Comparison of Immediate With Delayed Stenting Using the Minimalist Immediate Mechanical Intervention Approach in Acute ST-Segment–Elevation Myocardial Infarction

The MIMI Study

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Background—Delayed stent implantation after restoration of normal epicardial flow by a minimalist immediate mechanical intervention aims to decrease the rate of distal embolization and impaired myocardial reperfusion after percutaneous coronary intervention. We sought to confirm whether a delayed stenting (DS) approach (24–48 hours) improves myocardial reperfusion, versus immediate stenting, in patients with acute ST-segment–elevation myocardial infarction undergoing primary percutaneous coronary intervention.

Methods and Results—In the prospective, randomized, open-label minimalist immediate mechanical intervention (MIMI) trial, patients (n=140) with ST-segment–elevation myocardial infarction ≤12 hours were randomized to immediate stenting (n=73) or DS (n=67) after Thrombolysis In Myocardial Infarction 3 flow restoration by thrombus aspiration. Patients in the DS group underwent a second coronary arteriography for stent implantation a median of 36 hours (interquartile range 29–46) after randomization. The primary end point was microvascular obstruction (% left ventricular mass) on cardiac magnetic resonance imaging performed 5 days (interquartile range 4–6) after the first procedure. There was a nonsignificant trend toward lower microvascular obstruction in the immediate stenting group compared with DS group (1.88% versus 3.96%; P=0.051), which became significant after adjustment for the area at risk (P=0.049). Median infarct weight, left ventricular ejection fraction, and infarct size did not differ between groups. No difference in 6-month outcomes was apparent for the rate of major cardiovascular and cerebral events.

Conclusions—The present findings do not support a strategy of DS versus immediate stenting in patients with ST-segment–elevation infarction undergoing primary percutaneous coronary intervention and even suggested a deleterious effect of DS on microvascular obstruction size.

Clinical Trial Registration—URL: http://www.clinicaltrials.gov. Unique identifier: NCT01360242.

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Key Words: infarction • myocardial infarction • percutaneous coronary intervention • stent • ST-segment–elevation myocardial infarction

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*A list of all MIMI study participants is given in the Data Supplement.


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Primary percutaneous coronary intervention (PCI) is the pivotal step in the management of acute ST-segment-elevation myocardial infarction (STEMI). Although primary PCI frequently restores normal epicardial coronary flow in STEMI, suboptimal myocardial perfusion—low-/no-reflow phenomenon or microvascular obstruction (MVO)—occurs in approximately two thirds of patients. Numerous mechanisms may explain the development of MVO in STEMI, including PCI-induced distal embolization of thrombus and friable atheromatous plaques.

In an attempt to decrease the rate of distal embolization and impaired myocardial reperfusion, the concept of delayed stent implantation after restoration of normal epicardial flow by a minimalist immediate mechanical intervention (MIMI) was initiated by Isaaz et al. Limited data from retrospective, observational, and matched-comparison studies have suggested that delayed stenting (DS) is associated with higher rates of procedural success compared with immediate stenting (IS), higher 6-month left ventricular (LV) ejection fraction, and lower rates of adverse events. A single-center proof-of-concept study reported a lower rate of angiographic no-reflow in patients treated with DS versus IS, but the population was limited to individuals with a high risk of no-reflow.

The MIMI trial was conducted to confirm whether delayed (24–48 hours) versus immediate stent implantation significantly reduced myocardial MVO as determined by cardiac magnetic resonance imaging (MRI), thus improving myocardial reperfusion in patients with acute STEMI undergoing primary PCI.

**Methods**

MIMI (ClinicalTrials.gov number NCT01360242) was a multicenter, prospective, randomized, open-label trial with blinded end point evaluation. The study was performed in accordance with the Declaration of Helsinki and French laws. The study protocol was approved by the local ethics committee (IRB 2010–048). All subjects gave written informed consent. High-volume PCI centers with MRI expertise were selected (Table I in the Data Supplement).

Adults (≥18 years) presenting with symptoms consistent with STEMI ≤12 hours, with ST-segment–elevation ≥1 mm in ≥2 contiguous limb leads or ≥2 mm in ≥2 precordial leads on ECG, intended for primary PCI were eligible for enrollment at the time of coronary angiography. The main clinical exclusion criteria were left bundle branch block, contraindication to MRI, contraindication to antplatelets or glycoprotein IIb/IIIa inhibitors, cardiogenic shock or cardiac arrest as the initial presentation, coronary artery bypass graft scheduled within 7 days, rescue or systematic emergent PCI after fibrinolysis, and life expectancy <6 months. Angiographic eligibility were preprocedural Thrombolysis In Myocardial Infarction (TIMI) flow 0 or 1, >10 minutes of sustained TIMI 3 flow in the infarct-related artery after thrombus aspiration, and a culprit lesion suitable for coronary stent implantation. The occlusion had to involve a ≥2.5 mm segment of the coronary artery in the proximal or mid left descending artery, right coronary artery before the posterior descending artery ostium, circumflex artery before the first obtuse marginal. Patients with a large thrombus (4× longer than the width of the coronary artery) were excluded because investigators were reluctant to implant a stent immediately in these individuals due to their high risk of no-reflow.

