Transluminal angioplasty of occluded coronary arteries: use of a movable guide wire system

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ABSTRACT Of 47 consecutive patients referred for coronary angioplasty, the procedure was attempted in 13 patients despite occlusion of the involved vessel. This included four patients with total coronary occlusion and nine with functional coronary occlusion (faint, late antegrade opacification in the absence of a discernible luminal continuity). All procedures were performed with an angioplasty system in which the leading guide wire could be moved independently of the dilatation catheter. Primary success was obtained in 54% (7/13) of patients with coronary occlusion compared with 85% (29/34) in the remaining patients with conventional stenoses between 75% and 95% (91 ± 5%, mean ± SD; p < .02). In patients with coronary occlusion, the mean residual stenosis after angioplasty (41%), the abrupt reclosure rate (8%), and the incidence of angiographically evident dissection (29%) were similar to those seen in the 34 patients who underwent angioplasty of conventional stenoses, although restenosis tended to be more common (43% vs 23%) in patients with coronary occlusion. No evidence of coronary perforation or distal embolization was found in either group, and no patient undergoing angioplasty of an occluded vessel required emergency surgery, despite one case of abrupt reclosure. All patients with coronary occlusion had prominent collateral flow to the occluded vessel, which could no longer be visualized after successful angioplasty. These collaterals were associated with a higher distal pressure (35 ± 10 mm Hg) in patients with coronary occlusion than that seen in patients with less severe stenoses and no visible collaterals (distal occluded pressure 20 ± 7 mm Hg; p < .001). Although the primary success rate is lower than that associated with conventional stenotic lesions, coronary angioplasty can be performed safely and successfully in the majority of patients with coronary occlusion.

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CORONARY ANGIOPLASTY was developed by Gruentzig et al. in 1979 as a nonoperative technique for treatment of discrete, noncalcific, subtotal proximal stenosis. Reports from several laboratories have confirmed the efficacy of angioplasty in this carefully selected patient population. However, most investigators performing coronary angioplasty have experienced a lower primary success rate in patients with severe stenosis (>95%) than in those with moderate stenosis (70% to 95% diameter reduction) and have considered coronary angioplasty to be contraindicated in totally occluded vessels. Angioplasty systems in which the leading guide wire can be moved independently of the balloon catheter have recently been developed and offer advantages over fixed wire systems in the performance of coronary angioplasty. These advantages are mentioned in our experience with 13 such patients, with attention to the unique technical and coronary hemodynamic considerations present in this patient population.

Methods

Of 47 consecutive patients (ages 35 to 81 years) who underwent coronary angioplasty at the Beth Israel Hospital between December 1981 and February 1983, 13 patients (group A) did so despite total occlusion (100%) or functional total occlusion (99%) of the involved vessel. Total vessel occlusion (figure 1) was defined as absent antegrade filling beyond the lesion. Functional total occlusion (figure 2) was defined as faint, late antegrade opacification of the distal segment in the absence of a discernible luminal continuity on detailed review of the cineangiogram. The remaining 34 patients (group B) had conventional stenoses between 75% and 95% (mean 91 ± 5%) with evident luminal continuity.

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All patients had angina refractory to drug therapy and gave informed consent for coronary angioplasty under a protocol approved by the Beth Israel Hospital Committee on Clinical Investigations. Angioplasty was attempted only when standby cardiac surgery was available. Beginning 1 day before the procedure, each patient received aspirin (325 mg daily), dipyridamole (50 mg qid), and nifedipine (20 mg qid). These medications were continued for 6 months after a successful procedure.

**Angioplasty technique.** Before angioplasty, baseline coronary angiography was performed under systemic heparinization (5000 IU) with standard diagnostic brachial or femoral angiographic catheters. An additional 5000 IU of heparin was given at the time of guiding catheter introduction. To exclude coronary spasm, 200 to 300 μg of intracoronary nitroglycerin was injected into the involved vessel during baseline angiography.

Angioplasty of the left coronary artery was performed via a percutaneous femoral approach with a No. 8.8F Judkins left 3.5, 4, or 4.5 guiding catheter. Angioplasty of the right coronary artery was performed via a brachial cutdown with a No. 8.3F Stentzer guiding catheter (U.S.C.I., Inc., Billerica, MA) in 11 cases and via the femoral approach with a No. 8.8F Amplatz catheter in two cases. A No. 6F bipolar pacing wire was positioned in the vena cava to permit rapid initiation of emergency pacing if required. The Simpson-Robert movable guide wire dilatation system (Advanced Cardiovascular Systems, Inc., Mountain View, CA) was used exclusively.

