

Usefulness of Quantitative and Qualitative Angiographic Lesion Morphology, and Clinical Characteristics in Predicting Major Adverse Cardiac Events During and After Native Coronary Balloon Angioplasty

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Major, adverse cardiac events (death, myocardial infarction, bypass surgery and reintervention) occur in 4 to 7% of all patients undergoing coronary balloon angioplasty. Prospectively collected clinical data, and angiographic quantitative and qualitative lesion morphologic assessment and procedural factors were examined to determine whether the occurrence of these events could be predicted. Of 1,442 patients undergoing balloon angioplasty for native primary coronary disease in 2 European multicenter trials, 69 had major, adverse cardiac procedural or in-hospital complications after ≥ 1 balloon inflation and were randomly matched with patients who completed an uncomplicated in-hospital course after successful angioplasty. No quantitative angiographic variable was associated with major adverse cardiac events in univariate and multivariate analyses. Univariate analysis showed that major adverse cardiac events were associated with the following preprocedural variables: (1) unstable angina (odds ratio [OR] 3.11; $p < 0.0001$), (2) type C lesion (OR 2.53; $p < 0.004$), (3) lesion location at a bend $>45^\circ$ (OR 2.34; $p < 0.004$), and (4) stenosis located in the middle segment of the artery dilated (OR 1.88; $p < 0.03$); and with the following postprocedural variable: angiographically visible dissection (OR 5.39; $p < 0.0001$). Multivariate logistic analysis was performed to identify variables independently corre-

lated with the occurrence of major adverse cardiac events. The preprocedural multivariate model entered unstable angina (OR 3.77; $p < 0.0003$), lesions located at a bend $>45^\circ$ (OR 2.87; $p < 0.0005$), and stenosis located in the middle portion of the artery dilated (OR 1.95; $p < 0.04$). If all variables were included, then angiographically visible dissection (OR 6.58; $p < 0.0001$), unstable angina (OR 3.46; $p < 0.002$) and lesions located at a bend $>45^\circ$ (OR 2.54; $p < 0.006$) were independent predictors of major adverse cardiac events.

(Am J Cardiol 1993;72:14-20)

In the initial "National Heart, Lung, and Blood Institute Percutaneous Transluminal Coronary Angioplasty Registry" publication, which described the immediate results of patients treated by balloon angioplasty, major adverse cardiac events (i.e., death, myocardial infarction, coronary artery bypass grafting and repeat dilatation) were reported in 13.6% of patients.¹ Because of improvement in operator experience, as well as radiographic equipment and balloon catheter design over the succeeding 5 years, this percentage decreased to 4 to 7%, despite extension of the indications for coronary balloon angioplasty to include patients aged >70 years, and those with multivessel disease or poor left ventricular function, prior bypass surgery, and more severe and complex lesions.²⁻⁶ Many clinical factors such as multivessel disease, female gender, unstable angina and multiple lesions, as well as qualitative angiographic lesion morphology, including eccentricity, presence of calcium, lesion length, stenosis at a bend, stenosis at a branch point, presence of thrombus, and complex lesions, have been suggested to be predictors of a major procedural or in-hospital cardiac event.³⁻⁹ Previous studies used visual interpretation of the coronary angiogram, which is now known to be limited by considerable inter- and intraobserver variability.¹⁰⁻¹² Thus, quantitative coronary angiographic systems are now the "gold standard" for objective geometric assessment of coronary narrowings, and for assessing the short- and long-term results of interventions.^{13,14} In addition to the actual degree of lumen narrowing, these quantitative coronary

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systems can also provide detailed lesion morphologic characteristics such as lesion length, atherosclerotic plaque area, lesion eccentricity and vessel curvature.¹³ The present study investigated whether comprehensive evaluation of lesion morphology by quantitative coronary analysis, in addition to conventional qualitative assessment, and inclusion of baseline, clinical characteristics and procedural details, could identify patients at particularly high risk for major procedural or in-hospital adverse cardiac events. The identification of risk factors for the occurrence of these complications may be of considerable clinical value in deciding which patients or lesions would be suitable for an alternative treatment to balloon angioplasty.