Before catheterization, patients were administered oral or intravenous aspirin 250 to 500 mg, clopidogrel 600 mg, prasugrel 60 mg, or ticagrelor 180 mg and a bolus of unfractionated heparin or low-molecular-weight heparin. If all angiographic eligibility criteria were met, the patient was given an intravenous glycoprotein IIb/IIIa inhibitor (full-dose bolus and 12-h infusion with abciximab, or 24- to 48-h infusion with tirofiban or eptifibatide) before being randomized at the end of the thrombus aspiration to IS or DS (see Figure in the Data Supplement for DS technique). Participants were allocated in a 1:1 ratio to either arm using permuted block randomization stratified by site.

Use of a balloon catheter was left to the discretion of the operator. Patients in the DS group underwent a second coronary arteriography 24 to 48 hours after the first for stent implantation. Patients were treated with unfractionated heparin or enoxaparin for at least 48 hours after the PCI (after the second procedure in the DS group).

Coronary angiograms were anonymized and centrally assessed by an expert observer from the coordinating center blinded to all other clinical data. Twelve-lead ECGs were obtained before and 60 to 90 minutes after the procedure; ECG data were assessed by an independent investigator blinded to the treatment strategy. Patients underwent a cardiac MRI 3 to 8 days after the first procedure. The scans were reviewed, and a consensus reached, by 2 expert observers at an independent core laboratory. These observers were blinded to the treatment strategy and all other clinical data (Table II in the Data Supplement). Clinical follow-up was performed at 6 months. Data management and statistical analysis were performed by the research department at University Hospital, Grenoble. Independent study monitors reviewed all source documents onsite for accuracy and completeness. Adverse events were verified by a blinded adjudication committee.

The primary end point was MVO, expressed as the relative percentage of total LV mass on the cardiac MRI done 3 to 8 days after the first procedure. Secondary outcomes included end points on MRI, angiography, ECG, and clinical end points.

MRI studies were performed on 1.5-T MR systems (see Methods in the Data Supplement). LV myocardium area at risk was measured according to the Myocardial Jeopardy Index from the Bypass Angioplasty Revascularization Investigation. An angiographic intraprocedural thrombotic event was defined as distal embolization, per-procedural increase in thrombus burden, per-procedural infarct-related artery or collateral branch (re)occlusion, and temporary and definitive no-/low-reflow at any time during the procedure. Stent thrombosis was defined according to the Academic Research Consortium definition and major bleeding according to the TIMI definition. Spontaneous and peri-procedural infarctions were defined according to the 2007 European Society of Cardiology definition.

**Statistical Methods**

With 120 assessable patients, the trial had 80% power to demonstrate a 33% relative decrease in the median MVO (% LV mass), from 4.0% to 2.8% (±2.5%),14 with a 2-sided alpha of 0.05. Assuming a 75% rate of assessable cardiac MRI scans, enrollment of 160 patients was planned.
The primary analysis was performed in the sample of modified intention-to-treat patients. Missing data were not replaced. Categorical variables and outcomes were compared using the χ² test or Fisher exact test. Continuous variables were presented as medians with interquartile ranges and were compared using the Mann–Whitney U test. Wilcoxon’s signed-rank test was used for the comparison from the end of the first procedure to the beginning of the second in the DS group. Multivariable analysis was performed using an ordered logistic regression to generate odds ratios for the DS group, adjusted for variables associated with significant differences in baseline characteristics between groups. MVO (% LV mass), the dependent variable, was analyzed in 4 ranks: 0, >0 to 5, >5 to 10, and >10.

All statistical tests were 2-sided. A P value <0.05 was considered significant for all analyses. All statistical analyses were performed using Stata version 12.0 (StataCorp, College Station, TX).

**Results**

Between June 2011 and December 2012, 160 patients were enrolled and randomized at 16 sites to IS (n=83) or DS (n=77). Data from 140 patients with interpretable cardiac MRI scans were included in the final analysis (Figure 1). MRI was not performed in 16 patients (14/16 because of patient refusal).

Primary PCIs were performed in 1200 patients at the 4 largest recruiting centers during the study period; 240 of these patients (20% of the primary PCIs) met the study inclusion/exclusion criteria, of whom 88 were enrolled in the study (37% of the 240 eligible patients).

Baseline characteristics were well matched between groups, with the exception of age, hypertension, and initial TIMI 0 flow (Table 1). All 73 patients in the IS group had a stent implanted. Patients in the DS group underwent a second scheduled angiogram (median delay between procedures 36 [29–46] hours). Patients’ angiographic characteristics after thrombus aspiration are shown in Table 2. The rate of TIMI 3 flow after aspiration at randomization was similar in the 2 groups.

**Delayed-Stenting Group**

The same access site was used in the first and the second procedure in 58 of 67 (87%) patients (54 in the right radial artery). TIMI flow at the beginning of the second procedure was 3 in 65 patients and 2 in 2 patients. Fifty-nine patients underwent PCI (58 had a stent implanted and 1 was dilated with a balloon) during the second procedure; 4 patients did not undergo a PCI during this procedure because of the persistence of a large thrombus burden and underwent stent implantation during a third procedure (2, 9, 10, and 54 days later); and 4 patients (without significant residual stenosis) did not undergo PCI.

