In-hospital morbidity and mortality in patients undergoing elective coronary angioplasty

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ABSTRACT We prospectively recorded all in-hospital complications of the first 3500 consecutive patients to undergo elective coronary angioplasty (PTCA) at Emory University Hospitals from July 14, 1980, to August 28, 1984, by three operators. PTCA was attempted in a total of 3933 lesions, with a primary success rate of 91%. Multiple-lesion PTCA was performed in 401 patients, and PTCA of saphenous vein grafts was attempted in 172. No complications were recorded in 3116 (89%) cases, isolated minor complications occurred in 241 (6.9%), and major complications (emergency surgery, myocardial infarction, death) were observed in 145 (4.1%). Emergency coronary artery bypass graft surgery (CABG) was performed in 96 patients (2.7%), with a myocardial infarction rate of 49% (47/96), a Q wave infarction rate of 23% (22/96), and an emergency surgery mortality rate of 2% (2/96). Hospital discharge occurred within 2 weeks of attempted PTCA in 91% (87/96) of patients undergoing emergency CABG. The overall myocardial infarction rate was 2.6% (94/3500). There were two nonsurgical deaths, giving a total mortality rate of 0.1% (4/3500). Univariate and multivariate analysis of 3099 patients undergoing single-lesion PTCA identified five preprocedure predictors of a major complication: multivessel coronary disease, lesion eccentricity, presence of calcium in the lesion, female gender, and lesion length. Unstable angina, duration of angina, lesion severity, previous CABG, and vein graft dilatation were not associated with an increased incidence of major complications. The strongest predictor of a major complication was the procedural appearance of an intimal dissection. Intimal dissection was evident in 894/3099 (29%) patients. Of these, 93 (10.4%) patients developed a major complication vs only 35 of 2205 (1.6%) patients without evidence of an intimal dissection (p < .0001). Angiographic evidence of intimal dissection resulted in a 6.5-fold increase in the risk of a major complication. In conclusion, these results illustrate what can be expected when elective PTCA is performed with current techniques and good surgical and anesthetic support.


IN PATIENTS with critical stenoses in proximal segments of major arteries, coronary revascularization is now favored over medical management for relief of symptoms. If myocardial ischemia, left ventricular damage, and progressive deterioration in left ventricular function can be avoided, prognosis may also be improved. However, comparative trials of medical and surgical therapy have provided clear answers only in left main and severe triple-vessel disease.

Percutaneous transluminal coronary angioplasty (PTCA) in selected patients can provide the same degree of effective coronary revascularization as surgery by means of a less invasive approach. The widespread use of PTCA has nonetheless been impaired by the incidence of short-term complications associated with the procedure. To date, assessment of complications has been based on reports of limited series and data available from the NHLBI PTCA Registry. The latter represents the pooled results of many centers performing PTCA on relatively small numbers of patients with what are now considered to be outdated techniques. In the last 4 years, technical advances have occurred and physician experience has increased. The Emory University experience comprises a large series of patients, which enables us to analyze the initial results obtained in over 3500 consecutive PTCA attempts to determine (1) the complication rates when PTCA is performed by three experienced operators at a single center using updated techniques and (2) the clinical, arteriographic, and

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technical factors that predispose to these complications.

Methods

Patients. From July 14, 1980, through August 28, 1984, a total of 3530 PTCA procedures were undertaken at Emory University Hospitals. During this 50 month interval, 30 procedures were done in the setting of an acute myocardial infarction defined as typical ischemic chest pain (≥30 min) with associated electrocardiographic changes. These patients were excluded from the analysis. The remaining 3500 attempts form the basis for this study.

