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Clinical and Angiographic Implications of Coronary Stenting in Thrombus-Containing Lesions

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Objectives. **This study sought to determine the results of coronary stenting in thrombus-laden lesions.**

Background. **The angiographic evidence of intracoronary thrombus has classically been considered a formal contraindication to stent implantation. However, with increasing use of stenting, the indications for this technique have widened to include treatment of patients who have an acute coronary syndrome or lesions with adverse anatomic features.**

Methods. **We studied 86 consecutive patients (mean age ± SD 61 ± 11 years, 14 women) undergoing coronary stenting of a thrombus-containing lesion; the procedure was performed electively in 39% and after angioplasty failure in 61%. Sixty-four patients (75%) were treated for unstable angina, and 19 (22%) underwent the procedure during an acute myocardial infarction. A specific protocol that included clinical and late angiographic follow-up was used.**

Results. **Angiographic success was obtained in 83 patients (96%). Five patients (6%) died during the hospital stay despite angiographic success; four of these had cardiogenic shock, and one (1%) had subacute stent thrombosis. Non-Q wave myocardial infarction developed in five additional patients (6%), and four of these five had data consistent with distal embolization. Of the 78 patients discharged with angiographic success, 67 (86%) were event-free and clinically improved at last follow-up visit (12 ± 11 months). During the follow-up period, eight patients required repeat angioplasty, one patient required heart transplantation, and two patients died. Quantitative angiography demonstrated excellent angiographic results after stenting (minimal lumen diameter 0.31 ± 0.4 vs. 2.77 ± 0.6 mm). Late angiographic follow-up (5.5 ± 1 months) was obtained in 50 patients with 54 lesions (93% of eligible), revealing a minimal lumen diameter of 2.0 ± 1 mm and restenosis (lumen narrowing >50%) in 18 lesions (33%).**

Conclusions. **Coronary stenting constitutes an effective therapeutic strategy for patients with thrombus-containing lesions, either after failure of initial angioplasty or electively as the primary procedure. Coronary stenting in this adverse anatomic setting results in a high degree of angiographic success, a low incidence of subacute thrombosis and an acceptable restenosis rate.**

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Coronary stenting is a therapeutic strategy increasingly used during coronary interventions (1,2). The value of intracoronary stenting as the procedure of choice for the management of abrupt vessel closure and suboptimal angiographic results after coronary angioplasty has been well established (1–6). Recently, two major randomized trials comparing coronary stenting with conventional balloon angioplasty in selected patients with de novo lesions (7,8) demonstrated the efficacy of stent implantation in reducing the rate of restenosis. Coronary stents also appear to confer superior long-term clinical benefit in these patients (9). The expanded use of coronary stenting has been associated with the development of new strategies for optimal stent deployment (10) and it has been bolstered by recent data (11,12) demonstrating the excellent outcome of patients undergoing this procedure without anticoagulation. Nevertheless, uncertainties remain with regard to the use of these metallic prostheses in certain clinical and anatomic situations. Although conventional guidelines (2,13) consider thrombus-containing lesions an absolute contraindication for coronary stenting, this technique has been used with favorable results in patients with an acute coronary syndrome (14–20) in whom the underlying pathologic substrate frequently includes intracoronary thrombi (21–23). In addition, preliminary data (24–26) suggest the possibility of successful stent deployment in the presence of angiographically visible thrombus. However, procedural results and long-term clinical and angiographic implications of coronary stenting in this setting have not been

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Abbreviations and Acronyms

CK = creatine kinase
ECG = electrocardiogram, electrocardiographic
TIMI = Thrombolysis in Myocardial Infarction

established. To address this issue we analyzed the clinical and angiographic results of patients undergoing coronary stenting in lesions with angiographic evidence of intracoronary thrombus.

Methods

Patient group. From March 1990 to April 1996, 659 consecutive patients were treated with intracoronary stenting (742 lesions, 831 stents) at our institution. Of these, 86 patients (13%) underwent stent implantation in a thrombus-containing lesion (88 vessels, 92 lesions), and they comprise the study group. All patients undergoing coronary stenting in our hospital are included in a prospective protocol including close clinical follow-up (in a dedicated outpatient clinic) and systematic late angiography. Procedural and angiographic data were obtained from our coronary angioplasty data base and by careful review of the hospital records and cine films.

