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Elective PTCA of totally occluded coronary arteries not associated with acute myocardial infarction; short-term and long-term results

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KEY WORDS: Percutaneous transluminal coronary angioplasty, occluded coronary arteries, long-term follow-up, angiography, ventriculography.

Of 652 consecutive patients referred for coronary angioplasty between September 1980 and March 1984, 49 patients presented with total or functional 'occlusion' of the involved vessel. Total vessel occlusion was defined as absent anterograde filling beyond the lesion. Functional occlusion was defined as faint, late anterograde opacification of the distal segment in the absence of a discernible luminal continuity. In 39 patients, the total or functional occlusion represented a progression, without acute myocardial infarction, of a previously diagnosed stenotic lesion.

The maximal potential duration of occlusion was estimated to be 4 weeks or less in 21 patients, more than 4 to 8 weeks in 12, and more than 8 weeks in 16. Dilation of the occluded artery was attempted in the left anterior descending coronary artery in 30 patients, in the right coronary artery in 8, in the circumflex coronary in 7 and in 4 jumpgrafts. For the whole group, angioplasty was successful in 28 patients (57%). The primary success rate with the functionally occluded vessel (81%) was significantly higher than with the total occlusion (45%). In 33 patients with an occlusion estimated to be of 8 weeks or less, angioplasty was successful in 65%. In the 16 patients with an occlusion estimated to be of more than 8 weeks duration, dilation was successful in 44%. Of the 21 patients in whom angioplasty was unsuccessful, 11 required surgery (1 urgent with persistent pain and ST elevation and 10 elective). Ten patients were maintained on medical treatment. Of the 28 patients in whom angioplasty was successful, 10 patients had recurrence of symptoms during follow-up (1–42 months). Four were kept on medical therapy, three required bypass surgery and three underwent repeat percutaneous transluminal coronary angioplasty (PTCA).

After primary success, late angiographic studies obtained in 20 out of 28 patients showed reocclusion in 8.

In conclusion, elective PTCA of totally occluded coronary arteries is feasible but the primary success rate is lower (57%) than that associated with conventional lesions. The long-term clinical results following successful angioplasty are satisfactory (64%), but the incidence of reocclusion is higher (40%).

Introduction

Coronary angioplasty was introduced in 1978 by Grüntzig[1] as a non-operative technique for treatment of single, discrete and proximal coronary artery stenosis in patients with symptomatic ischaemic heart disease.

Today, after six years of experience with percutaneous transluminal coronary angioplasty (PTCA), these indications have been extended to include distal stenotic lesions in up to three vessels requiring multiple dilations[2]. Patients with unstable angina[3] and impaired ventricular function[4] have been included. Furthermore, PTCA is performed in stenotic bypass grafts[5] and for residual stenosis after fibrinolytic recanalization[6] during acute or impending myocardial infarction.

In 1982, we reported[7] that a fixed guide wire angioplasty catheter could be used to dilate totally

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occluded coronary arteries and in the same year, Savage *et al.*[8] reported 39 patients who had progressed to total or functional total occlusion between their diagnostic angiogram and scheduled dilatation and in whom angioplasty was attempted despite arterial occlusion.

Recently, Dervan *et al.*[9] emphasized the advantages of a movable guide wire system for performing coronary angioplasty of functionally occluded vessels and Holmes *et al.*[10] demonstrated that the duration of occlusion is an important factor determining the primary success rate. This study describes our experience in 49 patients with attention to the short and long term clinical results.

Methods

STUDY POPULATION

Of 652 consecutive patients referred for coronary angioplasty at the Thoraxcenter and at the University Hospital of Gent between September 1980 and March 1984, 49 patients presented with total or functional 'occlusion' of the involved vessel. According to the criteria proposed by Dervan *et al.*[9], total vessel occlusion was defined as absent anterograde filling beyond the lesion whereas functional occlusion was defined as faint, late anterograde opacification of the distal segment in the absence of a discernible luminal continuity.

The study population consisted of 44 males and 5 females. The mean age was 54 ± 11 years. Eight patients had a previously documented transmural myocardial infarction in the region of distribution of the occluded vessel.

At the time of the attempted angioplasty no patient had a documented evolving transmural infarction and none of them had received fibrinolytic therapy. All patients had prior recurrent angina pectoris (mean duration 21 m; range 0·5–156 m) unresponsive to drug therapy. 16 were in New York Heart Association functional class IV, 22 were in class III and 11 were in class II. A retrospective review of the clinical records in the study group showed that all but 4 patients had experienced recent exacerbation of their anginal symptoms. In the 39 patients with recent coronary occlusion, as evidenced by sequential angiograms, no patient had overt clinical or electrocardiographic signs of recently sustained acute myocardial infarction. One patient with right coronary artery involvement was suspected of having developed a silent myocardial infarction, since a new Q wave appeared in the inferior leads of his electrocardiogram.

ANGIOGRAPHIC FINDINGS PRIOR TO PTCA

Ten patients had a total occlusion at the time of the initial diagnostic studies which were performed a mean of 52 days (range 7–240) before attempted angioplasty (Fig. 1).