Two patients experienced a rise in troponin concentration during the second procedure (from 2.4 to 3.7 μg/L and from 79.2 to 95.2 μg/L). Compared with the results at the end of the first procedure, the median infarct-related artery reference diameter was larger (3.2 [3.0–3.5] versus 3.0 [2.6–3.3] mm; P<0.01), the percentage narrowing was smaller (75% [60–80] versus 60% [50–70]; P<0.01), and thrombus burden (2 [1–3] versus 2 [1–2]; P<0.01) was statistically significantly smaller at the beginning of the second procedure (Figure 2). ECG data were available in 37 patients before and after the second procedure; 3 of these patients showed a >50% elevation of the ST-segment on the second ECG.

**Cardiac MRI Primary and Secondary End Points**

Cardiac MRI was performed at a median of 5 days (interquartile range 4–6) after the first procedure (both groups). Median MVO size (% LV mass) was lower in the IS group (P=0.051;
Table 1. Baseline Clinical Characteristics at Randomization

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Immediate Stenting (n=73)</th>
<th>Delayed Stenting (n=67)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>55.0 (47.9–63.1)</td>
<td>60.6 (50.3–70.5)</td>
<td>0.034</td>
</tr>
<tr>
<td>Men</td>
<td>63 (86.3)</td>
<td>51 (76.1)</td>
<td>0.12</td>
</tr>
<tr>
<td>Medical history</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angina pectoris</td>
<td>6 (8.2)</td>
<td>4 (6.0)</td>
<td>0.75</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>6 (8.2)</td>
<td>10 (14.9)</td>
<td>0.21</td>
</tr>
<tr>
<td>Hypertension</td>
<td>14 (19.2)</td>
<td>28 (41.8)</td>
<td>0.004</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>4 (5.5)</td>
<td>3 (4.5)</td>
<td>1.00</td>
</tr>
<tr>
<td>PCI</td>
<td>3 (4.1)</td>
<td>3 (4.5)</td>
<td>1.00</td>
</tr>
<tr>
<td>Smoker (current)</td>
<td>54 (74.0)</td>
<td>40 (59.7)</td>
<td>0.07</td>
</tr>
<tr>
<td>Stroke</td>
<td>2 (2.7)</td>
<td>0 (0.0)</td>
<td>0.50</td>
</tr>
<tr>
<td>Clinical status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>26.5 (24.1–29.3)*</td>
<td>26.1 (23.9–29.0)</td>
<td>0.58</td>
</tr>
<tr>
<td>MICU as first medical contact</td>
<td>65 (89.0)</td>
<td>57 (85.1)</td>
<td>0.48</td>
</tr>
<tr>
<td>Killip class</td>
<td></td>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>I</td>
<td>71 (98.6)</td>
<td>64 (95.5)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>1 (1.4)</td>
<td>3 (4.5)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Delay, from symptom onset to arrival at cath laboratory, min</td>
<td>190 (140–300)†</td>
<td>210 (142–333)‡</td>
<td>0.55</td>
</tr>
<tr>
<td>Delay, from cath laboratory arrival to randomization, min</td>
<td>32 (25–48)*</td>
<td>34 (23–45)</td>
<td>0.68</td>
</tr>
<tr>
<td>Maximum creatinine kinase, IU/L</td>
<td>2217 (1212–3884)*</td>
<td>2481 (1269–4233)*</td>
<td>0.38</td>
</tr>
<tr>
<td>Maximum troponin, μg/L</td>
<td>63 (16–129)*</td>
<td>67 (13–166)*</td>
<td>0.45</td>
</tr>
<tr>
<td>Initial angiographic status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial TIMI flow 0</td>
<td>62 (84.9)</td>
<td>64 (95.5)</td>
<td>0.037</td>
</tr>
<tr>
<td>Infarct artery location</td>
<td></td>
<td></td>
<td>0.89</td>
</tr>
<tr>
<td>LAD</td>
<td>28 (38.4)</td>
<td>26 (38.8)</td>
<td></td>
</tr>
<tr>
<td>Left circumflex artery</td>
<td>8 (11.0)</td>
<td>9 (13.4)</td>
<td></td>
</tr>
<tr>
<td>Right coronary artery</td>
<td>37 (50.7)</td>
<td>32 (47.8)</td>
<td></td>
</tr>
<tr>
<td>Bifurcation culprit lesion</td>
<td>12 (16.4)</td>
<td>14 (20.9)</td>
<td>0.50</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>53 (46–60)§</td>
<td>51 (48–58)</td>
<td>0.70</td>
</tr>
<tr>
<td>Area at risk (BARI), % [IQR]</td>
<td>30 (25–38)‡</td>
<td>33 (27–40)†</td>
<td>0.20</td>
</tr>
<tr>
<td>Collateral Rentrop grade</td>
<td></td>
<td></td>
<td>0.66</td>
</tr>
<tr>
<td>0 (no visible filling of any collateral channel)</td>
<td>30 (50.8)</td>
<td>21 (42.0)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Continued

