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CLINICAL INVESTIGATIONS

Successful multiple segment coronary angioplasty: Effect of completeness of revascularization in single-vessel multilesions and multivessels

A long-term follow-up study was performed to evaluate the long-term value of performing multiple dilatations according to their procedural (single-vessel multilesion or multivessel dilatations) and anatomic types (single-vessel disease with multiple dilatations or multivessel disease dilatations with complete and incomplete revascularization). From 1980 until 1988, 248 patients met the following criteria: (1) at least two lesions dilated (range: 2 to 4) and (2) all attempted lesions successfully dilated. The mean length of follow-up was 33 months. The end points analyzed were death, myocardial infarction, redilatation, and bypass surgery. No differences were found for these events between the single-vessel multilesion group (144 patients) and the multivessel group (104 patients). The 4.5-year probability of event-free survival was 68% and 70%, respectively, for the multilesion group and the multivessel group. In the event-free patients, 57% versus 59% were asymptomatic and 45% versus 46% were not taking antianginal drugs. In the anatomic subgroups, there were less event-free patients in the cohort of incompletely revascularized multivessel disease patients (55% of 55 patients) when compared with the cohort of those who were completely revascularized (84% of 79 patients) or when compared with the single-vessel disease multiple dilatation patients (74% of 107 patients). The 4.5-year event-free survival probability for each group was 44%, 78%, and 74%, respectively. This difference was caused by more infarctions (9% versus 2% versus 4%, respectively) and bypass operations in the multivessel disease, incomplete revascularization group (20% versus 5% versus 10%, respectively). In event-free patients, improvement of angina was similar and was documented in over 85% of patients in each group. Furthermore, the number of asymptomatic patients at follow-up was similar in all groups except that within the incomplete revascularization group, less patients were free of antianginal drugs (21% versus 51% versus 48%). Finally, 48% of the entire cohort performed an exercise test 4.6 months (mean) after dilatation and no difference was found in any of the variables in any group. About 10% of the patients experienced angina and approximately 30% had a positive exercise test for ischemia by ST segment criteria. The functional performance in every group was over 90% of the predicted work load. These results suggest that completeness of revascularization in multivessel disease patients is an important prognostic variable. However, the symptomatic improvement after dilatation is very rewarding in all subsets of patients and argues in favor of the continued use of multiple dilatations as a treatment strategy. (Am Heart J 1990;120:1.)

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Since its introduction by Grüntzig,[1] percutaneous transluminal coronary angioplasty has been shown to be effective in a wide variety of coronary artery disease subsets and clinical situations.[2] In particular, balloon angioplasty of multiple segments is becoming increasingly frequent.[3] The success rate and acute complication rate of such procedures have been shown to be acceptable.[4-6] However, the long-term

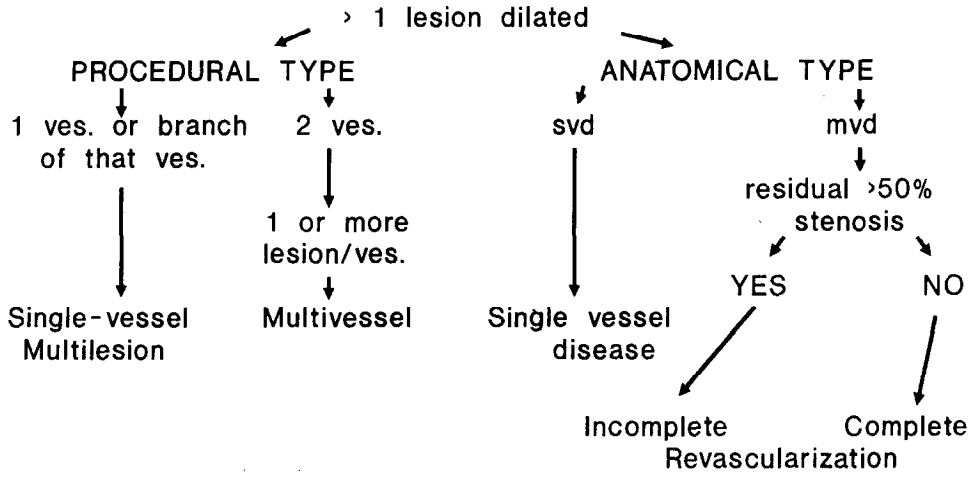

Fig. 1. Subgrouping methods. Two methods used: procedural and anatomic type. *mvd,* Multivessel disease; *svd,* single vessel disease; *ves.,* vessel.

Table I. Baseline characteristics of successfully dilated multiple segment patients, subgrouped by two different methods

	Subgroup method[a]				
	Procedural type		*Anatomic type*		
			svd	*mvd*	
Characteristics	*SVML-PTCA*	*MV-PTCA*		*CR*	*IR*
No. of patients	144	104	107	79	55
Age (yr ± SD)	57.3 ± 9.4	57.6 ± 9.1	57.3 ± 9.3	58.1 ± 9.1	57.0 ± 9.6
Sex (% male)	81	83	81	78	87
Anginal status (% unstable)	34	31	35	29	34
Hypertension (%)	41	43	38	47	47
Hyperlipemia (%)	25	27	29	24	20
Diabetes (%)	6	7	7	7	4
Smokers (%)	50	53	52	53	47
Old infarct (%)	36	55†	28‡	51	62
Ejection fraction (% < 0.50)	13	14	10	14	15
Number of segments dilated (mean ± SD)	2.0 ± 0.5	2.2 ± 0.2	2.0 ± 0.2	2.2 ± 0.5	2.1 ± 0.4
Number of vessels diseased					
	% 1vd* 76	0	100	0	0
	% 2vd* 22	75	0	96	56
	% 3vd* 2	25	0	4	44

CR, Complete revascularization in multivessel disease; IR, incomplete revascularization in multivessel disease; MV, multivessel; mvd, multivessel disease; svd, single-vessel disease; SVML, single-vessel multilesion; PTCA, percutaneous transluminal coronary angioplasty.