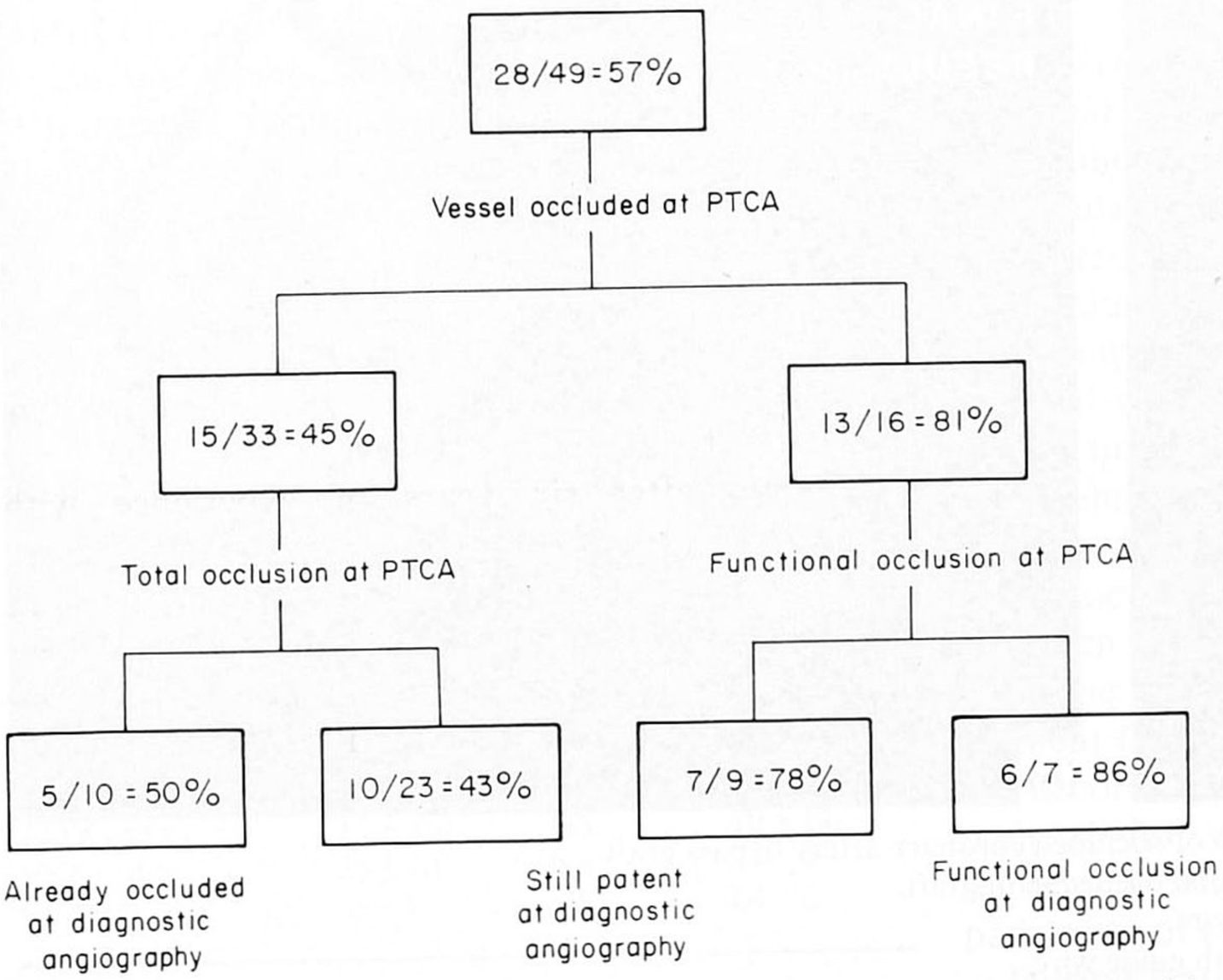

Figure 1 Primary success rate of angioplasty according to the angiographic finding at the time of the diagnostic angiography.

Thirty-two patients had a non-occluded discrete stenotic lesion at the time of the diagnostic angiography that was thought to be technically suitable for angioplasty. In these patients, the time interval between diagnostic angiography and angioplasty was 67 days (range 1–293). Nine of these 32 patients progressed from severe stenosis to functional occlusion over this time interval, while 23 of these patients progressed to total occlusion.

The remaining 7 patients had a functional occlusion at the time of diagnostic angiography.

The occluded vessel was the left anterior descending coronary artery in 30 patients, the right coronary artery in 8, the circumflex coronary artery in 7, and a coronary artery bypass graft in 4 (Fig. 2).

At the time of the diagnostic angiography, collateral vessels were seen in 8 of the 10 patients

