Initial and Long-term Outcome of 354 Patients After Coronary Balloon Angioplasty of Total Coronary Artery Occlusions

Malcolm R. Bell, MB, BS, FRACP; Peter B. Berger, MD, FACC; John F. Bresnahan, MD, FACC; Guy S. Reeder, MD, FACC; Kent R. Bailey, PhD; and David R. Holmes Jr., MD, FACC

Background. Coronary balloon angioplasty of chronic total occlusions is associated with relatively low success rates and a high incidence of restenosis. Whether there is long-term benefit in performing angioplasty of these lesions is unknown. The purpose of the present report was to analyze the long-term outcome of a large series of patients undergoing this procedure.

Methods and Results. A computerized database analysis of 354 consecutive patients (from 1979 to 1990) who underwent coronary angioplasty of a chronic total coronary occlusion was performed (mean age, 62.3 years). Initial technical success was achieved in 69%; in 66%, success was achieved without procedural death or need for coronary artery surgery. During hospitalization, six patients suffered myocardial infarction, nine required emergency bypass surgery, and nine patients died. During a mean follow-up period of 2.7 years, no difference was found in survival or freedom from myocardial infarction among 234 successfully dilated patients compared with 120 patients with a failed attempt. However, the use of coronary artery bypass surgery was significantly less after successful dilation (p<0.0001 versus failed attempt). No significant difference in the cumulative incidence of severe angina was observed between these two patient populations, with the majority remaining asymptomatic. Restenosis occurred in 59% of 69 patients who returned for follow-up angiography.

Conclusions. Successful recanalization is achieved in the majority of patients undergoing angioplasty of chronic total occlusions and reduces the need for coronary artery bypass surgery. However, no major impact on either survival or incidence of myocardial infarction was noted after successful recanalization when patients with surgery were included. (Circulation 1992;85:1003–1011)

KEY WORDS • coronary artery disease • follow-up • revascularization • coronary artery bypass graft surgery • occlusions

Coronary balloon angioplasty continues to assume an increasing role in the treatment of patients with coronary artery disease since its introduction by Grünzig in 1978. Initial use in patients with one-native-vessel disease has rapidly expanded to include patients with multivessel disease and dilation of saphenous vein and mammary artery bypass grafts.

Total coronary occlusions have also been attempted with balloon angioplasty; the most recent coronary angioplasty registry report from the National Heart, Lung, and Blood Institute documented that chronic total occlusions accounted for 10% of all attempted coronary angioplasties during the period 1985–1986. However, the success rate is lower than with other lesions, and the inability to dilate totally occluded arteries contributes to the failure to achieve complete revascularization among many patients with multivessel disease undergoing balloon angioplasty.7,9

See p 1214

Most of the early reported series of patients undergoing angioplasty of totally occluded coronary arteries were confined to small numbers of patients with success rates between 54% and 63% and few complications. Recently, a number of larger series reported initial success rates from as low as 51% to as high as 73%. Despite these data, there is a paucity of information regarding the long-term clinical outcome of patients undergoing this procedure. Analysis of the long-term clinical outcome is particularly important in view of the complexity of the procedure, relatively low initial success rates, increasing numbers of chronic total occlusions attempted with angioplasty, and relatively high restenosis rates that have been reported to range from 43% to 75%. The purpose of the present report was to analyze the results of our experience with balloon angioplasty of total coronary occlusions with particular emphasis on initial outcome and assessment of long-term outcome.


Address for correspondence: Malcolm R. Bell, MB, BS, Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic, 200 First Street SW, Rochester, MN 55905.

Received April 22, 1991; revision accepted October 22, 1991.
Methods

Patient Selection and Characteristics

All patients in whom dilation of a total coronary artery occlusion was attempted between October 1979 and September 1990 were eligible for the study. Patients with a myocardial infarction within 24 hours before the procedure, as well as patients undergoing coronary atherectomy, laser angioplasty, or intracoronary stent placement, were excluded. Three hundred fifty-four consecutive patients identified from our laboratory's database, representing 8% of the 4,220 patients undergoing percutaneous transluminal coronary angioplasty during the same period, met these criteria and constitute the study population.