PTCA procedure. All procedures were performed by one of three independent operators. The technique used has been described elsewhere.27 With Seldinger’s entry technique from the groin, arterial and venous sheaths with PTCA guiding and pacemaker catheters were inserted, followed by the administration of heparin (10,000 U iv bolus), nitroglycerin (0.4 mg sublingually), and nifedipine (10 mg sublingually). Heparin boluses (5000 U) were repeated hourly during the procedure. Preliminary angiography of the coronary artery to be dilated was performed in at least two projections with biplane angiographic equipment. The balloon catheter system was inserted and selective intracoronary nitroglycerin (200 μg) was given. The balloon was positioned across the stenosis, a pressure gradient was recorded, and the balloon was inflated as many times as needed to produce the optimal hemodynamic and angiographic result. At the end of the procedure, all catheters were removed and the sheaths were left in place. Sheaths were removed 2 to 3 hr later unless angiographic evidence of intimal dissection or coronary thrombus was seen. These patients were maintained on heparin infusion overnight, with removal of sheaths 2 to 3 hr after discontinuing heparin the next morning.

All patients were taken to a postprocedure monitoring ward or coronary care unit, where they were on telemetry for at least 16 hr after PTCA. A 12-lead electrocardiogram was obtained immediately after PTCA and daily for 2 days. Creatine kinase (CK) levels, including isoenzyme determinations, were performed immediately after PTCA and at 8 and 16 hr. All patients were medicated with cutaneous nitroglycerin (1 inch every 4 hr), isosorbide dinitrate (5 mg sublingually every 4 hr), calcium-blocking agent, and aspirin (325 mg/day orally). If stable, they were discharged 2 days after PTCA.

Data collection and entry. Clinical information, angiographic measurement, and intra- and post-PTCA complication data were recorded during the hospitalization by a physician on standard forms. Specific laboratory data, including electrocardiographic results, creatine kinase levels (including CK-MB fractions), and other post-PTCA complication information, was recorded by a physician at the time of hospital discharge. This information was audited for completeness and entered into a computerized electronic caliper system, using the mean diameter stenosis calculated in at least two angiographic views.39 In patients undergoing multiple-lesion PTCA, primary success was defined as 20% or greater reduction in percent diameter stenosis of at least one lesion. Intimal dissection was defined as in the NHLBI Registry as the presence of angiographically evident intimal damage producing an intraluminal filling defect, extraluminal extravasation of contrast material, linear luminal density, or luminal staining.18 Multivessel coronary artery disease was defined as at least 50% diameter stenosis in a major branch of at least two of the three main arterial systems: left anterior descending (LAD), left circumflex (LCX), and right (RCA) coronary arteries. Unstable angina was defined as new onset of angina or progressive symptoms during the previous 2 months.

Statistical analysis. Statistical analysis with the chi-square significance test was used to assess differences in categorical variables. Univariate and multivariate analysis was performed to determine clinical and angiographic predictors of a major complication.30 This analysis was performed on (1) the entire study population of 3500 patients and (2) the more homogeneous subset of 3099 patients who had only single-lesion PTCA. Baseline data analyzed included age, sex, hypertension, diabetest, smoking, previous myocardial infarction, previous coronary artery bypass graft surgery (CABG), unstable angina, anginal functional class, β-blocker therapy, extent of coronary artery disease, PTCA vessel, number of PTCA sites attempted, number of vessel systems in which PTCA was attempted, lesion severity (% diameter stenosis), lesion length, lesion morphol-
PTCA attempts and 93.7% in repeat PTCA attempts performed for restenosis after a previously successful PTCA.

The primary success rate per patient was 90% for the entire study population. The primary success rate per patient in those patients with single-vessel disease was 92%, and that in patients with multivessel disease was 88%. To evaluate trends in the primary success rate over time, we arbitrarily divided the study population into three equal groups that embraced the time periods shown in figure 1. In the first period the primary success rate per patient was 87%. It rose to 92% and remained stable during the last 2334 attempts.

Complications. The distribution of in-hospital complications that occurred during or after attempted PTCA is shown in figure 2. No complication occurred in 3114 (89%) attempts. Major complications occurred in 145 (4.1%) patients and minor complications not associated with a major complication occurred in 241 (6.9%) patients (table 3).

As illustrated in figure 3, a total of 194 major complications occurred in 145 patients (4.1%). More than one major complication occurred in 45 patients who had emergency surgery and myocardial infarction and in two patients who had emergency surgery, myocardial infarction, and death.

