Coronary dissection and total coronary occlusion associated with percutaneous transluminal coronary angioplasty: significance of initial angiographic morphology of coronary stenoses

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ABSTRACT Coronary dissection and total coronary occlusion leading to emergency coronary surgery are the most frequent complications of percutaneous transluminal coronary angioplasty (PTCA) and their occurrence usually is unpredictable. To identify angiographic characteristics of coronary stenoses that may affect the incidence of these complications, the diagnostic pre-PTCA coronary angiograms of 38 consecutive patients (group I) undergoing emergency coronary surgery for dissection or occlusion were reviewed and compared with the angiograms of a random sample of 38 patients (stratified for left anterior descending and right coronary arteries) from a group of 1151 who did not need emergency coronary surgery (group II). Stenosis morphology before angioplasty was considered "complicated" if at least one of the following criteria was present: irregular borders, intraluminal lucency, and localization of stenosis in curve or at bifurcation. Baseline characteristics, maximum inflation pressures, types of balloon catheters used, and routinely registered angiographic stenosis properties (severity, length, eccentricity, and calcification) were similar in both groups. Irregular borders before PTCA were present in 22 of 38 patients in group I vs 10 of 38 in group II (p < .05), intraluminal lucency in 22 of 38 vs nine of 38 (p < .05), localization in curve in 27 of 38 pts vs 16 of 38 (p < .05), and localization at bifurcation in 11 of 38 vs 15 of 38 (NS). Complicated angiographic morphology of coronary stenosis may represent a risk factor for dissection or occlusion. Therefore, although the predictive value of these findings is low, detailed evaluation of angiographic morphology of coronary stenoses may improve patient selection and reduce complication rates of PTCA.

Circulation 74, No. 6, 1371-1378, 1986

CORONARY DISSECTION and total coronary occlusion, which are inherent risks of coronary dilatation, account for most of the ischemic complications necessitating emergency coronary surgery.1 The immediate risk of percutaneous transluminal coronary angioplasty (PTCA) is proportionate to the amount of myocardium in jeopardy in the event of an acute ischemic complication. Although the extent of myocardial ischemia resulting from acute coronary obstruction usually may be predicted from the patient’s diagnostic angiogram, the occurrence of coronary dissection or total occlusion is not foreseeable.

As angiographers gain experience with PTCA and as catheter technology improves, complication rates of PTCA have declined and primary success rates have increased. However, according to the recent report of the PTCA Registry of the National Heart, Lung, and Blood Institute,1 which summarizes the results of 34 centers, complications leading to emergency coronary surgery occur at a rate of about 7%. Therefore efforts have been made to analyze the clinical and angiographic factors that may predict the outcome of PTCA and the risk of complications.1-5

This study addresses the significance of the initial angiographic morphology of coronary stenoses for the prediction of outcome of PTCA.
FIGURE 1. Angiogram of LAD immediately before (A) and after (B) balloon dilatation. The initial coronary lesion (arrows in panel A) exhibits marked luminal irregularities. Balloon inflation resulted in dissection of the artery (dissection line is indicated by arrows, panel B).

Patients and methods

From July 1980 until January 1983, a total of 49 patients underwent emergency coronary surgery within 24 hr after failed PTCA at Emory University Hospital. The coronary angiograms taken immediately before PTCA of 38 patients who underwent emergency coronary surgery for coronary dissection or total coronary occlusion were available for review (group I). The pre-PTCA angiograms of a sample of 38 patients (group II) with successful PTCA served as controls. Because the incidence of emergency surgery with PTCA was not equally frequent in the major coronary vessels, the control group was matched to group I for the vessels dilated: left anterior descending (LAD) or right coronary artery (RCA). This was achieved by selecting the last patient with a matching and successfully dilated vessel before the patient undergoing emergency surgery. Selection of the control group was made by one of the authors (K. G.) who had no knowledge of the diagnostic angiograms except for the vessels dilated.

The angiograms were evaluated independently by two angiographers who were not aware of the patient’s identity or outcome of the procedure. The presence (in at least one projection) of one or more of the following morphologic criteria of the coronary stenosis to be dilated was assessed by consensus of the two reviewers: irregularity of borders of the stenosis (figure 1 A) (as opposed to smooth angiographic outline of the borders), intraluminal lucency (filling defect) (figures 2, A, and 3, A) or disruption of the column of contrast media at the stenosis (disruption of flow) (figures 4, A, and 5, A), and eccentricity of the stenosis. The latter was assessed according to the definition published previously. Additional criteria were localization of

FIGURE 2. A, Angiogram of the RCA immediately before PTCA. The stenosis (arrows) shows intraluminal lucency and is localized between two major vessel curves. B, Same artery after balloon inflation, with total occlusion distal to the initial lesion.
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FIGURE 3. Angiogram of the RCA of a patient with previous bypass surgery before (A), during (B), and after (C) balloon dilatation. In panel A, angiographic evidence of a filling defect is present (arrow). Balloon dilatation (B), resulted in further compromise of coronary flow at the level of initial lesion (C, arrows). The filling defect is still present and may be consistent with intracoronary thrombus.