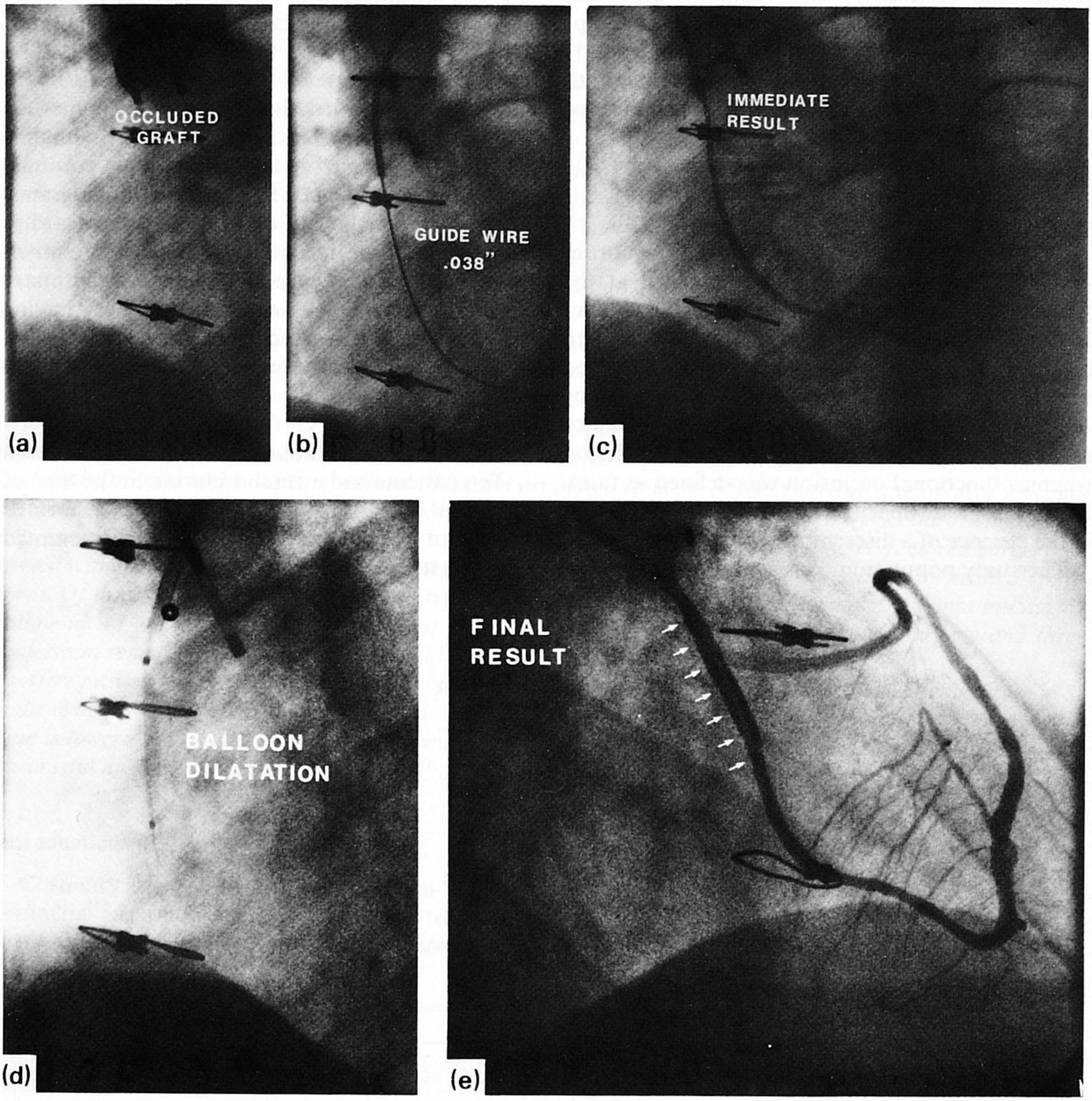

Figure 2 Example of successful dilatation of occluded coronary artery bypass graft.
A. Pre-PTCA angiogram demonstrating total occlusion of graft.
B. Successful perforation with ·38″ guide wire.
C. Angiogram following recanalization with guide wire.
D. Dilatation with 3·7 mm balloon.
E. Post-PTCA angiograms of successfully dilated bypass graft. Arrows indicate area of minor vessel dissection.

with total occlusion, in 5 of the 7 patients with functional occlusion and in 11 of the 32 patients with a patent vessel.

At the time of angioplasty, collateral vessels provided some degree of opacification in 37 of the 49 patients; the collateral filling was provided by the contralateral coronary artery alone in 21, from the ipsilateral coronary artery alone in 9, and from both coronary arteries in 7.

DURATION OF OCCLUSION

In 32 patients the maximal possible duration of occlusion was defined as the time interval elapsed between diagnostic angiography and the time of attempted dilation. This time interval averaged 65 days (range 1–293 days).

In the remaining 17 patients with functional or total occlusion at diagnostic angiography, the minimal established duration of occlusion was on the average 49 days (range 7 to 240 days).

ANGIOPLASTY TECHNIQUE

After puncturing the femoral vein and artery, one hundred mg of heparin and 250 mg acetosalicylic acid were administered intravenously. Before attempted recanalization and angioplasty and following baseline angiography, 3 mg of isosorbide dinitrate and 0·2 mg nifedipine was injected into the involved vessel to exclude coronary spasm and to improve collateral filling of the distal vessel so that the course of the post-occlusion vessel could be assessed. Since our early experience in 1980, the technique of recanalization has varied considerably (Table 1). Thirteen occlusions were crossed with the soft guide wire affixed to the tip of the dilatation catheter, while 10 occlusions required initial passage of either a separate stiffer guide wire (0·032, 0·035, 0·038 in) or a thin 3F catheter. In the remaining 26 patients, a movable guide wire system was used to cross the lesion. After that, the balloon catheter was advanced into the stenosis, a series of three to 10 balloon inflations were carried out at pressures varying from four to twelve atmospheres.

The total occlusion time varied from 10 up to 750 s. Individual occlusions ranged from 10 to 70 s. Stenotic areas were filmed in two different projections in procedures on the right (RCA) and circumflex (LCX) coronary arteries and in at least three projections including one cranio-caudal in stenoses of the left anterior descending artery (LAD).

After the dilatation procedure the sheath was left in place for the next 24 h and nifedipine 10 mg every 2 h was given during the first 24 h. From the second day following angioplasty, all patients received 500 mg acetosalicylic acid and nifedipine, 60 mg a day. This regimen was continued during the next six months.

A dilatation was considered successful when the remaining stenosis was less than 50% and the mean pressure gradient (mmHg) across the stenosis, normalized for mean aortic pressure, was less than 0·2. Quantitative analysis of selected coronary segments was carried out with the Coronary Angiographic Analysis System (CAAS)[11,12], which measures lumen diameters in absolute values (mm). From these measurements the relative obstruction of a vessel after the PTCA procedure can be defined[13].

ANALYSIS OF GLOBAL AND REGIONAL LV FUNCTION

Global and regional left ventricular function was studied from the 30° right anterior oblique left ventricular cine-angiogram with an automated hardwired endocardial contour detector linked to a mini-computer[14]. Left ventricular volume was computed according Simpson's rule. Systolic regional wall displacement is determined along a system of 20 coordinates based on the pattern of actual endocardial wall motion in normal individuals[15] and generalized as a mathematical expression amenable to automatic data processing[16]. For each segment, segmental volume is computed from the local radius (R) and the height of each segment (1/10 of left ventricular long axis length) (L) according the formula: $1/20\ R^2L$. When normalized for end-diastolic volume, the systolic segmental volume change can be considered as a parameter of regional pump function (Fig. 3).

During systole this parameter expresses quantitatively the contribution of a particular segment to

Table 1 Left ventricular volume or ejection fraction derived from pre and post PTCA ventriculograms

	Pre PTCA ($N=9$)		Late follow-up ($N=9$)
EDV (ml m^{-2})	83 ± 35	NS	70 ± 14
ESV (ml m^{-2})	26 ± 10	NS	25 ± 9
EF (%)	68 ± 9	NS	64 ± 6

EDV: end-diastolic volume; ESV: end-systolic volume; EF: ejection fraction. NS: non significant.