<table>
<thead>
<tr>
<th>1 (filling of side branches of the occluded artery, with no dye reaching the epicardial segment)</th>
<th>Immediate Stenting (n=73)</th>
<th>Delayed Stenting (n=67)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 (25.4)</td>
<td>18 (36.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 (partial filling of the epicardial vessel)</td>
<td>11 (18.6)</td>
<td>8 (16.0)</td>
<td></td>
</tr>
<tr>
<td>3 (complete filling of epicardial vessel by collateral vessels)</td>
<td>3 (5.1)</td>
<td>3 (6.0)</td>
<td></td>
</tr>
<tr>
<td>Calcification (moderate or severe)</td>
<td>9 (12.9)§</td>
<td>7 (10.9)‡</td>
<td>0.73</td>
</tr>
<tr>
<td>Other diseased coronary arteries</td>
<td>19 (26.0)</td>
<td>17 (25.4)</td>
<td>0.93</td>
</tr>
<tr>
<td>Thrombus burden score before aspiration</td>
<td>0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3 (4.3)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>8 (11.4)</td>
<td>3 (4.7)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>59 (84.3)</td>
<td>61 (95.3)</td>
<td></td>
</tr>
<tr>
<td>Radial approach</td>
<td>64 (87.7)</td>
<td>61 (91.0)</td>
<td>0.52</td>
</tr>
<tr>
<td>Pre-/per-procedural antiplatelet and anticoagulant agents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspirin</td>
<td>65 (91.5)*</td>
<td>62 (92.5)</td>
<td>0.83</td>
</tr>
<tr>
<td>Clopidogrel</td>
<td>30 (41.7)</td>
<td>31 (46.3)</td>
<td>0.59</td>
</tr>
<tr>
<td>Prasugrel</td>
<td>39 (53.4)*</td>
<td>31 (46.3)</td>
<td>0.31</td>
</tr>
<tr>
<td>Ticagrelor</td>
<td>2 (2.8)*</td>
<td>3 (4.5)</td>
<td>0.67</td>
</tr>
<tr>
<td>Unfractionated heparin</td>
<td>40 (56.3)*</td>
<td>38 (56.7)</td>
<td>0.96</td>
</tr>
<tr>
<td>Enoxaparin</td>
<td>34 (47.2)</td>
<td>29 (43.3)</td>
<td>0.64</td>
</tr>
<tr>
<td>Glycoprotein Ib/IIa inhibitor</td>
<td></td>
<td></td>
<td>0.61</td>
</tr>
<tr>
<td>Abciximab</td>
<td>55 (75.3)</td>
<td>51 (76.1)</td>
<td></td>
</tr>
<tr>
<td>Eptifibatide</td>
<td>15 (21.9)</td>
<td>16 (23.9)</td>
<td></td>
</tr>
<tr>
<td>Tirotifan</td>
<td>2 (2.7)</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Values are count (percentage) or median (interquartile range). BARI indicates Bypass Angioplasty Revascularization Investigation Myocardial Jeopardy Index; IQR, interquartile range; LAD, left anterior descending coronary artery; LVEF, left ventricular ejection fraction; MICU, mobile intensive care unit; NA, not applicable; PCI, percutaneous coronary intervention; and TIMI, Thrombolysis In Myocardial Infarction.

*Missing for 1 patient.
†Missing for 2 patients.
‡Missing for 4 patients.
§Missing for 3 patients.

Table 3 and Figure 3). This difference remained not statistically significant after adjustment on age, hypertension, and initial TIMI flow in the culprit coronary artery (odds ratio 1.65, 95% confidence interval 0.86, 3.19; P=0.13). However, the percent of MVO on the area at risk (% area at risk) was significantly lower in the IS group as compared with the DS group (Bypass Angioplasty Revascularization Investigation;
After Thrombus Aspiration

one patient had an ischemic stroke on day 1, one patient had a

risk of no-/slow-reflow in the IS group in this study.11 In the MIMI study, despite the hemorrhagic stoke mentioned above, no TIMI major bleeding events occurred in either group. There was no significant difference in bleeding at the radial or femoral access site between both groups.

Discussion

The results of the present trial, involving a strategy of delayed stent implantation after TIMI 3 flow restoration with thrombus aspiration in patients with acute STEMI, did not show any reduction in MVO (percent LV mass) when compared with immediate stent implantation, and this result remained non-significant after adjustment on age, hypertension, and initial TIMI flow. On the contrary, DS tended to increase MVO size compared with that achieved in the IS group ($P=0.051$), and no difference was apparent in infarct size or LV ejection fraction.

Our results do not support the benefit of DS on the incidence of no-/slow-reflow suggested by the A Randomized Trial of Deferred Stenting Versus Immediate Stenting to Prevent No- or Slow-Reflow in Acute ST-Segment Elevation Myocardial Infarction (DEFER-STEMI) study.11 That study involved 101 patients with a high risk of no-/slow-reflow treated with primary PCI and randomized to either an IS or a 4- to 16-hour DS strategy; the primary end point was no-/slow-reflow at angiography. No-/slow-reflow may be transient, however, depending on the operator’s opacification performance and with a potentially unblinded examination done by the independent core laboratory. No-/slow-reflow at angiography testifies an immediate MVO; however, MVO is a dynamic and complex process that develops in the 48 hours after reperfusion.19 An evaluation performed 5 days after the procedure, as with MRI in the MIMI study, would be more accurate.20 One hypothesis to explain the greater extent of MVO with DS in our study is that IS could seal the lesion, whereas DS may leave the unstented lesion at risk of microembolization.21,22 Moreover, the rate of stent thrombosis at 2 months, and one died unexpectedly at 45 days. In the DS group, one patient had a hemorrhagic stroke at 3 months. None of the patients in the DS group had a clinical event suggesting infarct-related artery reocclusion after the first procedure.