METHODS

In all, 1,442 patients were enrolled in 2 randomized, double-blind, placebo-controlled, restenosis prevention trials (CARPORT [n = 707] and MERCATOR [n = 735]) between December 1987 and June 1990. Neither trial (described in detail previously) found any clinical or angiographic benefit from the agent under investigation.^{15,16} For the purpose of this ancillary study, the patient cohort comprised those who had major procedural or in-hospital complications (as previously defined) after ≥ 1 balloon inflation, regardless of the final result of balloon angioplasty (group I; n = 69). Each patient in group I was randomly matched with 3 control patients by the date of angioplasty (to the nearest week in the same hospital) (group II; n = 207) to assess the predictability of major adverse cardiac events. In cases of multilesion dilatation, the most severe lesion was selected and used for comparison. Each available cineangiogram was separately reviewed by 2 experienced interventionalists who were unaware of clinical or procedural information, or the outcome of intervention.

Percutaneous transluminal coronary angioplasty procedure and angiographic analysis: At the beginning of the angioplasty procedure, all patients received a bolus of 10,000 IU of intravenous heparin; for prolonged procedures, an additional infusion of 5,000 IU/hour was commenced after 2 hours and continued until the end of the procedure. Aspirin was routinely administered to all patients in the MERCATOR trial and to those randomized to placebo in the CARPORT trial.^{15,16} Use of a calcium antagonist was permitted for 24 to 48 hours after coronary balloon angioplasty. The choices of guiding catheter, guide wire, balloon type, inflation duration and pressure were made by the operator. Primary angioplasty success was defined at the time the guide catheter was removed as diameter stenosis $< 50\%$ by visual estimation, without the occurrence of a major adverse cardiac event.

At least 2 angiographic projections (orthogonal if possible) were recorded in such a way that they were suitable for quantitative analysis by the Coronary Angiography Analysis System, which was validated and described in detail previously.¹³ An example of an analysis is shown in Figure 1.

The absolute stenosis and reference diameters were measured by the computer using the known contrast-empty, guiding catheter diameter as a scaling device. For that purpose, the catheter tips were retained for accurate

measurement with a micrometer. To achieve maximal coronary vasodilation, either nitroglycerin (0.1 to 0.3 mg) or isosorbide dinitrate (1 to 3 mg) was administered (intracoronary) to each affected coronary artery before angiography. All contour positions of the catheter and arterial segment were corrected for "pincushion distortion" introduced by the image intensifiers. Because the algorithm cannot measure total occlusions or lesions with Thrombolysis in Myocardial Infarction grade 1 perfusion, a value of 0 mm was substituted for the minimal lumen diameter and 100% for percent diameter stenosis in such cases.

Variables used in the analysis: **BASILINE CLINICAL CHARACTERISTICS:** The following patient-related variables were recorded in the patient files: age, gender, duration of angina, cholesterol level, previous myocardial infarction, current smoking, diabetes mellitus, extent of atherosclerotic disease (single or multivessel), Canadian Cardiovascular Society angina classification, and unstable angina (defined as pain at rest needing treatment with intravenous nitrates).¹⁷

QUALITATIVE ANGIOGRAPHIC CHARACTERISTICS: The following qualitative lesion parameters were assessed: (1) vessel dilated (right, left anterior descending or left circumflex); and (2) location of the stenosis in the vessel dilated, according to the numeric scheme proposed by Austen et al.¹⁸ The following subdivisions were used for location of the stenosis: proximal corresponding with segments 1, 6 and 11; middle corresponding with segments 2, 7, 13 and 15; distal corresponding with seg-

