Effect of Coronary Angioplasty on Electrocardiographic Changes in Patients With Unstable Angina Secondary to Left Anterior Descending Coronary Artery Disease

FAYAZ A. SHAWL, MD, FACC, CARLOS E. VELASCO, MD,* THOMAS S. GOLDBAUM, MD, FACC, MERVYN B. FORMAN, MD, PhD, FACC*
Takoma Park, Maryland and Nashville, Tennessee

The effect of semiemergent percutaneous transluminal coronary angioplasty on clinical and electrocardiographic (ECG) variables was assessed in 76 patients with unstable angina secondary to an isolated severe proximal left anterior descending coronary artery stenosis. All patients manifested symmetric T wave inversion in two or more anterior ECG leads. Wall motion abnormalities were present in 37 patients on ventriculography before dilation.

Angioplasty was successful in 70 patients (92%), resulting in a reduction in luminal diameter stenosis from 91 ± 8% to 21 ± 6%, with no major acute procedure-related complications observed. The other six patients underwent semiurgent (<48 h) coronary artery bypass surgery and three patients experienced a myocardial infarction (before bypass surgery in two). Serial ECGs revealed complete resolution of ST-T wave changes in 51% of patients at 14 weeks and in 90% at 28 weeks. In contrast, prolongation of the corrected QT interval, which was present in 16 patients (8%), normalized within 48 h of successful angioplasty. Twelve of these 16 patients with a prolonged QT interval had nonocclusive thrombus formation and poor collateral circulation on angiography.

Patients were followed up for 6 to 43 months (mean 23 ± 10). Angiographic evidence of restenosis was present in 34% of patients, all of whom underwent a successful second or third procedure. One death occurred at 8 months after successful angioplasty. Wall motion abnormalities had completely resolved in 13 of 15 patients who underwent repeat ventriculography, at which time 10 had a normal ECG.

This study demonstrates that ECG changes may persist for up to 7 months in patients who undergo successful angioplasty for severe left anterior descending coronary artery disease and unstable angina. Semiemergent angioplasty was associated with a high initial success rate and excellent long-term outcome.

(J Am Coll Cardiol 1990;16:325-31)

Symmetric T wave inversion is a frequent finding in patients who present with unstable angina secondary to severe stenosis of the proximal left anterior descending coronary artery (1,2). These electrocardiographic (ECG) changes identify a group of patients with a poor prognosis when treated medically (3,4). Percutaneous transluminal coronary angioplasty has been successfully applied in the treatment of patients with various ischemic heart syndromes, including unstable angina (5-9). Several studies (10-13) have demonstrated that angioplasty in this setting is associated with a high success rate, low morbidity and improved short-term event-free survival.

Short-term follow-up evaluation has demonstrated (14) that successful angioplasty is associated with significant improvement in angiographic, hemodynamic and functional variables in patients with unstable angina secondary to critical left anterior descending artery stenosis. The long-term efficacy of angioplasty in such patients has not been evaluated. This study describes the clinical, ECG and angiographic findings in a large group of patients with unstable angina and T wave inversion in the anterior leads who underwent semiemergent angioplasty of the left anterior descending coronary artery and who were followed up for a mean period of approximately 2 years.
Methods

Study patients. From August 1982 to March 1986, 570 patients at Washington Adventist Hospital underwent cardiac catheterization for the evaluation of unstable angina. Patients who were diagnosed as having unstable angina (defined as new onset [<2 months] angina pectoris present at rest or with minimal exertion or a change in the pattern of previously described stable angina), associated with the presence of symmetric T wave inversion in two or more adjacent anterior ECG leads (I, aVL, V1 to V4) were included in the study. The ECG changes either were present on admission or developed within the first 48 h of hospitalization. T wave inversion was defined as ≥2 mm deviation from the isoelectric line. Patients who manifested an isoelectric, depressed or minimally elevated (≥1 mm) J point followed by a convex, concave or straight ST segment associated with T wave inversion also qualified for the study.

Exclusion criteria included the development of new ST segment elevation or Q waves, or both, in the anterior ECG leads, previous angioplasty of the left anterior descending artery, prior coronary artery bypass surgery and the presence of right or left bundle branch block or left ventricular hypokinesia. One hundred two patients met these criteria and form the basis of this report. Their ages ranged from 34 to 76 years (mean 58) and there were 68 men and 34 women.

Catheterization and angioplasty procedure. Diagnostic cardiac catheterization using the Judkins technique was performed within the first 48 h of admission. Coronary angiography was performed in multiple standard and angled views for optimal visualization of stenotic segments. The extent of coronary artery disease was assessed by two independent angiographers using a caliper method. Patients were characterized as having single, double or triple vessel disease when a significant lesion (defined as >50% luminal diameter reduction) was present in one or more coronary arteries. The majority of patients (91%) underwent repeat cardiac catheterization within 3 to 12 months (mean 4.2 ± 2) after angioplasty or earlier if symptoms recurred. Restenosis was defined as a persistent filling defect present in at least two angiographic projections. Collateral blood supply to the left anterior descending artery was graded 0 to 3+, as previously described (15).