Despite the hemorrhagic stoke mentioned above, no TIMI major bleeding events occurred in either group. There was no significant difference in bleeding at the radial or femoral access site between both groups.

<table>
<thead>
<tr>
<th>Thrombus score after aspiration</th>
<th>Immediate Stenting (n=73)</th>
<th>Delayed Stenting (n=67)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2 (2.9)</td>
<td>5 (7.8)</td>
<td>0.63</td>
</tr>
<tr>
<td>1</td>
<td>23 (33.3)</td>
<td>16 (25.0)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>17 (24.6)</td>
<td>19 (29.7)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>14 (20.3)</td>
<td>13 (20.3)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>13 (18.8)</td>
<td>11 (17.2)</td>
<td></td>
</tr>
<tr>
<td>TIMI 3 flow after aspiration</td>
<td>69 (94.5)</td>
<td>63 (94.0)</td>
<td>1.00</td>
</tr>
<tr>
<td>Culprit lesion length, mm</td>
<td>12 (10–15)*</td>
<td>10 (8–13)*</td>
<td>0.31</td>
</tr>
<tr>
<td>Culprit residual stenosis, %</td>
<td>70 (60–80)†</td>
<td>75 (60–80)</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Values are count (percentage) or median (interquartile range). TIMI indicates Thrombolysis In Myocardial Infarction.

*Missing for 3 patients.
†Missing for 2 patients.

$P=0.049$). Median LV ejection fraction, infarct weight, and infarct size (% area at risk) did not differ between groups (Table 3). Qualifying baseline and postprocedure ECGs were available for 130 patients. The degree of ST-segment resolution summed across the 12-lead ECG was not significantly different between the 2 groups (Table 3).

When comparing the first procedure of IS group with the second in the DS group, we found no significant differences between the IS and DS approaches, with the exception of a higher rate of nonculprit artery angioplasty in the second procedure in the DS group and a numerically but not statistically significantly lower rate of intraprocedural thrombotic events (Table III in the Data Supplement).

Six-month follow-up data were available in 138 of 140 patients. No difference in outcomes was apparent for the rate of major cardiovascular and cerebral events: in the IS group, one patient had an ischemic stroke on day 1, one patient had a
Disadvantages of DS are the need to perform 2 procedures, with the associated costs, discomfort for the patient, prolonged hospitalization, and risks related to the repeated invasive procedure. Moreover, clinicians may be concerned about leaving an unstented lesion at the site of the thrombus, leaving patients at risk of infarct-related artery reocclusion before the second procedure. Indeed, 2 cases of reocclusion were reported in DEFER-STEMI. Souteyrand et al showed that it can take >7 days to achieve complete thrombus regression.

The interventional cardiology community is facing disappointing results from various studies that have attempted to improve reperfusion techniques around primary PCI and increase the amount of salvaged myocardium. Medical treatments for no-/slow-reflow have failed to show convincing results, and recent studies assessing thrombus aspiration have been disappointing. Recently, cyclosporine failed to demonstrate clinical benefit in patients with an acute myocardial infarction. To be recommended for clinical routine management of STEMI patient, any innovative strategy has to prove a clinical benefit in sufficiently powered phase III clinical studies. To go into a phase III trial with greater chances of success, new strategies, such as DS, need to show important benefit in phase II studies, and our study failed to show such a benefit. Larger multicenter studies with increased statistical power are currently underway with the Danish Study of Optimal Acute Treatment of Patients With ST-Segment Elevation Myocardial Infarction (DANAMI-3; NCT01435408) and Immediate Versus Delayed Stenting After Primary Percutaneous Reperfusion in ST Elevation Myocardial Infarction (PRIMACY;
Limitations
We cannot exclude the possibility of selection bias because results for eligible patients who were not included in the study (37% of patients in the 4 largest centers) are not reported. However, the characteristics of our population (eg, age, sex, left anterior descending as the infarct-related artery, diabetes mellitus, reperfusion delay) do not differ from those of other studies.11,28 We reported differences in the baseline characteristics between groups, but after adjustment, the primary end point results did not change. TIMI 3 flow restoration after thrombus aspiration was an inclusion criterion; however, after centralized assessment of angiograms, 8 patients (4 in each group) were reported with TIMI 2 flow in the infarct-related artery at randomization and were, per the modified intent-to-treat principle, included in the analysis; however, the results did not change in a per-protocol analysis. The study was designed to address the hypothesis of reducing MVO and was not sufficiently powered to address safety in terms of infarct-related artery reocclusion. The DS approach was tested under cover of oral antiplatelet therapy anticoagulation, with >48 hours of anticoagulation after PCI, and glycoprotein IIb/IIIa inhibitor treatment started before the procedure. Results may differ with other drug strategies, especially with current recommendations that do not integrate glycoprotein IIb/IIIa inhibitors on a systematic basis.1