In each case, we attempted to advance a floppy-tip 0.018 inch (0.46 mm) guide wire gently beyond proximal side branches, across the occlusion, and into the distal vessel. In the last 21 patients, including seven with total occlusion, a new steerable, floppy-tip guide wire that permits continuous distal pressure measurement through the dilatation catheter (PDT; Advanced Cardiovascular Systems, Inc.) was used. Once the tip of the guide wire was free in the distal vessel, the balloon catheter was advanced coaxially over the guide wire and into the stenosis. A series of three to five balloon inflations were performed to a peak inflation pressure of 90 to 120 psi (6 to 8 atmospheres), for inflation durations of 15 to 90 sec, until the residual transstenotic gradient was reduced to less than 20 mm Hg or failed to decrease further with additional inflations. The distal occluded coronary arterial pressure was measured during balloon inflation via the central lumen of the dilatation catheter. In our first

**FIGURE 1.** Dilatation of a totally occluded right coronary artery (patient 9). A, Late retrograde filling of large dominant right coronary artery to the point of occlusion (arrow) during injection of a normal left coronary artery in the left anterior oblique projection. B, Injection of the right coronary artery demonstrates total midvessel occlusion (arrow). C, The floppy-tipped guide wire has been advanced through the occlusion (arrow) without resistance, so that its tip (white arrow) lies free in the distal vessel. D, Inflation of the 3 mm balloon within the occluded segment shows an hourglass deformity, which subsequently resolved at higher inflation pressure. E, Right coronary artery immediately after angioplasty with brisk antegrade filling and no residual stenosis or dissection at the site of previous total occlusion. Repeat injection of the left coronary artery (not shown) showed resolution of collateral flow to the distal right coronary branches. F, Return of angina 6 weeks after initially successful angioplasty was associated with restenosis (arrow) slightly distal to the site of previous vessel occlusion and with partial return of left to right collateral flow (not shown). G, Right coronary artery segment immediately after successful repeat angioplasty. The patient is now free of angina 3 months after repeat angioplasty.
cases, this measurement required removal of the standard guide wire, but more recently use of the PDT wire has permitted continuous recording of the distal pressure with the guide wire in place. After coronary angioplasty, the dilatation catheter was withdrawn while the guide wire was left in place across the dilated segment for 15 min. Repeat angiography was performed over a 15 min period with the guide wire in place, and then over a 15 to 30 min period after the guide wire was removed, to monitor for abrupt vessel reclosure.

A 3.0 mm balloon catheter was used initially in eight patients, a 2.5 mm balloon in three patients, and a 2.0 mm balloon in two patients with total coronary occlusion. The 2.0 mm balloon catheter was used in patients 8 (figure 3) and 12 (figure 4) because its substantially lower deflated profile was required to cross the occlusion. After the 2.0 mm balloon was inflated within the stenotic segment, a 260 cm, 0.018 inch guide wire was inserted through the balloon catheter and used to exchange the 2.0 mm balloon catheter for a 3.0 mm balloon catheter under fluoroscopic control. The 3.0 mm balloon catheter was then inflated within the lesion to complete the dilatation process.

After coronary angioplasty, patients were returned to their rooms for further monitoring. All patients in whom the dilatation was anatomically successful were followed with serial exercise tolerance tests at 6 weeks, 3 months, and 6 months. Repeat coronary angiography was performed promptly in any patient who either redeveloped angina or had a positive exercise test, and at 3 to 6 months in the remaining asymptomatic patients. Restenosis was defined as an increase of 30% or more in stenosis severity relative to the immediate postangioplasty appearance.

Statistical analysis was performed with unpaired t tests (two-tailed), chi-square analysis, or Fisher’s exact test.

Results

Patient characteristics. The characteristics of the 13 patients with coronary occlusion (group A) and the 34 patients with coronary stenoses (group B) are outlined in tables 1 and 2. Except for the severity of the coronary lesion, patient characteristics and the distribution of involved vessels of all patients were similar and were comparable to cases reported in the NHLBI registry.