The decision to dilate a total coronary artery occlusion was based on two factors. The first involved the clinical impression that restoring patency to the occluded vessel would improve the symptoms of myocardial ischemia, implying the presence of viable myocardium supplied by the vessel to be dilated. In general, this was assessed by documentation of at least some retained wall motion in the distribution of the target vessel by contrast ventriculography, echocardiography, or radionuclide angiography. The second factor involved in the decision to dilate a total occlusion depended on the operator's judgment as to the feasibility of the procedure. Favorable technical factors usually included the presence of a short occlusion, a tapered segment leading into the occlusion, lack of bridging collateral vessels, and lack of a major side branch arising at the site of the total occlusion. However, the presence of any of these factors did not always necessarily mean that those lesions were not attempted in individual cases.

Angiographic Definitions

A total occlusion was defined in the present study by the absence of antegrade flow of contrast distal to the lesion. The duration of the total occlusion was estimated from information provided by sequential angiograms when these were available. Otherwise, whenever possible, the duration of occlusion was estimated from the onset of symptoms, that is, date of myocardial infarction or new or worsening angina. The duration of occlusion was divided into four duration groups: <8 days, 8–30 days, 31–90 days, and >90 days.14

Coronary lesions were visualized from at least two orthogonal views if possible, and their severity was estimated visually or with hand-held calipers. One-vessel disease was defined as ≥70% diameter stenosis in one coronary artery (left anterior descending and its major branches, left circumflex and its major branches, or right coronary artery with its terminal major branches). Multivessel disease was defined as a ≥70% diameter stenosis in one major coronary artery in addition to a ≥50% diameter stenosis in one or more other major coronary arteries.1 Left ventricular ejection fraction was determined by left ventriculography performed using biplane 30° right anterior oblique and 60° left anterior oblique projections.

Initial technical success was defined as improvement of the stenosis by at least 40% of the vessel's luminal diameter. Clinical success was defined by this same angiographic criterion and by the absence of procedure-related mortality or need for in-hospital coronary artery bypass graft surgery. The occurrence of myocardial infarction was considered a major complication of the procedure and was diagnosed when two or more of the following three criteria were met: 1) new Q waves present on ECG (Minnesota code), 2) creatine kinase elevation to at least two times normal or abnormally elevated MB isoenzyme, and 3) prolonged chest pain.

Follow-up

All patients were contacted at 6 months after initial angioplasty and yearly thereafter. Contact consisted of a telephone interview of all referral patients by a research assistant and by office visits of patients followed at this institution. Follow-up events were analyzed and classified by a physician when the event occurred outside this institution. Death, myocardial infarction, occurrence of severe angina (Canadian Cardiovascular Society class III or IV),27 and coronary artery bypass graft surgery were all recorded as major events.

Restenosis

Angiographic restenosis was defined at follow-up angiography (>14 days after successful angioplasty) as an increase of ≥30% from the immediate postdilation diameter stenosis. Follow-up angiography was usually performed only in patients who developed recurrent symptoms suggestive of recurrent or worsening myocardial ischemia.

Angioplasty Technique

Although there are some differences in the approach to dilating total coronary occlusions among various operators in our laboratory, the following is a description of the general approach used in our laboratory. Patients are all pretreated with 325 mg aspirin and receive 10,000–15,000 units heparin i.v. at the beginning of the procedure. Standard Judkins catheters are usually adequate for left anterior descending coronary arteries, and left Amplatz guiding catheters are often used for occlusions of the right and left circumflex coronary arteries. Attempts to cross the occlusion are initially made with 0.014-in. guide wires progressing from flexible to stiffer wires. The occluded segment is probed in an attempt to cross the occlusion, ensuring that the guide wire is in line with the major axis of the vessel. Larger wires (0.016 or 0.018 in.) are used if the stiffest 0.014-in. guide wire is unsuccessful.