Conclusions
Our results suggest that DS could increase MVO size, as compared with IS, in patients undergoing primary PCI. Larger

<table>
<thead>
<tr>
<th>Table 3. Primary and Secondary End Points</th>
<th>Immediate Stenting (n=73)</th>
<th>Delayed Stenting (n=67)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catheterization laboratory data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microvascular obstruction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight, g</td>
<td>3.11 (0–8.41)*</td>
<td>5.61 (0.65–10.3)†</td>
<td>0.12</td>
</tr>
<tr>
<td>% LV mass</td>
<td>1.88 (0–5.03)‡</td>
<td>3.96 (0.39–6.66)†</td>
<td>0.051</td>
</tr>
<tr>
<td>Infarct size</td>
<td>9.77 (0–28.58)†</td>
<td>18.84 (4.72–27.29)†</td>
<td>0.22</td>
</tr>
<tr>
<td>% area at risk (BARI)</td>
<td>5.47 (0–16.48)§</td>
<td>12.30 (1.71–18.67)‖</td>
<td>0.049</td>
</tr>
<tr>
<td>Infarct size</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight, g</td>
<td>29.97 (14.03–44.67)*</td>
<td>28.52 (20.36–48.06)*</td>
<td>0.60</td>
</tr>
<tr>
<td>% area at risk (BARI)</td>
<td>59.78 (36.52–80.13)§</td>
<td>60.67 (43.60–83.47)§</td>
<td>0.64</td>
</tr>
<tr>
<td>LVEF, %</td>
<td>53 (46–60)</td>
<td>51 (48–58)</td>
<td>0.70</td>
</tr>
<tr>
<td>Angiographic measures after first PCI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final TIMI flow</td>
<td></td>
<td></td>
<td>0.68</td>
</tr>
<tr>
<td>2</td>
<td>4 (5.7)</td>
<td>4 (6.0)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>66 (94.3)†</td>
<td>63 (96.9)</td>
<td></td>
</tr>
<tr>
<td>Post-stent residual stenosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td>68 (97.1)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>10% to 20%</td>
<td>2 (2.9)</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Intra-aortic balloon pump</td>
<td>1 (1.4)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Distal embolization</td>
<td>10 (14.3)</td>
<td>12 (18.8)</td>
<td>0.49</td>
</tr>
<tr>
<td>Increase in thrombus burden</td>
<td>3 (4.3)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Per-procedural artery occlusion</td>
<td>1 (1.4)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Collateral branch occlusion</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>No reflow or slow reflow</td>
<td>7 (10.0)</td>
<td>4 (6.0)</td>
<td>0.43</td>
</tr>
<tr>
<td>Intraprocedural thrombotic events</td>
<td>16 (22.9)‡</td>
<td>15 (23.4)¶</td>
<td>0.94</td>
</tr>
<tr>
<td>Electrocardiographic data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay from end of the procedure to postprocedural ECG, min</td>
<td>79 (41–108)</td>
<td>80 (52–102)</td>
<td>0.93</td>
</tr>
<tr>
<td>ST-segment resolution: sum of all leads, %*</td>
<td>84 (60–100)</td>
<td>82 (40–100)</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Table 3. Continued

<table>
<thead>
<tr>
<th>Degree of resolution, %#</th>
<th>Immediate Stenting (n=73)</th>
<th>Delayed Stenting (n=67)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absent (&lt;30)</td>
<td>4 (6.7)</td>
<td>11 (19.3)</td>
<td></td>
</tr>
<tr>
<td>Partial (≥30 to &lt;70)</td>
<td>16 (26.7)</td>
<td>12 (21.1)</td>
<td></td>
</tr>
<tr>
<td>Complete (≥70)</td>
<td>40 (66.7)</td>
<td>34 (59.6)</td>
<td></td>
</tr>
</tbody>
</table>

Values are count (percentage) or median (interquartile range). BARI indicates Bypass Angioplasty Revascularization Investigation Myocardial Jeopardy Index; IQR, interquartile range; LV, left ventricular; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; and TIMI, Thrombolysis In Myocardial Infarction.

*Missing for 1 patient. †Missing for 3 patients. ‡Missing for 2 patients. §Missing for 5 patients. || Missing for 6 patients.

ST-segment resolution interpretable in 60 patients in the immediate stenting group and 57 in delayed stenting group.
studies are currently ongoing that will evaluate the potential clinical effect of delayed stent implantation.

Acknowledgments

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Disclosures


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19. Rochitte CE, Lima JA, Bluemke DA, Reeder SB, McVeigh ER, Furuta T, Becker LC, Melin JA. Magnitude and time course of microvascular


Comparison of Immediate With Delayed Stenting Using the Minimalist Immediate Mechanical Intervention Approach in Acute ST-Segment–Elevation Myocardial Infarction: The MIMI Study

Loïc Belle, Pascal Motreff, Lionel Mangin, Grégoire Rangé, Xavier Marcaggi, Antoine Marie, Nadine Ferrier, Olivier Dubreuil, Gilles Zemour, Géraud Souteyrand, Christophe Caussin, Nicolas Amabile, Karl Isaaaz, Raphael Dauphin, René Koning, Christophe Robin, Benjamin Faurie, Laurent Bonello, Stanislas Champin, Cédric Delhaye, François Cuilleret, Nathan Mewton, Céline Genty, Magalie Viallon, Jean Luc Bosson, Pierre Croisille and on behalf of the MIMI Investigators

