converting enzyme inhibitor; CK = creatine kinase; ESV = end-systolic volume; MI = myocardial infarction; LV = left ventricle; TIMI = Thrombolysis In Myocardial Infarction.

### Table 2. Percutaneous Intervention

<table>
<thead>
<tr>
<th></th>
<th>Time From MI to Procedure (Days)</th>
<th>Reference Vessel (mm)</th>
<th>MLD (mm)</th>
<th>Diameter Stenosis (%)</th>
<th>TIMI Grade Flow (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-PTCA/stent* (n = 32)</td>
<td>26.3 ± 17.6</td>
<td>2.7 ± 0.6</td>
<td>2.3 ± 0.5</td>
<td>14.8 ± 10.0</td>
<td>0 3.1 6.3 90.6</td>
</tr>
<tr>
<td>Follow-up angiogram</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed (n = 32)</td>
<td>375 ± 32</td>
<td>2.5 ± 0.8</td>
<td>0.5 ± 0.1</td>
<td>77.4 ± 7.1</td>
<td>62.5 18.6 18.6 0</td>
</tr>
<tr>
<td>Open (n = 27)</td>
<td>365 ± 34</td>
<td>2.9 ± 0.5</td>
<td>2.0 ± 0.7</td>
<td>29.6 ± 23.3</td>
<td>11.1 0 18.5 70.4</td>
</tr>
</tbody>
</table>

*3-mm stents were used in most cases (67%), 3.5-mm stents in 30%, and 2.5-mm stents in 3%. Average stent length was 21.5 ± 5.7 cm (mean ± SD).

MI = myocardial infarction; MLD = minimum lumen diameter; PTCA = percutaneous transluminal coronary angioplasty; TIMI = Thrombolysis In Myocardial Infarction.
angiography demonstrated stent occlusion. The five urgent revascularizations in the open group were due to reinfarction (3 cases; see above) and aneurysmal dilatation of the LV (2 patients; 1 complicated by non-sustained ventricular tachycardia and 1 by severe progressive heart failure). Elective revascularization was recommended in two open artery patients, as angiography at 12 months demonstrated severe in-stent restenosis (left main stem involvement in one case), and in three closed artery patients (prognostic indications).

Overall, there were 17 clinical events in the open artery group and 12 in the closed artery group, representing a 42% increase in the risk of the combined clinical event after delayed intervention (p < 0.05). When data were analyzed with respect to the first clinical event, there were 13 events in the open group and nine in the closed group, representing a 44% relative increase in the risk of a major adverse event after intervention (p = 0.052).

**DISCUSSION**

We have demonstrated that while late intervention to open occluded infarct-related arteries in patients after transmural anterior MI is technically feasible, this strategy is associated with significantly greater LV dilation than a non-invasive strategy. The strategy of late intervention, however, may lead to an improved QoL and increased exercise tolerance.

Our results contrast with an earlier report in similar patients showing significantly reduced clinical events and beneficial effects on LV function after late PCI (10). Of note, however, other larger studies comparing late intervention with conservative management in patients after MI have not demonstrated superiority of either strategy with respect to clinical outcome (7,22). Furthermore, our results are consistent with those of Thrombolysis and Angioplasty in Myocardial Infarction (TAMI-6) trial in which, although no significant differences in LV ESV at six months were observed between patients undergoing late PCI and patients

![Figure 2](image_url). Left ventricular size and function. Serial changes in left ventricular end-systolic volume, end-diastolic volume, and ejection fraction after myocardial infarction are shown with respect to patients randomized to the open artery group (open circles; n = 28) and to the closed artery group (open squares; n = 33).

![Figure 3](image_url). Exercise tolerance. Serial changes in maximal exercise duration (min) on the Bruce exercise protocol and peak rate-pressure product (product of heart rate and systolic blood pressure at point of peak exertion) after myocardial infarction are shown with respect to patients allocated to the open artery group (open circles; n = 26) and to the closed artery group (open squares; n = 27).
treated medically, absolute ESV increased by 9% in the interventional group and decreased by 13% in the medical group (9).

During follow-up, the incidence of five pre-defined clinical events was also recorded in the current study as part of a secondary efficacy measure. Table 3 illustrates the combined clinical events. Our combined event rate also favors a policy of conservative therapy, with a 44% increased risk of suffering an adverse event in patients undergoing late PCI.

Of the three re-infarctions in the open artery group, one was directly related to the interventional procedure, and the other two occurred six and eight weeks after intervention. Mechanisms other than sub-acute stent thrombosis (e.g., regression of pre-existing collateral vessels) may therefore underlie these events (see description under possible adverse effects) (23). The two sudden deaths in the open artery group (six and eight months after MI) are attributed to arrhythmic causes. Although late reperfusion has been shown to favorably alter the arrhythmic substrate with respect to the prevalence of ventricular late potentials (24), there is also the possibility that late reperfusion may promote a pro-arrhythmic environment by maintaining islands of viable cells within a fibrotic scar (25). This remains an important clinical issue in need of further investigation.

Timing of late reperfusion may be an important factor. Pfisterer et al. (26), for example, reported significant attenuation of LV dilation in patients undergoing intervention two to three weeks after MI but not in patients undergoing the same procedure three months later. One-third of patients in the present study underwent PCI between 3 and 7 days of MI, while in another one-third it was between 36 and 42 days. The LV ESV changes between 6 weeks and 12 months of MI in the two sub-groups, however, were similar. Thus, in the present study, neither the direction nor the amplitude of the changes in LV ESV was dependent on the timing of PCI. However, since PCI was not performed in the first three days after MI, we cannot rule out the presence of an early time-dependent benefit.

