

Multiple Lesion Transluminal Coronary Angioplasty in Single and Multivessel Coronary Artery Disease: Acute Outcome and Long-Term Effect

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Multiple lesion transluminal coronary angioplasty was performed in 428 patients. Angioplasty was attempted in 1,047 lesions (2.4/patient), with an angiographic success achieved in 94%: 2 lesions were attempted in 74%, 3 in 21%, 4 in 5% and 5 or more in 1% of cases. A clinical success was achieved in 404 (94%) of the patients: 95% with and 93% without prior surgery and in 94% of those with single vessel disease and 94% of those with multivessel disease. Significant complications occurred in 17 patients (4.0%): 11 (2.5%) had a transmural infarction, 9 (2.1%) required urgent surgery and 6 (1.4%) died. An apparent lesion recurrence occurred in 106 (26%) of 404 patients with 81 of 89 patients (91%) having a successful second angioplasty. A second apparent lesion recurrence occurred in 15 patients (19%), with 13

of the 15 patients having a successful third angioplasty.

A sustained clinical improvement (mean follow-up period 28.3 ± 16 months) was obtained in 208 (83%) of 250 patients with successful angioplasty. The cumulative probability of survival at 51 months was 93% in these 250 patients. Survival was adversely affected by the presence of prior bypass surgery (no prior surgery 97% versus prior surgery 81%; $p < 0.05$).

These data suggest that multiple lesion angioplasty can be successfully performed with a good success rate, an acceptable incidence of complications and a reasonable expectation of satisfactory long-term clinical improvement.

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Percutaneous transluminal coronary angioplasty (1) has become an effective alternative to medical management or myocardial revascularization surgery, or both, in selected patients with obstructive coronary artery disease. The demonstrated safety and efficacy of angioplasty in patients with one or more isolated proximal coronary stenoses (2) allowed evaluation of this procedure in patients with extensive coronary artery disease (3-12). This study examines the short- and long-term follow-up of patients who underwent multiple lesion angioplasty.

Methods

Study patients (Table 1). The data are derived from 428 consecutive patients who underwent multiple lesion

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angioplasty between February 1979 and April 1986 (86 months) at our institution. All data were collected in a prospective manner in all patients undergoing multiple vessel angioplasty, including those with left main coronary artery disease (with or without prior bypass surgery), multiple prior bypass operations, cardiogenic shock or severe concomitant medical illness. The patients either had significant angina pectoris or had no or minimal angina (13) with significant documented myocardial ischemia. Their clinical characteristics are listed in Table 1. Sixteen of the patients underwent angioplasty of different vessels during the same hospitalization (staged procedure).

The population studied represents the personal experience of all consecutive cases performed by the senior author (G.D.), and does not represent the experience of all physicians performing angioplasty at St. Luke's Hospital. The data represent 42% of all cases performed during the same time period. The proportion of cases in which multilesion angioplasty was performed increased over the years as more experience was gathered and better equipment became available.

Anatomic factors. The patient's coronary anatomy (that is, the site of the stenosis or stenoses determined by the

Table 1. Characteristics of 428 Patients Undergoing Multiple Lesion Angioplasty

Patients*	428
Men	333 (78%)
Women	95 (22%)
Age (yr)	58.8
Extent of coronary disease	
Single vessel	69 (16%)
Multivessel	359 (84%)
Left ventricular ejection fraction \leq 35%	22 (5%)
Prior bypass surgery	115 (27%)
Anginal class†	
Class 0 (no angina)	63 (15%)
Class I	52 (12%)
Class II	150 (35%)
Class III	103 (24%)
Class IV	61 (14%)
Prior myocardial infarction (documented)	201 (47%)
Diabetes mellitus	57 (13%)
Hypertension	176 (41%)
Prior stroke	12 (2.8%)
Chronic renal failure	7 (1.6%)
Chronic obstructive lung disease	12 (2.8%)

*Sixteen patients underwent two procedures during the same hospitalization to achieve the multiple dilations; †Canadian Cardiovascular Society classification.

coronary cinearteriograms) was the primary determinant of whether angioplasty could be attempted. The definitions of single vessel disease (2), multivessel disease (4), lesion significance (2), techniques (2,4,14) and complications (14-16) have been reported.