Procedure and protocol. The protocol of coronary angioplasty and the technique of coronary stenting in our institution have been described elsewhere (6,27). Balloon catheters and the stent type were selected at the discretion of the primary operator. Small vessels (diameter <2.5 mm on visual estimation) and those with severe proximal tortuosities or with diffuse disease were not considered suitable for coronary stenting. A total of 116 stents were used to treat 92 thrombus-containing lesions in these 86 patients. Several types of stents were used in this study (Palmaz-Schatz [Johnson and Johnson Interventional Systems, n = 71], Gianturco-Roubin Flex-stent [Cook, n = 21], Wallstent [Schneider, Switzerland, n = 11], NIR stent [Boston Scientific, n = 6], Cordis stent ([n = 3] and other types [n = 4]). Stenting for thrombus-containing lesions was indicated either electively, as the primary selected therapy, or nonelectively, after unsuccessful angioplasty. Before nonelective coronary stenting, intracoronary nitroglycerin was administered to rule out vasospasm, and repeat balloon angioplasty was always attempted after dilation failure. Alternatively, elective coronary stenting was considered most commonly after dilation of total occlusions or when the lesion and the thrombotic material appeared to be easily covered by the selected stent. Before elective coronary stenting, the lesion was predilated. In patients in whom a large amount of thrombotic material was suspected, a significantly undersized balloon was used. This strategy was selected to facilitate subsequent advancement of the balloon-stent assembly without increasing the risks of distal embolization. Special care was taken during elective stent deployment to cover both the site of the stenosis and the intraluminal filling defect. In patients in whom these sites were slightly separated, the stent was located at the site showing the most significant narrowing after predilation or, alternatively, multiple stents were used. In this cohort of patients, intravascular ultrasound studies were not routinely performed during coronary stenting.

The stenting protocol was modified in two important aspects over the study period. Beginning in 1994, relatively high pressure (≥10 atm) balloon inflations, with noncompliant balloons, were routinely used. This change was coincident with the substitution of a combination of antiplatelet agents for the classic anticoagulation regimen. Thus, the initial 25 patients (29%) received standard anticoagulation with intravenous heparin, dextran, aspirin and dypiridamole. In these patients the heparin infusion was continued until a stable degree of oral anticoagulation (international normalized ratio ≥3) was achieved. The remaining 61 patients (71%) did not receive oral anticoagulation and were treated with heparin for 24 to 48 h and a combination of aspirin (250 mg daily) and ticlopidine (250 mg daily) after hospital discharge. Nitrates and calcium channel blocking agents were recommended for 6 months.

Angiographic analysis. Angiographic data were prospectively evaluated by two investigators who did not know the results of coronary stenting. Lesion characteristics were established after the administration of 0.2 mg of intracoronary nitroglycerin by qualitative evaluation of each lesion in different projections (28). In this study, two previously validated definitions (23,29,30) were used for thrombus. First, thrombus was defined as discrete intraluminal filling defects outlined by contrast material in at least two orthogonal projections. Second, in the presence of a totally occluded vessel, thrombus was considered when a readily identifiable convex edge with angiographic staining or haziness could be documented at the site of the occlusion (Fig. 1 and 2). All films were reviewed to verify that an angiographic image strongly suggestive of thrombus was present. Special care was taken to classify anterograde coronary flow before and after the procedure. Vessels with Thrombolysis in Myocardial Infarction (TIMI) grade 0 or 1 flow (31), were classified as occluded. The modified American College of Cardiology/American Heart Association (ACC/AHA) criteria were used to classify the target lesion (32). Quantitative angiographic analysis was carried out off-line without knowledge of the patient's clinical or procedural characteristics by an experienced operator who used a commercially available, previously validated, interactive automatic edge-detection computer program (ARTREK, Quantim 2000I, QCS, Inc, ImageComm Systems, Inc.) (33,34). End-diastolic frames displaying the most severe lumen narrowing, without foreshortening of the selected coronary segment, were selected from among multiple projections. Frames with significant overlapping of the study vessel with other branches and those in which the region of interest was not relatively centered were rejected. The view showing the smallest minimal lumen diameter was selected as the working projection. In our experience this system provides good intraobserver variability in absolute measurements (6). The distal end of the guiding catheter was used for absolute calibration in each selected