[a]The groups SVML-MV are the same patients as svd-CR-IR; they differ by seven patients because of nonavailable information on the diagnostic catheterization.

*$p < 0.0001$ between SVML and MV and between CR and IR; †$p = 0.01$ between SVML and MV; ‡$p = 0.003$ between svd and CR and $p < 0.0001$ between svd and IR.

effect of the procedure is less well known, in part because of the heterogeneity of the study populations, which differed with respect to distinct anatomic and procedural characteristics.

The purpose of this study was to examine the long-term follow-up results of patients who underwent successful multiple segment angioplasty, according to the completeness of the revascularization and with respect to the different types of procedures (Fig. 1). Thus we specifically analyzed multivessel disease patients, separating them on the basis of completeness of revascularization, and then compared them with patients who had single-vessel disease yet who had had multiple lesions dilated. We also examined the effect of performing single-vessel multilesion or multivessel dilatations on the clinical

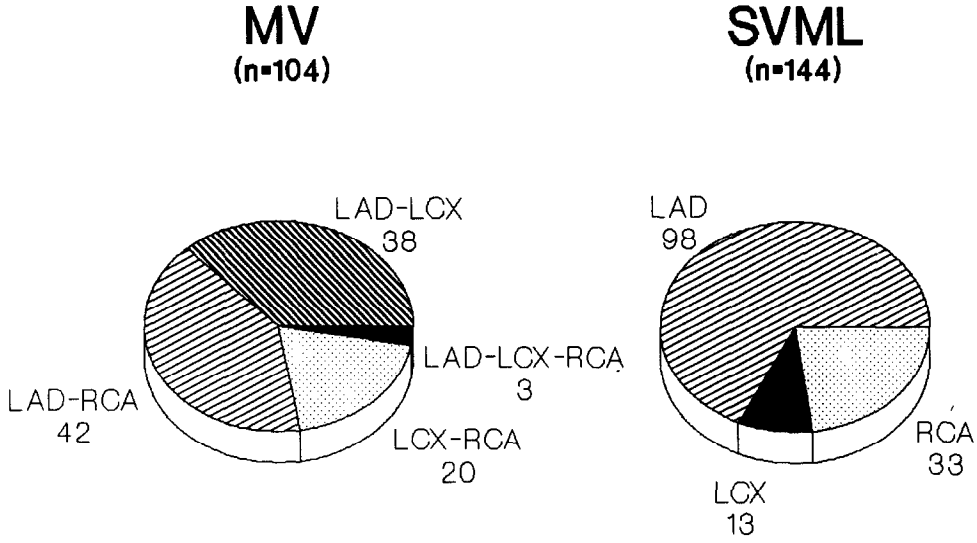

Fig. 2. Sites of dilatation. *LAD,* Left anterior descending; *LCX,* left circumflex; *MV,* multivessel; RCA, right coronary; *SVML,* single-vessel multilesion. Left main and diagonals considered as LAD; obtuse marginals considered as LCX. MV group may have more than one lesion dilated by artery.

outcome. Finally, our results were compared with the results reported in the literature.

METHODS

Study patients. During the period from September 1980 until January 1988, balloon angioplasty was performed in a total of 2098 consecutive patients at the Thoraxcenter in Rotterdam. Of these, 248 met the following criteria and made up the study group: (1) at least two lesions dilated in the same procedure (range: 2 to 4) and (2) all attempted lesions successfully dilated. Reasons for exclusion included emergency angioplasty for acute myocardial infarction, patients with previous angioplasty, and patients with previous coronary artery bypass surgery.

Patients were classified according to the type of procedure (Fig. 1). Of the study group, 144 patients (58%) had single-vessel multilesion angioplasty, defined as at least two segments dilated in a single vessel even in the presence of multivessel disease; and 104 patients (42%) had multivessel angioplasty, defined as more than one vessel or major branches dilated in one or more segments. Patients were further separated on the basis of anatomic type (Fig. 1), namely, single-vessel disease, 107 patients (44%), or multivessel disease 134 patients (56%). Dilatations of the single-vessel disease patients encompassed lesions dilated in the main vessel and/or its major branches. The multivessel disease patients were grouped, following dilatation, according to their revascularization status. Incomplete revascularization, 55 patients (41%), was defined as persistence of at least one undilated stenosis >50% in at least one vessel; complete revascularization, 79 patients (59%), was defined as absence of any remaining >50% stenosis. The single-vessel disease patients were not grouped in this way because they were all completely revascularized. Due to the retrospective nature of this study, seven patients (3% of the total group) could not be categorized in this manner because the diagnostic angiograms were performed in another hospital and were unavailable for analysis.