In patients with multiple lesion angioplasty, the significant culprit lesion (or lesions) was considered to be accessible to the angioplasty catheter. Selected individuals underwent angioplasty of multiple lesions despite the presence of significant disease in other coronary vessels. These latter diseased vessels were not dilated because they were either occluded or of such small caliber or poor condition (diffusely diseased, that is, on cineangiography, the vessel appeared to be small, the luminal wall appeared to be irregular with multiple noncritical narrowings or the vessel had a beaded appearance) that they were considered unsuitable for any intervention (either angioplasty or bypass surgery). In this group of patients, if the stenosis (or stenoses) considered critical (culprit lesion or lesions) was successfully dilated, the patient was considered to be amenable to medical management despite incomplete revascularization.

Lesion severity was estimated by visual assessment of the percent diameter stenosis obtained in multiple views before and after angioplasty. Hemodynamic assessment of lesion severity was ascertained by measurement of the mean transstenotic pressure gradient.

Patient selection. Selected patients (17%) preferentially underwent angioplasty because they were anticipated to have a prohibitively high surgical risk (morbidity or mortality,

or both, in light of their medical history and clinical status, the presence of multiple prior operations [12%], a functioning internal mammary artery graft or grafts [1.8%], concomitant severe, debilitating medical conditions, a recent myocardial infarction complicated by severe congestive heart failure [1%], cardiogenic shock [1%] or severe left ventricular dysfunction [5%]).

These patients were preferentially referred for multiple lesion angioplasty because they were in clinically unstable condition after recent (days to weeks) bypass surgery, they were not a candidate for reoperation, there were no obvious vein graft donor sources, the significant lesion (or lesions) was in a vessel that had undergone endarterectomy, or it was hoped that the procedure would avoid the need for future valve replacement. These high risk patients agreed to attempted angioplasty with the realization that intraaortic balloon counterpulsation would be utilized if necessary, but that immediate myocardial revascularization would be avoided or not performed under any circumstance.

Technical considerations and approach. Each patient was maintained on an antiplatelet aggregation regimen of aspirin (325 mg/day) and dipyridamole (150 mg/day) for 1 or 2 days before and indefinitely after the procedure. Treatment with a calcium channel antagonist (nifedipine, 30 mg, or diltiazem, 120 mg, daily) was initiated the day before and empirically continued for 1 week after angioplasty unless clinically required longer. All patients received heparin (10,000 to 15,000 IU), nitroglycerin ointment and sublingual nitroglycerin at the beginning of the procedure. Intracoronary nitroglycerin was rarely utilized. The cardiovascular surgical team was aware of all patients; however, since 1982, the operating theater has not been reserved for possible emergency use during the procedure itself.

In multiple lesion angioplasty the first dilation attempted was that of the stenosis considered critical (that is, the culprit lesion or the lesion that was the presumptive cause of the patient's problems). Only after successful dilation of the culprit lesion was angioplasty of additional stenoses of less importance attempted. However, when a severely diseased vessel supplied collateral flow to another diseased vessel, then the collateralized vessel was dilated initially to protect the collateral blood supply. Angioplasty of subsequent significant lesions of less critical importance was attempted only when the preceding critical lesions were satisfactorily dilated. If a problem arose during the procedure or the angiographic appearance of the dilation was not satisfactory, the procedure was terminated. The patient was observed in an intensive care setting and received intravenous heparin (1,000 IU/h) and intravenous nitroglycerin (15 to 20 μ g/min) for 8 to 12 hours. If indicated, another procedure was then scheduled. This approach was instituted to lessen the extent of myocardial ischemia should vessel occlusion occur.