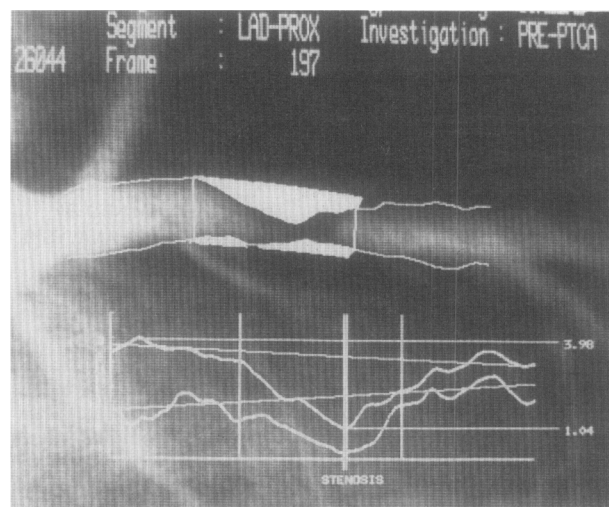


FIGURE 1. Single-frame angiogram of proximal left anterior descending (LAD) artery stenosis before dilatation in right anterior oblique (30°) projection. Quantitative coronary analysis was performed using Cardiovascular Angiography Analysis System. Arterial boundaries automatically detected by system are shown on angiogram, and diameter function curve derived from these contours by interpolating is shown in middle part of figure (upper curve). Lower horizontal line (1.04 mm) is minimal lumen diameter. Outside vertical lines on graph, and 2 vertical lines on angiogram are lesion boundaries (lesion length 8.6 mm). Innermost vertical line is position of minimal luminal diameter, and point where this line intersects diameter function curve (upper horizontal line) is considered reference diameter (3.25 mm; value not shown). Lesion length is automatically determined by curvature analysis of detected vessel contours.

ments 8 to 10, 12 and 14; (3) type of lesion, defined by a modified Ambrose classification, as follows: concentric, eccentric (a stenosis asymmetrically positioned in the vessel in any nonforeshortened angiographic projection), tandem (2 discrete lesions in the same coronary segment separated by an apparently normal segment), multiple irregularities (≥ 2 serial diffuse irregularities in the same coronary segment), and totally occluded vessel¹⁹; (4) a bend $>45^\circ$ was considered present if in any nonforeshortened projection, the balloon in position to dilate was located in a portion of the vessel with a $\geq 45^\circ$ angulation at end-diastole²⁰; (5) presence of a side branch in the lesion to be dilated; (6) presence of a side branch, separate from the actual lesion but within the dilated segment; (7) presence of intracoronary thrombus (a noncalcified filling defect within the lumen, surrounded by contrast material observed in multiple projections or the persistence of contrast material within the lumen, or a visible embolization of intraluminal material "downstream")²¹; (8) presence of calcification (defined as fixed radiopaque densities in the area of the stenosis to be dilated); and (9) type of lesion (A, B or C) according to the American College of Cardiology/American Heart Association Task Force.²²

QUANTITATIVELY ANGIOGRAPHIC CHARACTERISTICS: The following quantitative measurements were obtained: mini-

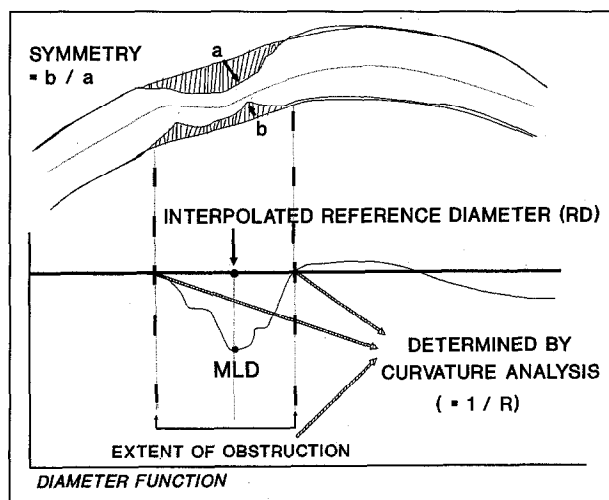


FIGURE 2. Area between actual and reconstructed contours at obstruction site is measure of amount of atherosclerotic plaque. Length of obstruction is determined from diameter function on basis of automatically detected curvature analysis without interference by analyst. Symmetry is defined as coefficient of left- and right-hand distance between reconstructed interpolated reference diameter and actual vessel contours at site of obstruction. In this equation, largest distance between actual and reconstructed contours becomes denominator, so that symmetrical lesion has value of 1, and a severely eccentric lesion has value of 0. To assess extent of coronary bending, curvature value at obstruction site is computed as average value of all individual curvature values along centerline of coronary segment, with curvature defined by rate of change of angle through which tangent to curve turns in moving along curve, and which for circle is equal to reciprocal of radius. Curvature value and symmetry index are determined in projection in least foreshortened view (in which analyzed segment was longest between 2 defined landmarks and is expressed as continuous integer value, ranging from 0 for straight segment to 90 for segment with 90° bend). MLD = minimal lumen diameter.

mal lumen and interpolated reference diameters, diameter stenosis, lesion length and eccentricity, atherosclerotic plaque area and vessel curvature (Figure 2).