Five of the 13 patients in group A had progressed from severe stenosis (90% to 99%, mean 93%) to coronary occlusion over the brief interval (1.5 to 13 weeks, mean 4.8) after diagnostic arteriography (figure 4). Eight other patients had total occlusion at the time of the initial diagnostic studies, which were performed a mean of 3.3 weeks before attempted angioplasty. Patient 9 (figure 1) underwent a combined diagnostic and therapeutic study at the time of coronary angioplasty because his clinical situation suggested a high probability of single-vessel disease. All patients with coronary occlusion had experienced some increase in the severity or frequency of their anginal symptoms over the 2 months preceding angioplasty, but only patient 9 was having episodic rest angina in the period immediately preceding angioplasty. Four patients had sustained a subendocardial myocardial infarction before angioplasty, but only patient 7 had sustained a transmural infarction in the territory supplied by the occluded vessel. In this patient, left ventriculography showed a small zone of anterior akinesis surrounded by mild hypokinesis. The remaining 12 pa-
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Patients exhibited either normal or only mildly hypokinetic systolic contraction of the myocardium supplied by the occluded vessel. This finding suggested extensive preservation of the distal myocardium by collaterals, despite virtual elimination of antegrade coronary flow.

Outcome of dilatation procedures. The primary success rate was 54% in group A patients, significantly below the primary success rate of 85% in group B patients, who had less severe baseline lesions. Although the primary success rate was lower in group A, the 41 ± 15% residual stenosis in the seven patients whose arteries were successfully dilated was identical to the 41 ± 12% residual stenosis in patients in group B whose arteries were successfully dilated. Within group A, the success rate tended to be higher in patients with total occlusions (3/4) than in those with functional total occlusions (4/9) and higher in interval occlusions after diagnostic angiography (4/5) than in established occlusions (3/8). Figures 2 and 3 illustrate the angioplasty technique and results in patients with functional total occlusions, while figures 1, 4, and 5 illustrate the technique in patients with total occlusions.

All 13 patients with coronary occlusion had prominent collaterals providing retrograde filling of the distal vessel. In the seven patients in this group who had successful dilatation, collateral flow was no longer demonstrable immediately after the angioplasty (table I). The prominent collaterals in group A patients were associated with a comparatively higher distal occluded

FIGURE 3. Dilatation of functional total occlusion of the left anterior descending artery (patient 8). A, Baseline injection of the left coronary artery in the right anterior oblique projection shows total occlusion of the middle left anterior descending artery (arrow), with faint late filling of the distal vessel (short arrow) in the absence of visible luminal continuity. B, Floppy-tipped guide wire and noninflatable tip of the 3.0 mm dilatation catheter were advanced into the distal vessel, but the inflatable segment (open arrow) could not be advanced. An exchange wire was used to pass a 2.0 mm dilatation catheter through the occlusion, which was inflated twice before a second exchange was made for the original 3.0 mm catheter. C, Left coronary injection immediately after angioplasty shows brisk antegrade flow in the left anterior descending artery, with residual eccentric 50% stenosis most evident in the left anterior oblique projection (not shown).
TABLE 1
Clinical and hemodynamic characteristics of patients with total coronary occlusion (group A)