The baseline characteristics of the subgroups are indicated in Table I. Unstable angina was defined as crescendo angina, de novo angina, or angina at rest. Prior infarction was defined according to the Minnesota code.[7] Ejection fraction was calculated from the contrast ventriculography, as previously described.[8] There were significantly more previous infarctions in the multivessel group (57 patients; 55%) than in the single-vessel multilesion group (52 patients; 36%). There were also significantly more previous infarcts in the complete and incomplete revascularization group compared with the single-vessel disease group: 40 (51%), 34 (62%), and 30 (28%), respectively. The number of vessels diseased in the subgroups was also significantly different, as would be expected from the study design. No other significant differences existed between the groups. The vessel dilated, for the single-vessel multilesion group, and the combination of vessels, for the multivessel group, are indicated in Fig. 2. Left main and diagonal arteries were considered as left anterior descending artery, and obtuse marginals were considered as left circumflex artery.

Coronary angiography. Coronary angiograms were obtained in multiple views and included hemiaxial angulations. The angiograms were interpreted by at least two experienced angiographers. A significant stenosis was defined as a luminal narrowing of more than 50%.

Coronary angioplasty. The procedure used in our laboratory has been previously described.[10] Before the procedure, 250 mg of acetylsalicylic acid and 100 mg of heparin were administered intravenously. To prevent coronary spasm, intracoronary isosorbide dinitrate was given. All procedures were performed with a surgeon on standby. The method of angioplasty changed during the study period.

Table II. Follow-up events

	Subgroup method				
	Procedural type		*Anatomic type*		
			svd	*mvd*	
Event	*SVML-PTCA*	*MV-PTCA*		*CR*	*IR*
Total no. patients	144	104	107	79	55
Patients with F-UP	137	101	102	77	53
Years of F-UP ±SD	2.68 ± 1.47	2.72 ± 1.45	2.73 ± 1.49	2.75 ± 1.41	2.55 ± 1.49
Death (no. of patients)	5 (3%)	7 (7%)	3 (3%)*	3 (4%)	6 (11%)
Myocardial infarct (no. of patients)	8 (6%)	4 (4%)	4 (4%)	2 (2%)	5 (9%)‡
RePTCA (no. of patients)	13 (9%)	4 (4%)	10 (10%)	3 (4%)	3 (6%)
CABG (no. of patients)	17 (12%)	8 (8%)	10 (10%)	4 (5%)	10 (20%)§
Event-free patients	94 (69%)	78 (77%)	75 (74%)†	65 (84%)	29 (55%)‖

CABG, Coronary artery bypass grafting; F-UP, follow-up; other abbreviations as in Table I.
*Death status is known for the total group of patients: six were cardiac, five were noncardiac, and the cause is uncertain for one patient.
*$p = 0.06$, †$p < 0.025$ between svd and IR.
‡$p = 0.02$, §$p = 0.01$, ‖$p = 0.0002$ between CR and IR.

Table III. Clinical status at follow-up in event-free patients

	Subgroup method				
	Procedural type		*Anatomic type*		
			svd	*mvd*	
Variable	*SVML-PTCA*	*MV-PTCA*		*CR*	*IR*
No. of patients	94	78	75	65	29
Improvement of angina since PTCA (no. of patients)	94 (100%)*	68 (87%)	71 (95%)†	56 (86%)	28 (96%)
Free of angina at F-UP (no. of patients)	54 (57%)	46 (59%)	46 (61%)	38 (58%)	14 (48%)
Free of antianginal drugs (no. of patients)	42 (45%)	36 (46%)	36 (48%)‡	33 (51%)§	6 (21%)

Abbreviations as in Tables I and II.
*$p < 0.0005$ between SVML and MV.
†$0.1 > p > 0.5$ between svd and CR.
‡$p < 0.025$ between svd and IR.
§$p < 0.01$ between CR and IR.

Before February 1983 a nonsteerable catheter system was used; from February 1983 through January 1986 a steerable system was used. Since then, the long guide wire technique or a monorail system has been in use.

Angioplasty of the lesion considered to be the most important (according to severity and morphology of the lesion, size of vessel, wall motion of area at risk, and localization of ischemic electrocardiographic changes at rest) was performed first. A stenosed vessel providing collaterals to another vessel was always dilated *after* the collateralized vessel. Incomplete revascularization resulted from intentionally avoided lesions (chronic total occlusion, or an akinetic muscle region supplied by a stenotic vessel) and unattempted lesions because of an unsatisfactory result with the first attempted lesion. Also in unstable patients, it has been our policy to dilate only the culprit lesion.

After the procedure, patients continued to receive treatment with nifedipine, 40 to 60 mg/day, and acetylsalicylic acid, 500 mg/day, for a period of 6 months. Procedural success was defined as reduction in the severity of the obstruction to less than 50% luminal diameter narrowing without major complications within 24 hours (myocardial infarct, emergency bypass surgery, or death).

Follow-up. The following events were studied: death, myocardial infarction, redilatation, late coronary bypass surgery, presence of angina, improvement in anginal status after dilatation, and use of antianginal medications (nitrates, β-blockers, calcium channels blockers). This information was based on personal interviews, hospital data bases, questionnaires, or civil registries. Clinical follow-up data were obtained in 96.3% of the patients. The few remaining patients were all living abroad and were unavailable for follow-up.

Exercise test. Patients performed a symptom-limited test on a bicycle ergometer with stepwise increments of 10 W/min, as previously described.[10] The three orthogonal

X,Y,Z leads of the Frank lead system were monitored. ST segment depression of at least 1 mm, 0.08 second after the J point was defined as an ischemic response. The maximal work load achieved was expressed as a percent of the normal work load predicted for age, sex, and height. Complete information was obtained in 120 patients (48% of the total group).