PROCEDURAL FACTORS: Balloon-artery ratio was used to assess the suitability of the balloon size for the vessel segment, and was defined as the ratio between the measured mean balloon size and the (interpolated) reference diameter of the dilated segment. Angiographically visible dissections were defined according to modified National Heart, Lung, and Blood Institute criteria.²²

Reproducibility of morphologic assessment: Interobserver variability of the 2 reviewers for qualitative lesion assessment was examined in an arbitrarily selected number of lesions. The coronary angioplasty films of 138 patients with 151 lesions (consecutive films reaching the core laboratory) were independently assessed for the diverse lesion morphologic characteristics by each observer on 2 separate occasions, 3 months apart, with blinding for earlier assessment. Interobserver discordance was as follows: lesion eccentricity 21%; branch point location 29%; branch point location in dilated segment 19%; bend point location 14%; presence of thrombus 2%; presence of calcification 10%; presence of dissection 11%; and lesion type according to the American College of Cardiology/American Heart Association Task Force classification 25%.

Statistical analysis: Analyses were performed to test the hypothesis that clinical, qualitative and quantitative lesion morphologic and procedural characteristics are important determinants of major adverse cardiac events. The risk of major cardiac adverse events for each variable was expressed as an odds ratio: (probability of an event variable present/probability of no event variable present)/(probability of an event variable absent/probability of no event variable absent).

Continuous variables were dichotomized by cut points derived by dividing the data into 2 groups, each containing approximately 50% of the population. This method of subdivision has the advantage of being consistent for all variables and thus avoids any bias in selection of subgroups, which may be performed to emphasize a particular point. An odds ratio (OR) of 1 for a particular variable suggests that its presence poses no additional risk for a major event. An OR $>$ or $<$ 1 suggests additional or reduced risk, respectively. The 95% confidence intervals (CI) were calculated to describe the statistical certainty. If the CI included 1, no significant increased or reduced risk was deemed to be conferred by the variable. Multivariate analysis by multiple logistic regression was performed to identify variables independently correlated with the occurrence of a major cardiac, procedural or in-hospital adverse event, using only those variables significant at the $p < 0.1$ level in the univariate analysis. All statistical analyses were performed with a commercial statistical package (BMDP Statistical Software Package 1990).

RESULTS

Of 1,442 patients recruited, balloon angioplasty was not performed in 9 patients, because the lesion severity had changed or because of equipment failure. A further 43 patients had (sub)totally occluded lesions that could

TABLE I Clinical Variables and the Risk for a Major Procedural or In-Hospital Adverse Cardiac Event

Variable	Patient Positive for Variable (event/total)	Patient Negative for Variable (event/total)	Odds Ratio (95% CI)
Myocardial infarction (history)	23/107	46/169	0.73 (0.41 to 1.30)
Currently smoking	10/45	59/231	0.83 (0.39 to 1.79)
Multivessel coronary narrowing	29/117	39/146	0.89 (0.51 to 1.51)
Diabetes mellitus	6/25	63/251	0.94 (0.36 to 2.46)
Age (<58 years)	35/136	34/140	1.08 (0.63 to 1.86)
Duration of angina (>142 days)	35/137	31/135	1.15 (0.66 to 2.01)
Total cholesterol (<6.2 mmol/L; <240 mg/dl)	34/129	27/132	1.39 (0.78 to 2.48)
Canadian Cardiovascular Society class III or IV	47/169	21/100	1.45 (0.81 to 2.61)
Men	59/221	10/55	1.64 (0.78 to 3.46)
Unstable angina	29/69	39/206	3.11 (1.72 to 5.61)

CI = confidence interval.