FIGURE 4. A, Angiogram of the RCA before PTCA. Severe narrowing (arrow) with total disruption of the column of contrast medium. The lesion is localized in a bend of the artery. B, Balloon inflation resulted in total occlusion of the vessel, probably due to dissection as reflected by a faint double contour (arrows).

stenosis in or near a vessel curve (so that the inflated balloon would be bent by the curve as seen angiographically) (figures 2, A, 4, A, and 5, B) and localization at or near a vessel bifurcation (so that the inflated balloon would still lie within the bifurcation). The degree of a vessel curve was estimated from the angiographic projection that showed it most markedly. An estimated angle of 45 degrees or greater was considered a curve, but variations with different angiographic projections were great. Disagreement between the reviewers with regard to the presence of a vessel curve occurred in 29% or 24 of all 76 reviewed cases and in 7% to 14% with regard to the other criteria.

Other properties such as degree, length, and calcification of the stenosis were also compared between the groups. These data and clinical baseline characteristics were retrieved from the cardiac data bank of Emory University Hospital, where routine angiographic and clinical data of all patients before and after angioplasty are registered.

PTCA was performed according to the technique described previously5, 6 with types DG and G (sizes 20-20 to 20-37) and over-the-guidewire balloon catheters (Gruentzig steerable balloon dilatation system, USCI and Simpson-Roberts balloon catheter system, ACS). Balloon size was chosen according to the smallest diameter of the normal part of the arterial segment in which balloon inflation was to be performed. Stenosis length and eccentricity were defined as described earlier.4

The angiographic definitions of coronary dissection were per-
FIGURE 5.  A, Angiogram of the RCA immediately before PTCA. Severe lesion (arrow) immediately after a curve of the artery. Almost total disruption of the column of contrast medium is present (arrow).  
B, Inflated balloon across stenosis. The balloon is shown to be bent by the curve of the artery.  
C, Immediately after inflation of balloon, which is shown being withdrawn from the lesion. A double contour beginning at the distal marker of the balloon (arrows) is visible.  
D, Control angiogram after withdrawal of balloon. Total occlusion of the artery due to dissection. The double contour is the characteristic angiographic feature of coronary dissection and is clearly visible (arrows).

Consistent staining of the dissected vessel wall by contrast media, frequently leading to the typical double contour, as shown in figures 4, B, and 5, D. We used the term "total coronary occlusion" to describe complete obstruction with the absence of typical angiographic features of dissection (figure 2, B). The mechanisms of total coronary occlusion as a complication of PTCA may include coronary obstruction by plaque material, the development of intracoronary thrombus, refractory coronary artery spasm, and angiographically undetectable dissection. In most instances the angiographic picture does not allow distinction of different causes of total occlusion.

Statistical analysis was done by the chi-square test and analy-
TABLE 1
Incidence of emergency coronary surgery after failed PTCA in different vessels

<table>
<thead>
<tr>
<th>Vessel dilated</th>
<th>Total (n)</th>
<th>ECS (n)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAD</td>
<td>827</td>
<td>27</td>
<td>3</td>
</tr>
<tr>
<td>RCA</td>
<td>318</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>LCX</td>
<td>120</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Diagonal</td>
<td>26</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Left main</td>
<td>6</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>Grafts</td>
<td>53</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>1350</td>
<td>49</td>
<td>3.5</td>
</tr>
</tbody>
</table>

ECS = emergency coronary surgery; LCX = left circumflex coronary artery.

sis of variance. Differences were considered significant when the p value was less than .05.

Results

From July 1980 until January 1983, 49 of 1200 patients underwent emergency coronary surgery subsequent to failed coronary angioplasty. The most common reasons for emergency coronary surgery were coronary dissection (33/49, 67%) or total coronary occlusion (14/49, 29%). One patient developed intractable hypotension immediately after an attempt to dilate the left main stem. One other patient had cardiac tamponade due to perforation of the right ventricle with the pacing wire after unsuccessful PTCA. Both patients (2/49, 4%) underwent coronary bypass surgery. Emergency coronary surgery was more frequent with angioplasty attempts in the RCA (21/343, 6%) as compared with the LAD (26/872, 3%) and the left circumflex artery (1/128, 1%; p < .05) (table 1).