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age/Sex</th>
<th>Angina type</th>
<th>NYHA class</th>
<th>Prior MI</th>
<th>Vessel involved</th>
<th>Degree of occlusion</th>
<th>Nature of occlusion</th>
<th>Interval since Dx angiogram</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49/M</td>
<td>Stable</td>
<td>II</td>
<td>SEMI</td>
<td>LAD</td>
<td>Subtotal</td>
<td>Established</td>
<td>4 wk</td>
</tr>
<tr>
<td>2</td>
<td>50/F</td>
<td>Stable</td>
<td>II</td>
<td>—</td>
<td>LAD</td>
<td>Subtotal</td>
<td>Established</td>
<td>10 wk</td>
</tr>
<tr>
<td>3</td>
<td>42/M</td>
<td>Stable</td>
<td>II</td>
<td>—</td>
<td>RCA</td>
<td>Subtotal</td>
<td>Established</td>
<td>5 wk</td>
</tr>
<tr>
<td>4</td>
<td>69/M</td>
<td>Stable</td>
<td>II–III</td>
<td>—</td>
<td>LAD</td>
<td>Subtotal</td>
<td>Established</td>
<td>1 day</td>
</tr>
<tr>
<td>5</td>
<td>40/M</td>
<td>Stable</td>
<td>III</td>
<td>SEMI</td>
<td>LAD</td>
<td>Subtotal</td>
<td>Progressive</td>
<td>13 wk</td>
</tr>
<tr>
<td>6</td>
<td>39/M</td>
<td>Stable</td>
<td>II</td>
<td>—</td>
<td>LCX</td>
<td>Subtotal</td>
<td>Progressive</td>
<td>1.5 wk</td>
</tr>
<tr>
<td>7</td>
<td>52/M</td>
<td>Stable</td>
<td>II</td>
<td>ASMI</td>
<td>LAD</td>
<td>Subtotal</td>
<td>Progressive</td>
<td>4 wk</td>
</tr>
<tr>
<td>8</td>
<td>40/M</td>
<td>Stable</td>
<td>II</td>
<td>—</td>
<td>LAD</td>
<td>Subtotal</td>
<td>Established</td>
<td>2 wk</td>
</tr>
<tr>
<td>9</td>
<td>51/M</td>
<td>Unstable</td>
<td>IV</td>
<td>SEMI</td>
<td>RCA</td>
<td>Total</td>
<td>Established</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>51/M</td>
<td>Stable</td>
<td>II</td>
<td>—</td>
<td>LCX</td>
<td>Subtotal</td>
<td>Established</td>
<td>2 wk</td>
</tr>
<tr>
<td>11</td>
<td>69/F</td>
<td>Stable</td>
<td>II</td>
<td>—</td>
<td>LAD</td>
<td>Total</td>
<td>Progressive</td>
<td>4 wk</td>
</tr>
<tr>
<td>12</td>
<td>64/M</td>
<td>Stable</td>
<td>II</td>
<td>SEMI</td>
<td>RCA</td>
<td>Total</td>
<td>Progressive</td>
<td>3.5 wk</td>
</tr>
<tr>
<td>13</td>
<td>72/M</td>
<td>Stable</td>
<td>III</td>
<td>—</td>
<td>RCA</td>
<td>Total</td>
<td>Established</td>
<td>2 wk</td>
</tr>
</tbody>
</table>

LAD = left anterior descending artery; LCX = left circumflex artery; RCA = right coronary artery; SEMI = subendocardial myocardial infarction; ASMI = anteroseptal myocardial infarction; PTCA = percutaneous transluminal coronary angioplasty; NYHA = New York Heart Association; Dx = diagnostic.

1Crossed with wire but not catheter.
2Failure to cross the occluded segment with the guide wire.
3Pressures not obtained.
4Successfully redilated.
5Lesion crossed only by the guide wire and noninflatable tip of the dilatation catheter.

pressure (24 to 55 mm Hg, mean 35 ± 10) (figure 5) than that observed in those group B patients dependent on antegrade perfusion with no angiographically evident collaterals (distal occluded pressure 10 to 32 mm Hg, mean 20 ± 7; p < .001).

In two of the six primary failures in group A, the lesion was crossed with the movable guide wire but could not be crossed with either a 3.0 or 2.5 mm balloon catheter. These failures occurred before the availability of the 2.0 mm low-profile balloon catheter, which has a substantially lower deflated diameter of 0.038 inches (0.96 mm) compared with 0.049 inches (1.24 mm) for the 2.5 or 3.0 mm balloon. In other primary failures (patients 7 and 13), the wire was passed into but not beyond the occluded segment. In a fifth patient, a functionally occluded vessel was successfully diluted but then abruptly reclosed 15 min after balloon removal. No adverse sequelae occurred, presumably because of uninterrupted collateral supply to the distal myocardial territory. In a sixth patient, we were unable to pass the dilatation system to the point of occlusion in a left circumflex obtuse marginal branch.

There was no evidence of distal embolization, coronary perforation, or creatine kinase (CK) elevation in any patient in group A. One patient in group B had a postangioplasty elevation of CK to 220 IU with 12% MB fraction. Two of the seven (29%) group A patients whose occluded vessels were successfully dilated had evident intimal dissection, which progressed to abrupt reclosure in one. Ten of 35 (29%) group B patients had angiographically evident intimal dissection, with abrupt reclosure in two patients (neither of whom had evident luminal dissection immediately after angioplasty). Emergency bypass surgery in these two patients was associated with nontransmural infarction but preserved regional wall motion on follow-up radionuclide ventriculography. The incidence of abrupt reclosure after initially successful dilatation is thus similar for the two groups of patients: 8% in group A and 6% in group B.