Statistics. BMDP software (Biomedical Data Package; University of California Press, Berkeley, Calif.) was used. Continuous variables were studied with Student's t test while categorical variables were analyzed with the chi square or Fisher's exact tests, whenever appropriate. Differences were considered significant at a probability value of < 0.05. The life-table analysis was done with the Kaplan-Meier method. The generalized Wilcoxon test was utilized to detect differences between subgroups. All statistical tests were two-tailed.

RESULTS

Clinical outcome at an average follow-up of 2.70 ± 1.46 years (range: .09 to 7.04 years) was compared for all subgroups. The length of follow-up was identical for all groups.

Events (Tables II and III)

Patients with single-vessel multilesion versus multivessel dilatation. Overall, there were no significant differences in the following events: death, myocardial infarct, redilatation, and bypass surgery in the subgroups with single-vessel versus those with multi-vessel disease. In the patients without adverse events during the time elapsed since the angioplasty, there were significantly more patients with single-vessel multilesion dilatation who had an improvement in their anginal status (single-vessel multilesion: 100% versus multivessel: 87%; $p < 0.0005$), although no differences were found either in the number of asymptomatic patients or in the number requiring antianginal drugs.

Patients with multivessel disease, complete versus incomplete revascularization. There was a highly significant difference in the total number of events between the complete versus the incomplete revascularization groups (complete revascularization: 16% versus incomplete: 45%; $p = 0.0002$). This was explained by a greater number of bypass operations (complete revascularization: 5% versus incomplete: 20%; $p = 0.01$) and infarctions in the incomplete revascularization group (complete: 2% versus incomplete: 9%; $p = 0.02$). Furthermore, incompletely revascularized and event-free patients more frequently required antianginal drugs (incomplete: 21% versus complete: 51%; $p < 0.01$). Finally, there were no significant differences in the number of deaths, and the number of patients with redilatation, between the complete versus the incomplete revascularization groups.

Patients with multivessel disease, incomplete revascularization versus patients with single-vessel disease. A significant difference was found between the multivessel, incomplete revascularization subgroup versus the subgroup with single-vessel disease in the total number of adverse events (incomplete: 45% versus single-vessel disease: 26%; $p < 0.025$). The patients with multivessel disease and incomplete revascularization had a trend toward a greater number of deaths, infarctions, and bypass operations. In the event-free patients, the requirement for antianginal drugs was significantly different between the single-vessel disease patients and the multivessel disease patients with incomplete revascularization (free of antianginal drugs; incomplete: 21% versus single-vessel disease: 48%; $p < 0.025$).

Patients with multivessel disease and complete revascularization versus patients with single-vessel disease. There were no significant differences between the follow-up course of the group with multivessel disease and complete revascularization and the group with single-vessel disease.

Exercise testing (Table IV). The exercise test was performed an average of 5.1 months (range = 0.1 to 19.9 months) after the dilatation. There were no differences between the subgroups, and the functional performance was excellent for all patients. Few patients had angina (8% to 16%), but an ischemic response was demonstrated in one third of the patients.

Life table analysis (Figs. 3 and 4). Since the number of patients who died was small, instead of a survival curve, the event-free survival (survival without redilatation, bypass surgery, or infarction) was computed for both types of subgroup assignments.

Patients with single-vessel multilesion versus multivessel dilatation. No differences were found between the patient group with single-vessel multilesion dilatation compared with the group with multivessel dilatation. The 4.5-year probability of being alive and event-free was 68% (single-vessel) and 70% (multivessel).

Patients with multivessel disease, complete versus incomplete revascularization. There was a highly significant difference between the complete and incomplete revascularization groups in that the incompletely revascularized patients had a much shorter event-free survival (mean ± SE = 3.98 ± 0.48 years for the incomplete revascularization group and 5.08 ± 0.23 years for the complete revascularization group, $p = 0.0001$) (Fig. 3). The 4.5-year event-free survival probability was 78% and 44%, respectively, for both groups.

Patients with multivessel disease and incomplete revascularization versus patients with single-vessel