The incidence of major complications during each of the three periods outlined previously is summarized in figure 4. The major complication rate was highest for period 1 (4.8%) but has remained stable over periods 2 (3.7%) and 3 (3.9%).

Major complications

Emergency surgery. Emergency CABG was the most frequent major complication and was performed in 96 patients (2.7%). The mean age of patients undergoing emergency surgery was 56 years, with seven patients over 70 years old. Sixty-nine patients (72%) were men, five had had prior CABG, and five had akinetic myocardial wall segments on ventriculography as a result of prior myocardial infarction. Unstable angina was present in 54 patients (56%). The vessel dilated was the LAD in 60 (62%), the RCA in 29 (30%), the LCX in five (5%), the left main in one, and a saphenous vein graft in two patients, the overall distribution not being significantly different from that of the total study population. The indication for emergency surgery was clinical or angiographic evidence of compromised coronary blood flow in 93 patients and cardiac tamponade in three patients. The latter was caused by

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**TABLE 1**

Baseline patient characteristics

<table>
<thead>
<tr>
<th></th>
<th>EUH</th>
<th>NHLBI[^1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total patients</td>
<td>3500</td>
<td>3079</td>
</tr>
<tr>
<td>Age (mean)</td>
<td>55 yr</td>
<td>54 yr</td>
</tr>
<tr>
<td>Males (%)</td>
<td>79</td>
<td>77</td>
</tr>
<tr>
<td>Previous MI (%)</td>
<td>28</td>
<td>25</td>
</tr>
<tr>
<td>Previous CABG (%)</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Unstable angina (%)</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Angina CHC III or IV (%)</td>
<td>42</td>
<td>63</td>
</tr>
<tr>
<td>Coronary artery disease (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single vessel</td>
<td>81</td>
<td>72.5</td>
</tr>
<tr>
<td>Multiple vessel</td>
<td>19</td>
<td>27.5</td>
</tr>
<tr>
<td>Previous PTCA (%)[^4]</td>
<td>12.7</td>
<td>7</td>
</tr>
<tr>
<td>Lesion morphology (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eccentric lesions</td>
<td>37</td>
<td>—</td>
</tr>
<tr>
<td>Calcium in lesion</td>
<td>5</td>
<td>—</td>
</tr>
<tr>
<td>Lesion length ≥10 mm</td>
<td>17</td>
<td>—</td>
</tr>
<tr>
<td>Lesion % diameter stenosis ≥90</td>
<td>13</td>
<td>35</td>
</tr>
</tbody>
</table>

[^1]: EUH = Emory University Hospital; NHLBI = National Heart, Lung, and Blood Institute PTCA Registry; MI = myocardial infarction; CHC = Canadian Heart Class; CAD = coronary artery disease.

[^4]: Same lesion site, initial PTCA successful.

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**FIGURE 1.** Primary success rate of PTCA in 3500 patients. The study population is divided into three periods. N = number of PTCA attempts in each period.
perforation of the right ventricle by a pacemaker catheter (No. 6F).

All emergency surgery procedures took place within 20 hr of the PTCA. The majority of emergency surgery patients (67/96, 70%) went directly from the catheterization suite to the operating room. There were 29 patients (30%) who initially left the catheterization laboratory in stable condition but subsequently developed evidence of acute coronary ischemia. Twenty-three of these initially stable patients were transported directly to operating room from the ward or the coronary care unit. Emergency repeat PTCA was attempted in the remaining six patients, all of whom then went

**TABLE 3**

Minor complications of PTCA (n = 3500)

<table>
<thead>
<tr>
<th>Episode</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side-branch closure</td>
<td>59</td>
</tr>
<tr>
<td>Ventricular arrhythmia (DC shock)</td>
<td>54</td>
</tr>
<tr>
<td>New conduction defect</td>
<td>31</td>
</tr>
<tr>
<td>Emergency cath.</td>
<td>27</td>
</tr>
<tr>
<td>Repair of femoral artery</td>
<td>22</td>
</tr>
<tr>
<td>Atrial fibrillation/flutter</td>
<td>14</td>
</tr>
<tr>
<td>Excessive blood loss requiring transfusion</td>
<td>9</td>
</tr>
<tr>
<td>Coronary embolus</td>
<td>5</td>
</tr>
<tr>
<td>Tamponade</td>
<td>3</td>
</tr>
<tr>
<td>Stroke</td>
<td>1</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>19</td>
</tr>
<tr>
<td>Total episodes</td>
<td>244</td>
</tr>
<tr>
<td>Total patients</td>
<td>241</td>
</tr>
</tbody>
</table>