At present, the 43% restenosis rate in patients with baseline coronary occlusion (group A) is higher than the 23% restenosis rate observed in group B patients, although the difference does not reach statistical significance. Restenosis was severe (90% to 100%) in all three group A patients in whom it has occurred, but repeat angioplasty was successful in two of the three patients (figure 1). These patients remain asymptomatic 3 and 4 months after a second angioplasty. The third patient continues to have stable angina on maximal drug therapy.

Discussion
Since technical advances have resulted in smaller deflated diameter and increased maximum inflation pressure of coronary dilatation catheters, angioplasty
TABLE 1
(Continued)

<table>
<thead>
<tr>
<th>Distal occluded pressure (mm Hg)</th>
<th>Gradient (mm Hg)</th>
<th>% Stenosis after PTCA</th>
<th>Cause of PTCA failure</th>
<th>Collaterals</th>
<th>Balloon diameter (mm)</th>
<th>Follow-up of 1° successes</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>60</td>
<td>25</td>
<td>50</td>
<td>Reversed</td>
<td>3.0</td>
<td>Restenosed</td>
</tr>
<tr>
<td>c</td>
<td>c</td>
<td>c</td>
<td>99</td>
<td>Catheter^</td>
<td>2.5, 3.0</td>
<td>—</td>
</tr>
<tr>
<td>28</td>
<td>70</td>
<td>10</td>
<td>60</td>
<td>Reversed</td>
<td>2.5</td>
<td>Restenosed^</td>
</tr>
<tr>
<td>c</td>
<td>c</td>
<td>c</td>
<td>100</td>
<td>Abrupt closure</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td>30</td>
<td>65</td>
<td>7</td>
<td>50</td>
<td>Reversed</td>
<td>2.5</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td>24^c</td>
<td>65^c</td>
<td>65^c</td>
<td>99</td>
<td>Catheter</td>
<td>2.5</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td>c</td>
<td>c</td>
<td>c</td>
<td>99</td>
<td>Wire^</td>
<td>3.0</td>
<td>—</td>
</tr>
<tr>
<td>35</td>
<td>51</td>
<td>16</td>
<td>50</td>
<td>Reversed</td>
<td>2.0, 3.0</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td>c</td>
<td>c</td>
<td>c</td>
<td>25</td>
<td>Reversed</td>
<td>3.0</td>
<td>—</td>
</tr>
<tr>
<td>55</td>
<td>35</td>
<td>0</td>
<td>25</td>
<td>Reversed</td>
<td>2.5</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td>40</td>
<td>75</td>
<td>0</td>
<td>25</td>
<td>Reversed</td>
<td>2.0, 3.0</td>
<td>Asymptomatic</td>
</tr>
</tbody>
</table>

FIGURE 4. Dilatation of interval total occlusion of right coronary artery (patient 12). A, Diagnostic angiogram taken 4 weeks before angioplasty demonstrated high-grade (90%) stenosis in the middle portion of the dominant right coronary artery. One week later, the patient sustained a severe episode of chest pain that was associated with inferior T wave inversion and elevation of serum CK to 250 IU (normal <200 IU). Because of recurrent episodes of angina, he was referred for coronary angioplasty. B, Preangioplasty angiography demonstrated progression of the previous stenosis to total occlusion, with interval appearance of brisk filling of the distal right coronary artery left-to-right collaterals (not shown). C, While the floppy-tipped guide wire and the noninflatable tip of the 3.0 mm dilatation catheter crossed the total occlusion easily, the inflatable portion of the dilatation catheter (arrows) could not be advanced into the occluded segment. After distal contrast injection confirmed intraluminal position, an exchange guide wire (260 cm) was inserted. D, The exchange wire was maintained in the distal right coronary artery (white arrow) to permit advancement and inflation of a 2.0 mm low-profile balloon within the occluded segment. E, With the exchange guide wire again maintained in the distal right coronary artery, the 2.0 mm balloon was replaced by the original 3.0 mm balloon to complete the dilatation process. F, Right coronary artery after angioplasty shows 25% residual stenosis.
TABLE 2
Comparison of vessel distribution and success rates in patients with coronary occlusion vs coronary stenosis

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of patients</th>
<th>Sex (M/F)</th>
<th>Stenosis</th>
<th>Vessel involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>13</td>
<td>11/2</td>
<td>Pre-PTCA</td>
<td>Post-PTCA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LAD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100 *</td>
<td>41 ± 15%</td>
</tr>
<tr>
<td>B</td>
<td>34</td>
<td>27/7</td>
<td>Pre-PTCA</td>
<td>Post-PTCA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>91 ± 5%</td>
<td>41 ± 12%</td>
</tr>
</tbody>
</table>

See table 1 for abbreviations.