After crossing the occluded segment, the guide wire is rotated around its axis. The ability to freely rotate the distal tip indicates that the wire is probably intraluminal rather than intramural. Contrast injection often helps locate the distal vessel at this time. When the guide wire tip is confirmed to be intraluminal, the guide wire is then advanced as far distally as possible down the vessel, and a 2.0-mm balloon is advanced over the wire across the occlusion. Occasionally, repeatedly moving the wire to and fro in a “sawing” motion may enlarge the stenosis enough to allow passage of the balloon. In the rare case that a wire has crossed the lesion but the balloon cannot, either a 1.5-mm balloon is tried, or the wire is removed and a balloon-on-a-wire is used. After placement of the balloon across the occlusion, serial inflations are performed. When necessary, the balloon is exchanged for a larger balloon appropriately sized to the vessel.
TABLE 1. Baseline Clinical Characteristics of 354 Patients Undergoing Attempted Dilation of Total Coronary Occlusions

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender</td>
<td>264 (74.6)</td>
</tr>
<tr>
<td>Age (mean±SD years)</td>
<td>62.3±10.9</td>
</tr>
<tr>
<td>Predominant symptom</td>
<td></td>
</tr>
<tr>
<td>Angina pectoris</td>
<td>306 (86.4)</td>
</tr>
<tr>
<td>Other (including cardiac failure, arrhythmias)</td>
<td>48 (13.6)</td>
</tr>
<tr>
<td>Angina Canadian Cardiovascular Society class III or IV</td>
<td>262 (74.0)</td>
</tr>
<tr>
<td>Rest pain</td>
<td>223 (63.0)</td>
</tr>
<tr>
<td>Prior coronary artery bypass surgery</td>
<td>28 (7.9)</td>
</tr>
<tr>
<td>History of prior myocardial infarction</td>
<td>224 (63.3)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>76 (21.5)</td>
</tr>
<tr>
<td>History of congestive heart failure</td>
<td>34 (9.6)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>50 (14.1)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>147 (41.5)</td>
</tr>
</tbody>
</table>

Statistical Analysis

All continuous data are presented as mean±SD unless otherwise stated. Comparisons between dichotomous variables were performed using \( \chi^2 \) analysis: \( t \) tests or Wilcoxon rank sum tests were used for comparisons of continuous data. Survival curves were performed using the Kaplan-Meier method with the log rank test for assessing differences between group outcomes. A logistic model was used to identify preprocedural predictors of technical success. Based on 24 univariate associations, eight clinical and angiographic baseline variables were analyzed with the use of Cox proportional hazards models to determine predictors of late events. Once these models had been constructed, the initial outcome of dilation was entered to determine whether it was an independent predictor of long-term outcome. Statistical significance was assumed using \( \alpha \leq 0.05 \).

Results

Baseline Characteristics

The baseline clinical characteristics of the study population are listed in Table 1. The majority of patients had definite or probable angina, whereas the remainder were treated for cardiac failure, cardiac arrhythmias, or other symptoms felt clinically to be secondary to myocardial ischemia.

The number of patients with one-, two-, or three-vessel disease was approximately equal within the study group (Table 2). The one patient who underwent attempted angioplasty of a left main coronary artery occlusion had a patent bypass graft to the left coronary system. The median estimated duration of occlusion was 30 days (range, 1–1,095 days).

Initial Success

Three hundred sixty-three total coronary occlusions were attempted, and 251 (69%) were successfully dilated. The clinical success rate per patient was slightly lower at 66%. The median postdilation residual stenosis was 40%. The most common technical reason for failure to dilate an occluded segment was the inability to cross the lesion with a guide wire (95 of 112 segments), and failure to cross the lesion or dilate it with a balloon accounted for 17 of 112 technical failures.

Figure 1 shows the success rate per lesion based on the estimated duration of the occlusion. The highest success rates were found for occlusions between 8 and 30 days old (93.3%), and the lowest were obtained in occlusions >90 days old (64.4%). The vast majority of lesions were between 31 and 90 days old and were associated with a success rate of 67.5%; these differences were not significantly different from each other (\( p=0.16 \)). Assessed as a continuous variable, the duration of occlusion was shorter, but not significantly so, for successfully dilated lesions compared with those that were associated with failure (43±68 versus 63±136 days, respectively; \( p=0.06 \)) and was found to be a weak predictor of success with multivariate analysis (\( p=0.05 \)). Multivariate analysis of 19 baseline clinical and angiographic variables also identified the absence of calcium in the occlusion (\( p=0.04 \)) as the only other significant independent predictor of success. Although success rates improved during the first few years of our experience, they have plateaued during the past 5 years at about 60–80% (Figure 2).