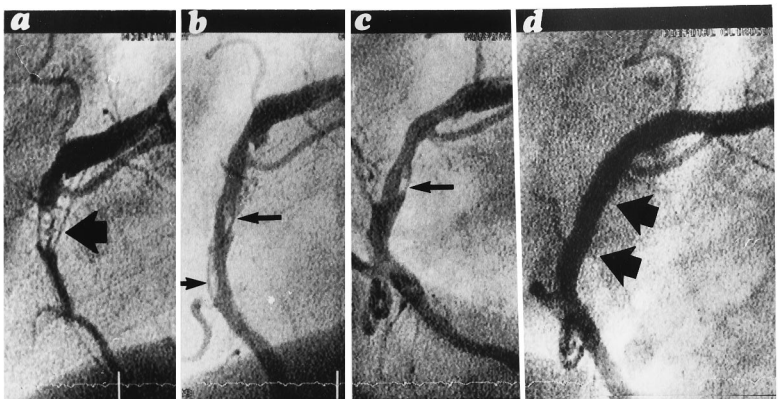
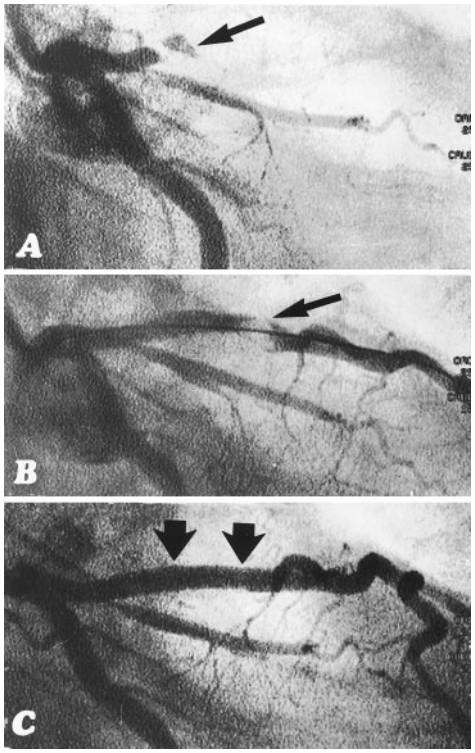


Figure 1. a, Coronary angiogram revealing a complex, severe stenosis with an intraluminal filling defect **(arrow)** in the proximal right coronary artery. **b** and **c,** After conventional balloon coronary angioplasty and despite multiple balloon inflations, a suboptimal outcome was obtained as the result of significant residual filling defects **(small arrows)**. **d,** Subsequent stent implantation provided an excellent angiographic result and no visible residual thrombus **(arrows)**.

projection. Quantitative analysis of the follow-up angiogram was performed, again after the administration of intracoronary nitroglycerin, by using matching views. The reference segment was user-defined before intervention and the same reference segment was selected after intervention and at follow-up. A binary definition for restenosis (stenosis >50% at follow-up angiography) was used.

Figure 2. A, Complete occlusion of the left anterior descending coronary artery in a patient presenting with an acute anterior myocardial infarction. Staining of contrast material and haziness **(arrow)** were visualized at the site of occlusion after intracoronary nitroglycerin. **B,** After several balloon inflations the artery opened, and TIMI grade 2 coronary flow was obtained, but a large filling defect **(arrow)** persisted at the previously occluded site. **C,** Stent implantation was required to obtain a satisfactory angiographic result **(arrows)** and brisk antegrade coronary flow.



Definitions and follow-up. Angiographic success was defined as successful stent deployment with a residual stenosis <50% by quantitative angiography. Procedural success was defined as angiographic success in the absence of major in-hospital complications (including death, myocardial infarction or the need for coronary bypass surgery) (6,27). Complete blood counts and serial (every 8 h) enzyme measurements and 12-lead electrocardiograms (ECGs) were obtained for 2 days after stenting in all patients (6,27). The creatine kinase (CK) MB isoenzyme measurement was routinely performed when an increase in CK concentration was documented. Coronary angiography was repeated in patients with suspected myocardial ischemia to rule out subacute stent thrombosis. During follow-up, clinical events were defined as death, myocardial infarction or requirement for revascularization (either aortocoronary bypass surgery or angioplasty), whichever occurred first. Deaths were considered to be cardiac unless a noncardiac cause could be established. Most patients were followed up (1 month, 6 months and yearly thereafter) in an outpatient clinic specifically dedicated to patients undergoing interventional procedures. Telephone contact with the patient or referring physicians was also used when needed for follow-up purposes. All patients gave informed consent to the procedure. In addition, all patients agreed to return for routine late clinical and angiographic follow-up 6 months after stent implantation. Because some patients included in the study were at high risk (such as those in cardiogenic shock), procedure-related events and the events occurring after discharge were studied separately to better evaluate the long-term implications of stent implantation in thrombus-containing lesions.

Statistical analysis. All continuous variables were expressed as mean value ± SD. Continuous variables were compared with a two-tailed Student *t* test or by using repeated measures analysis of variance with comparison of data among the different groups, as required. Categoric data were presented as absolute value and percent. Nonparametric tests (chi-square and Fisher exact test) were used for discrete variables. Rates of event-free survival were studied with Kaplan-Meier analysis. A p value <0.05 was considered statistically significant.