\*See definition of functional total occlusion in Methods and figures 2 and 3.

has been applied increasingly to patients with anatomic features that were previously believed to render angioplasty difficult or impossible. Thus high-grade, distal, and partially calcific stenoses are now routinely crossed and dilated in many centers.

Recently, two preliminary reports\(^7,8\) have suggested that fixed guide wire angioplasty catheters can be used to dilate totally occluded coronary arteries. Savage et al.\(^7\) reported 39 patients who had progressed to total or functional total occlusion between their diagnostic angiogram and scheduled dilatation and in whom angioplasty was attempted despite interval occlusion. Their success rate of 67% suggests that coronary angioplasty is feasible if the preocclusion anatomy is known. Heyndrickx et al.\(^8\) reported 11 patients with functional coronary occlusion, including six patients who had

FIGURE 5. Dilatation of chronic total occlusion of proximal left anterior descending artery (patient 11). A, Baseline injection of the left coronary artery in the right anterior oblique projection shows total occlusion in the proximal left anterior descending artery. The remainder of the left anterior descending artery fills via right-to-left and left-to-left (marginal-to-diagonal) collaterals. B, Appearance of the left anterior descending artery immediately after successful angioplasty with prompt antegrade flow. Previously noted right-to-left collaterals resolved after angioplasty. C, Recording of the proximal left coronary pressure (PROX) and distal occluded left anterior descending artery pressure (DIST) shown at the time of balloon crossing and during the terminal portion of a prolonged (90 sec) inflation. The distal occluded pressure remains 50 mm Hg throughout the inflation. Upon balloon deflation (bold arrow) there is rapid rise in distal occluded pressure and resolution of the transstenotic gradient.
progressed to occlusion in the interval since diagnostic angiography, and five patients who had chronic occlusions demonstrated 20 to 45 days before attempted dilatation. Seven occlusions were crossed with the soft guide wire affixed to the tip of the dilatation catheter, while four occlusions required initial passage of a separate stiffer guide wire.

Despite these encouraging preliminary reports, coronary angioplasty is still withheld from patients with total vessel occlusion in most centers. This pro- gestion against attempting dilatation of occluded vessels has stemmed from the evident difficulty of crossing high-grade stenoses and the fear that lack of an angiographically visible lumen would increase the risks of intimal damage, perforation, or embolus. Although instrumentation of coronary stenoses or occlusions with large or stiff guide wires does raise the possibility of intimal damage, our experience with floppy-tipped 0.018 inch (0.46 mm) guide wires suggests no difference in the frequency of angiographically evident dissection or abrupt reclosure in patients with coronary occlusion as compared with those with conventional stenosis. The ease with which soft-tipped wires crossed total occlusions in this study and the low incidence of dissection suggest that the guide wire is probably following the latent true lumen — the path of least resistance — rather than tunneling through the plaque itself. The movable guide wire angioplasty system may afford an advantage by allowing the operator to monitor this ease of guide wire advancement through the obstruction, while fixed wire systems often resist advancement as the lesion is engaged by the shoulder of the balloon catheter before the leading wire reaches the distal vessel. Movable guide wire systems are also advantageous in allowing exchange of the low-profile balloon catheters required to cross many occlusions for the full-size balloons required to complete dilatation, without the need to withdraw the guide wire and recross the lesion. This is an important consideration, since both of our failures to cross total occlusions with the dilatation catheter occurred before the availability of the 2.0 mm low-profile balloon, and two subsequent cases have required initial use of this device for successful completion.

One additional concern in crossing an occluded segment is the possibility that a fragment of the occlusive material will embolize, leading to obstruction of a distal vessel branch. In a vessel that has become progressively narrowed to the point of occlusion, the amount of potentially embolic thrombus is likely to be quite small, and we have seen no evidence of embolization (pain, loss of distal branches, CK increase) in patients undergoing coronary angioplasty of functional occlusions. If angioplasty were attempted in fresh, predominantly thrombotic occlusions, however, embolization might be a greater problem. Thus, although distal embolization has not been observed in patients undergoing combined streptokinase thrombolysis and coronary angioplasty during acute myocardial infarction, the application of angioplasty alone in this setting would require further study.