FIGURE 1. Bar graph of technical success rate of attempted angioplasty of 363 occluded segments according to estimated age of occlusion.
In-Laboratory and In-Hospital Complications

Figure 3 shows that successful dilation was complicated by myocardial infarction in one patient immediately after the procedure due to a side branch occlusion, despite patency of the target vessel. Two other patients subsequently suffered myocardial infarctions in hospital, but neither of these appeared to have been related to the recanalized site. There were three in-hospital deaths in this group: One occurred in a patient with cardiogenic shock present before the procedure, one occurred after a postprocedural infarction in a different vascular territory from the recanalized site, and the third was noncardiac in origin after lung surgery.

Figure 3 also shows the major complications for those patients who had failed dilation. Three patients suffered myocardial infarction during their hospitalization: One of these represented an extension of an earlier myocardial infarction, whereas in two patients, the infarction was definitely related to acute closure of a concomitantly dilated subtotal occlusion in a separate vessel. There were six deaths in this group, of which only two definitely appeared to be related to the attempted dilation of a total occlusion. One of these occurred during emergency coronary artery bypass graft surgery after the patient developed a left main coronary occlusion during attempted dilation of a total occlusion in the left anterior descending coronary artery (patient 3; Table 3). The other died soon after an intracerebral hemorrhage that occurred during the angioplasty procedure. Of the remaining four deaths, three were cardiac in origin but could not be easily ascribed to the attempted dilation of the total occlusion, and one was noncardiac in origin. Thus, there was a total of nine in-hospital deaths, resulting in an overall hospital mortality of 2.5%.

Forty-seven patients underwent coronary artery surgery during the hospital stay in which angioplasty of the occlusion was performed. Surgery was usually performed either because of failed dilation of the total occlusion (most common) or because of incomplete revascularization in patients with multivessel disease in whom attempted dilation of other lesions had been unsuccessful. In nine of these patients (2.5% overall), coronary artery bypass graft surgery was performed as an emergency immediately after attempted angioplasty (Table 3).

Follow-up

Patients have been followed for a mean of 2.7±2.3 years (range, 9 years) from the time of their initial procedure. Twenty-six patients died during follow-up, and 14 patients suffered late myocardial infarctions.

The effect of the initial outcome of balloon angioplasty on long-term outcome was assessed by comparing the outcomes of patients with successful dilation with those of failed dilation of the total occlusion. Cumulative survival at 7 years among those with successful angioplasty of a total occlusion (82%) was not significantly different from those with unsuccessful angioplasty (75%) (Figure 4). There was also no significant difference observed in the occurrence of myocardial infarction between patients with or without a successful procedure (Figure 5).

The only major difference between the two groups in terms of long-term outcome was in the reduced frequency of coronary artery bypass graft surgery in patients in whom successful dilation of a total occlusion was achieved (Figure 6); after 5 years, the probability of undergoing coronary artery bypass graft surgery in this group was 18% compared with 58% for those with unsuccessful dilation (p<0.0001). Multivariate analysis identified successful dilation of a total occlusion as a
TABLE 3. Summary of Patients Who Underwent Emergency Coronary Artery Bypass Graft Surgery Immediately After Attempted Dilation of a Total Coronary Occlusion