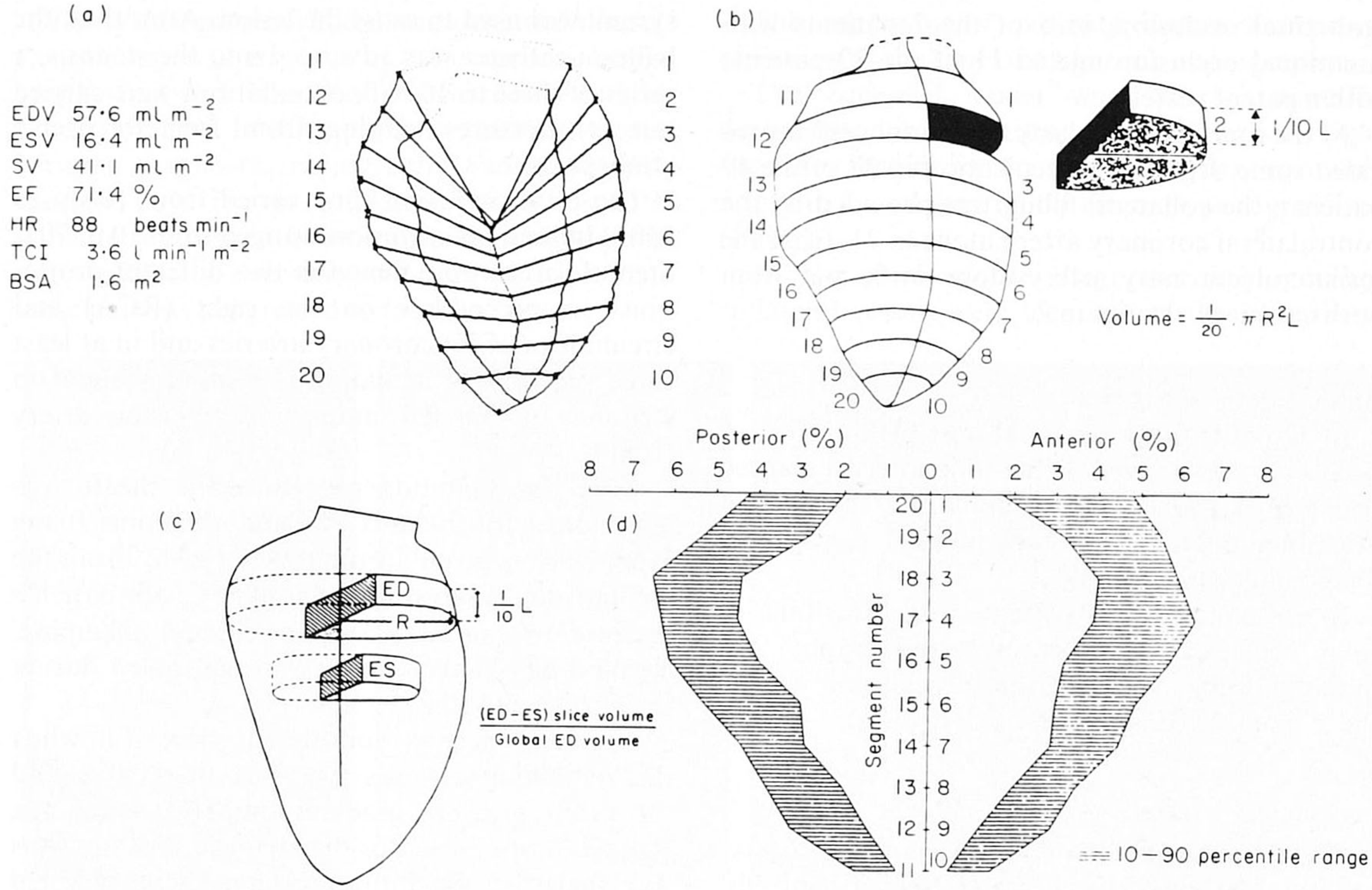

Figure 3 (a) Example of the computer output showing the end-diastolic and end-systolic contours of the 30° RAO left ventriculogram and the system of coordinates along which left ventricular segmental wall displacement is determined. The corresponding volume data, ejection fraction and other parameters are shown in the upper left corner. (b) The left ventricular end-diastolic cavity is divided into 20 half slices. The volume of each half slice is computed according to the given formula, R is radius and L is left ventricular long axis length. (c) The regional contribution to global ejection fraction (CREF) is determined from the systolic decrease of volume of the half slice which corresponds to a particular wall segment. The systolic volume change is mainly a consequence of the decrease of radius (R) of the half slice, which is expressed by the X-component (x) of the displacement vector (d). (d) The shaded zones represent the 10th–90th percentiles area of CREF values in normal individuals. On the X-axis the CREF values of the anterior and infero-posterior wall areas are displayed (%), while on the Y-axis the segment numbers of the anterior wall (1–10) and of the infero-posterior wall (11–20) are depicted.

global ejection fraction, termed regional contribution to global ejection fraction or CREF[16,17].

The sum of the values for all segments equals the global ejection fraction.

STATISTICAL ANALYSIS

Data are expressed as mean ± SD; Student's paired or unpaired t tests were applied to the hemodynamic data, as appropriate; differences in baseline characteristics between groups were tested by the Fisher's exact test.

Results

OUTCOME OF DILATATION PROCEDURE

The occlusion was successfully recanalized in 43 patients (88%), but the stenotic lesion could be crossed with the balloon catheter in only 38 patients (78%). A successful dilatation according to the criteria mentioned above was obtained in 28 patients (57%): 19 (63%) of the 30 patients with a left anterior descending coronary occlusion, 5 (63%) of the 8 with a right coronary artery occlusion, 3 of the 7 (43%) with a circumflex coronary artery occlusion, and 1 of the 4 (25%) with a jumpgraft occlusion. The residual percentage diameter stenosis in the 28 patients whose arteries were successfully dilated was 34·6 ± 10·5% while the mean pressure gradient normalized for mean aortic pressure decreased from 0·51 ± 0·15 to 0·18 ± 0·11. The success rate was significantly higher in patients with functional occlusion (13/16, 81%) than in those with total occlusion (15/33, 45%, $P = 0·04$).

In these 33 patients with total occlusion at the time of angioplasty, the success rate was similar between those who had a total occlusion at the time of diagnostic angiography (5/10, 50%) and those who previously had a stenotic lesion (10/23, 43%).