**FIGURE 2.** Complications in 3500 elective PTCA attempts. N = number of patients with major, minor, or no complications. The major complication group (4.1%) includes all patients who had a myocardial infarction or emergency surgery or who died, whether or not they also had minor complications. The minor complication group (6.9%) includes those patients that had only minor complications.

**FIGURE 3.** Interrelationship of myocardial infarction, emergency surgery, and death in 145 patients with a major complication.

directly from the catheterization laboratory to the operating room. Preoperative insertion of an intra-aortic balloon pump was necessary in 32 of 96 (33%) patients, 21 of whom underwent LAD angioplasty. Ventricular arrhythmias requiring cardioversion occurred in 13 of 96 (14%) patients and preoperative cardiopul-

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Monary resuscitation (sustained closed-chest massage) was necessary in seven of 96 (7%) patients (six of whom had LAD angioplasty).

Initially successful emergency CABG was performed in all 96 patients, with the exception of one patient who underwent a thoracotomy for relief of pericardial tamponade. A total of 165 bypass grafts were placed. Reverse saphenous vein grafts were used in 160 vessels and internal mammary artery grafts to the LAD were used in five. Revascularization was performed to a single coronary arterial system (i.e., LAD or LCX or RCA) in 64 patients (90 grafts), a double arterial system in 30 patients (70 grafts), and all three arterial systems in one patient (five grafts).

The mortality rate for the 96 emergency surgery patients was 2%. Both patients who died had multivessel coronary artery disease, and abnormal left ventricular function caused by previous myocardial infarction, underwent LAD angioplasty attempt, and were hemodynamically unstable in the catheterization laboratory. There were no deaths among patients with single-vessel coronary artery disease or with normal left ventricular function undergoing emergency surgery for failed PTCA. In addition, there were no deaths in the five patients with a history of previous CABG who underwent emergency surgery for a failed PTCA. The duration of hospital stay for the 94 patients who survived surgery was 7 days or less for 53 patients, 8 to 14 days for 33 patients, and over 14 days for eight patients. Fifty-six percent of the emergency surgery patients were discharged within 1 week and 91% were discharged within 2 weeks of attempted PTCA.

An additional 89 patients who had an unsuccessful PTCA went on to elective CABG during the same hospitalization. None of these patients died and only one developed a myocardial infarction.

**Myocardial infarction.** The overall myocardial infarction rate was 2.6% (94/3500) and the Q-wave infarction rate was 1.1% (38/3500). In the emergency surgery group there was a total of 47 myocardial infarctions (49%), of which 22 (47%) were Q-wave infarctions. In the 3404 patients who did not have emergency surgery there was a total of 47 myocardial infarctions (1.4%), of which 16 (0.5%) were associated with new Q waves.

**Fatal complications.** The in-hospital mortality rate was 0.1% for the entire study population of 3500 patients. All four deaths occurred in patients undergoing LAD angioplasty (table 4). Two patients had single-vessel disease and initially successful PTCA. In one case, a 51-year-old man with a residual post-PTCA coronary thrombus was treated with 144,000 U of intracoronary streptokinase and a continuous infusion of heparin. The patient died of an intracerebral hemorrhage 5 hr after PTCA. The second patient was a 69-year-old woman in whom ventricular fibrillation (successfully cardioverted) occurred during the pre-PTCA guiding angiogram. A subsequent left ventricular angiogram showed new anterior/apical akinesis, but this wall motion abnormality improved after successful LAD angioplasty. Sudden refractory electromechanical dissociation occurred 16 hours after PTCA. Total CK, including isoenzyme determination, performed 2 hr before death (14 hr after PTCA) was normal. Autopsy revealed an occlusive LAD thrombus at the PTCA site.