Definitions. Multiple lesion angioplasty was defined as the dilation of two or more discrete lesions in varying com-

Table 2. Summary of 428 Multiple Lesion Angioplasty Procedures

Angioplasty attempts (no. of lesions)	1,047
No. of lesions attempted per patient	
2	74%
3	21%
4	<5%
5	<1%
Vessel dilated	
Left anterior descending coronary artery	446 (42%)
Left circumflex coronary artery	233 (22%)
Right coronary artery	258 (25%)
Left main coronary artery	10 (1%)
Vein graft	100 (10%)
Successes	
Successes/total lesions	985 of 1,047 (94%)
Successes/total patients	404 of 428 (94%)
In cases without prior bypass surgery	307 of 324 (95%)
In cases with prior bypass surgery	111 of 120 (93%)
In single vessel coronary disease	65 of 69 (94%)
In multivessel coronary disease	353 of 375 (94%)
Reasons for unsuccessful dilations	
Inability to cross the lesion with guide wire or dilation catheter	49
Lesion rigidity	6
Vessel dissection/occlusion before balloon inflation	5
Other	2

binations of two or more coronary vessels, vein grafts, internal mammary artery grafts or different segments of the same vessel. Multiple lesion angioplasty included the dilation of tandem (sequential) lesions in different segments of the same vessel (for example, proximal and distal segments of the left anterior descending coronary artery, proximal right coronary artery and distal posterior descending artery) when they were separated by an angiographically lesion-free segment.

A multiple dilation procedure was considered successful when all attempted dilations were successfully (a \geq 20%

reduction in percent diameter stenosis) or when only the culprit lesion (or lesions) was successfully dilated, and when these angiographically successful results were accompanied by a clinical improvement within 1 week of the procedure. The mean transstenotic pressure gradient was not measured in all lesions and, therefore, was not utilized within the definition of success. Clinical improvement (by two or more Canadian Cardiovascular Society functional classes) was evaluated by the patient's subjective assessment of anginal status or by noninvasive techniques, or both. An apparent symptom-related lesion recurrence was considered to be present when clinical improvement manifested after angioplasty began to deteriorate in association with angiographic evidence of restenosis of one or more lesions, disease progression or new lesion development.

The definitions of transmural myocardial infarction, coronary spasm, coronary occlusion and emergency bypass surgery were consistent with those utilized by the National Heart, Lung, and Blood Institute Percutaneous Transluminal Coronary Angioplasty Registry Manual (2).

Follow-up data. Follow-up data on all patients (with successful or unsuccessful angioplasty) were obtained by periodic (within 1 week, at 3 and 6 months and yearly) interviews conducted during office visits or by telephone calls or written questionnaires. These interviews provided information on the patient's vital status, anginal status, occurrence of a myocardial infarction, repeat hospitalization or the need for subsequent angioplasty or bypass surgery. A late death was defined as a death that occurred after hospital discharge. At a mean follow-up time of 28.3 ± 16 months, data regarding vital status and subsequent bypass surgery were obtained in 98% of patients; data on anginal status were obtained in 92%.

Statistical analysis. All data are presented as the mean value \pm 1 standard deviation. The chi-square test with Yates' correction was utilized to determine differences between groups in relation to long-term follow-up (univariate

Table 3. Coronary Vessel Combinations in Multiple Lesion Angioplasty

Vessels Attempted	Lesion Successes per Total Lesion Attempts	Case Successes per Total Cases
LAD + Diag	75 of 80 (94%)	38 of 40 (95%)
LAD + RCA	115 of 128 (90%)	60 of 64 (94%)
LAD + LCx	103 of 106 (97%)	48 of 53 (91%)
RCA + LCx	49 of 52 (94%)	25 of 26 (96%)
LMCA + RCA/LCA/SVG*	10 of 12 (83%)	5 of 6 (83%)
SVG + LCA/RCA/SVG†	72 of 88 (82%)	38 of 44 (86%)
>2 lesions dilated	266 of 272 (98%)	77 of 80 (96%)

*Left main coronary artery lesion and right coronary or left coronary or vein graft lesion; †Saphenous vein graft lesion and left coronary or right coronary or another vein graft lesion. Diag = diagonal branch; LAD = left anterior descending coronary artery; LCA = left coronary artery; LCx = left circumflex coronary artery; LMCA = left main coronary artery; RCA = right coronary artery; SVG = saphenous vein graft; more than two lesions dilated = lesions in different vessels or in conjunction with lesions in different segments of the same vessel, or both.