All patients underwent left ventriculography in the right anterior oblique projection. Left ventricular ejection fraction was calculated by the area-length method of Dodge et al. (16). The degree of hypokinesia (mild, moderate or severe) was graded according to the criteria reported in the Coronary Artery Surgery Study (CASS) (17).

Angioplasty utilizing the standard Gruentzig technique (18) was performed within 24 h of diagnostic angiography. Aspirin (375 mg), heparin (intravenously) and either nitrates or a calcium channel blocker (nifedipine 10 to 30 mg), or both, were administered before the procedure. Low molecular weight dextran infusion was given to all patients before, during and after the procedure. Once arterial access had been obtained, an additional 10,000 U of heparin was given as an intravenous bolus injection. Multiple dilations (mean 3 ± 1) utilizing inflation pressures of up to 12 atm for a maximum of 90 s were performed. Successful angioplasty was defined as a decrease of ≥50% in luminal diameter narrowing before angioplasty. Intravenous heparin in a mean dose of 1,000 U/h was continued as a constant infusion for at least 24 h, after which the vascular sheath was removed. Myocardial infarction was diagnosed by the development of new Q waves or a twofold increase in the MB fraction of serum creatine kinase, or both.

Follow-up. Follow-up study has ranged from 6 to 43 months (mean 23 ± 10). Serial ECGs were obtained when clinically indicated and before and immediately after angioplasty. before discharge and at 10, 14, 21, 28 and 34 weeks. Creatine kinase, MB fraction (MB CK) was measured every 8 h for the first 24 h after angioplasty or when clinically indicated.

Clinical variables assessed included persistence or recurrence of angina, need for coronary artery bypass surgery, occurrence of myocardial infarction and sudden death. The majority of patients (91%) underwent repeat cardiac catheterization within 3 to 12 months (mean 4.2 ± 2) after angioplasty or earlier if symptoms recurred. Restenosis was defined as ≥50% reduction in coronary luminal narrowing at the site of prior dilation.

Results

Angiographic features (Table 1). Isolated stenosis of the left anterior descending coronary artery was the most prevalent angiographic finding (76 patients). Multivessel disease was present in 23 patients (all with proximal left anterior descending artery stenosis) and 3 had angiographically normal vessels. The majority of the patients with isolated left anterior descending artery disease had a stenosis distal to the first septal perforator but proximal to the first diagonal.

Table 1. Angiographic Findings in 76 Patients With Unstable Angina

<table>
<thead>
<tr>
<th>Stenosis location</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal to FSP</td>
<td>15</td>
</tr>
<tr>
<td>Distal to FSP but proximal to SSP or D1</td>
<td>61</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percent stenosis</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>75% to 90%</td>
<td>6</td>
</tr>
<tr>
<td>90% to 99%</td>
<td>59</td>
</tr>
<tr>
<td>100%</td>
<td>11 (all with collateral vessels)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thrombus</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>14 (12 had a prolonged QTc interval)</td>
</tr>
<tr>
<td>Absent</td>
<td>62</td>
</tr>
</tbody>
</table>

FSP = first septal perforator; QTc = corrected QT; SSP = second septal perforator.
The extent of luminal diameter reduction in the patients with single vessel disease is illustrated in Table 1. Most patients had a critical reduction in luminal diameter (>90%). In the 11 patients with total occlusion of the left anterior descending artery, the distal vessel was opacified by grade 2 or 3 collateral vessels arising predominantly from the right coronary artery. Filling defects compatible with thrombus formation were present in 18% of patients.

The majority of patients had a normal global left ventricular ejection fraction (>50%). Moderate left ventricular dysfunction (ejection fraction 35% to 40%) was present in two patients and severe dysfunction (ejection fraction <35%) was present in another patient. Regional wall motion was normal in 39 patients. Mild to moderate hypokinesia involving apical or anterolateral segments, or both, was present in 36 patients and apical dyskinesia in 1 patient.

Angioplasty results (Fig. 1 and 2). Angioplasty was attempted in the 76 patients with single vessel disease. The procedure was successful in 70 patients (92%), resulting in a reduction in luminal diameter from 91 ± 8% to 21 ± 6%. Examples of coronary angiographic changes before and after angioplasty in a patient whose ECG only normalized 10 weeks after angioplasty are shown in Figures 1 and 2. Total creatine kinase and isoenzymes remained normal in all patients undergoing successful angioplasty. Sixteen patients (21%) showed a small increase in MB CK (no more than two times the normal value) before diagnostic angiography. Five of these patients had a totally occluded left anterior descending artery and another five manifested a filling defect compatible with thrombus formation. Angioplasty was angiographically unsuccessful in six patients because of inability of either the wire or the balloon to cross the culprit lesion. All six patients underwent semiurgent coronary bypass surgery. Two of the six patients had greater than twofold increase in MB CK after unsuccessful angioplasty and a third patient sustained a non-Q wave infarction perioperatively.