TABLE II Lesion and Procedural Variables, and the Risk for a Major Procedural or In-Hospital Adverse Cardiac Event

Variable	Patient Positive for Variable (event/total)	Patient Negative for Variable (event/total)	Odds Ratio (95% CI)
Coronary artery dilated			
Right	15/67	54/209	0.83 (0.43 to 1.59)
Left circumflex	17/72	52/204	0.90 (0.48 to 1.69)
Left anterior descending	37/137	32/139	1.24 (0.72 to 2.14)
Multiple site dilated	12/45	57/231	1.11 (0.54 to 2.29)
Total occlusion	8/24	61/252	1.57 (0.64 to 3.84)
Middle portion of vessel dilated	36/112	33/164	1.88 (1.08 to 3.26)
Lesion morphology quantitatively derived before angioplasty			
Symmetry index (<0.34)*	30/121	32/131	1.00 (0.56 to 1.77)
Minimal lumen diameter (>0.98 mm)	35/139	34/137	1.02 (0.59 to 1.76)
Diameter stenosis (<62%)	35/136	34/140	1.08 (0.63 to 1.86)
Length lesion (>5.8 mm)*	32/127	29/125	1.12 (0.63 to 1.99)
Vessel size (>2.53 mm)	37/140	30/134	1.25 (0.72 to 2.17)
Atherosclerotic plaque (>6.1 mm ²)*	35/127	26/125	1.45 (0.81 to 2.59)
Curvature index (>19)*	37/128	24/124	1.69 (0.94 to 3.05)
Lesion morphology; qualitative assessment			
Side branch in area of balloon	46/186	20/80	0.99 (0.54 to 1.81)
Calcified lesion	9/33	57/233	1.16 (0.51 to 2.63)
Side branch in stenosis	38/144	28/122	1.20 (0.69 to 2.11)
Eccentric located stenosis	36/130	30/136	1.31 (0.75 to 2.28)
Bend >45°	31/86	35/180	2.34 (1.31 to 4.15)
Type C lesion	19/46	47/220	2.53 (1.32 to 4.86)
Procedural variables			
Balloon-artery ratio (>1.02)	17/110	16/105	1.02 (0.48 to 2.14)
Thrombus after dilatation	4/7	62/259	4.31 (0.94 to 19.80)
Intimal tear or dissection	47/111	19/155	5.39 (2.90 to 10.00)

*Although 276 lesions were analyzed in total, some could not be analyzed for certain variables. CI = confidence interval.

be neither reached nor crossed with the guide wire or balloon catheter. Thus, of 1,390 patients in whom balloon dilatation was actually performed, 69 had a major adverse cardiac event. Myocardial infarction occurred during or shortly after the procedure in 15 patients (1%) and during the hospital stay in an additional 22 (1.5%). Emergency coronary bypass graft surgery was necessary immediately after unsuccessful coronary balloon angioplasty in 18 patients (1.3%), and the indication for surgery occurred after leaving the catheterization laboratory in a further 9 (1%). In 5 patients, a redilatation was performed during the hospital stay. No patient died during the procedure or hospital stay.

Clinical characteristics as predictors of major adverse cardiac events (Table I): Patients with unstable angina had more coronary events than did those without unstable angina (OR 3.11; $p < 0.0001$; 95% CI 1.72 to 5.61). Age, gender, duration of angina, serum cholesterol, history of myocardial infarction, diabetes mellitus, multivessel disease and Canadian Cardiovascular Society angina class did not influence the occurrence of a major adverse cardiac event.

Angiographic lesion characteristics as predictors of major adverse cardiac events (Table II): Location of the target lesion in the middle segment of the coronary artery dilated (OR 1.88; $p < 0.03$; 95% CI 1.08 to

3.26), lesions located at a bend $>45^\circ$ (OR 2.34; $p < 0.004$; 95% CI 1.31 to 4.15), and type C lesions (OR 2.53; $p < 0.004$; 95% CI 1.32 to 4.86) were significantly associated with the occurrence of major adverse cardiac events; no other lesion morphologic characteristic (whether assessed qualitatively or by quantitative analysis) predicted subsequent development of these events.