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age/gender</th>
<th>Clinical status</th>
<th>Vessel dilated</th>
<th>PTCA outcome</th>
<th>CABG outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73/F</td>
<td>UAP 15 days after anterior MI</td>
<td>LAD</td>
<td>Restoration of patency followed by persistent thrombotic reocclusion and chest pain</td>
<td>Uneventful</td>
</tr>
<tr>
<td>2</td>
<td>43/M</td>
<td>UAP</td>
<td>RCA</td>
<td>Unable to cross lesion with balloon; persistent chest pain</td>
<td>Uneventful</td>
</tr>
<tr>
<td>3</td>
<td>58/M</td>
<td>UAP</td>
<td>LAD</td>
<td>Restoration of patency followed by persistent thrombotic reocclusion involving left main; recurrent VF; IABP required</td>
<td>Died during surgery</td>
</tr>
<tr>
<td>4</td>
<td>76/F</td>
<td>UAP</td>
<td>LCx</td>
<td>Dissection of left main during attempted PTCA of LCx; IABP</td>
<td>Uneventful</td>
</tr>
<tr>
<td>5</td>
<td>36/M</td>
<td>UAP with shock; on IABP</td>
<td>LCx and LAD</td>
<td>Successful PTCA of LCx but unable to dilate LAD; stable but CABG for complete revascularization</td>
<td>Uneventful</td>
</tr>
<tr>
<td>6</td>
<td>66/M</td>
<td>UAP 21 days after non-Q wave MI</td>
<td>LAD</td>
<td>Patency restored but abrupt closure occurred due to dissection; hemodynamically stable but referred for CABG</td>
<td>Uneventful</td>
</tr>
<tr>
<td>7</td>
<td>75/F</td>
<td>UAP</td>
<td>LAD</td>
<td>Dissection of left main during attempted PTCA of LAD; stable hemodynamics but IABP inserted before CABG</td>
<td>Uneventful</td>
</tr>
<tr>
<td>8</td>
<td>64/M</td>
<td>UAP</td>
<td>LAD</td>
<td>Successful PTCA; additional PTCA of 80% stenosis of RCA complicated by dissection and occlusion</td>
<td>Uneventful</td>
</tr>
<tr>
<td>9</td>
<td>64/M</td>
<td>UAP</td>
<td>LCx</td>
<td>Failed but uncomplicated PTCA; also LAD total occlusion; continued rest pain in CCU—referred for emergency CABG</td>
<td>Uneventful</td>
</tr>
</tbody>
</table>

PTCA, percutaneous transluminal coronary angioplasty; CABG, coronary artery bypass graft surgery; UAP, unstable angina pectoris; MI, myocardial infarction; LAD, left anterior descending coronary artery; RCA, right coronary artery; LCx, circumflex artery; VF, ventricular fibrillation; IABP, intra-aortic balloon pump; CCU, coronary care unit.

significant predictor of reduced use of coronary artery bypass graft surgery ($p<0.0001$).

Differences in cumulative survival and occurrence of myocardial infarction according to the outcome of angioplasty were also analyzed by dividing the group into those with one-vessel disease and those with multivessel disease (Figures 7 and 8). These results demonstrate that no benefit to survival or freedom from infarction could be attributed to successful recanalization of total occlusions, regardless of the number of vessels diseased. Multivariate analysis, accounting for baseline differences between the two groups, failed to identify successful dilation of a total occlusion as an important predictor of survival.

Similarly, no significant difference in the cumulative incidence of severe angina (class III or IV) was found between patients with successful versus unsuccessful procedures. This is also demonstrated in Figure 9, which shows the symptomatic status of patients alive at 6 months and 1, 2, and 5 years after attempted angioplasty. The majority of patients were asymptomatic at each interval, but there were no significant differences in the level of anginal symptoms present when comparing successfully dilated with unsuccessfully dilated patients.

Restenosis

Seventy patients who had had successful dilation of a total occlusion returned for follow-up coronary angiog-
coronary transluminal coronary outcome of FIGURE 7. Plots of cumulative survival according to the outcome of initial angioplasty shown for patients with one-vessel coronary disease (panel A) and for patients with multivessel coronary disease (panel B). PTCA, percutaneous transluminal coronary angioplasty. restenosis could coronary occlusion again. patients (59%) had angiographic restenosis documented, with 10 lesions having progressed to complete occlusion again. Nine patients with restenosis underwent repeat balloon angioplasty of the previously occluded segment; angioplasty was successful in eight patients. The failure occurred in the one patient in whom restenosis had resulted in recurrent total occlusion. Two additional patients with restenosis had successful laser angioplasty assisted by balloon angioplasty. Of the eight successful second angioplasty procedures, restenosis recurred in four: two patients had a successful third dilation performed, and the remaining two patients were treated medically. Three of the 10 patients with documented reocclusion suffered non-Q wave infarctions before documentation of restenosis, whereas the remaining seven were free of infarction. All of these patients have remained alive during the current follow-up period.