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SUPPLEMENTAL MATERIAL

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Supplementary Methods

Magnetic Resonance Imaging Technique

The imaging protocol included cine MRI for LV function assessment, first-pass rest perfusion, and early and late gadolinium enhancement imaging. All sequences were performed on MAGNETOM Avanto (Siemens, Erlangen, Germany) 1.5 T systems equipped with 30 mT.m\(^{-1}\) or 40 mT.m\(^{-1}\) gradient systems, using vectocardiogram monitoring and 12-element phased-array cardiac receiver coils. After localization, rest left ventricular function was assessed with retrospective electrocardiogram-gated steady-state free precession pulse cine sequences (cine TrueFISP) in long- and short-axis views in the true heart axis (TR 3.2 ms, TE 1.6 ms, slice thickness 7 mm, at least 20 phases, matrix size 256 × 184, breath-hold duration 12–15 s). The short-axis scans covered the whole left ventricle with 8–12 contiguous slices from base to apex. A first-pass perfusion rest cardiac magnetic resonance study was then performed for every patient (saturation recovery, gradient echo turbo-flash sequence, TR/TE 159 ms/1.1 ms, flip angle 12°, slice thickness 10 mm, matrix size 128 × 104) after an intravenous bolus injection of gadolinium-DOTA (0.2 mmol/kg body weight; Dotarem, Guerbet France). In this study, perfusion was used only for timing and quality control of contrast injection. Contrast enhancement was evaluated in short-axis orientation covering the whole ventricle after contrast injection using 3D-gradient spoiled TurboFLASH sequences with a selective 180° inversion recovery pre-pulse (typical parameters: TR 5.6 ms, TE 1.5 ms, flip angle 10°, read-out duration 186 ms, slice thickness 5 mm, matrix 256 × 184, grappa factor 2, slices number 16–20, breath-hold duration ≤16 s).\(^1\) For microvascular obstruction assessment, an early (early gadolinium enhancement) acquisition was performed 4 minutes after bolus injection, with a TI set to 400 ms to optimize identification of no or hypoenhanced areas. For sizing of the myocardial infarct, a second late gadolinium enhancement acquisition was performed 10 minutes after injection, and TI was determined individually to null the myocardial signal typically ranging from 240-280 ms. Additional 2-chamber and 4-chamber long-axis 3D-sequences were also performed to ease analysis. Quantitative analysis was performed using cvi42 software (Circle Cardiovascular Imaging Inc, Calgary AB, Canada).

Off-line image analysis was performed by two experienced observers using CMR\(^42\) analysis package (Circle, Calgary, Alberta, Canada). LV volumes and function were first calculated. Infarct zone was defined semi-automatically on late gadolinium enhancement imaging using the full-width half-maximum technique. MVO was defined as areas of hypo-enhancement on the early gadolinium enhancement images.

The extent of myocardial MVO and infarcted myocardium was expressed in grams of tissue according to the following formula:

\[
\sum (\text{hypoenhanced or hyperenhanced area [in cm}^2\text{]}) \times \text{slice thickness (in cm)} \times \text{myocardial specific density (1.05 g/cm}^3)\]

The percentage of MVO within the final infarct size ratio was calculated according to the following formula:

\[
\text{MVO extent within infarct} = \left(\frac{\text{late MVO mass/infarct size mass}}{\text{100}}\right)
\]
## Supplementary Table 1. MIMI Investigators

<table>
<thead>
<tr>
<th>Site</th>
<th>Investigator</th>
<th>Patients enrolled (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre hospitalier d’Annecy, Annecy</td>
<td>Dr Belle</td>
<td>33</td>
</tr>
<tr>
<td>University Hospital of Clermont-Ferrand, Clermont-Ferrand</td>
<td>Pr Motreff</td>
<td>22</td>
</tr>
<tr>
<td>Centre hospitalier de Vichy, Vichy</td>
<td>Dr Marcaggi</td>
<td>16</td>
</tr>
<tr>
<td>Les Hôpitaux de Chartres, Chartes</td>
<td>Dr Rangé</td>
<td>17</td>
</tr>
<tr>
<td>Hospital of St Luc St Joseph, Lyon</td>
<td>Dr Dubreuil</td>
<td>13</td>
</tr>
<tr>
<td>Centre hospitalier de Cannes, Cannes</td>
<td>Dr Zemour</td>
<td>7</td>
</tr>
<tr>
<td>Institut Mutualiste Montsouris, Paris</td>
<td>Dr Caussin</td>
<td>6</td>
</tr>
<tr>
<td>University Hospital of Saint-Etienne, Saint-Etienne</td>
<td>Pr Isaaz</td>
<td>6</td>
</tr>
<tr>
<td>University hospital La Croix Rousse, Lyon</td>
<td>Dr Dauphin</td>
<td>5</td>
</tr>
<tr>
<td>Clinique Saint Hilaire, Rouen</td>
<td>Dr Koning</td>
<td>4</td>
</tr>
<tr>
<td>Groupe hospitalier mutualiste, Grenoble</td>
<td>Dr Faurie</td>
<td>2</td>
</tr>
<tr>
<td>Clinique Convert, Bourg en Bresse</td>
<td>Dr Robin</td>
<td>3</td>
</tr>
<tr>
<td>University Hospital of Marseille, Marseille</td>
<td>Dr Bonello</td>
<td>2</td>
</tr>
<tr>
<td>Hopital de Valence, Valence</td>
<td>Dr Champin</td>
<td>2</td>
</tr>
<tr>
<td>University Hospital of Lille, Lille</td>
<td>Dr Delhaye</td>
<td>1</td>
</tr>
<tr>
<td>Hospital of Macon, Macon</td>
<td>Dr Cuilleret</td>
<td>1</td>
</tr>
</tbody>
</table>
### Supplementary Table 2. MIMI Committees