Table 1. Baseline Clinical Characteristics of 86 Study Patients

Age (yr)	61 ± 11
Female	14 (16%)
Clinical presentation	
Unstable angina	64 (75%)
Stable angina	3 (3%)
Acute MI	19 (22%)
Anterior	10
Inferior	9
Cardiogenic shock	6 (7%)
Previous intravenous thrombolysis	17 (19%)
Prior MI	51 (59%)
Prior CABG surgery	10 (11%)

Data are presented as mean value ± SD or number (%) of patients. CABG = coronary artery bypass graft; MI = myocardial infarction.

Results

Clinical data of the 86 study patients are listed in Table 1. The mean age of the group was 61 ± 11 years (range 37 to 80) and 64 patients (75%) were treated for unstable angina. In 19 patients (22%) the angioplasty procedure was performed in the acute phase of a myocardial infarction (direct angioplasty in 16, rescue angioplasty in 3). Peak CK in these patients with infarction was 1,813 ± 1,212 U/liter. Before angioplasty 80 patients (93%) were receiving antiplatelet agents, 78 (90%) nitrates, 75 (87%) calcium antagonist or beta-adrenergic blocking agents (24 received triple therapy); 49 patients (57%) were fully anticoagulated with heparin. Baseline angiographic characteristics (88 vessels, 92 lesions) are presented in Table 2. Most stents were implanted in the left anterior descending or right coronary artery. Ten patients had bulky complex lesions, with clear filling defects, located on saphenous vein grafts (mean graft age 10.3 ± 2.5 years). Of the 92 thrombus-containing lesions, 59 (64%) had the appearance of intraluminal filling defects, whereas the remaining 33 were occluded vessels fulfilling the previously defined criteria for thrombus. Of these occluded vessels, 17 were in patients with acute myocardial infarction; in the remaining 16 occluded vessels, the clinically estimated occlusion time was 30 ± 14 days (4 patients had chronic [>3 months] occlusions).

Table 2. Baseline Angiographic Findings (88 vessels, 92 lesions)

LVEF (%)*	61 ± 16
Multivessel disease	48 (56%)
Collateral circulation	16 (19%)
Target vessel	
LMCA	4 (4%)
LAD	34 (39%)
RCA	35 (40%)
LCx	5 (6%)
SVG	10 (11%)
TIMI flow grade 0–1	33 (36%)
Calcified lesion	14 (15%)
ACC/AHA classification	
B_1	3 (3%)
B_2	57 (62%)
C	32 (35%)

*Measurement not performed in 19 patients in unstable clinical condition. Data are expressed as mean value ± SD or number (%) of patients. ACC/AHA = American College of Cardiology/American Heart Association classification; LAD = left anterior descending coronary artery; LCx = left circumflex coronary artery; LMCA = left main coronary artery; LVEF = left ventricular ejection fraction; RCA = right coronary artery; SVG = saphenous vein graft; TIMI = Thrombolysis in Myocardial Infarction trial coronary flow.

Table 3. Procedural Data for 86 Study Patients

Indications for stenting	
Elective (planned)	36 (39%)
Angioplasty failure	56 (61%)
Suboptimal result	29 (32%)
Threatened closure (thrombus/dissection)	27 (29%)
Largest balloon diameter (mm)	3.5 ± 0.4
Maximal pressure (atm)	11.8 ± 4
Dilation of other lesions	8 (14%)
Multiple stenting at the target lesion	17 (18%)
Average no. of stents/patient	1.3
TIMI flow after stenting	
0–1	3 (3%)
2	4 (4%)
3	85 (93%)

Data presented are mean value ± SD or number (%) of patients. TIMI = Thrombolysis in Myocardial Infarction trial coronary flow grade.

The most relevant procedural data are presented in Table 3. In 30 patients (35%) the angioplasty procedure was considered an emergency, and in 39 (45%) it was performed during diagnostic coronary angiography. Intraaortic balloon pumping was required in 6 patients. In 62 lesions (67%) high pressure (>10 atm) inflations were used. In most patients a single stent was used at the target lesion. However, multiple stenting was required in 17 lesions (four stents in 3 lesions, three stents in 1 lesion, two stents in 13 lesions). Elective stenting was used in 36 lesions (39%). However, most patients in this series underwent coronary stenting after unsuccessful angioplasty. Atherectomy was initially performed in four of these patients (directional atherectomy in two extraction atherectomy in two), but in the remaining patients conventional balloon angioplasty was used. Before nonelective stenting was performed, repeat dilations (mean number 7 ± 4) and prolonged balloon inflations (total inflation time 440 ± 290 s) were unsuccessful in providing a satisfactory angiographic result. Intracoronary urokinase was administered in three patients before stent implantation.