Although five of our patients had progressed to occlusion in the interval between diagnostic angiography and scheduled angioplasty, eight had total functional occlusion demonstrated on diagnostic angiograms up to 10 weeks before attempted coronary dilatation. Since angioplasty was successful in three of the eight patients with established occlusion, knowledge of preocclusive luminal anatomy does not appear to be an absolute requirement for successful coronary dilatation. No patient in our series had progression or established occlusion of greater than 13 weeks duration, however, so that we cannot corroborate recent suggestions that occlusions present for periods greater than 3 months are associated with a lower primary success rate.

Patients with functional coronary occlusion and ongoing angina are totally dependent on collaterals for perfusion of the distal myocardium. Robust collateral flow may explain why only five of our 13 patients with total vessel occlusion had sustained infarction of the myocardium supplied by the occluded vessel, similar

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**TABLE 2**

(Continued)

<table>
<thead>
<tr>
<th>Primary success</th>
<th>Primary failure</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resulted in restenosis</td>
<td>Resulted in successful repeat angioplasty</td>
<td>Cont. success/primary success</td>
</tr>
<tr>
<td>7/29 (24%)</td>
<td>2/3</td>
<td>6/7 (86%)</td>
</tr>
<tr>
<td>29/85%</td>
<td>p &lt; .02</td>
<td>7/7 (14%)</td>
</tr>
<tr>
<td>3/7 (43%)</td>
<td>6/7</td>
<td>26/29 (90%)</td>
</tr>
</tbody>
</table>

**THERAPY AND PREVENTION-CORONARY ARTERY DISEASE**
to the experience of Buda et al. It may also explain why patients with coronary occlusion showed no apparent difference in the severity of ischemic symptoms compared with patients with conventional stenosis. Although collaterals may provide adequate resting blood flow to prevent or minimize infarction, they are usually inadequate to meet myocardial oxygen demand during exercise, hence the continued presence of exertional angina. Although experimental preparations suggest that maintenance of resting coronary blood flow requires distal perfusion pressures greater than 50 mm Hg, a mean distal occluded pressure of 30 mm Hg has been observed at the time of surgery in patients with angiographically evident collaterals. Since the surgical patients were not limited to those with total coronary occlusion, however, it is not clear whether these comparatively lower distal occluded pressures were associated with adequate myocardial perfusion. In contrast, perfusion of the distal bed in patients undergoing angioplasty of total coronary occlusions is accomplished entirely by collateral inflow. Their observed distal pressures of 24 to 55 (mean 35) mm Hg must therefore be providing adequate baseline coronary perfusion, although the flow per unit of myocardial mass is probably lower than that present in adjacent normal areas. Finally, these high distal pressures caused by collateral inflow impose a substantial limitation on the predilatation transstenotic gradient as an index of stenosis severity in functionally occluded vessels, since relatively small gradients (30 to 35 mm Hg) (figure 5) may be present despite severe (99% to 100%) stenosis. In summary, coronary angioplasty can be performed successfully in a majority of patients with coronary occlusion, although the overall primary success rate is less than that seen in patients with conventional 70% to 95% stenosis. Despite comparable residual postangioplasty stenosis, the incidence of restenosis in patients with coronary occlusion has tended to be higher than that seen in patients undergoing dilatation of conventional stenoses. The use of a movable guide wire system may decrease the chance of intimal damage when crossing coronary occlusions and allows the serial use of different size balloon catheters to cross and fully dilate these lesions. There has been no evidence of distal embolic phenomena or coronary perforation in the patients studied to date. Since the involved vessel is already totally occluded and since adequate collateral flow is present, angioplasty can be attempted in this patient population with almost no risk of precipitating severe ischemia or necessitating emergency coronary bypass surgery.

Addendum

Since submission of this manuscript, we have performed four additional dilatations of total coronary occlusions — one right coronary artery and three left anterior descending coronary arteries. Three of the four procedures were successful, giving a primary success rate of 80% in the right coronary artery, 60% in the left anterior descending coronary artery, and 59% overall.

We express our thanks and appreciation to the nursing and technical staffs of the Cardiovascular Catheterization Laboratory of the Beth Israel Hospital.

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