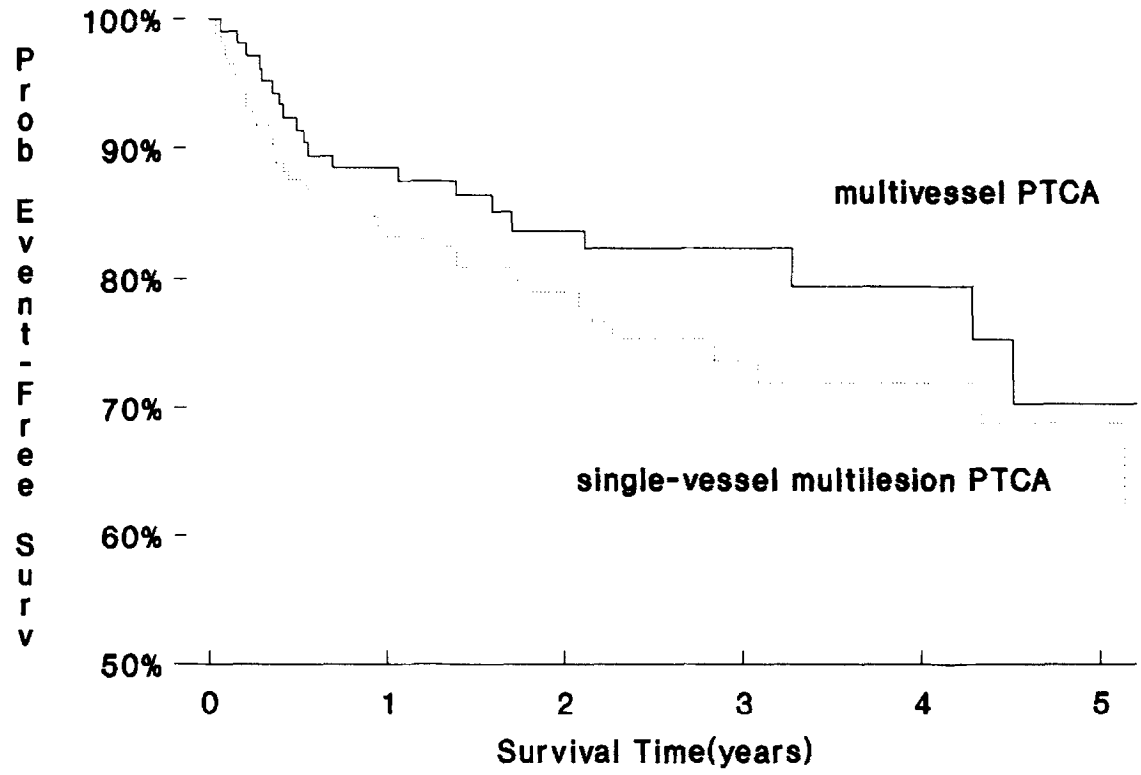

Fig. 3. Event-free survival for both procedural types of dilatation (multilesion and multivessel dilatations). *PTCA,* Percutaneous transluminal coronary angioplasty. No significant difference found between both groups.

Table IV. Results of exercise testing after PTCA

	Subgroup method				
	Procedural type		*Anatomic type*		
			svd	*mvd*	
Parameter	*SVML*	*MV*		*CR*	*IR*
No. of patients	73	47	52	33	34
Time to test (months ± SD)	4.27 ± 4.16	4.89 ± 3.50	4.47 ± 4.38	4.98 ± 3.36	4.08 ± 3.74
Work load (% predicted ± SD)	0.99 ± 0.24	0.96 ± 0.14	1.01 ± 0.24	0.99 ± 0.15	0.93 ± 0.18
Double-product (HR · BP) ± SD	24,459 ± 9,291	26,762 ± 8,548	24,987 ± 9,036	26,631 ± 9,030	24,662 ± 9,201
Angina (no. of patients)	6 (9%)	6 (13%)	4 (8%)	3 (9%)	5 (16%)
ST depression (no. of patients)	15 (31%)	12 (44%)	15 (31%)	8 (23%)	10 (31%)

BP, Blood pressure; HR, heart rate; other abbreviations as in Tables I and II.
$p > 0.05$ for all parameters.

disease. There was also a significant difference between the group with multivessel disease and incomplete revascularization and the group with single-vessel disease in the mean event-free survival (incomplete: 3.98 ± 0.48 years, single-vessel disease: 4.89 ± 0.27 years, $p = 0.01$). This trend was reversed in a 4.5-year probability of event-free survival of 44% and 74%, respectively, for both groups.

Patients with multivessel disease and complete revascularization versus patients with single-vessel disease. No differences were found between the group with multivessel disease and complete revascularization and the group with single-vessel disease.

Other findings. Due to a difference in the extent of coronary artery disease between the complete and incomplete revascularization groups, an event-free survival curve was computed separately for the two- and the three-vessel disease patients. The mean ± SE event-free survival was 5.51 ± 0.29 years for the two-vessel disease patients and was 3.53 ± 0.54 years