Procedural predictors of major adverse cardiac events: The presence of any type of angiographically visible dissection after the procedure was strongly associated with the subsequent occurrence of a major adverse cardiac event (OR 5.39; $p < 0.0001$; 95% CI 2.9 to 10.0). Neither thrombus after dilatation nor balloon-artery ratio was found to be predictive of major adverse cardiac events (Table II).

Logistic regression analysis: In considering only baseline preprocedural factors, the model entered unstable angina (OR 3.77; $p < 0.0003$; 95% CI 1.89 to 7.48), lesions located at a bend $>45^\circ$ (OR 2.87; $p < 0.0005$; 95% CI 1.47 to 5.59), and stenosis located in the middle portion of the artery dilated (OR 1.95; $p < 0.04$; 95% CI 1.01 to 2.74). When postprocedural variables were added, then unstable angina (OR 3.46; $p < 0.002$; 95% CI 1.67 to 7.17), lesions located at a bend $>45^\circ$ (OR 2.54; $p < 0.006$; 95% CI 1.26 to 5.13), and angiographically visible dissection (OR 6.58; $p < 0.0001$; 95% CI 3.17 to 13.7) were independent predictors of major adverse cardiac events.

DISCUSSION

Despite the improvements in equipment and technique that have made it possible to dilate >90 to 95% of coronary obstructions, the occurrence of procedural and in-hospital cardiac adverse events due to acute or subacute vessel closure continues to be largely unpredictable. The reported frequency of so-called major cardiac adverse events depends on the time window applied — after the patient left the catheterization laboratory 1 to 2%, or during and after the procedure 4 to 7%. In the present study, major adverse cardiac events were observed in 33 of 1,390 patients (2.4%) after ≥ 1 balloon inflation in the catheterization room and in a further 36 (2.6%) during the hospitalization period.

Risk factors of major procedural and in-hospital adverse cardiac events: In 1988, Ellis et al³ reported the results of 4,772 procedures performed between April 1, 1982 and March 31, 1986, and found (using multivariate analysis) 7 independent preprocedural factors related to abrupt vessel closure: stenosis length ≥ 2 lumen diameters, female gender, stenosis at a bend point $\geq 45^\circ$, stenosis at a branch point, stenosis-associated thrombus (filling defect or staining), other stenoses in the same vessel, and multivessel disease. They concluded that although an estimation of risk can be obtained before performing coronary balloon angioplasty, the most powerful predictors of closure can only be assessed during the procedure (postangioplasty percent diameter stenosis, intimal tear or dissection, and prolonged postangioplasty use of heparin). The 1985–1986 National, Heart, Lung, and Blood Institute Percutaneous Transluminal Coronary Angioplasty Registry study analyzed 1,801 patients, and

revealed that baseline factors inherently associated with increased occlusion rates included 3-vessel disease, high-risk status for surgery, and acute coronary insufficiency, and lesion characteristics included severe stenosis before coronary angioplasty, diffuse disease or multiple discrete lesions, thrombus and collateral flow from the lesion. De Feyter et al⁵ reported an acute coronary artery occlusion rate of 7.3% (total population 1,423), with unstable angina, multivessel disease and complex lesions as predictors for closure during or after the procedure.

In all the aforementioned studies that involved large groups of patients, lesion characteristics were visually assessed. No data are available on the predictability of major cardiac complications from quantitative coronary analysis, which has now emerged as the gold standard for assessment of long-term angiographic outcome of percutaneous transluminal coronary interventions.^{15,16} In addition to the “simple” quantitative parameters of minimal lumen (obstruction) diameter, reference diameter (or vessel size) and percent diameter stenosis, quantitative analysis computes length of the obstruction, area of atherosclerotic plaque, symmetry index of the stenosis, and curvature of the vessel. In the present study, quantitative coronary analysis was combined with assessment of qualitative lesion morphology and clinical characteristics to determine whether this thorough, integrated approach could improve the prediction of major adverse cardiac events.

