

Effect of Intraaortic Balloon Pumping on Left Ventricular Function in Patients With Persistent ST Segment Elevation After Revascularization for Acute Myocardial Infarction

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The purpose of the present study was to assess the impact of intraaortic balloon pumping (IABP) in patients with persistent ST elevation who underwent revascularization within 6 h of their first acute anterior myocardial infarction (AMI). Persistent ST elevation after revascularization was defined as being ≥50% of the initial value on return to the coronary care unit. Twenty-four patients were treated without IABP (control group) and 27 patients were treated with IABP (IABP group). There was no significant difference between the 2 groups in pretreatment left ventricular ejection fraction (LVEF), end-diastolic volume index or end-systolic volume index. After 137±46 days, the change in the LVEF was significantly higher in the IABP group than in the control group (5±13% vs 13±15%, p=0.04). However, the left ventricular end-diastolic volume index was similar between the 2 groups during follow-up (pretreatment: 77±19 ml/m² vs 74±13 ml/m², p=0.54; follow-up: 86±22 ml/m² vs 83±18 ml/m², p=0.60). These data suggest that IABP enhances the improvement in LVEF independent of remodeling in AMI patients with persistent ST elevation after revascularization.

Key Words: Reperfusion; ST segment; Ventricular function

Methods

Study Population

Between January 1991 and June 2001, 279 patients presented with a first anterior AMI and underwent emergency coronary angiography within 6 h of the onset of chest pain. The data relating to these patients were prospectively entered into a computer database, and from this we selected 51 patients who met the following criteria: (1) ischemic chest pain lasting for >30 min; (2) ST segment elevation of at least 0.2 mV in 2 or more contiguous electrocardiographic (ECG) leads; (3) elevation of serum creatine kinase concentration to more than twice the normal upper limit; (4) total occlusion (TIMI grade 0 or 1) of the proximal left anterior descending coronary artery; (5) >50% of the initial value of ST segment elevation on return to the coronary care unit; (6) >50% of the initial value of ST segment elevation on return to the coronary care unit.

In acute myocardial infarction (AMI), early, complete and sustained restoration of blood flow in the occluded coronary artery can salvage myocardium at risk and improve survival. Revascularization of the occluded coronary artery with balloon angioplasty can be achieved in >90% of patients. However, even early restoration of thrombolysis-in-myocardial-infarction (TIMI) grade 3 flow is not always associated with myocardial reperfusion because of microvascular damage. Recent studies have demonstrated that persistent ST segment elevation after revascularization is a marker of impaired microvascular reperfusion and is associated with a worse clinical outcome. Intraaortic balloon pumping (IABP), which can reduce the rate of infarct-related artery reocclusion, augment myocardial recovery and improve clinical outcome after AMI would be expected to be most effective in AMI patients with persistent ST segment elevation after revascularization.

This study was undertaken to assess the impact of IABP on left ventricular function in AMI patients with persistent ST segment elevation after revascularization.

Fig 1. Electrocardiograms before and after revascularization show that the sum of ST segment elevation increases from 15 mm to 30 mm.
Follow-up angiography was performed 4–6 months later. Ticlopidine (minimum dosage 100 mg/day) for 4 weeks. Aspirin (81 mg/day) and after stenting were treated with on the physician’s decision. All patients were treated with modality of treatment was not randomized, and was based since 1995, balloon angioplasty aimed to obtain a residual stenosis of <50% and restoration of brisk anterograde flow. Since 1995, coronary stenting has been performed if appropriate. The coronary angiography was performed after an intracoronary infusion of nitroglycerin, and collateral vessels were

### Table 1 Baseline Clinical and Angiographic Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Control group (n=24)</th>
<th>IABP group (n=27)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>60±9</td>
<td>58±10</td>
<td>0.38 (NS)</td>
</tr>
<tr>
<td>Male</td>
<td>18 (75%)</td>
<td>22 (81%)</td>
<td>0.57 (NS)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>6 (25%)</td>
<td>4 (15%)</td>
<td>0.29 (NS)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>8 (33%)</td>
<td>5 (19%)</td>
<td>0.23 (NS)</td>
</tr>
<tr>
<td>Serum cholesterol ≥220 mg/dl</td>
<td>2 (8%)</td>
<td>5 (19%)</td>
<td>0.26 (NS)</td>
</tr>
<tr>
<td>Smoker</td>
<td>13 (54%)</td>
<td>16 (59%)</td>
<td>0.71 (NS)</td>
</tr>
<tr>
<td>Previous angina</td>
<td>17 (70%)</td>
<td>14 (52%)</td>
<td>0.17 (NS)</td>
</tr>
<tr>
<td>Time to reperfusion (h)</td>
<td>2.9±1.3</td>
<td>2.4±1.2</td>
<td>0.10 (NS)</td>
</tr>
<tr>
<td>Multivessel disease</td>
<td>7 (29%)</td>
<td>7 (26%)</td>
<td>0.78 (NS)</td>
</tr>
<tr>
<td>Collateral circulation ≥2</td>
<td>9 (38%)</td>
<td>12 (44%)</td>
<td>0.61 (NS)</td>
</tr>
</tbody>
</table>