Two other fatal complications occurred in patients with multivessel disease and LAD dissection requiring emergency CABG. Both patients had previous myocardial infarction and impaired left ventricular function. Brief occlusion of the LAD resulted in severe hemodynamic deterioration in spite of intra-aortic balloon pump support and emergency surgery. Both died.

**TABLE 4**

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>PTCA site</th>
<th>CAD</th>
<th>Complication</th>
<th>Cause of death</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>M</td>
<td>LAD</td>
<td>SVD</td>
<td>Success/IC thrombus</td>
<td>Cerebral bleeding (5 hr)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Streptokinase 144,000 U</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IC Heparin</td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>F</td>
<td>LAD</td>
<td>SVD</td>
<td>Success/acute reocclusion</td>
<td>3° Heart block (16 hr)</td>
</tr>
<tr>
<td>63</td>
<td>F</td>
<td>LAD</td>
<td>MVD</td>
<td>Dissection/unstable</td>
<td>Renal failure (36 hr)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IABP/EM-CABG</td>
<td>Bradycardia</td>
</tr>
<tr>
<td>68</td>
<td>M</td>
<td>LAD</td>
<td>MVD</td>
<td>Dissection/stable</td>
<td>Multiple organ</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EM-RePTCA (3 hr)</td>
<td>failure (2 wk)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IABP/EM-CABG</td>
<td></td>
</tr>
</tbody>
</table>

SVD = single-vessel disease; MVD = multivessel disease; IC = intracoronary; IABP = intra-aortic balloon pump; EM-CABG = emergency coronary artery bypass graft surgery; EM-RePTCA = emergency repeat coronary angioplasty.
in the postoperative period from complications related to a low cardiac output state.

Predictors of major complications. To determine the preprocedure predictors of a major complication in patients undergoing single-lesion PTCA, we analyzed the relatively homogeneous subgroup of 3099 patients who had PTCA at only one coronary site in the presence of either single-vessel or multivessel disease (table 5). In this subgroup there was a total of 128 patients who experienced at least one major complication (emergency surgery, 85; myocardial infarction without surgery, 41; death without emergency surgery, two). Patients were at a higher risk of developing a major complication if they had multivessel disease (6.1%) vs single-vessel disease (3.7%), an eccentric lesion (5.2%) vs a concentric lesion (3.5%), or calcification of the lesion (8.0%) vs no calcification (3.9%). There was a trend toward increased complications in women but this did not reach statistical significance.

The strongest independent preprocedure predictor of a major complication by multivariate analysis was multivessel coronary disease (p = .0099) followed by lesion eccentricity (p = .0136), calcification of the lesion (p = .0197), female gender (p = .0298), and lesion length (p = .0706). However, only 64% of the patients were correctly classified. Unstable angina, duration of angina, lesion severity, previous CABG, and vein graft dilatation were not associated with an increased incidence of major complications. Inclusion of the smaller, heterogeneous subgroup of highly selected patients undergoing multiple-site PTCA in single-vessel or multivessel disease did not change the factors selected in the analysis.

The strongest predictor of a major complication by univariate (p < .0001) and multivariate analysis was the procedural appearance of an intimal dissection. An intimal dissection was evident in 894 patients (29%). Of these, 93 patients (10.4%) developed a major complication. Of the 2205 patients without an intimal dissection, only 35 (1.6%) developed a major complication. Angiographic evidence of intimal dissection at the time of PTCA resulted in a 6.5-fold increase in the risk of developing a major complication. The other relatively weak procedural predictor of a major complication was a pre-PTCA transstenotic gradient of 50 mm Hg or greater.