Procedural and in-hospital results. Of the 86 study patients, 83 (96%) had successful stent implantation. In three patients with occluded vessels after initial balloon angioplasty, the stent was deployed at the target site but was unsuccessful in opening up the vessel (despite the use of two stents in one patient and intracoronary urokinase in two patients). In all three patients large residual filling defects could be appreciated at some point within the stent or its boundaries during the procedure. These three patients with dilation failure had a nonfatal Q wave myocardial infarction. Despite initial angiographic success five additional patients (6%) had a non-Q wave

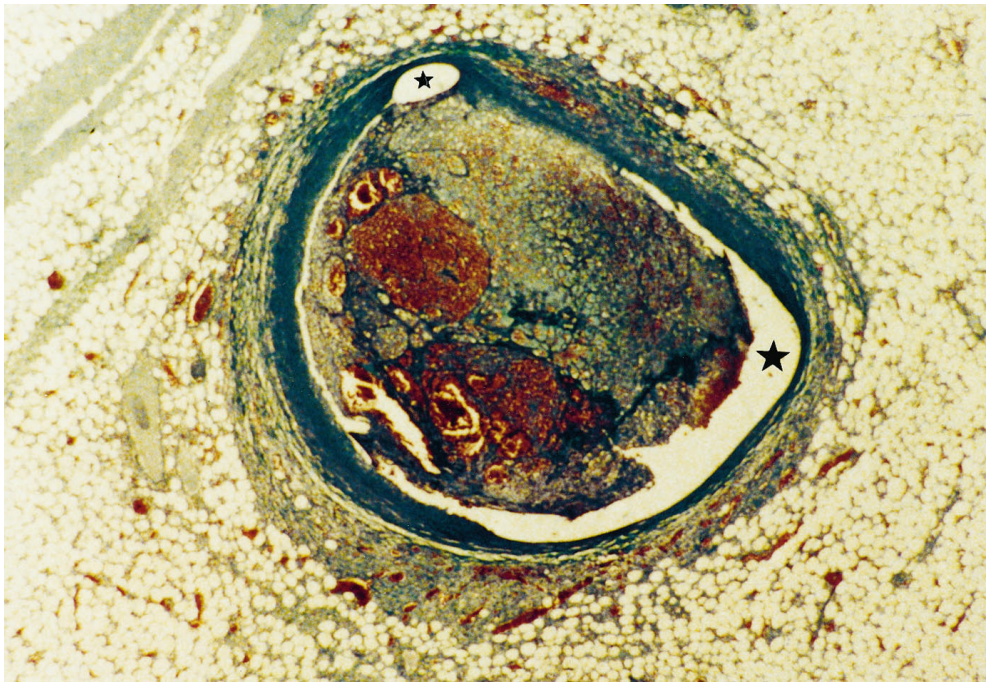


Figure 3. Pathologic findings in the patient who experienced subacute stent thrombosis and died. A large thrombus completely occluding the coronary lumen is visualized. Histologic analysis revealed different stages of thrombus organization at various levels. The circular and semilunar empty spaces (**stars**) represent the fingerprints of the removed Gianturco-Roubin stent.

myocardial infarction after the procedure with mild enzyme changes (mean CK peak = 466 ± 52 U/liter). In four of them a slow flow (TIMI grade 2), highly suggestive of distal embolization was documented during stenting (in one patient before and in three patients during stent deployment). In the remaining patient the non-Q wave myocardial infarction was the result of a dilation at a different site. Angiographic data consistent with distal embolization into a small branch were documented in two additional patients who remained asymptomatic and showed no enzyme or ECG changes. Five patients (6%) died during the hospital stay despite initial angiographic success. Three patients, who had cardiogenic shock during a myocardial infarction, eventually died from multiorgan failure (two patients within 24 h, one patient 2 weeks later). Another patient, awaiting cardiac surgery for severe left main coronary artery stenosis, suddenly collapsed in the intensive care unit with electromechanical dissociation. After 30 min of unsuccessful cardiopulmonary resuscitation maneuvers he was brought to the catheterization laboratory where the left main stem was found occluded. An excellent angiographic result was obtained after stent implantation. Although the patient briefly regained hemodynamic stability and an intraaortic balloon pump was implanted, he died 4 h later in cardiogenic shock. None of these four patients presented ECG changes suggestive of subacute stent thrombosis. The last patient who died had successful placement of two stents in the left anterior descending coronary artery during a primary angioplasty of a large anterior myocardial infarction. Subsequently, he remained asymptomatic, but 8 days later he died from refractory ventricular arrhythmias. Autopsy examination (Fig. 3) disclosed a massive anterior myocardial infarction and thrombosis of the stents. No other patient in this series had clinical data suggestive of stent thrombosis. There were no referrals for coronary artery bypass grafting. Four patients (three receiving oral anticoagulation) required vascular surgery for hemorrhagic complications. No other events were documented during the hospital stay. Thus, angiographic success without complications was eventually obtained in 73 patients (85%). Procedural success was not related to the implantation strategy (Table 4).