Possible adverse effects of late PCI after MI. There is increasing evidence that after a large MI, the distal microcirculation has a high resistance, leading to low-reflow and stasis within the epicardial vessel (27). Thus, an occluded infarct-related artery may indicate high microvascular resistance. Intervention in this situation would therefore not be expected to carry any appreciable benefits. A similar explanation may explain the lack of advantage of fibrinolytics in combination with IIb/IIIa receptor blockers over fibrinolytics alone, despite a markedly higher prevalence of infarct artery patency (28).

In the setting of an occluded infarct vessel, distal ischemic myocardium is often supported by collateral vessels. After intervention, collateral vessels may become embolized, and this may be one mechanism contributing to the documented and rapid regression of recruitable collateral support after PCI for total occlusions (23). Interestingly, the two open artery patients in our study who had re-infarctions six to

### Table 3. Clinical Events

<table>
<thead>
<tr>
<th>Event</th>
<th>Closed Artery (n = 34)</th>
<th>Open Artery (n = 32)</th>
<th>Closed Artery (n = 34)</th>
<th>Open Artery (n = 32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>0 (0%)</td>
<td>1 (3.1%)</td>
<td>1 (2.9%)</td>
<td>2 (6.3%)</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>1 (2.9%)</td>
<td>3 (9.4%)</td>
<td>1 (2.9%)</td>
<td>3 (9.4%)</td>
</tr>
<tr>
<td>Stroke</td>
<td>0 (0%)</td>
<td>1 (3.1%)</td>
<td>1 (2.9%)</td>
<td>1 (3.1%)</td>
</tr>
<tr>
<td>Heart failure</td>
<td>6 (17.7%)</td>
<td>4 (12.5%)</td>
<td>6 (17.7%)</td>
<td>4 (12.5%)</td>
</tr>
<tr>
<td>Revascularization (all)</td>
<td>2 (5.9%)</td>
<td>4 (12.5%)</td>
<td>3 (8.8%)</td>
<td>7 (21.9%)</td>
</tr>
<tr>
<td>Revascularization (urgent)</td>
<td>0 (0%)</td>
<td>2 (6.3%)</td>
<td>0 (0%)</td>
<td>5 (15.6%)</td>
</tr>
<tr>
<td>Revascularization (elective)</td>
<td>2 (5.9%)</td>
<td>2 (6.3%)</td>
<td>3 (8.8%)</td>
<td>2 (6.3%)</td>
</tr>
<tr>
<td>Combined event rate†</td>
<td>9 (26.5%)</td>
<td>13 (40.6)†</td>
<td>12 (35.3%)</td>
<td>17 (53.1)‡</td>
</tr>
</tbody>
</table>

Risk increase (%) 44% 42%

*Combined event rate represents the composite rate of death, myocardial infarction, stroke, heart failure, and need for revascularization (all). †p = 0.05 (open group vs. closed group). ‡p = 0.02 (open group vs. closed group).
eight weeks after PCI were found to have well developed collateral vessels at the time of their initial intervention (Rentrop grades 2 and 3, respectively). Angiography shortly after re-occlusion, however, failed to show significant collateral support.

Medical treatment in the two study groups was standardized. After stent deployment, however, patients received clopidogrel together with high-dose aspirin for two weeks. An adverse remodeling effect from increased anti-inflammatory activity in the open artery patients cannot be excluded (29,30), but seems unlikely, given the known benefits of this combination (31).

**QoL and exercise tolerance after late intervention.** Despite our findings of significant LV dilation in patients treated with late intervention, QoL and exercise tolerance either tended to, or actually, improved in these patients. The NHP is a sensitive tool that has been validated for use in patients with cardiovascular disease. Previously, for example, it was utilized to compare angioplasty with surgery in patients with coronary artery disease, in which both invasive strategies were shown to result in improved QoL (32). More recently, in a thrombolytic study, health-related QoL was assessed in more than 1,800 patients by telephone interview using a combination of various questionnaires. Interestingly, health-related QoL was found to relate to early LV ejection fraction (myocardial salvage), but not infarct artery patency (33).

**Study limitations.** Our study has several limitations. First, this is a small study powered to compare only LV ESV. Second, echocardiographic estimates of LV volume post MI are disturbed by various assumptions. Third, although micro-embolization may represent a potential mechanism that contributed to the lack of benefit in the open artery group, we did not formally assess the extent of peri-procedural micro-infarction by routine measurement of cardiac enzymes. Fourth, although we excluded patients with a positive exercise test early after MI, we cannot exclude a selection bias in terms of residual myocardial viability. Fifth, as evidenced by the exclusion in Figure 1, our study population was highly selected, limiting the generalizability of our findings. Finally, the role of the micro-vascular circulation is inadequately addressed. Future studies combining the use of platelet IIb/IIIa receptor antagonists and pressure wires may help clarify this issue.

**Clinical implications.** Observational data show that sustained infarct artery patency after MI confers long-term benefits. Our study, however, demonstrates that although late intervention after MI is technically feasible, in our highly selected patient group, it is associated with significant LV dilation compared with medical therapy. Thus, patients remaining symptom-free after MI may not derive objective benefits from late mechanical revascularization. If such procedures are considered in this patient group, they should be within the context of ongoing clinical trials.

**Acknowledgments.** We are also grateful to the following for their assistance: Rekha Dave, Huseyin Ahmet, Anne Topham and Alex Crowther. The following were referral centers: Eastbourne District General Hospital; Guys and St Thomas’ Hospitals; Joyce Green Hospital; William Harvey Hospital; Maidstone District Hospital; Queen Elizabeth the Queen Mother Hospital; Epsom District Hospital; University Hospital Lewisham; Greenwich District Hospital; Kent and Sussex Hospital; Kent and Canterbury Hospital; Southampton General Hospital.

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