The present results are in agreement with those of the earlier published studies showing that unstable angina, lesions located at a bend $>45^\circ$, and angiographically visible dissection after angioplasty were independent predictors of major procedural or in-hospital cardiac events. Lesion morphology as assessed by quantitative coronary analysis was not useful for the prediction of major adverse cardiac events.

The well-described association of unstable angina with the occurrence of major adverse cardiac events was confirmed in this study. Patients presenting with the clinical syndrome of unstable angina continue to provide the clinician with the difficult task of selecting a suitable management strategy that usually needs to be applied on an urgent basis. The increasing use of intracoronary angiography may be helpful in substratifying these patients and therefore guiding therapeutic strategies that may improve short- and long-term outcome.²³

The location of the target lesion in a bend $>45^\circ$ was previously identified by Ellis et al³ as a risk factor for acute vessel closure. Their explanation was that the balloon must necessarily tear an atherosclerotic fixed and rigid bend lesion, as it straightens and stretches the lesion. In addition, the maximal stress is several times greater when there is a geometric discontinuity in the object to which the stress is applied.

The association of midsegment balloon dilatation with a greater risk of major adverse cardiac events is not readily explicable and could simply be a chance finding.

The most powerful predictor for major adverse cardiac events is the occurrence of an angiographically visible dissection after angioplasty, which is not surprising

because all patients with procedural events had a dissection with flow limitation on their postdilatation angiogram, in agreement with previous reports.^{3,9}

Other investigators have found that thrombus on the predilatation angiogram was predictive for a major adverse cardiac event.³⁻⁵ However, thrombus was seldom observed on the predilatation angiogram in the present study, although unstable angina, in which the presence of intracoronary thrombus is frequently observed,^{23,24} was a risk factor for a major adverse cardiac event. In this study, patients with unstable angina were aggressively treated with intravenous heparin that may have effectively dealt with intracoronary thrombus in some cases. Therefore, thrombus was not a remarkable angiographic feature in the study.

In contrast with Black et al,⁹ the balloon-artery ratio was not a factor for predicting major adverse cardiac events in the present study, although there was a difference in definition. Because of such previously published findings, many investigators may have carefully ensured appropriate matching of balloon with artery size.

From the literature, one would expect that dilation of type C lesions would be a risk factor for a major adverse cardiac event, because it is associated with a <60% acute success rate according to the American College of Cardiology/American Heart Association Task Force.²² However, a recent study of 1,000 lesions by Myler et al²⁵ reported an angioplasty success rate of 90% for type C lesions, which was only slightly less than that for type A and B. In the present study, type C lesions were predictive of major adverse cardiac events in univariate but not multivariate analysis. The relatively high discordance between observers suggests that the use of this subjective evaluation should be cautiously interpreted.²⁶

Study limitations: The study cohort of this retrospective analysis comprised patients recruited for 2 multicenter, restenosis, pharmacologic prevention trials in Europe. Although in both trials, consecutive patients of the participating clinics were recruited, only 25% of those undergoing angioplasty were recruited, because ≥ 1 specific exclusion criterion was found.^{15,16}

In the CARPORT trial, patients treated with the new thromboxane A₂-receptor blockade did not receive aspirin before or during the angioplasty procedure, but all others did; this may have influenced the incidence of major adverse cardiac events.²⁷

Although the Cardiovascular Angiography Analysis System has been validated and extensively described in the literature, validation studies of quantitatively derived, lesion morphologic characteristics such as lesion length and eccentricity, and vessel curvature have not been performed.¹³

Coronary angiography, as a 2-dimensional silhouette of the vessel lumen, is inherently limited for the assessment of atherosclerotic plaque morphology, as has been increasingly demonstrated by intravascular ultrasound techniques.²⁸ Furthermore, the use of objective quantitative analysis does not provide insight to the prediction of major adverse cardiac events from angiographic measurements and lesion morphology. Newer and more sophisticated quantitative analysis systems may be more

helpful in this regard²⁹; however, the combined use of intracoronary angiography and ultrasound is more likely to shed new light on the continued unpredictability of major adverse cardiac events after coronary interventions.

Acknowledgment: The logistic and technical support of Jaap Pameijer, RN, and the statistical advice of Jaap W. Deckers, MD, is greatly appreciated.

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