Clinical follow-up. Clinical follow-up was obtained in the 78 patients who were discharged with angiographic success. At last clinical follow-up (mean 12 ± 11 months, range 1 to 67), 67 (86%) of these patients were event-free and clinically improved. Eight patients underwent repeat coronary angioplasty (four for restenosis, four for treatment at a different site) because of recurrence of symptoms (unstable angina in six non-Q wave myocardial infarction in two). One patient with extensive coronary artery disease and very poor left ventricular

Table 4. Procedural Success in the 92 Stented Lesions in Relation to Implantation Strategy

	Elective		High Pressure		Oral Anticoagulation	
	Yes	No	Yes	No	Yes	No
Success	30 (83%)	49 (87%)	54 (87%)	25 (83%)	24 (89%)	55 (84%)
Failure	6 (17%)	7 (13%)	8 (13%)	5 (17%)	3 (11%)	10 (16%)

Data presented are number (%) of lesions.

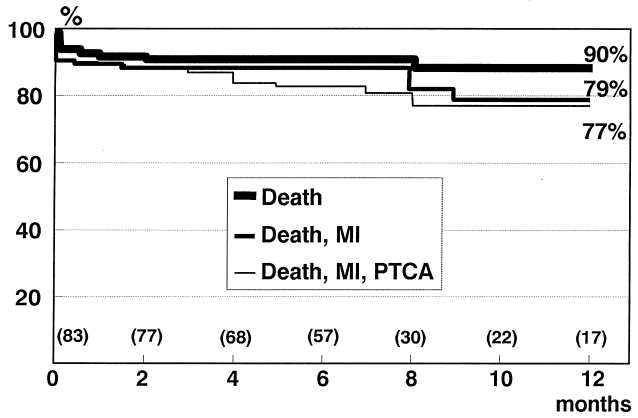


Figure 4. Kaplan-Meier life-table analysis depicting event-free survival for the 86 patients undergoing stent implantation in thrombus-containing lesions. **Numbers in parentheses** represent the number of patients at risk at each time interval. MI = myocardial infarction; PTCA = percutaneous transluminal coronary angioplasty.

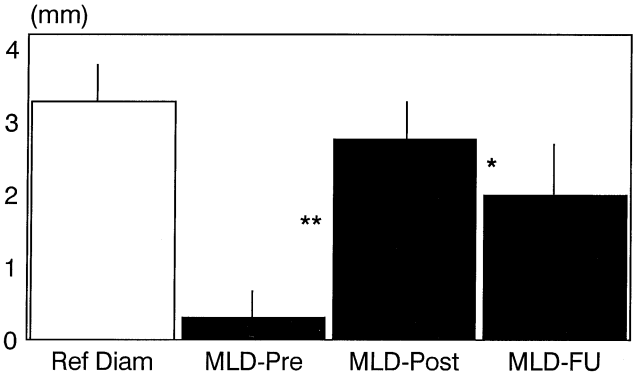


Figure 5. Bar graph showing coronary artery diameter of reference segment (Ref Diam **[open bar]**) and stented site (**solid bars**) as assessed by quantitative angiographic analysis. *$p < 0.05$, minimal lumen diameter after stenting (MLD-Post) versus after follow-up (MLD-FU). **$p < 0.01$, minimal lumen diameter before (MLD-Pre) versus after stenting and after follow-up.

function had successful orthotopic heart transplantation. Two patients died after a myocardial infarction during follow-up. Figure 4 shows the event-free survival, on actuarial analysis, of the 86 initial patients (including those who died from cardiogenic shock).

Angiographic follow-up. Late angiography was not available in one of the patients who died before 6 months and in the heart transplant recipient. Four patients refused repeat angiography; all of them were asymptomatic and had a negative exercise test result. Accordingly, late angiography (5.5 ± 1 months after stenting) was performed in 50 patients (54 lesions) (93%) of the 54 eligible patients (elapsed time from stenting >6 months). Figure 5 displays early and late results of quantitative angiography. Minimal lumen diameter was 0.3 ± 0.4 mm before dilation, 2.77 ± 0.6 mm after stenting and 2.0 ± 1 mm at follow-up. Restenosis, using the >50% lumen narrowing binary definition, was found in 18 lesions (33%). Twelve patients with restenosis were asymptomatic, whereas four had symptoms and required a new angioplasty. There was a trend to a lower restenosis rate for stents implanted electively (5 [23%] vs. 13 [39%], $p = 0.1$), but the use of high pressures or oral anticoagulation did not influence the restenosis rate.