OCCLUSION DURATION AND OUTCOME OF DILATATION PROCEDURE

The outcome of the dilatation procedure was evaluated by taking into account the duration (estimated or established) of occlusion and the functional or total nature of the occlusion. The success rate for the patients in whom the occlusion was estimated to be less than 4 weeks was 62% (13/21) and for those in whom the occlusion was more than 4 weeks but less than 8 weeks, it was 67% (8/12).

Of the patients in whom the duration of occlusion was estimated to be more than 8 weeks the success rate was only 44% (7/16). The primary success rates in patients with functional or total occlusion versus the time elapsed since diagnostic angiography are shown in Fig. 4.

HOSPITAL COURSE

Ten of 21 patients with unsuccessful PTCA underwent elective coronary artery bypass surgery, while one had emergency surgery because of persisting chest pain following attempted recanalization. The remaining 10 patients were kept on medical therapy.

Of the 28 patients with primary success, 8 had an elevation of serum creatine phosphokinase (61–190 U), but without appearance of a new Q wave or loss or R wave.

One patient had a subarachnoid hemorrhage several hours following the procedure which necessitated a trepanation — the neurological deficit initially observed subsided completely following the neurosurgical intervention.

LONG-TERM ANGIOGRAPHIC AND CLINICAL FOLLOW-UP

Of the 28 patients with successful dilatation, 10 patients had recurrence of anginal symptoms at a mean follow-up of 7 months (range 1–42 months). Nine of these 10 patients underwent follow-up angiography which showed reocclusion in six (Figs 5 and 6). Three patients required coronary artery bypass graft surgery, three had repeat dilatation for re-stenosis ($N=2$) or reocclusion ($N=1$) while four were maintained on medical therapy. The three patients who underwent coronary artery bypass graft surgery were all patients who had had an occlusion at the time of the initial diagnostic angiography. Since they had only transient improvement of PTCA therapy previously and again were presenting with coronary artery occlusion alternative surgical therapy was chosen. In the four patients who were maintained on medical therapy after reocclusion, the previous decision to proceed with PTCA was made at the time of a planned PTCA of a non-occluded vessel. After reocclusion, assessment of all factors (regional LV function, functional class, distal coronary anatomy) with the prior information that the

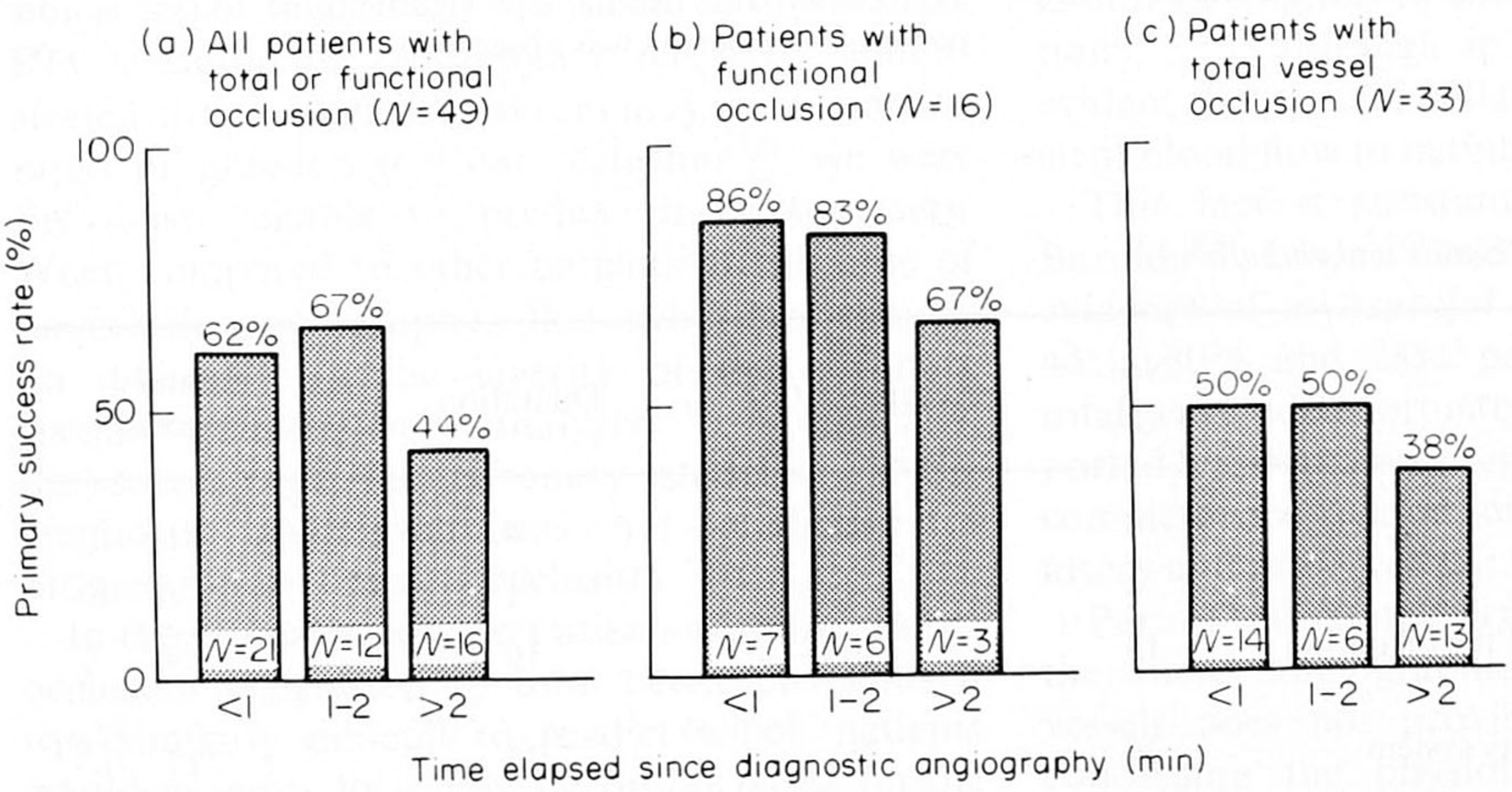

Figure 4 Primary success rates in patients with total and/or functional occlusion versus the time elapsed since diagnostic angiography.