Electrocardiographic findings (Fig. 2 to 5). Electrocardiographic findings for all 102 patients are illustrated in Figure 3. As defined in the inclusion criteria, all patients manifested T wave inversion in at least two adjacent anterior ECG leads (V2 and V3). Figure 2 demonstrates resolution of T wave abnormalities in a patient 10 weeks after angioplasty. Prolongation of the corrected QT (QTc) interval was present in 16 patients. Twelve (88%) of these patients had angiographic evidence of thrombus formation, which was associated with total occlusion of the vessel in five. None of these patients had electrolyte abnormalities or were taking pharmacologic agents that could have prolonged the QT interval. The mean QTc interval was 490 ± 6 ms before angioplasty and had normalized to 416 ± 4 ms within 48 h in all patients after successful dilation (Fig. 4).

The time to normalization of T wave abnormalities for the 70 patients who underwent successful angioplasty is illustrated in Figure 5. Some degree of T wave abnormality persisted in all patients during hospital admission (mean 3.7 ± 1 day). Minor improvement in ECG abnormalities (less T wave inversion or normalization in one or two leads) was noted before discharge in 17 patients. However, complete resolution of T wave abnormalities in all ECG leads occurred in 20 patients (36%) at 10 weeks after angioplasty. In 36 patients (51%) at 14 weeks, in 50 patients (71%) at 21 weeks and in 63 patients (90%) at 28 weeks. The presence of collateral circulation, increased CK before dilation or the degree of stenosis before or after angioplasty did not predict the time course of T wave normalization.

Follow-up. Follow-up study has ranged from 6 to 43 months (mean 23 ± 10). The majority (80%) of the patients...
were free of angina. Fourteen patients had either Canadian Heart Association class I or II angina. The patient with the most severe left ventricular dysfunction died suddenly 8 months after successful angioplasty. A follow-up angiogram performed 6 months after angioplasty had revealed a widely patent vessel.

Repeat coronary angiography was performed within 12 months after successful angioplasty in 64 patients (91%) at a mean of 4.2 ± 2 months. The six patients who refused repeat study were asymptomatic and had normalization of ECG T wave abnormalities within 14 weeks after angioplasty. Thirty-four percent of patients developed restenosis and all of them underwent a successful second angioplasty procedure. Restenosis did not predict either T wave normalization or

Figure 2. Electrocardiograms from the same patient as in Figure 1. A, On admission, T wave inversion is evident in the anterior precordial leads; B, 10 weeks after successful angioplasty, these changes have resolved.

Figure 3. Bar diagram showing distribution of T wave inversion in anterior limb and precordial leads in all 102 patients.

Figure 4. Graph of 16 patients who manifested a prolonged corrected QT (QTc) (ms) interval before angioplasty (PRE-PTCA). Twelve of these patients had angiographic evidence of intraluminal thrombus. The QTc interval normalized in all 16 patients within 48 h of successful angioplasty (POST-PTCA).
QT interval prolongation. A third angioplasty procedure was successful in all seven patients with recurrent symptoms. Elective coronary artery bypass surgery was performed in two of the three patients who developed symptomatic restenosis after the third angioplasty procedure. The other patient underwent a successful fourth angioplasty procedure.

Repeat ventriculography was performed in 15 of 23 patients who had wall motion abnormalities before angioplasty. None of these patients had developed restenosis at the time of repeat study. Wall motion was normal in 13 patients and 10 of them had a normal ECG. In the other two patients, minor hypokinesia persisted but had decreased from that in the acute study.

Discussion

Present study. Our data demonstrate that symmetric anterior T wave inversion is commonly present in patients with severe stenosis of the proximal left anterior descending coronary artery and these changes may persist for >28 weeks in spite of successful revascularization with angioplasty. Only 51% of patients demonstrated complete normalization of T wave abnormalities within 14 weeks after successful mechanical revascularization. Prolongation of the QTc interval appeared to be a less sensitive but highly specific marker of impending myocardial necrosis in this subset of patients. Most of the patients with this ECG finding manifested a nonocclusive thrombus associated with absent or poor collateral blood supply and a wall motion abnormality at catheterization. In contrast to persistence of T wave abnormalities, normalization of the QTc interval was observed in all patients within 48 h of successful angioplasty. Semiemergent angioplasty was highly efficacious in relieving myocardial ischemia in the majority of patients with single vessel disease and was associated with a low morbidity and an excellent long-term outcome.