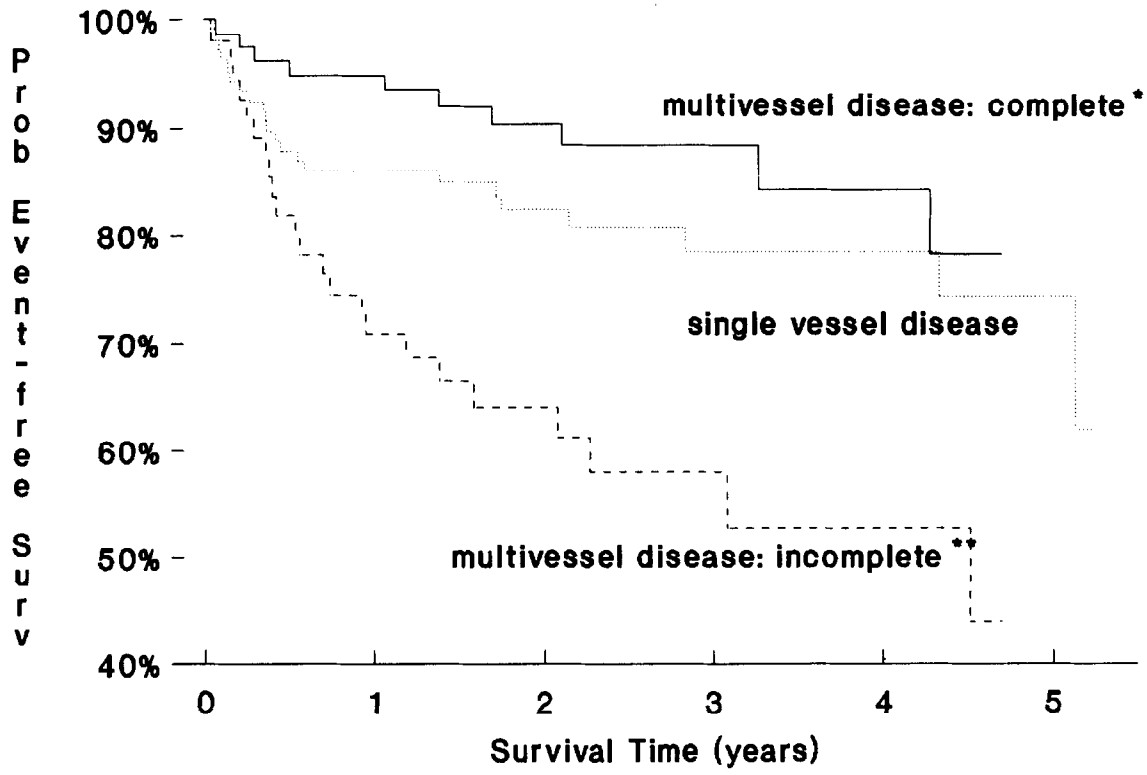

Fig. 4. Event-free survival for the different anatomic types of dilatation. *p = 0.0001 between multivessel disease complete and incomplete revascularization; *p = 0.01 between single-vessel disease with multiple dilatations and multivessel disease, incomplete revascularization.

for the three-vessel disease patients (p = 0.01). Because of this difference, the event-free survival analysis was again performed for both complete and incomplete revascularization groups, but the three-vessel disease patients (n = 27 patients) were now excluded. This analysis again yielded a significant difference between patients in the complete and incomplete revascularization groups (complete: 5.50 ± 0.22 years versus incomplete: 4.04 ± 0.68 years; p = 0.001). For the completely revascularized patients, the 4.5 year-probability of event-free survival was 81%, and this figure was 47% at 3 years for incompletely revascularized patients.

When we looked at different baseline characteristics (infarction, ejection fraction, unstable angina), there were no significant changes in the results of the life table analysis. Finally, it was also noticed that more than 50% of the events occurred in the first 7 to 8 months of follow-up.

DISCUSSION

Multiple segment coronary angioplasty follow-up studies are notoriously different in terms of populations involved, definitions used, and methods of reporting the results. They are thus difficult to interpret comprehensively. Outcome has often been reported as a total result without subgroup analysis (Table V). The effect of completeness of revascularization has also been reported, but some studies have not separated single-vessel disease patients and multivessel disease patients, and some studies have also sometimes included single-vessel single lesion dilatation in the comparisons (Table VI). Consequently, to obtain a clearer view of the long-term benefit of more than one dilatation done in the same procedure, we excluded single vessel single-lesion angioplasty and we report the results in terms of procedural type (multivessel versus single-vessel multilesion dilatations) in addition to anatomic type (single-vessel disease versus different revascularization status for multivessel disease). Last, to exclude the effect of the changing technology,[9] and since our interest was in the long-term effect of the procedure, our study consists of only successfully dilated cases.

First, comparing patients succesfully dilated in one artery with those having more than one artery dilated, the only significant difference was the superior improvement in anginal status at follow-up in the event-free single-vessel multilesion population. However, the fact that the number of asymptomatic patients and the number of patients not using antianginal drugs was the same, counterbalances this

Table V. Reported follow-up of multiple-lesion PTCA

First author	*No. of patients*	*MV (%)*	*SVML (%)*	*Lesion by patients*	*F-UP (mo)*	*Death (%)*	*RePTCA (%)*	*CABG (%)*	*AMI (%)*	*Symptoms*
DiSciascio[19]	194	61.8	41.2	—	>12	—	—	—	—	37-27% recurrence
Halon[20]	68	65	35	2.4	30	—	—	—	—	97% improvement
DiSciascio[21]	50	100 (3vDil)	—	5	18.4	10	30	4	4	34% recurrence
Lambert[14]	206	62	38	2.2	>6	0.9-1.0	18-15	1.8-3.8	1.8-2.6	70% ≤ class 1
Finci[22]	80	100	—	2.1v	12	—	—	—	—	60% = class 1
Roubin[23]	298	100	—	—	23	99act	—	88act	93act	—
Dorros[15]	428	84	16	2.4	28.3	3.5	20.8	5.8	—	68% no angina
Hartzler[18]	500	—	—	2.7	27	5.6	27	15	7.3	64% improvement
Cowley[16]	100	86	14	2.7	26	0	20	18	2.3	34% recurrence
Myler[24]	494	—	—	2.3v	20.5	1	20.8	—	—	83% ≤ class 1
This study	248	42	58	2.2	33	7-3	4-9	8-12	4-6	Improvement = 87%-100%* / No angina = 59%-57% ††

act, Actuarial survival; AMI, acute myocardial infarction; vDil, vessel dilated; v, vessel; other abbreviations as in Tables I and II.
*Significant difference.
†Dual statement concerns MV versus SVML.

difference. The diminished use of antianginal medication is in agreement with the results of a former study from our institution, which showed that there was a clear reduction in the use of these medications after angioplasty.[11] The absence of any significant difference in the single-vessel multilesion group compared with the multivessel group may seem surprising at first glance, since 76% of the patients of the former group had only single-vessel disease and they also had fewer previous infarctions. However, the fact that these patients had a multisegment dilatation implies that they had at least one diffusely diseased coronary artery, which may in turn imply more severe disease in the other arteries, even if these were not significantly diseased by the usual criteria. Furthermore, Roubin et al.[12] have found that the restenosis rate is associated with the number of segments dilated only in multilesion and not in multivessel dilatations. This may also help us to understand the absence of a difference between these two groups, since it is known that the clinical recurrence after dilatation is usually caused by restenosis.[13, 40] In addition, restenosis probably explained the finding that the majority of events occurred in the first months after the procedure.[13] Only one other study[14] has analyzed the influence of different types of procedures by making the differentiation in multivessel and single-vessel multilesion dilatations. Despite different definitions of their subgroups, Lambert et al.[14] reported identical follow-up results for these groups, and our results are similar to theirs. Compared with other long-term follow-up studies (Table V), our results showed a lower event rate. This difference can probably be attributed, at least in those studies with a longer follow-up,[15, 16, 18] to the increased severity of coronary disease of their patients, as is suggested by the greater number of lesions dilated.