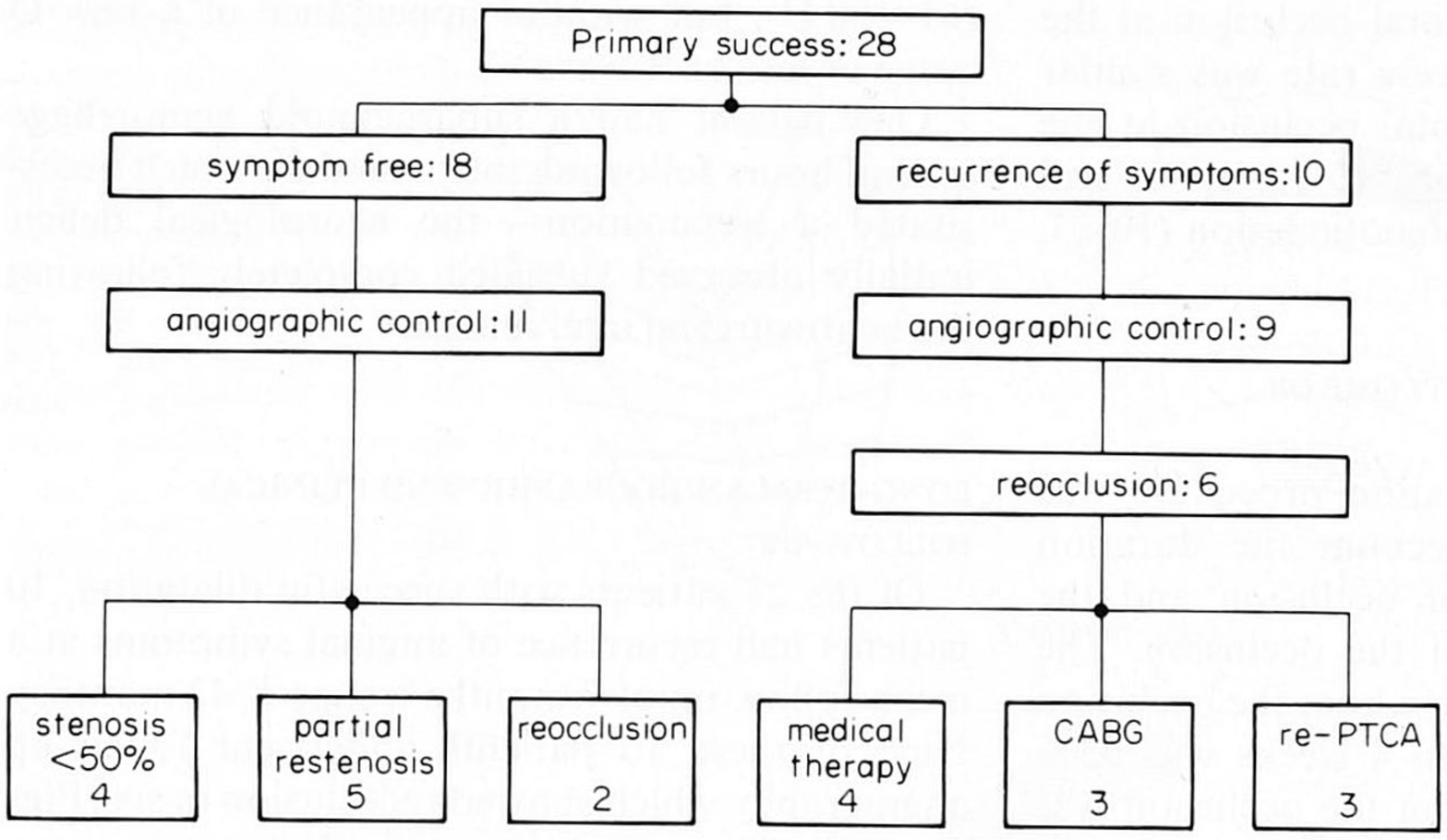

Figure 5 Long-term angiographic and clinical follow-up of 28 patients who underwent a successful angioplasty.

vessel was occluded, led to a conservative medical approach.

Eighteen patients were asymptomatic. Late angiographic follow-up was available in 11 of the asymptomatic patients.

Cineangiograms disclosed two reocclusions, 5 partial restenoses (an increase of 20% in luminal diameter stenosis) and four persistent successful dilatations (Fig. 5). In the seven other cases, either the referring physician or the patient declined repeat catheterization. All of these patients were symptom free. Since two other symptom free patients who did undergo repeat catheterization did have reocclusion, it is possible that the true incidence of reocclusion would be even higher than 2/11.