Revascularization therapy
- Balloon angioplasty: 4 (17%) vs 14 (52%), p<0.01
- Coronary stenting: 20 (83%) vs 13 (48%)
- ST segment elevation
  - Before revascularization (mm): 17.8±8.7 vs 17.1±8.8, p=0.78 (NS)
  - After revascularization (mm): 15.8±7.8 vs 13.3±5.6, p=0.18 (NS)

Medication
- Nitrates: 22 (92%) vs 25 (93%), p=0.90 (NS)
- ACE inhibitors: 10 (42%) vs 10 (37%), p=0.74 (NS)
- Peak creatine kinase (IU/L): 3,969±2,066 vs 4,434±2,505, p=0.48 (NS)

ACE, angiotensin-converting enzyme.

anterior descending artery; (5) TIMI grade 3 and postprocedural diameter stenosis <50% after revascularization; (6) persistent ST segment elevation after revascularization; and (7) left ventriculography carried out before revascularization and at follow-up. Twelve-lead ECGs were recorded just before revascularization and on return to the coronary care unit. The sum of ST segment elevation was measured 20 ms after the end of the QRS complex from leads I, aVL, and V1–6. Patients with a bundle branch block or persistent ventricular arrhythmia were excluded. Persistent ST segment elevation after revascularization was defined as ≥50% of the initial value on return to the coronary care unit (Fig 1).9,11 Patients were excluded if they had cardiogenic shock, hypotension (systolic blood pressure <90 mmHg) unresponsive to intravenous fluids or pressor therapy, or pulmonary edema requiring IABP, because the goal of the current study was to assess the impact of IABP on left ventricular function in patients with uncomplicated AMI and persistent ST segment elevation.

**Cardiac Catheterization**

After intravenous infusion of 5,000 U of heparin, left ventriculography and coronary angiography were performed by the femoral or brachial approach. Left ventriculography was performed in a 30-degree right anterior oblique projection. The left ventricular ejection fraction (LVEF) and end-diastolic and end-systolic volumes were measured by 2 independent technicians using the area–length method. Coronary angiography was performed after an intracoronary infusion of nitroglycerin, and collateral vessels were graded according to Rentrop’s classification.15 Multivessel disease was defined as the presence of a lesion with ≥75% stenosis in a non-infarct-related artery. Conventional balloon angioplasty aimed to obtain a residual stenosis of <50% and restoration of brisk anterograde flow. Since 1995, coronary stenting has been performed if appropriate. The modality of treatment was not randomized, and was based on the physician’s decision. All patients were treated with aspirin (81 mg/day) and after stenting were treated with ticlopidine (minimum dosage 100 mg/day) for 4 weeks. Follow-up angiography was performed 4–6 months later.

### IABP Insertion

All IABP were inserted by a cardiologist experienced with the percutaneous insertion technique. A 10.5F balloon catheter was inserted via the femoral artery, and the IABP was usually inserted after the final image of acute angiography. The IABP was continued for approximately 24 h at a rate of 1:1, and the patient was gradually weaned from the pump during 3 h before removal of the catheter. The use of IABP was based on the physician’s decision.

### Measurements of Creatine Kinase Concentration

In order to determine the peak creatine kinase concentration, blood samples were obtained every 3 h during the first 24 h and then once daily from the second day until a normal value was obtained.

### Statistical Analysis

Data are presented as mean±SD. Within-group comparisons were obtained using paired t-test, and between-group comparisons using unpaired t-test. Categoric variables were analyzed by the chi-squared test. A p value <0.05 was considered to be statistically significant in all cases.

### Results

### Baseline Characteristics

A total of 51 patients were enrolled: 24 were treated without IABP (control group) and 27 were treated with IABP for 22±4 h (IABP group). Baseline clinical and angiographic variables are shown in Table 1. There was no significant difference in age or gender; prevalence of diabetes, hypertension, hypercholesterolemia, smoking, previous angina, multivessel disease, collateral circulation, or time to reperfusion. Coronary stenting was performed more frequently in the control group (83% vs 48%, p<0.01). No major complications occurred with the IABP procedure. There was no significant difference between the 2 groups in the frequency of administration of nitrates or angiotensin-converting enzyme inhibitors (ACEI). Peak creatine kinase concentration was obtained in all patients and averaged 3,969±2,066 IU/L in the control group and 4,434±
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2,505 IU/L in the IABP group (p=0.48).

Ventricular Function
There was no significant difference in pretreatment LVEF between the 2 groups (49±10% vs 49±8%, p=0.89). Follow-up angiography was carried out 137±46 days after AMI at which time the incidence of TIMI grade 3 did not differ between the 2 groups (100% vs 93%, p=0.28). There was a tendency toward a higher LVEF at follow-up in the IABP group (54±15% vs 62±14%, p=0.06), and changes in LVEF were significantly higher in the IABP group than in the control group (5±13% vs 13±15%, p=0.04) (Fig 2).