Table 4. Complications* Encountered During Multiple Lesion Angioplasty in 428 Patients

	No.	%
Transmural myocardial infarction	11	(2.5%)
Coronary spasm	26	(6.0%)
Coronary occlusion	16	(3.7%)
Mortality†	6	(1.4%)
Emergency bypass surgery	9	(2.1%)

*Complications listed were not mutually exclusive and multiple complications often were encountered in the same patient; 361 (84%) of the 428 patients had no complication and 17 patients (4.0%) experienced a significant complication. †All six deaths occurred in patients without prior coronary bypass surgery.

analysis). Variables included age, left ventricular function and history of prior bypass surgery. A probability (p) value of <0.05 was considered statistically significant. Life table analysis was performed according to previously published methods (17).

Results

Angioplasty procedure (Tables 2 and 3). An angiographic success was achieved in 94% of the 1,047 lesions, and clinical improvement occurred in 94% of the 428 patients. Mean percent stenosis diameter was reduced from 82 ± 13 to $17 \pm 21\%$ and mean transstenotic pressure gradient from 47 ± 18 to 7 ± 8 mm Hg before and after angioplasty. The final residual stenosis was <50% in 97% of lesions, and between 50 and 60% in 3% of lesions. The mean maximal balloon inflation pressure was 8.3 ± 1.5 bars for a mean time of 0.9 ± 0.2 minutes. The mean number of inflations per lesion was 3.2 ± 2.2 . Table 3 lists the combinations of dilations attempted, successful dilations and patient successes. No statistically significant differences were found in success rates among the vessels attempted (or different patient subgroups).

Complications (Table 4). A significant complication (death, emergency surgery or transmural myocardial infarction) occurred in 17 (4%) of the 428 patients. There were six in-hospital deaths (mortality rate 1.4%). None of

Table 5. Clinical Status ≥ 1 Year After Successful Multiple Lesion Coronary Angioplasty

Mean time from first angioplasty to last contact (mo) (for patients >1 yr after angioplasty)	28.3 \pm 16
Mean average time from last contact (mo)	6.2 \pm 6.7
Successful patient follow-up ≥ 1 year after angioplasty	92%
Patient data	
Total no. of patients	428
Patients <12 mo after angioplasty	113
Patients >12 mo with no follow-up of anginal status	25
Patients* >12 mo after successful angioplasty	250
Patients who underwent bypass surgery after successful first angioplasty	25
Patients excluded because of death or subsequent bypass surgery	40
Clinical patient data (>12 mo after successful angioplasty)	
Patients with angina reported at time of angioplasty	208 (83%)
Angina frequency at latest follow-up	
None	141 (68%)
1 time/wk	18
1 to 2 times/mo	39
Daily	6
No record†	2
Anginal status since angioplasty	
Less	173 (83%)
Worse	7
Same	10
No record	18
Patients with no angina reported at time of angioplasty	42 (17%)
Angina frequency at latest follow-up	
None	35 (83%)
1 time/wk	1
1 to 2 times/mo	6
Daily	0
No record	0
Late deaths	
Total number	14
Cardiac related	12

*Excludes patients who subsequently died or underwent bypass surgery during follow-up; †no record indicates that the patient is known to be alive, but failed or refused to answer questionnaire.

the six patients had had prior bypass surgery. All six patients had undergone apparently successful angioplasty (that is, the angioplasty was carried out without incident) and the postangioplasty cinearteriograms showed successful dilations. Five of the six patients who died had a coronary occlusion (four patients within 30 minutes of angioplasty, and one patient 6 hours after angioplasty). Three patients who died underwent emergency bypass surgery on the day that angioplasty had been performed. In each case, visual inspection of the heart revealed no gross evidence of coronary dissection, vessel rupture, epicardial hematoma or intracoronary thrombus. These findings coupled with the cinearteriograms, which showed no intimal tear or disruption, gave credence to the presumption that the coronary occlusion may have been the result of severe coronary spasm or an intramural hemorrhage.