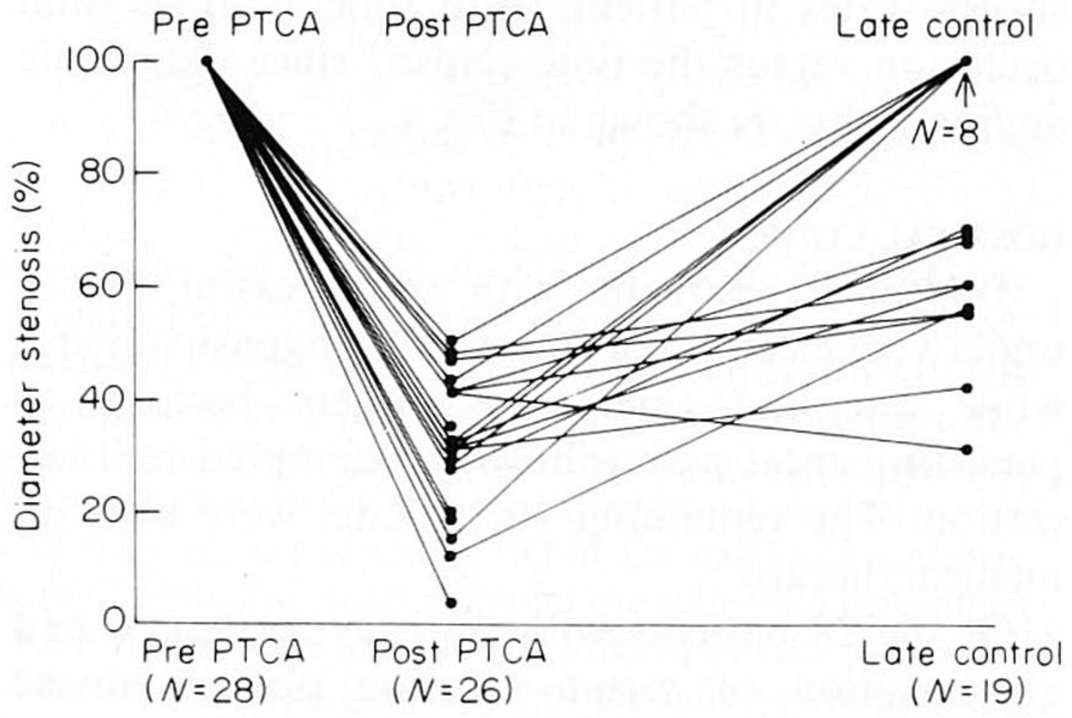

Figure 6 Percentage diameter stenosis following successful angioplasty and during late angiographic follow up. In 8 patients, reocclusion was observed.

Table 2 Technique of recanalization and dilatation

	No. of pts	Recanalization	Dilatation	Primary success
Guide wire 0·032/0·035/0·038	6	4	4	1
3F perfusion catheter	4	4	1	1
Guide wire affixed to the tip of the dilatation catheter	13	10	10	9
Movable guide wire angioplasty system	26	25	23	17
	100%	88%	78%	57%

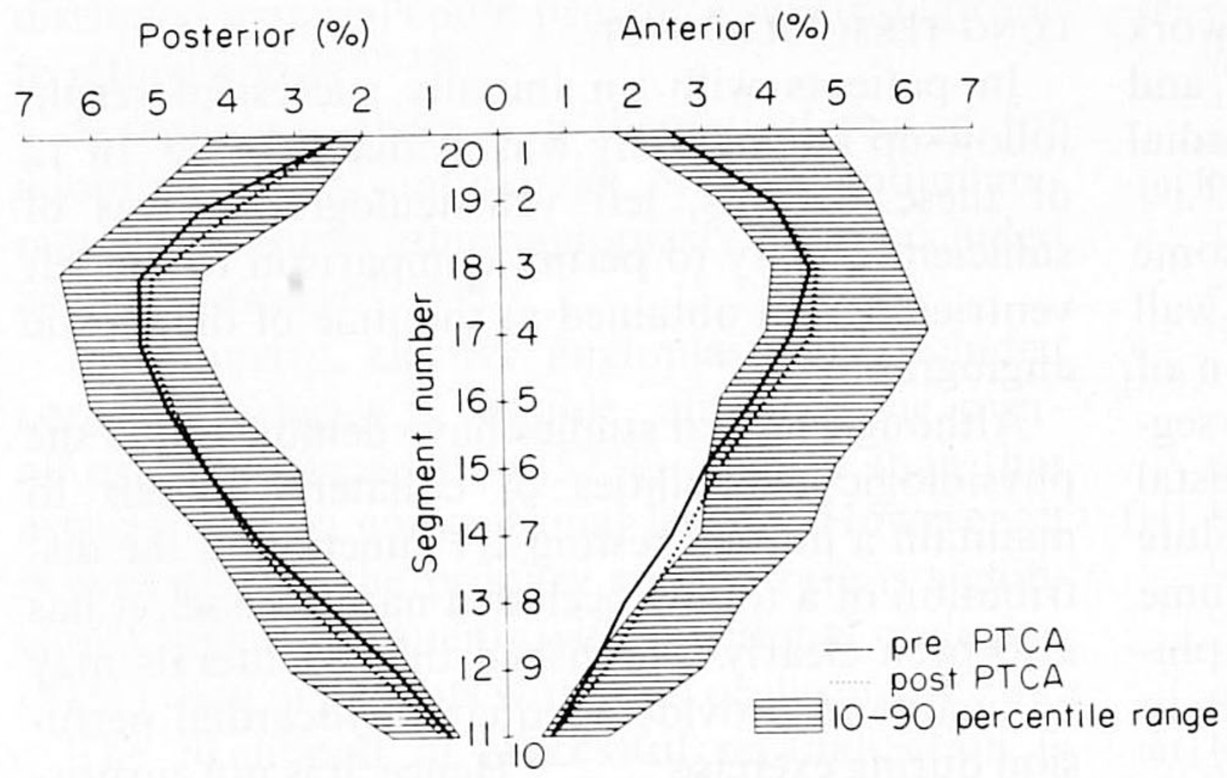

Figure 7 Regional contribution to the global ejection fraction in 9 patients with intercurrent occlusion of the left anterior descending artery (LAD). Solid line: wall motion at the time of the diagnostic angiography, when the LAD was still patent. Dotted line: wall motion during late angiographic follow up.

The 9 patients with either partial restenosis or persistent successful dilatation underwent follow-up left ventriculography. All had LAD lesions. No significant changes in left ventricular volume or ejection fraction were found when comparing the pre and post PTCA left ventriculograms (Table 2). The regional contributions to the global ejection fraction were also not affected by the intercurrent episode of coronary occlusion (Fig. 7).

Discussion

PROGRESSION TO COMPLETE OCCLUSION

Unexpected progression to complete obstruction (total or functional) was observed in 6% of all PTCA candidates. Although it has been demonstrated that certain risk factors may predispose to rapid progression to total occlusion[18], we were previously unable to predict this progression. When compared to other patients at the time of diagnostic angiography, this subgroup showed no difference in the severity of the coronary lesions, quantitatively analyzed[19]. Specifically, the severity of the coronary stenosis on the diagnostic angiogram was not predictive of progression to complete occlusion.

In the present study, no patients with functional occlusion progressed to total occlusion. Thus it was similarly difficult to predict which patients would progress to a total occlusion based on the severity of their stenosis at the time of diagnostic study.