The reasons for emergency surgery in the patients of group I (n = 38) were coronary dissection by the balloon catheter in 26 patients (68%) (a typical example is shown in figure 5, D), dissection by the guiding catheter in one (3%), and total coronary occlusion in 11 (29%) (a typical example is shown in figure 2, B). Dissection in two patients (one LAD, one RCA) was shown to be a result of advancing the balloon catheter into a false channel. In one patient (RCA), dislodgment of the atherosclerotic plaque was seen to cause total coronary occlusion. Total occlusion developed in one patient (LAD lesion) on the day after the procedure, 4 hr after infusion of heparin was discontinued.

Baseline characteristics of the patients undergoing emergency coronary surgery (group I) and of the control patients (group II) are compared in table 2 and show the two groups to be similar. The angiographic properties of coronary stenoses, which were routinely assessed on the diagnostic pre-PTCA angiogram (degree, length, calcification), and the procedural characteristics such as types of balloon catheters used and maximum inflation pressures are also similar (tables 3A and 3B).

The detailed evaluation of angiographic stenosis morphology on the pre-PTCA angiograms available for review, however, yielded significant differences between the two groups. Irregularities of the angiographic borders of the lesion were present in 22 of 38 patients of group I vs 10 of 38 patients of group II (p < .05). Angiographic evidence of intraluminal lucency (n = 9) or disruption of flow (n = 13) was present in 22 of 38 patients of group I vs nine of 38 patients (intraluminal lucency n = 5, disruption of flow n = 4) of group II (p < .05). Localization of the stenosis in the vicinity of a major curve in the vessel was present in 27 of 38 patients vs 16 of 38 patients (p < .05). Localization of the stenosis close to or involving a

TABLE 3A
Properties of coronary stenoses routinely assessed on the pre-PTCA angiograms

<table>
<thead>
<tr>
<th>Stenosis properties</th>
<th>Group I (n = 38)</th>
<th>Group II (n = 38)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of stenosis (% diameter)</td>
<td>75 ± 16</td>
<td>71 ± 13</td>
<td>NS</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>5.2 ± 4</td>
<td>5.5 ± 3</td>
<td>NS</td>
</tr>
<tr>
<td>Calcifications (n)</td>
<td>2</td>
<td>2</td>
<td>NS</td>
</tr>
</tbody>
</table>
vessel bifurcation was similar in both groups. These results are summarized in table 4.

Intimal tear or dissection not resulting in compromised coronary flow was angiographically demonstrated in eight of the control patients (group II).

One patient in group II who had a very eccentric and irregular LAD stenosis experienced total occlusion of the dilated vessel 2 days after PTCA and subsequently underwent coronary surgery.

Discussion

Although operator experience and improved catheter systems have reduced the frequency of failure of PTCA due to the inability to reach, cross, or dilate the coronary lesion, a considerable risk of emergency coronary surgery due to dissection or coronary occlusion still exists. These complications are the most common causes of PTCA-related deaths and have been thought to be unpredictable. Since there is no technical means available to safely avoid intimal tear or dissection, it would be useful to identify criteria that predispose a patient to such complication.

Attempts to predict these complications on the basis of clinical data have been made. In the recent report from the PTCA Registry of the NHLBI, unstable angina correlated with higher incidence in overall nonfatal complications, and a history of previous coronary artery bypass surgery was found to be related to higher mortality.

Analysis of the coronary arteriogram plays a key role in the selection process of patients for PTCA. The importance of the site of the coronary lesion has been emphasized by several investigators. Lower success rates have been reported in the RCA than in the LAD and left circumflex artery. Our results indicate that the incidence of emergency coronary surgery is higher with PTCA attempts in the RCA than in the LAD or left circumflex artery (table 1). Both the lower success rate and higher emergency surgery rate after PTCA in the RCA may partially be due to the tortuosity of this vessel. The inability to cross the lesion is increased as well as the risk of dissection by balloon inflation in a bend of the artery.

Properties of the stenosis itself also influence the outcome of PTCA. Tight stenoses (equal or more than 90%) are associated with lower success rates and higher overall complication rates. Long and eccentric coronary stenoses also appear to cause higher complication and emergency surgery rates.

In coronary angiograms, focal coronary lesions customarily are described only in terms of localization and the degree of percent luminal diameter (or area) narrowing they produce. Current scoring systems used for the interpretation of coronary angiograms do not consider other characteristics of the angiographic morphology of the coronary lesion. Yet atherosclerotic coronary narrowing is a complex process that may lead to fatty, fibrous, or “complicated” types of atherosclerotic plaques. Complicated lesions are associated with plaque rupture, ulceration, subintimal hemorrhage, or superimposed or recanalized thrombus. These lesions may be more dangerous than fatty or fibrous coronary lesions (uncomplicated lesions) in that they may be more likely to become acutely occluded.