The complications encountered were not mutually exclusive, with multiple complications occurring in the same patient. Three patients who died had evidence of an acute transmural myocardial infarction.

Follow-up (Table 5). There were 250 patients with successful angioplasty alive and without subsequent bypass surgery >12 months after their initial angioplasty procedure. Follow-up of patients who had angina at the time of angioplasty showed that 68% had no and 83% had less angina at the time of the last contact. There were 14 late deaths, of which 12 were ascribed (on the death certificate) to atherosclerotic heart disease.

A first apparently symptom-related lesion recurrence (Fig. 1) occurred at a mean time of 6.6 months in 106 patients (26%). A second angioplasty was attempted in 89 of these patients, and was successful in 81 (91%). It was unsuccessful in eight: one of these patients died, one underwent emergency surgery, five underwent elective surgery and one patient was medically treated. A second apparent symptom-related lesion recurrence occurred at a mean time of 11.3 months in 15 (19%) of the 81 patients who had undergone a second angioplasty. A third angioplasty was successful in 13 of these 15 patients; the remaining 2 patients underwent elective bypass surgery.

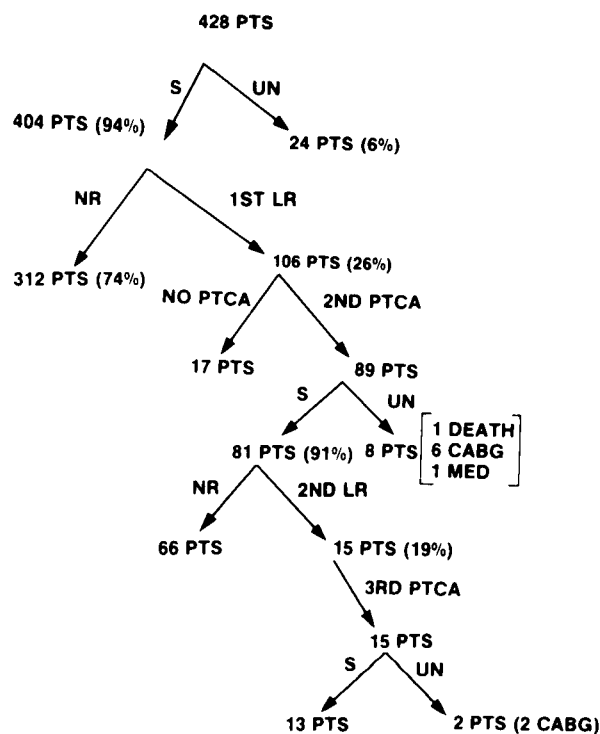
Life table analysis. The long-term survival of 404 patients after successful multiple lesion angioplasty was evaluated using the life table method (Fig. 2). The longest patient follow-up is 87 months. The sample size (n = 61) was sufficient at 51 months to show a 0.93 probability of survival (standard error = 0.019). Univariate analysis at 51 months showed survival to be adversely affected by the presence of prior surgery (no prior surgery 97% versus prior surgery 81%; $p < 0.05$). When death or postangioplasty surgery (Fig. 3) was used as the marker, at 51 months the probability was 88% that a patient would be alive and would not have undergone surgery. Univariate analysis showed that the probability of being alive and not having undergone surgery was adversely affected by the presence of prior

surgery (no prior surgery 94% versus prior surgery 72%; $p < 0.05$).