Discussion

The present study demonstrates that treatment of total coronary artery occlusions with coronary balloon angioplasty was associated with an overall technical success rate per lesion of 69% and a clinical success rate of 66%. This compares favorably with the findings of two other large studies20,23 and is somewhat higher than the 51–63% reported in most other series.13–19,21,22 Although the frequency with which total coronary occlusions are attempted with angioplasty has increased since our earliest experience at the beginning of the decade, the overall success rate has not continued to rise in recent years but rather has fluctuated despite a number of improvements in equipment design such as steerable guide wire systems and lower-profile balloons. This may be the result of more complex cases being
attempted today. It would thus appear from the combined experiences of more than 1,200 patients from the present study and that of Stone et al\textsuperscript{123} that a ceiling of about 70% has been reached in the anticipated success rates of these lesions using modern equipment, which is well below the angioplasty success rates for subtotally occluded coronary lesions.\textsuperscript{23,25,26}

**Influence of Duration of Occlusion**

In an early report from this laboratory, it was emphasized that the age of the total occlusion substantially influenced the chances of its subsequent successful dilation.\textsuperscript{14} Severe fibrosis of occlusions was thought to be responsible for the increased difficulty in crossing older occlusions with a guide wire. This finding has since been supported by subsequent studies\textsuperscript{15,16,18,20} but questioned by others.\textsuperscript{17} No major difference in the rate of procedural success was found in the present series when the duration of occlusion was analyzed as a discrete variable, although a trend (with univariate and multivariate analyses) in favor of greater success with occlusions of shorter duration was found when the duration of occlusion was analyzed as a continuous variable.

Stone et al\textsuperscript{123} also found no major difference in success rates between occlusions of differing ages. These findings probably reflect important trends in patient selection based on the knowledge of the findings of the earlier reports. It may be that only patients with older occlusions with more favorable angiographic anatomy were selected as candidates for angioplasty, which may have biased the success rates with these older lesions. As with most previous studies, the duration of occlusion was often estimated from clinical data (e.g., onset of symptoms); however, the only certain method of assessing the duration of occlusion is by examining sequential angiograms. The inherent limitation of assessing the duration of occlusion from clinical information in many of our patients may have misled us in this finding. Nevertheless, it appears that in carefully selected patients, successful angioplasty can be performed, even with old occlusions.

**Complications and Initial Outcome**

The overall hospital mortality for this study population was 2.5%. Acute myocardial infarction occurred in 1.7% of patients at the time of the procedure but was only rarely associated with the attempt to recanalize the occluded vessel. Emergency coronary artery bypass graft surgery was required in 2.5% of patients. The attempt to dilate a total occlusion was directly responsible for seven of the nine patients undergoing immediate coronary artery bypass graft surgery (including three with abrupt left main occlusion); the remaining two were related to abrupt occlusion during angioplasty of an additional subtotal stenosis in one and failed angioplasty with the need for complete revascularization in another. All nine of these patients had been referred for angioplasty because of unstable angina, often with medically refractory rest pain or angina occurring after myocardial infarction. These observations support the findings of previous studies in which the mortality associated with angioplasty of total occlusions was between 0% and 0.8% and in which the incidence of acute myocardial infarction and need for emergency bypass surgery also was extremely low.\textsuperscript{13,15–23}

**Follow-up**

Until recently, long-term follow-up data from patients undergoing dilation of total coronary occlusions were limited and confined to small populations followed for short periods of time.\textsuperscript{15–18} Although long-term outcome after successful dilation of a total occlusion does
not appear as favorable as in patients in whom subtotal occlusions have been successfully dilated.\textsuperscript{22} Nevertheless, all of these studies reported symptomatic relief from angina in the majority of patients during follow-up with a low incidence of death and myocardial infarction. In addition, it has recently been reported that the functional performance among patients after successful dilation of a total occlusion is superior to that in those in whom angioplasty failed.\textsuperscript{28}

The mean follow-up interval in the present study was 2.7 years (range, 9 years). The cumulative survival for the entire group of patients after attempted angioplasty was 90\% at 5 years and 79\% at 7 years. The important findings in the present study were that neither survival nor freedom from myocardial infarction was influenced by successful recanalization of a chronic total occlusion. However, the use of coronary artery bypass graft surgery in these patients was significantly reduced after successful dilation compared with unsuccessful dilation (18\% versus 58\% after 5 years, respectively; \(p<0.0001\)). This difference was evident immediately after attempted angioplasty and remained unchanged during follow-up (Figure 6).