Electrocardiographic abnormalities. This study confirms the findings of several previous reports (1,2) that abnormalities in the ST segment and T wave are frequently associated with severe stenosis in the left anterior descending coronary artery in patients presenting with unstable angina. The exact time course and effect of revascularization on the evolution of these abnormalities have not been systematically studied. de Zwaan et al. (19) reported on the effect of surgical intervention on ECG abnormalities in a group of patients who either were treated medically or underwent early or late surgical revascularization. Early coronary artery bypass surgery resulted in faster improvement in ST segment and T wave abnormalities compared with medical therapy at 6 months.

In the present study we performed serial ECGs for 34 weeks after angioplasty to investigate the evolution of ECG changes after mechanical revascularization in patients with unstable angina secondary to severe stenosis of the left anterior descending coronary artery. We found that T wave abnormalities may persist for up to 7 months despite early restoration of blood flow to the ischemic bed by angioplasty. The mechanism for this finding remains unknown, but it may represent delayed restoration of metabolic and electrolyte abnormalities in previously ischemic myocardial cells. This phenomenon may be similar to the prolonged contractile dysfunction that has been observed after an ischemic episode, so-called myocardial stunning. This hypothesis is supported by the observation that T wave changes had normalized in 10 of the 13 patients in whom wall motion abnormalities had resolved at repeat ventriculography. Although relatively insensitive, the presence of a prolonged QTc interval identified a high risk subgroup because most of these patients manifested intraluminal thrombus and poor collateral circulation at coronary angiography. Successful angioplasty was associated with rapid normalization of the QTc interval and prevented enzymatic evidence of myocardial necrosis.

Role of angioplasty in unstable angina. Coronary angioplasty has been extensively utilized in the treatment of various ischemic syndromes, including unstable angina (5–11), ischemic papillary muscle dysfunction (20) and evolving myocardial infarction with and without cardiogenic shock (21–23). Although the procedure is highly effective in relieving myocardial ischemia, the incidence of acute ischemic complications in the setting of unstable syndromes remains controversial (5–7,24–26). Variables associated with an increased risk of major acute procedural complications include ST segment elevation, T wave inversion, >30% residual stenosis after angioplasty and the extent of vascular injury as determined by length of dissection and presence of extraluminal contrast (24).

The low complication rate in this study is in agreement
with some reports (7, 8) that demonstrated a success rate comparable with that in patients with stable angina. The absence of angiographic evidence of severe vascular injury in association with the presence of a low grade residual stenosis may have been responsible for the absence of acute closure of the vessel in this study. Other possible factors include the improvement in angioplasty equipment technology, aggressive antiplatelet and anticoagulant therapy and the performance of the procedure by cardiologists with extensive angioplasty experience. Restenosis was noted in 33% of patients, a finding in agreement with previous angioplasty studies (27, 28) in both stable and unstable angina.

**Effect on mortality.** The long-term prognosis of patients with unstable angina and concomitant ECG changes treated medically is poor, with an increased incidence of myocardial infarction during the first few months and an increased 1 to 3 year mortality rate (29, 30). de Zwaan et al. (19) demonstrated that surgical revascularization is associated with improved survival in patients with unstable angina secondary to severe stenosis of the left anterior descending coronary artery. The present study highlights the long-term efficacy of semiemergent angioplasty in patients with this syndrome. Eighty percent of patients were asymptomatic and the remainder had class I or II angina as defined by the Canadian Heart Association over a mean follow-up period of 23 months. A second or third angioplasty procedure was required for restenosis in 34% of patients. One death was observed in a patient who had angiographic evidence of a patent artery 6 months after angioplasty. An autopsy was not performed in this patient, who had moderate left ventricular dysfunction.

**Conclusions.** Anterior T wave inversion is a common ECG finding in patients with unstable angina secondary to severe left anterior descending coronary artery stenosis. Recognition of such a distinct ECG pattern in patients with unstable angina allows awareness of a critical proximal left anterior descending artery stenosis with a poor prognosis without revascularization or angioplasty. Angiographic evidence of nonocclusive thrombus accompanied by poor collateral circulation was present in most of the patients with a prolonged QTc interval. Whereas the latter ECG changes rapidly normalized within 48 h, T wave abnormalities persisted for >3 months despite successful early revascularization with angioplasty. Successful angioplasty in these patients was associated with an improvement in symptoms and a reduction in long-term morbidity. This study demonstrates that semiemergent angioplasty is associated with a high initial success rate and improved long-term event-free survival in patients with unstable angina due to critical left anterior descending artery disease.

---

We thank Carolyn Colley for expert secretarial assistance. The contribution of Helen Robinson, RN in data collection is greatly appreciated.

## References