Discussion

Success rate. The data base consisted of data from all patients who underwent multiple lesion angioplasty between February 1979 and April 1986. The technique utilized to perform angioplasty before 1983 involved utilization of a fixed wire catheter system and, subsequent to 1983, the steerable, movable wire dilation catheter systems that have undergone considerable modification since that time. A comparison of the data from cases in which angioplasty was performed before 1983 (67 cases) with those in which it was performed after 1983 (361 cases) showed no statistically significant difference in patient clinical characteristics, mean number of lesions dilated per case, angiographic success rate, patient clinical success rate and complication rate. However, the lack of statistical differences does not take into account the technologic advances (that is, lower profile, higher pressure, more trackable dilation catheters coupled with the softer, steerable guide wire systems) that enabled more difficult, unusual and challenging cases to be successfully managed. These changes ultimately affected the

Figure 1. Results of follow-up of 428 patients (PTS) who underwent multiple lesion coronary angioplasty (PTCA). CABG = coronary artery bypass graft; LR = apparent symptom-related lesion recurrence; MED = medical treatment; NR = no apparent symptom-related lesion recurrence; S = successful; UN = unsuccessful.



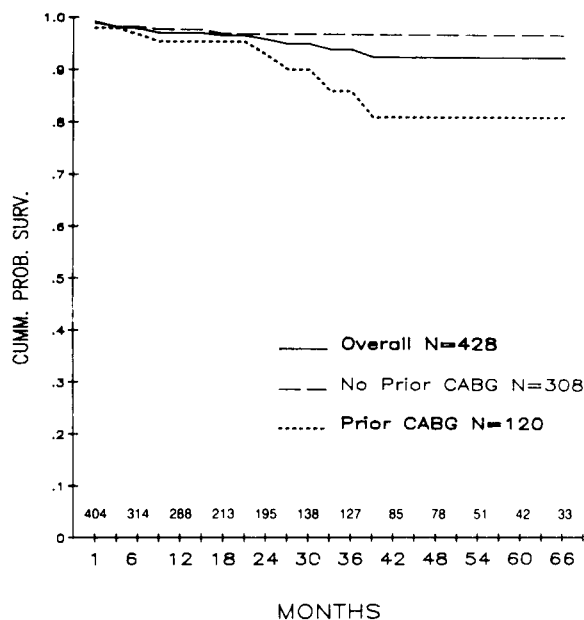


Figure 2. Life table actuarial analysis of mortality in 428 patients who underwent successful multiple lesion angioplasty. The numbers above the **horizontal line** represent the patients at risk at the end of each 6 month period. CABG = coronary artery bypass graft; CUMM. PROB. SURV. = cumulative probability of survival.

selection criteria, and this factor cannot be appreciated by looking only at the statistical analysis.

The success rates reported herein were similar to some published data (3-5,8) and higher than in the National Heart, Lung, and Blood Institute Percutaneous Transluminal Coronary Angioplasty Registry report (2). The 94% angiographic success rate produced a significant clinical improvement in 94% of the patients. This clinical success appeared to be related to the successful dilation of the culprit lesion (or lesions) and not to the presence of single or multivessel coronary disease or history of prior bypass surgery. The major complications encountered were comparable with those in published reports (12), and were not increased despite the increased number of patients with multivessel coronary artery disease (84% in our series) and the potentially high risk surgical patients (patients with severe left ventricular dysfunction [5.0%], prior stroke [2.7%], chronic renal failure [1.6%], severe chronic obstructive lung disease [2.7%] or prior coronary bypass surgery [27%]).

Complications of angioplasty procedure. The sudden loss or diminution of coronary blood flow resulting from coronary spasm, intraluminal thrombus, intramural hemorrhage or coronary dissection with a partially or totally obstructing intimal flap may result in profound left ventricular dysfunction, which may not be adequately or successfully managed by any form of intervention including emergency myocardial revascularization surgery (16). Presumably, patients with multivessel coronary artery disease who undergo