The second part of the study deals with the controversial topic of the influence of different degrees of revascularization.[5] While no differences were detected between the multivessel disease, complete revascularization group and the single-vessel disease group, the follow-up course of the multivessel disease, incomplete revascularization group contrasted markedly with both. This held true even when considering only the two-vessel disease patients in order to get a more homogeneous population. The discrepancy was particularly evident in the number of infarctions and bypass operations. The latter factor was probably in part due to the presence of totally occluded vessels, which led to a preference for bypass instead of dilatation. This was also noted in other studies (Table V). The difference between the groups becomes readily apparent in the first year after dilatation, and it becomes more pronounced as time passes. This agrees with the findings of the recent report of Holmes et al.[25] Thus our data, which contain the longest follow-up compared with the rest of the literature, confirm the findings of several reports stating that the degree of revascularization is important in determining the evolution of multiple segment dilatations,[5, 27, 28, 35, 36] although others studies present contradictory results.[26, 29, 30, 32] In particular, the study of Holmes et al.,[25] which contains a follow-up of 30 months' duration on a very large number of patients (1183 patients) showed, as did our study, an

Table VI. Reported follow-up of revascularization status studies

First author	*Patient type*	*No. of patients*	*CR (%)*	*IR (%)*	*Lesion by patients*	*F-UP (mo) (mean)*	*Death CR-IR (%)*	*RePTCA CR-IR (%)*	*CABG CR-IR (%)*	*AMI CR-IR (%)*	*Symptoms*	*Comments*
Holmes[25]	mvd svd	1183	61 (41mvd) (89svd)	39	—	30	3-6	16-17	9-17*	3-7	20%-27% recurrence	More events with time and IR > CR
Thomas[26]	mvd	92	20	80	—	12.1	0-0	11-12	5-1	0-1	63%-63% no angina	26%-21% no drugs
Deligonul[6]	mvd	470	32	68	2.2	27	5-5.5	13.5-13	6.7-15.6*	2.5-3.5	80%-80% cl = 1 (event-free)	
Deligonul[27]	mvd	229	34.5	65.5	2.3	11	2.6-2.5	24-17.7 (RePTCA or CABG)		3.3.-2.5	5.3-5.1 > cl 3	
Finci[28]	Mult	77	76	24	2.1	24	—	—	5-28	—	81%-24% no angina	
Reeder[29]	mvd	286	44	56	—	26.2	3.1-5*	19.7-8.8*	9.4-17*	7.1-9.4*	30.9%-32.5% angina	But no difference in events if adjusted for baseline differences
Ilsley[30]	mvd	200	43	57	2.1	11	—	14-15	4-4	—	20%-18% recurrence	No difference in events
De Feyter[31]	Unst	154	72svd	28mvd	1	6	—	—	—	—	16%-29%*	Good acute effect, more recurrence in IR
Wohlgelernter[32]	Unst	27	0	100	1	16	—	—	—	—	17% recurrence	
Hernandez[33]	mvd	157	25	75	—	10	0-1	5-13	5-11	8-1	66%-58% no angina (event-free)	No difference
Mata[34]	2VPTC	74	85	15	2.1v	5.5	—	—	—	2-10	44%-20% no angina	
Mabin[35]	mvd	66	47	53	—	10.5	0-0	6-6	13-23	—	80%-57% no angina	IR = worse F-UP
Vandormael[36]	Mult	135	46	54	2.4	6	0-3	3-16*	3-16*	3-0	90% less angina (both groups)	91%-65%* are event-free; good effect but more events
This study	Mult	134 (all mvd)	59	41	2.2	33	4-11	4-6	5-19*	2-9*	58%-48% no angina, 51%-21% no drugs*	IR = worse event-free survival

Mult, Multilesion PTCA; cl, New York Heart Association functional class; Unst, unstable; 2VPTC, two-vessel PTCA; other abbreviations as in Tables I, II, and V.
*Statistically significant differences; all the others are unstated or nonsignificant.

event-free survival probability difference increasing with time of 62% versus 37% at 5 years, respectively, for complete revascularization and incomplete revascularization patients. However, these investigators included in their study 40% of single-vessel disease patients who had an 89% complete revascularization rate. This obviously improves the outcome of their complete revascularization group. Deligonul et al.[27] also reported a significant difference in events between both revascularization groups at 27 months, the incompletely revascularized patients having the worse prognosis. Curiously, as opposed to our findings and the findings of others,[35, 36] they did not see any difference in the follow-up between the two- and three-vessel disease groups. On the other hand, Reeder et al.[29] showed, after correction by logistic

Table VII. Reported exercise test evaluation in multiple PTCA, multivessel disease PTCA, or with revascularization status studies