Minor complications. A total of 244 isolated minor complications occurred in 241 patients (6.9%) who did not experience a major complication (table 3). Closure of a sidebranch artery at the site of PTCA was recorded only when documented by angiography at the time of the procedure. Ventricular arrhythmia requiring cardioversion was statistically more frequent during RCA angioplasty (p < .001) and was successfully treated without sequelae in all patients in whom it occurred. New conduction defects (right bundle branch block, 20; first-degree atrioventricular block, six; left bundle branch block, two; Wenckebach block, one; second-degree atrioventricular block, one; sinus bradycardia requiring temporary pacer, one) resolved before discharge in all but one patient. Emergency repeat catheterization for unstable chest pain with or without electrocardiographic evidence of ischemia revealed a patent PTCA artery site in nine patients, restenosis followed by a successful emergency repeat PTCA in 14, restenosis successfully treated with intracoronary nitroglycerin in three, and restenosis with good collateral perfusion treated with elective surgery in one. Surgical exploration to repair a pseudoaneurysm or persistent hemorrhage at the femoral puncture was required in 17 women and eight men. New-onset atrial fibrillation or flutter requiring medical therapy returned to normal sinus rhythm in all but one patient. Angiographic evidence of coronary embolization occurred in the presence of residual coronary thrombus after myocardial infarction, total occlusion, and saphenous vein graft dilatations. Uncomplicated tamponade caused by perforation of the right ventricle by a No. 6F pacing catheter was treated by pericardiotomy in only three patients. Since switching to more flexible No. 5F pacing catheters, we have had no further episodes of tamponade. One patient developed a left hemianopsia after PTCA with an occipital lobe infarct documented on computed tomographic scan. Miscellaneous complications included elective repeat angiography and repeat PTCA, use of intra-aortic balloon pump for unstable symptoms, Staphylococcus aureus.

**TABLE 5**
Incidence of major complications in patients with/without a preprocedure risk factor (n = 3099)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>No. of patients with risk factor</th>
<th>No. of patients with major complications</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multivessel CAD</td>
<td>523 (17%)</td>
<td>32 (6.1%)</td>
<td>&lt;.025</td>
</tr>
<tr>
<td>Single-vessel CAD</td>
<td>2576 (83%)</td>
<td>96 (3.7%)</td>
<td></td>
</tr>
<tr>
<td>Eccentric lesion</td>
<td>1198 (39%)</td>
<td>62 (5.2%)</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Concentric lesion</td>
<td>1853 (61%)</td>
<td>65 (3.5%)</td>
<td></td>
</tr>
<tr>
<td>Calcium in lesion</td>
<td>152 (5%)</td>
<td>12 (8.0%)</td>
<td>&lt;.03</td>
</tr>
<tr>
<td>No calcium in lesion</td>
<td>2947 (95%)</td>
<td>116 (3.9%)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>687 (22%)</td>
<td>37 (5.4%)</td>
<td>&lt;.08</td>
</tr>
<tr>
<td>Male</td>
<td>2412 (78%)</td>
<td>91 (3.8%)</td>
<td></td>
</tr>
</tbody>
</table>

*Total coronary occlusions in 48 patients could not be classified as eccentric or concentric lesions.
groin infection, transient ischemic attack, LAD closure during RCA angioplasty, and pulmonary edema.

Discussion

The efficacy of any therapeutic procedure depends on its risk-benefit ratio. When this is applied to management of single-vessel coronary disease by PTCA the question of short-term complications assumes particular importance. The natural history of patients with single-vessel disease has been well described,\textsuperscript{21-24} In a recent report,\textsuperscript{21} the 5 year survival in potential ideal candidates for PTCA with single vessel disease treated medically was 97%. If PTCA is to be offered to improve functional capacity in these patients, the risks of the procedure must be comparable to the most favorable surgical results available in similar groups.

In this consecutive series of 3500 patients undergoing elective PTCA, the mortality rate of 0.1% is better than reported surgical results\textsuperscript{8} and the 0.9% mortality recorded from the NHLBI PTCA Registry.\textsuperscript{20} The Registry study population is of comparable size (3079 patients) but it differs in that data were collected from 106 institutions during an earlier, although overlapping, time period (1977 to 1982 vs 1980 to 1984). Nevertheless, the baseline patient characteristics and the anatomic location of attempted PTCA are similar to those of our study.\textsuperscript{26} The major complication rate for the two series is shown in figure 5.\textsuperscript{19, 20}

The lower incidence of major complications in this series can be explained in part by greater experience in case selection, technical expertise, and clinical judgment and by improvements in angioplasty equipment that have evolved since the NHLBI Registry data were collected.\textsuperscript{22, 23, 26, 37, 39} The routine use of biplane angiographic equipment and intracoronary hemodynamic measurements may play a role as well as increased familiarity and training of supporting hospital personnel. There has been no significant decrease in the incidence of major complications in our series over the 50 month period, as shown in figure 4, probably because of the increasing difficulty of attempted PTCA procedures.