One may speculate that occlusion of the PTCA-related vessel in these patients is not related to rapidly progressive atherosclerosis but is due to a thrombotic process. Evolving coronary thrombosis has been reported in unstable angina[20] and a review of the clinical records in our patients shows that progression to complete obstruction was clearly associated with worsening and instability of the anginal symptoms, but without occurrence of myocardial necrosis probably prevented by the development of collaterals.

COLLATERALS AND MYOCARDIAL VIABILITY

Controversy exists over the role of the collateral circulation in preserving myocardial function[21–24], although it has become increasingly evident that certain collateral vessels provide sufficient blood flow to maintain myocardial viability.

This fact is substantiated by the studies of Baroldi[25], Levin[26] and Hamby[23] who found no evidence of myocardial infarction in respectively 44%, 30% and 28% percent of patients with a totally occluded coronary artery and it is also supported by several case reports[27,28] of patients with complete obstruction of the left main coronary artery and preserved left ventricular function.

Part of this controversy stems from the fact that the mere angiographic presence of collateral vessels does not provide complete information concerning the physiologic significance of the vessels. It is well established that coronary cineangiography for evaluation of collateral

vessels underestimates the fine collateral network that is detected by post mortem angiography[29] and correlates poorly with normal resting myocardial blood flow distribution through these vessels[30].

Therefore, it is not surprising to see that some of our patients despite preserved regional wall function, did not exhibit discrete visualization of collateral filling of the post occlusive coronary segment. In our opinion, the visualization of distal occlusive luminal anatomy is not an absolute requirement for attempted dilatation. We assume that collateral filling, even when not angiographically demonstrable, is potentially sufficient to preserve good wall motion. Kolibash *et al.*[30] demonstrated that the prevalence of wall motion abnormalities was significantly less in the 'distribution' areas of totally occluded native vessels with normal perfusion at rest assessed from radioisotopic studies even in the absence of demonstrable angiographic collaterals. The purpose of this study was not to evaluate the contribution of tion of myocardial function; however, our wall motion analysis clearly indicates that collaterals may serve an important protective function since no deterioration in wall motion occurred despite prolonged periods of coronary occlusion in our patients with persistent long-term lesion patency.

OUTCOME OF THE DILATATION PROCEDURE

The primary success rate of transluminal angioplasty of occluded coronary arteries reported in the literature varied between 54% and 67%. To interpret this report with those percentages, the distinction between functional and total occlusion is meaningful since the success rates with these two types of occlusion differ considerably (81% *vs* 45%). On the other hand, our results partially corroborate recent suggestions[10,31] that either functional or total occlusions present for periods greater than 2 months are associated with lower primary success rates. In these patients the high percentage of failure may be related to progressive organization and fibrosis in the occluded area.

The success rate with the movable guide wire angioplasty system was higher (65%, 17/26) than with the previous techniques, (48%, 11/23) which required the initial use of either a separate stiff guide wire, catheter or guide wire affixed to the tip of a dilatation catheter.

Finally, although we have had no angiographic evidence of peripheral embolization, 8 patients had a slight elevation of myocardial enzymes and 2 of them experienced prolonged chest pain.

LONG-TERM FOLLOW-UP

In patients with an initially successful result, follow-up angiography was available in 20. In 12 of these patients, left ventriculography was of sufficient quality to permit comparison to the left ventriculogram obtained at the time of diagnostic angiography.

Although several studies have demonstrated the physiologic capabilities of collateral vessels to maintain a normal resting LV function in the distribution of a totally occluded native vessel, it has also been clearly established that collaterals may be unable to provide adequate myocardial perfusion during exercise[30–32]. Hence, it is not surprising to see that virtually all our patients still had severe exertional angina unresponsive to medical treatment at the time of angioplasty.

The early results were extremely promising since only one patient remained symptomatic. With long-term follow-up, however, the rate of recurrence of symptoms in these patients (36%) did not differ significantly from the rate usually reported in patients with dilatation of conventional stenoses[33].

Among the asymptomatic patients who underwent an angiographic follow-up study, two showed a reocclusion of their dilated lesion; both had a normal exercise stress test and one of them had even a normal myocardial perfusion scintigraphy during exercise. In contrast to the rate of recurrence of symptoms, the incidence of reocclusion in these patients was alarmingly high (8 of 20 angiographic studies) when compared to either angioplasty of conventional 60 to 95% stenoses or even angioplasty following fibrinolytic recanalization[6].

Two reasons may account for the high incidence of reocclusion in patients following successful dilatation of a recently occluded coronary lesion.

First, this group may represent a subset of the total PTCA population with a demonstrated intrinsic vascular or haematologic propensity to acute occlusion of existing atherosclerotic lesions.

Second, if the morphologic character of the recent occlusion is thrombus, then one would anticipate the presence of a progressively organizing dense fibrocellular tissue[34]. Instrumental recanalization and dilatation of this lesion must produce histologic disruption through the longitudinal and radial shearing of the atherosclerotic and fibrocellular material. This could initiate a non-specific proliferative process that could contribute to reocclusion of the vessel[35–37]. In addition, this

disrupted material could provide a substrate prone to rethrombosis[38,39].

Accordingly, there is a theoretical reason for adopting special antiplatelet or even antiinflammatory measures after angioplasty of an occluded coronary artery[40–43].

In summary, elective angioplasty of occluded coronary arteries is feasible, although the overall primary success rate (57%) is lower than that associated with conventional lesions. However, it is evident that the primary success rate is significantly higher in patients with functional occlusion (81%) than in patients with total occlusion (45%).

The likelihood of successful recanalization is inversely related to the duration of the occlusion. Despite a long duration of occlusion, no significant deterioration of wall motion or regional myocardial function may be present. The time between diagnostic angiography and angioplasty should be kept to a minimum to prevent the progression of a significant stenosis to an occlusion.

Finally, the long-term clinical results following successful recanalization were satisfactory in 64% of our patients. The incidence of restenosis or reocclusion has tended to be higher, though, than that seen in patients undergoing dilatation of conventional stenosis.

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