Although the majority of patients were either asymptomatic or had only mild angina during follow-up, there were no significant differences in anginal status between patients with successful angioplasty and those with unsuccessful angioplasty. It therefore appears that the greatest benefit derived from a successful angioplasty of a chronic total occlusion is the avoidance of early coronary artery bypass surgery, which confirms the recent findings of two smaller studies.\textsuperscript{21,28} It is likely that surgery, which was performed more frequently after failed angioplasty, contributed to the improved symptomatic status among those with failed angioplasty, explaining the lack of discernible difference in the severity of angina among patients with successful angioplasty and those with unsuccessful angioplasty during follow-up.

Therefore, successful recanalization of a total occlusion appeared to have no impact on the major long-term cardiac events of death and myocardial infarction. In addition to the influence of the disparate use of bypass surgery, this might be explained by the fact that the nonrecanalized vessel cannot directly contribute to these two events, and recanalization will therefore also be unable to impact on these. This is supported in part by the observation that although only 10 patients had documented recurrence of a total occlusion, all have remained alive and the three resulting myocardial infarctions were non–Q wave infarctions.

**Restenosis**

Restenosis rates after successful dilation of total coronary artery occlusions have been reported to range from 43\% to 75\%\textsuperscript{13,16-19,21} although angiographic follow-up has not been complete in these series. Of the 234 successfully treated patients in the present series, only 30\% returned for follow-up coronary angiography, with angiographic restenosis documented in 59\% of these patients. These rates are higher than those generally reported after balloon angioplasty of subtotally occluded coronary lesions.\textsuperscript{29,30} However, the finding of increased restenosis may be misleading, since the denominator included only the 30\% who returned for coronary angiography, usually for recurrent symptoms. The frequency of restenosis might have been lower if all patients had been restudied. On the other hand, in some patients not restudied, restenosis may have been silent if preexisting collateral vessels were recruited.

The outcome of second or third angioplasty attempts of dilated total occlusions that have restenosed has not been documented previously. In the present study, we found that eight of nine such patients were successfully redilated, and of the two repeat balloon angioplasty procedures performed for recurrent (third) restenosis, both were successful.

**Study Limitations**

The present study was a retrospective analysis of prospectively gathered data and is subject to the limitations inherent in any retrospective study. Another limitation is that the results have not been compared with a comparable group of patients with total occlusions undergoing medical or surgical therapy. However, it is highly probable that important patient selection biases for each of these treatment options would flaw such a comparison, and only a prospective and randomized study could adequately address this question.

**Alternative Technical Approaches to Recanalizing Total Occlusions**

The treatment of total coronary artery occlusions with conventional balloon angioplasty remains a challenging problem for the interventional cardiologist. The current plateau in the success rates of about 70\% in selected patients and the moderately high restenosis rates reinforce the need for the development of alternative interventional approaches to treating these patients. Although the recent use of specially designed catheters may complement and improve upon the results obtained with conventional equipment, the success rates remain no higher than 73\%.\textsuperscript{20} New technology such as low-speed rotational angioplasty\textsuperscript{31} has been applied to chronic total occlusions, but only preliminary results are available. Laser thermal angioplasty\textsuperscript{22} has also been refined for recanalization of total coronary occlusions, but no data are yet available regarding its efficacy. Meier et al\textsuperscript{32} developed a less-sophisticated and less-expensive system for approaching these occlusions, the so-called “Magnum wire,” but preliminary results comparing this with the conventional approach have been only modestly encouraging.\textsuperscript{34}

**Conclusions**

The most important finding in the present study is that successful recanalization of total occlusions can result in satisfactory late clinical outcome and reduces the use of subsequent coronary artery bypass graft surgery when compared with patients with a failed procedure. However, no significant benefits on either subsequent survival or incidence of myocardial infarction were found. The present study also confirms that dilation of total coronary occlusions can usually be performed relatively safely with a low incidence of major complications.
References

Acknowledgments
We wish to extend our thanks to Jon L. Kosanke, Department of Biostatistics, Health Sciences Research Division, Mayo Clinic, for his invaluable help in the statistical analysis of these data and to LaVon N. Hammes for her help with the data collection.
Initial and long-term outcome of 354 patients after coronary balloon angioplasty of total coronary artery occlusions.
M R Bell, P B Berger, J F Bresnahan, G S Reeder, K R Bailey and D R Holmes, Jr