Only recently it has been shown in a histopathologic study by Levin and Fallon that the postmortem angiographic morphology of a complicated coronary lesion (angiographically defined as an irregularity of the stenosis border and/or intraluminal lucency) correlates well with the suspected histopathologic properties. Our study relates the complex angiographic morphology of focal coronary stenoses and their location to the incidence of emergency coronary surgery as a result of coronary dissection or total coronary occlusion caused by PTCA. The results indicate that complicated lesions — stenoses with intraluminal lucencies or irregular borders — may carry a higher risk of severe coronary dissection and total coronary occlusion. This has been confirmed in a recent study relating the angiographic

<table>
<thead>
<tr>
<th>TABLE 3B</th>
<th>Procedural characteristics of patients</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Group I</td>
</tr>
<tr>
<td>Maximum inflation pressure (atm)</td>
<td>8 ± 2</td>
</tr>
<tr>
<td>Balloon catheters</td>
<td>NS</td>
</tr>
<tr>
<td>DG or DJ type</td>
<td>8</td>
</tr>
<tr>
<td>G type</td>
<td>21</td>
</tr>
<tr>
<td>Balloon size 20-37</td>
<td>4</td>
</tr>
<tr>
<td>Steerable catheter systems (over-the-wire)</td>
<td>6</td>
</tr>
</tbody>
</table>

TABLE 4

<table>
<thead>
<tr>
<th>Initial angiographic morphology of coronary stenoses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Border irregularity</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Intraluminal lucency or disruption of flow</td>
</tr>
<tr>
<td>Localization in vessel curve</td>
</tr>
<tr>
<td>Localization at bifurcation</td>
</tr>
<tr>
<td>Eccentric stenosis</td>
</tr>
</tbody>
</table>
finding of intracoronary thrombus to the occurrence of vessel occlusion during angioplasty.\textsuperscript{15}

The criterion “localization in vessel curve” is difficult to define and may therefore be of limited use as a predictor for the outcome of PTCA. One limitation of the study is that the original fixed-wire balloon catheters were used in the majority of the patients included in the study (table 3B). The use of modern over-the-wire dilatation systems has increased the safety of PTCA, particularly by reducing the risk of coronary vascular complications during passage of stenoses. The overall increase in primary success and reduction of emergency surgery rates partially reflects the increased potential of these newer (steerable) balloon catheters. However, the principle mechanism of action of PTCA has remained the same. The major mechanisms of transluminal angioplasty were shown to involve stretching (aneurysm formation) of elastic segments of the vessel wall and intimal splitting or dissection (plaque rupture) of inelastic portions of the vessel,\textsuperscript{13} usually at their weakest point. Plaque ulcerations as they occur in complicated stenoses may predispose to severe (obstructive) dissection caused by balloon distention. Angiographic luminal irregularity and intraluminal lucency may both be the correlate of plaque ulceration with or without intracoronary thrombosis. The traumatic mechanism may be enhanced when balloon inflation in a bend generates additional shearing forces.

When the balloon size is properly selected and over-distension of the vessel avoided, we propose the following mechanisms by which dissection or total occlusion may be more likely to occur in complicated lesions: Mechanical alteration or dislodgment of atherosclerotic or thrombotic material by crossing the stenosis or during dilatation may occur more easily in complicated lesions and cause total coronary occlusion, although this may be rarely demonstrable angiographically. However, in one of our patients this was clearly found to be the case. The opening of a false channel or enhancement of a preexisting dissection with the guidewire or balloon catheter may also be more likely inside an ulcerated lesion with irregular borders than in an hourglass-shaped fibrous plaque with smooth borders. This was demonstrated in two of our patients who needed emergency coronary surgery. Immediate elastic recoil of the dilated segment may be due to elasticity of thrombotic material or to intramural hematoma often associated with “complicated” lesions. Finally, balloon inflation in a vessel curve may lead to stretching and shearing forces and result in a more extensive damage than the usual and expected “controlled injury”\textsuperscript{13, 14} of the arterial wall by mechanical dilatation.

The presence of a complicated coronary lesion is not a contraindication for PTCA.\textsuperscript{16} The predictive value of these angiographic findings for the occurrence of coronary vascular complications is low (< 10%). However, complicated lesions may represent a higher risk of coronary dissection or total coronary occlusion (local coronary risk). This should be taken into account when informing and selecting the patient for PTCA. In particular, this applies to patients with a large amount of myocardium at risk (e.g., proximal LAD stenosis, multivessel disease, total occlusion of a coronary artery outside the distribution of the PTCA vessel), in whom an occlusive coronary complication would result in a critical reduction of left ventricular pump function and substantially increase the clinical risk (myocardial infarction and death) of the procedure.

Competent patient selection for PTCA is certainly a skill the cardiologist performing PTCA needs most in addition to practical abilities. Our observations indicate that detailed evaluation of the angiographic coronary anatomy and the morphology of coronary stenosis may improve patient selection for coronary angioplasty and reduce complications.

References
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_Circulation_. 1986;74:1371-1378
doi: 10.1161/01.CIR.74.6.1371

_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1986 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

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