First author	*Patient type*	*No. of patients*	*F-UP (mo)*	*Duration CR-IR (sec)*	*Work load CR-IR*	*Double product CR-IR*	*Angina CR-IR (%)*	*ST segment CR-IR (%)*	*Comments*
Halon[20]	Mult (64% mvd)	30	2	18.1-15.2 (min)	9.6-7.9 (METS)	29,000-23,000*		0.6-1.5* (max dep (mm))	CR = less ischemia
Thomas[37]	mvd	145	<2	459-450	—	22,968-23,120	13-13	19-34*	CR = less ischemia, but same capacity
Finci[22]	Mult (100% mvd)	43	11	—	117 (W)	26,400	—	—	35% positive test
Wohlgelernter[40]	mvd	70	0.5	—	—	—	6-6	—	
Vandormael[36]	Mult (84% mvd)	57	<10 days	514-492	—	—	0-20	26-37	No p value but said to be different
De Feyter[31]	Unst (28% mvd)	118	2.6	—	75%-61% (>90% predicted)	144-138 (max HR)	7-16*	15-31*	CR = svd IR = mvd same capacity
Deligonul[27]	All (54% mvd)	229	<1	488	85 (% age-predicted max HR)	168 (max BP)	7.5-14	10-36*	Increased F-UP events among mvd and IR = worse
This study	Mult (100% mvd)	67	4.5	—	99%-93%	26,631-24,662	9-16	23-31	no statistical difference

max BP, Maximal blood pressure; max dep, maximal depression (mm); max HR = maximal heart rate; METS, metabolic equivalents; other abbreviations as in Tables I, II, and VI.
*Statistically significant differences.

regression of important baseline mismatches in the patients of the National Heart, Lung, and Blood Institute (NHLBI) registry of angioplasty, no difference in mortality or in morbidity of the patients at 26 months between those with complete and those with incomplete revascularization.

Finally, when analyzing the clinical status of event-free patients, we found a uniformly excellent result (Table III). However, this was attained with a more frequent use of antianginal medication in the incomplete revascularization group of patients. Overall, about 90% of patients improved and 50% were asymptomatic, which is in general agreement with the reported results in the literature (Table VI). Only Thomas et al.[26] also reported on the use of medication and, while they had a proportion of asymptomatic patients similar to ours, a larger proportion of their completely revascularized patients needed antianginal medication compared with our patients (Thomas: 75% versus this study: 50%). The exercise testing also reflected this good clinical result (Table IV). It showed an excellent functional result that was associated with very few anginal symptoms (8% to 16%). Ischemia was found in almost one third of the patients, but the difference between the incomplete and the complete revascularization groups did not attain the significance level (23% and 31%; p = NS). In this respect, our data differ from the findings in the literature on the subject (Table VII). In interpreting the exercise data, one must realize the likely possibility of a selection biais, since probably more patients with recurrence of symptoms performed the test.

In conclusion, we have shown that the effect on late clinical outcome of the performance of more than one dilatation in the same procedure is generally acceptable. In fact, there seems to be no difference in performing single-vessel multilesion or multivessel dilatations. On the other hand, the completeness of revascularization in the multivessel subgroups is an important prognostic variable. The incompletely revascularized patients definitely fare less well with respect to follow-up events, especially when the necessity of coronary bypass is considered. However, it is also apparent that even for these patients the effect on their symptomatic status is very rewarding. Since all approaches to the treatment of coronary artery disease are condemned to be palliative, we

believe that multiple dilatations, regardless of the degree of revascularization achieved in the multivessel disease subset, are an acceptable therapeutic option if a careful selection of the patients is made to minimize acute complications.

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Defective coronary prostaglandin modulation in anginal patients

In order to investigate whether coronary vasodilating prostaglandins (PGI_2 and PGE_2) have a role in the pathophysiology of myocardial ischemia, 26 patients with angina pectoris and 23 control subjects (nonischemic patients) were studied by assessing coronary hemodynamics and prostaglandin formation in relation to sympathetic stimulation. Following a cold pressor test (CPT), coronary prostaglandin output markedly increased ($p < 0.001$) and coronary vascular resistance (CVR) decreased ($p < 0.001$) in all control subjects. In contrast, in anginal patients prostaglandins in the coronary sinus were undetectable and after CPT prostaglandin output did not increase, whereas CVR paradoxically increased ($p < 0.001$). In control subjects the inhibition of coronary prostaglandin formation (by ketoprofen [1 mg/kg intravenously] or by aspirin [15 mg/kg intravenously]) caused a paradoxical increase of CVR following CPT ($p < 0.001$). In anginal patients the inhibition of prostaglandins further exaggerated the increase of CVR after CPT ($p < 0.001$). These results indicate that coronary vasodilating prostaglandins PGI_2 and PGE_2 play a role in modulating coronary vascular response to sympathetic stimulation induced by CPT. Their defective production in anginal patients may be responsible for the paradoxical increase in CVR following sympathetic stimulation. (Am Heart J 1990;120:12.)

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Much evidence exists that the coronary vasculature of various animal species[1-3] and human cardiocoronary tissues[4] are able to synthesize prostaglandins. In experimental preparations prostaglandin biosynthesis was induced by different stimuli, such as hypoxia and angiotensin II,[5-7] and the formed prostaglandins have been shown to influence coronary vascular tone and coronary vascular resistance.[1-3] In man, a relevant formation of cardiac and coronary prostaglandins was found following sympathetic stimulation induced by the cold pressor test (CPT).[8] In this condition, vasodilating prostaglandins, i.e., prostacyclin (PGI_2) and prostaglandin E_2 (PGE_2), were the main prostaglandins formed.[8] Differing from the results in control subjects, in anginal patients only negligible amounts or no PGI_2 or PGE_2 have been found.[9] Since in a previous investigation[10] cardiac and coronary prostaglandins have been shown to modulate the

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