Specifically, the lower mortality in this series may be related to the surgical treatment of failed PTCA at our institution.\textsuperscript{15, 40, 41} The emergency surgery mortality was 2% (2/96) in our series vs 6.4% (13/202) in the NHLBI Registry.\textsuperscript{20} Emergency surgery initiated during full cardiac arrest appeared to be a life-saving procedure in six patients. In addition, there were no deaths in 89 elective post-PTCA CABG procedures in our series vs 10 deaths during elective post-PTCA surgery in the NHLBI Registry.\textsuperscript{20} These data suggest that when elective coronary angioplasty is performed for single-vessel coronary disease with good surgical and anesthetic support, the mortality should approach zero.

It is more difficult to find a surgical series of similar patients suitable for comparison. The overall mortality figures from the five centers with the best surgical results in the Coronary Artery Surgery Study ranged from 0.3% to 1%.\textsuperscript{6} For patients with single-vessel disease the overall mortality was 1.4%, and for patients with ejection fractions of 50% or greater the mortality was 1.9%.\textsuperscript{6} In our series, 19% of the patients had multivessel disease, 28% had a history of myocardial infarction, and 50% had a recent history of unstable symptoms. This last descriptor may have placed our patients at a higher risk, since patients with class III to IV symptoms were not randomized in the CASS study. These differences not withstanding, the mortality data for PTCA in our series (0.1%) appears to be better than one might have expected for CABG.

In an attempt to improve patient selection for PTCA and to identify high-risk patients, a univariate and multivariate analysis was performed on 20 clinical and angiographic potential predictors of a major complication. Five significant risk factors were identified: multivessel coronary artery disease, eccentric lesions, lesion calcification, female gender, and lesion length.

The only baseline clinical characteristic that was an independent predictor of a major complication was female gender. There were no baseline clinical characteristics identified as predictors of mortality in our series. This is in contrast to the NHLBI Registry data in which five clinical predictors of mortality were identified (female gender, age >60 yr, prior CABG, angina >6 months, and vein graft PTCA).\textsuperscript{20} In particular,
Cowley et al. showed that women had a sixfold higher PTCA-related mortality and a fivefold higher mortality with emergency surgery. In our series, the female mortality was increased (0.26% vs 0.073%) but this did not reach statistical significance because of the small number of deaths.

The angiographic predictors of a major complication were related to lesion morphology, and this is in agreement with data from the NHLBI Registry. However, the importance of multivessel disease as an independent risk factor has not previously been reported. The critical link between the morphologic extent of atherosclerosis and development of a major complication appears to be the appearance of angiographically evident intimal dissection. In our series, once this had occurred, 10% of the patients in this subgroup evolved a major complication. In the NHLBI series an intimal dissection was associated with a 30% incidence of major complications. The apparent discrepancy between these results may be related to the coding of patients with intimal dissection, since the recorded incidence of dissection was almost threefold higher in our series than in the NHLBI series (30% vs 12.9%). In addition, intimal dissection in our series was significantly correlated only with female gender and increasing lesion length. In the NHLBI series intimal dissection was associated with female gender, RCA dilatation, multivessel disease, eccentric lesions, and nonisotropic lesions.

In conclusion, the NHLBI Registry provided valuable information about PTCA during its early development. However, such data represent the initial results that were obtained with what are now considered to be outdated modes, and must be interpreted from this perspective. They no longer represent the state of the art of coronary angioplasty. The results presented in this article indicate what can now be expected when elective PTCA is performed by current techniques.

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