There was no significant difference in left ventricular end-diastolic volume index during the follow-up between the 2 groups (pretreatment: 77±19 ml/m² vs 74±13 ml/m², p=0.54; follow-up: 86±22 ml/m² vs 83±18 ml/m², p=0.60) (Fig 3). There was no significant difference in pretreatment left ventricular end-systolic volume index between the 2 groups (40±15 ml/m² vs 38±9 ml/m², p=0.61). There was a tendency toward a smaller left ventricular end-systolic volume index at follow-up in the IABP group (32±17 ml/m², p=0.08) (Fig 4).

Discussion
Present Findings
The major finding of the present study was that IABP enhanced the improvement in LVEF independent of remodeling in AMI patients with persistent ST segment elevation after revascularization.

Previous Studies
Coronary angioplasty is an effective reperfusion strategy, with early restoration of adequate coronary flow occurring in >90% of AMI patients; however, despite successful revascularization, a substantial number of patients still fail to obtain complete and sustained myocardial reperfusion. Previous studies with myocardial contrast echocardiography have revealed zones of impaired tissue flow, termed the ‘no-reflow’ phenomenon, in one-quarter to one-third of reperfused AMI patients3-5 and this is accompanied by ST segment elevation on the 12-lead ECG.6,17 Several studies have examined the implication of persistent ST segment elevation as a marker of impaired microvascular reperfusion for prognosis after AMI. Claeyss et al reported that impaired microvascular reperfusion, as evidenced by persistent ST segment elevation after successful revascularization (≥50% of the initial value), was observed in more than one-third of AMI patients, and was associated with more extensive infarction and a worse clinical outcome. Moreover, van’t Hof et al10 and Matetzky et al11 reported that persistent ST segment elevation was associated with worse recovery of left ventricular function. Although we have previously reported the ability of IABP to augment myocardial recovery after revascularization for AMI,13,18 there are no published data specifically focusing on the impact of IABP in AMI patients with persistent ST segment elevation and to our knowledge, the present study is the first to do so.

Ventricular Function
In the current study, we only included patients admitted within 6 h of the onset of their first anterior AMI. In addition, we excluded patients with cardiogenic shock or pulmonary edema requiring IABP, because the goal of the current study was to assess the impact of IABP on left ventricular function in patients with uncomplicated AMI and persistent ST segment elevation. As previously reported, the change in LVEF is minimal in AMI patients with persistent ST segment elevation who are not treated with IABP;10-12 however, in the present patients treated with IABP, significant improvement in LVEF was obtained during the follow-up period. Previous studies have demonstrated that infarct-related artery patency is an important determinant of ventricular remodeling after AMI.19,20 In the current study, the incidence of TIMI grade 3 at follow-up did not differ between the 2 groups. In addition, it is noteworthy that the use of medications, such as nitrates21 and ACEI, which might prevent ventricular remodeling after AMI, were similar between the 2 groups.22,23 In the current study, there was no significant difference in left ventricular end-diastolic volume index between the 2 groups during the follow-up period, which suggested that in AMI patients with persistent ST segment elevation, IABP enhanced the
improvement in LVEF independent of remodeling.

Proposed Mechanism

There are several physiologic effects of IABP that may explain the improvement in LVEF in patients with persistent ST segment elevation. First, IABP augments diastolic arterial pressure, which is an important determinant of the coronary driving pressure. We have previously demonstrated that IABP increases peak coronary blood flow velocity. A second possible mechanism is based on decreasing the systolic arterial pressure and left ventricular end-diastolic pressure, which then decreases the myocardial oxygen demand. These favorable hemodynamic effects of IABP may contribute to attenuation of impaired microvascular circulation and result in a reduced myocardial infarct. In the current study, infarct size assessed by peak creatine kinase concentration was similar between the 2 groups, possibly because increased washout of creatine kinase associated with improved perfusion by IABP might have been effected.

There are several possible reasons why IABP could not prevent left ventricular remodeling in AMI patients with persistent ST segment elevation despite its favorable hemodynamic effects. First, the effect of left ventricular unloading obtained by IABP may be too small; ventricular remodeling is influenced not only by ventricular load, but also by other factors such as neurohormonal activation or local tissue growth factors. Second, the duration of IABP in the present study may have been too short; ventricular remodeling continues for weeks or months until the distending forces are counterbalanced by the tensile strength of the collagen scar.

Study Limitations

The present study suffers from the limitations common to all nonrandomized, retrospective analyses. First, the allocation of revascularization strategy and the use of IABP were based on the physician's decision. Because IABP was performed, in part, to prevent abrupt vessel closure after revascularization, coronary stenting resulted in IABP being used less frequently. However, it is noteworthy that incidence of persistent ST segment elevation after revascularization was similar between balloon angioplasty and coronary stenting in the present patients. Second, we assessed myocardial infarct size only by peak creatine kinase concentration, and superior results may have been obtained from myocardial scintigraphy. Third, the small sample size is a major limitation and a larger study should be performed to confirm our findings.

Conclusions

In AMI patients with persistent ST segment elevation after revascularization, IABP enhances the improvement in LVEF independent of remodeling. Our data emphasize the importance of hemodynamic support under these conditions.

References