Discussion

Theoretically, the implantation of inherently thrombogenic metallic prostheses in patients with thrombotic material at the lesion site may present a nidus for further clot propagation. Accordingly, the deployment of stents in thrombus-laden lesions has been avoided until recently (2,13). Nevertheless, striking advances in antithrombotic regimens and implantation techniques have resulted in a dramatic increase in the application of these devices with a concomitant reduction in associated complications (11,12). In fact, the use of intracoronary stents, either electively or after dilation failure, in patients with an acute ischemic syndrome has gained widespread clinical acceptance (14–18). In these patients pathologic, angiographic and angioscopic data (21–23) have demonstrated that intracoronary thrombus is frequently present in the underlying substrate. To our knowledge, however, the present investigation is the first systematic study assessing the results of coronary stenting in a large series of consecutive patients with thrombus-containing lesions. Our patients were a rather heterogeneous cohort, but all showed angiographic evidence of thrombus at the lesion site. A significant subset were at high risk (including patients with cardiogenic shock, left main coronary artery disease or rescue angioplasty), and 61% of them required coronary stenting after failure or complication of a previous angioplasty. Nevertheless, the clinical results obtained in most of these patients were highly satisfactory considering that four of the five hospital deaths occurred in patients presenting with cardiogenic shock (35).

The most noteworthy finding of our study was the excellent angiographic result obtained with stent implantation in thrombus-containing lesions. Moreover, the incidence of subacute stent thrombosis (1%) was much lower than expected. In addition, our protocol with systematic use of late angiography demonstrated that the restenosis rate of these patients was acceptable and within the range of previous studies that also used quantitative angiography (7,8). However, this restenosis rate is probably higher than the rate that can now be obtained in selected patients with optimal anatomy by using current techniques of stent deployment (36,37). All these findings suggest that coronary stenting constitutes an attractive coronary intervention in patients with thrombus-containing lesions provided that a good initial angiographic result is obtained. In some patients the angiographic image suggestive of thrombus is slightly displaced from the proximal part of the target lesion. In these patients efforts should be made to completely cover both structures with the stent. If ultimately this cannot be achieved and significant residual stenosis or filling defects persist, additional stent implantation should be considered.

Recently Kaul et al. (25) reported on Palmaz-Schatz stent implantation in 12 patients with lesions with angiographically visible thrombus. In that study, all procedures were successful without major complications or the development of subacute stent thrombosis. Our findings also confirm preliminary data from Grinstead et al. (24) and Romero et al. (26) suggesting that elective stent implantation or stent deployment after failure of conventional angioplasty provides good clinical and angiographic results in thrombus-laden lesions. In contrast, some previous studies (1,2,7,8,13) suggested that one of the most important angiographic characteristics associated with subacute stent thrombosis is the presence of a coronary thrombus before or after stent deployment. However, most of the latter studies were performed before the widespread use of recently developed techniques for optimal stent deployment and newer antithrombotic therapies, at a time when subacute stent thrombosis remained a relatively frequent complication (1–5,7,8). In addition, multiple adverse factors that usually coincide in patients with thrombus-containing lesions may explain the less favorable results. In fact, in a recent multicenter study focused on identifying predictors of major adverse events after coronary stenting (38), the presence of an angiographically obvious thrombus was not associated, by multivariate analysis, with an adverse outcome; only in those patients undergoing elective stenting did this factor appear to confer a worse prognosis. However, our findings suggest that *elective* coronary stenting may constitute a reasonable alternative for selected patients with thrombus-containing lesions. Another previous concern was that the immediate angiographic benefits of coronary stenting in lesions with thrombus might be overshadowed by a higher rate of subacute stent thrombosis or late restenosis. Neither of these were documented in the present study. Finally, our results demonstrate an excellent clinical prognosis for patients with successful stent implantation in this particular setting.