<table>
<thead>
<tr>
<th>Committee</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECG core laboratory</td>
<td>Cardiology Department, Hospital de Saint Julien en Genevois, France</td>
</tr>
<tr>
<td>MRI core laboratory</td>
<td>Radiology Department, University hospital, Lyon and Saint Etienne, France</td>
</tr>
<tr>
<td>Adverse events adjudication committee</td>
<td>Cardiology Department, University hospital, Lyon and Grenoble, France</td>
</tr>
<tr>
<td>Data management and statistical analysis</td>
<td>Research Department, University hospital, Grenoble, France</td>
</tr>
</tbody>
</table>
### Supplementary Table 3. Second Procedure in Delayed-Stenting Group versus First Procedure in Immediate-Stenting Group

<table>
<thead>
<tr>
<th></th>
<th>Immediate Stenting</th>
<th>Delayed Stenting</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First Procedure (n=73)</td>
<td>Second Procedure (n=67)</td>
<td></td>
</tr>
<tr>
<td>No. PCIs / No. PCIs with stent</td>
<td>73/73</td>
<td>59/58</td>
<td></td>
</tr>
<tr>
<td>Balloon dilatation before stent</td>
<td>8/73 (11.0)</td>
<td>7/58 (12.1)</td>
<td>0.84</td>
</tr>
<tr>
<td>implantation / No. PCIs with stent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balloon dilatation post stent</td>
<td>11/73 (15.1)</td>
<td>14/58 (24.1)</td>
<td>0.19</td>
</tr>
<tr>
<td>implantation / No. PCIs with stent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥1 drug-eluting stent implanted / No. PCIs with stent</td>
<td>27/73 (37.0)</td>
<td>19/58 (32.2)</td>
<td>0.62</td>
</tr>
<tr>
<td>Stent minimal diameter, mm</td>
<td>3.5 (3.5)</td>
<td>3.3 (3.5)</td>
<td>0.59</td>
</tr>
<tr>
<td>Total length of stents, mm</td>
<td>18 (15-26)</td>
<td>18 (15-25)</td>
<td>0.37</td>
</tr>
<tr>
<td>Non-culprit lesion dilated / No. PCIs with stent</td>
<td>4/73 (5.5)</td>
<td>12/58 (20.7)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Final TIMI flow</td>
<td></td>
<td></td>
<td>0.68</td>
</tr>
<tr>
<td>2</td>
<td>4/70 (5.7)</td>
<td>2/65 (3.1)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>66/70 (94.3)</td>
<td>53/65 (96.9)</td>
<td></td>
</tr>
<tr>
<td>Post-procedural stenosis, %</td>
<td></td>
<td></td>
<td>0.50</td>
</tr>
<tr>
<td>0</td>
<td>68/70 (97.1)</td>
<td>59/59 (100)</td>
<td></td>
</tr>
<tr>
<td>≥10</td>
<td>2/70 (2.9)</td>
<td>0</td>
<td></td>
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<tr>
<td>Events between randomization (after thrombus aspiration) and end of procedure</td>
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<td></td>
<td></td>
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<tr>
<td>Embolizations</td>
<td>8/70 (11.4)</td>
<td>4/67 (6.0)</td>
<td>0.29</td>
</tr>
<tr>
<td>Increase in thrombus burden</td>
<td>3/70 (4.3)</td>
<td>1/65 (1.5)</td>
<td>0.62</td>
</tr>
<tr>
<td>Perprocedural artery occlusion</td>
<td>1 (1.4)</td>
<td>0 (0.0)</td>
<td>1.00</td>
</tr>
<tr>
<td>Collateral branch occlusion</td>
<td>0 (0.0)</td>
<td>2/65 (3.1)</td>
<td>0.23</td>
</tr>
<tr>
<td>No-reflow or slow reflow</td>
<td>7/70 (10)</td>
<td>6/67 (9.0)</td>
<td>0.90</td>
</tr>
<tr>
<td>Intraprocedural thrombotic events</td>
<td>14/70 (20.0)</td>
<td>8/65 (12.3)</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Values are count (percentage) or median (interquartile range).

PCI denotes percutaneous coronary intervention; other abbreviations as in Table 1.
Supplementary Figure. MIMI Technique: Delayed Stenting in Primary Percutaneous Coronary Intervention

TIMI 0          Thrombus aspiration          TIMI 3 flow restored for >10 min
Glycoprotein IIb/IIIa inhibitor therapy and delayed stenting for 24-48 hours.
Reference