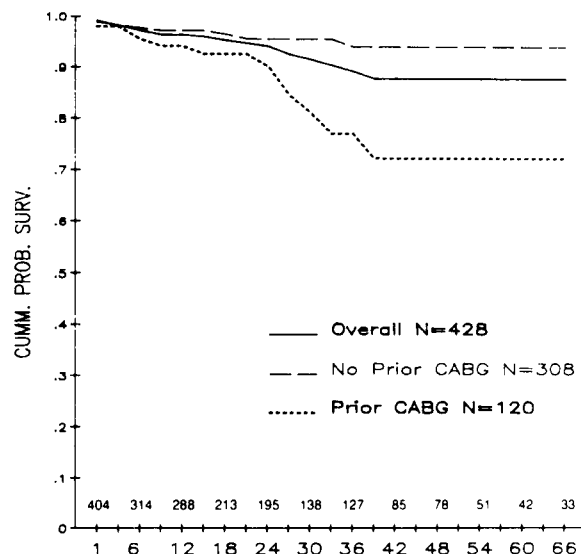
angioplasty with an increased potential for sudden simultaneous development of multiple areas of myocardial ischemia have less myocardial function reserve than that of patients with single vessel disease undergoing single vessel dilation.

From our viewpoint, the best therapeutic approach in such cases, after alerting the cardiovascular surgeon, was immediate percutaneous introduction of the intraaortic balloon pump and attempted recanalization of the occluded vessel (or vessels) with angioplasty or subsequent insertion of a coronary artery perfusion catheter beyond the occlusion into the distal vessel. This may permit stabilization of the patient's condition and either obviate the need for emergency surgery or enable the patient to reach the surgical suite in a more stable state.

If the planned angioplasty procedure did not go smoothly or the results of a particular dilation were not visually satisfactory, any contemplated additional angioplasty attempts were aborted. Subsequent dilations were not performed, no matter how "easy" they appeared to be.

Follow-up. At follow-up, 106 (26%) of the 404 patients who had undergone successful multivessel angioplasty had had an apparent symptom-related lesion recurrence. In almost all instances, the decision not to send the patient for repeat angioplasty was made by the referring physician or the patient, or both. Nevertheless, 82 (92%) of the 89 patients (81 with repeat angioplasty, 1 with medication) were managed without the need for subsequent surgery. Thus, 379 (94%) of the 404 patients who had undergone successful

Figure 3. Actuarial analysis of events (death or subsequent coronary bypass surgery) in patients who underwent multiple lesion angioplasty. The numbers above the **horizontal line** represent the patients at risk at the end of each 6 month period. Abbreviations as in Figure 2.



angioplasty continued to be managed without the need for subsequent surgery at a mean follow-up time of 28.3 ± 16 months.

Life table analysis of successful multiple lesion angioplasty in our patients showed a 93% probability of surviving 51 months ($n = 61$ patients) after the initial procedure. Survival was adversely affected by the presence of prior coronary bypass surgery. Similarly, the presence of prior surgery increased the likelihood of subsequently undergoing postangioplasty bypass surgery. Thus, patients with prior surgery who have progression of the atherosclerotic process (18) have a lower survival rate, despite successful angioplasty, but also an increased likelihood of undergoing repeat surgery rather than repeat angioplasty.

Conclusions. Patients with multiple coronary artery stenoses, the majority of whom had multivessel coronary artery disease, underwent multiple vessel angioplasty of varying combinations of arterial or vein graft stenoses. Angioplasty was successful in dilating 94% of the multiple lesions, and achieved a clinical improvement in 94% of the patients. The significant complications encountered included death (1.4%), transmural infarction (2.5%) and emergency surgery (2.1%). A sustained clinical improvement was obtained in 83% of patients undergoing angioplasty with or without the necessity for repeat angioplasty or medication. The anginal status in 83% of patients with angina before angioplasty was improved ≥ 12 months after angioplasty. Life table analysis showed a 93% survival at 51 months, which was adversely affected by the presence of prior bypass surgery. In addition, the probability was 88% that at 51 months, a patient would be alive and not have undergone subsequent bypass surgery. Further evaluation of this extended application of coronary angioplasty is necessary to establish its role in the therapy of extensive coronary artery disease.

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