The exact mechanisms leading to an excellent angiographic result after coronary stenting in a thrombus-containing lesion remain undetermined and are beyond the scope of the present study. However, our data suggest that the potentially thrombogenic stimulus of stents implanted in lesions with thrombus is counterbalanced by the brisk anterograde coronary flow associated with a widely patent lumen and absence of residual stenosis. The specific changes in lesion geometry after stent implantation may also provide some advantages over balloon angioplasty in this particularly thrombogenic environment. In vitro studies (39) have demonstrated that a large lumen and unrestricted coronary flow are the major factors preventing clot progression. The scaffolding properties of stents physically contain the thrombotic material, preventing its protrusion into the flowing blood, which could induce turbulence and increase thrombogenicity. Therefore, it is tempting to speculate that the residual thrombus anchored within the stent struts progressively disappears as the result of endogenous fibrinolysis or, alternatively, becomes organized and incorporated into the vessel wall. Minor distal thrombus embolization cannot be completely excluded (either during initial dilation or during stent deployment), but significant "late" embolization appears to be rare. Finally, the role of adjunctive thrombolysis at the time of coronary stenting in thrombus-containing lesions remains unsettled. However, the negative results of the Thrombolysis and Angioplasty in Unstable Angina (TAUSA) trial (40), where the addition of thrombolytic agents before conventional dilation of complex lesions increased the rate of adverse events, together with the good angiographic results obtained with conventional treatment in our series, do not appear to justify the potential risk associated with this therapy.

Previous studies of stenting in a thrombotic milieu. Several studies (14–17) have demonstrated that the indications for coronary stenting can be expanded and that the technique can provide excellent angiographic results even in nonideal situations. Recently, it was demonstrated (14) that immediate results and complications of stenting were similar in patients with stable and unstable coronary syndromes. In addition, direct coronary angioplasty has been increasingly used for mechanical revascularization in patients presenting with acute myocardial infarction (41,42), and several studies (15–17, 41,42) have demonstrated that selected patients with acute myocardial infarction and a failed balloon angioplasty may benefit from scaffolding of the coronary wall. García-Cantu et al. (17) reported clinical success in 33 of 35 patients undergoing coronary stenting as an adjunct to primary or rescue angioplasty, within the 1st 24 h of acute myocardial infarction. Although one third of the patients had angiographic evidence of thrombus after the initial angioplasty, no patient showed stent occlusion at repeat coronary angiography routinely performed before hospital discharge (17). In contrast, the role of intracoronary stenting in totally occluded vessels (another well demonstrated thrombotic milieu) (22,23) remains to be elucidated (18–20). The same factors responsible for the high incidence of acute vessel closure or restenosis after coronary angioplasty in occluded coronary arteries may play a role after stenting (23). However, several investigators (18,19) have suggested that, in selected patients with occluded vessels, stent placement is not associated with a higher risk of subacute stent thrombosis and may be beneficial. Furthermore, preliminary data from prospective randomized trials (20) comparing conventional angioplasty with elective coronary stenting suggest that stent implantation in occluded vessels is associated with a significant long-term angiographic benefit.

Study limitations. Several potential limitations of this study must be considered. First, our study included a consecutive series of patients presenting with various clinical indications. This rather heterogeneous patient group constitutes a study limitation but also provides a more comprehensive picture of the real world of patients with an acute coronary syndrome and thrombus-laden lesions undergoing coronary intervention. Second, the inclusion of high risk patients, such as those in cardiogenic shock, explains a relatively high hospital mortality rate as the result of progressive hemodynamic deterioration. Accordingly, this should not be used to argue against the benefits of coronary stenting in lesions with thrombus. In addition, our definition of procedural success was rather strict

and patients with angiographic success but presenting an asymptomatic and small rise in CK levels were considered to have had a procedural failure. Third, the stenting protocol was changed during the study period. However, the use of high inflation pressures and the abandonment of oral anticoagulation reflect current trends in clinical practice and were not related to procedural results or the restenosis rate in our series.

Conclusions and clinical implications. Our findings suggest that coronary stenting constitutes a safe and effective strategy for selected patients with thrombus-containing lesions and can provide satisfactory initial and long-term angiographic results in this particularly adverse anatomic setting. At present it is reasonable to use coronary stents for thrombus-containing lesions that are resistant or became complicated after treatment with conventional balloon angioplasty. Most patients with these lesions will obtain long-term clinical and angiographic benefit. Moreover, our data raise the possibility that elective coronary stenting might be used as the treatment of choice in selected patients with lesions bearing angiographic evidence of intracoronary thrombus. Recent data (43) have demonstrated that thrombus-containing lesions not only have a lower initial success rate after balloon dilation but also have a much higher restenosis rate. Because coronary stenting can achieve a better initial angiographic result, has a low incidence of subacute closure and an acceptable restenosis rate, this strategy may prove superior to conventional balloon angioplasty in these patients. Finally, no patient in the present study was treated with platelet glycoprotein IIb/IIIa receptor blocking drugs, which appear to be highly effective during coronary interventions in high risk patients with unstable angina (44,45). The potential additional benefit of this therapy during coronary stenting for thrombus-laden lesions warrants prospective evaluation.

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