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Abstract

We studied the factors which may induce acute high grade restenosis in emergency percutaneous transluminal coronary angioplasty (PTCA). PTCA was attempted in 50 patients with acute myocardial infarction, and the balloon catheter passed successfully across the occlusion site in 47 (94%) of the patients. These 47 patients were analyzed. "Acute restenosis" was defined as a lesion which was revascularized to less than 50% luminal reduction narrowed again to more than 75% luminal reduction 5 min after the balloon inflation. Univariate and multivariate analyses were used for determining factors which significantly influenced acute restenosis. The incidence of at least one restenosis episode was 45%. Multiple regression analysis selected 5 factors associated significantly with an increased rate of acute restenosis: 1) angiographic evidence of dissection, 2) lesion in the right coronary artery (RCA), 3) lack of or insufficient administration of thrombolytic agent preceding PTCA, 4) curved lesion and 5) relatively small balloon/artery diameter ratio. Acute restenosis correlated significantly with late reocclusion. This study indicates that it is important to administer a thrombolytic agent prior to emergency PTCA, and to use an adequately sized balloon to the artery when the acute restenosis occurs by using relatively smaller sized balloon. The present data also demonstrated that patients with RCA and a curved lesion have a relatively high risk of acute restenosis. This study indicates how patients with relatively high risk of acute restenosis may be identified.

KEYWORDS: emergency coronary angioplasty, restenosis, acute myocardial infarction, multivariate analysis

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Factors Influencing Acute High-Grade Restenosis in Emergency Percutaneous Transluminal Coronary Angioplasty for Acute Myocardial Infarction.

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We studied the factors which may induce acute high grade restenosis in emergency percutaneous transluminal coronary angioplasty (PTCA). PTCA was attempted in 50 patients with acute myocardial infarction, and the balloon catheter passed successfully across the occlusion site in 47 (94%) of the patients. These 47 patients were analyzed. "Acute restenosis" was defined as a lesion which was revascularized to less than 50% luminar reduction narrowed again to more than 75% luminal reducion 5 min after the balloon inflation. Univariate and multivariate analyses were used for determining factors which significantly influenced acute restenosis. The incidence of at least one restenosis episode was 45%. Multiple regression analysis selected 5 factors associated significantly with an increased rate of acute restenosis : 1) angiographic evidence of dissection, 2) lesion in the right coronary artery (RCA), 3) lack of or insufficient administration of thrombolytic agent preceding PTCA, 4) curved lesion and 5) relatively small balloon/artery diameter ratio. Acute restenosis correlated significantly with late reocclusion. This study indicates that it is important to administer a thrombolytic agent prior to emergency PTCA, and to use an adequately sized balloon to the artery when the acute restenosis occurs by using relatively smaller sized balloon. The present data also demonstrated that patients with RCA and a curved lesion have a relatively high risk of acute restenosis. This study indicates how patients with relatively high risk of acute restenosis may be identified.

Key words : emergency coronary angioplasty, restenosis, acute myocardial infarction, multivariate analysis

Experimental studies suggest that early recanalization of an occluded artery prevents the progression of myocardial ischemia to necrosis and limits infarct size (1, 2). Advanced interventional cardiologic management of patients with acute myocardial infarction has in recent years been directed toward rapid restoration of coronary blood flow in order to limit myocardial necrosis. For rapid recanalization, thrombolytic therapy has been advocated and studied extensively.

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However, 10-30% of occluded arteries can not be recanalized by thrombolytic agents (3-5). Moreover, high-grade stenotic legions remain in the occluded artery in most patients treated with thrombolytic agents. Recently, emergency percutaneous transluminal coronary angioplasty (PTCA) has become an attractive therapeutic procedure to recanalize acutely occluded coronary arteries (6-16). PTCA would produce more complete revascularization and reduce late reocclusions. Acute high-grade restenosis in catheterization laboratory, however, seems to be a serious problem in emergency PTCA. Acute repeated restenosis might result in the failure to achieve long-term recanalization. When acute high-grade restenosis or reocclusion occurs, an additional PTCA procedure is necessary and more time is required to achieve stable recanalization. It seems reasonable that acute reocclusion in catheterization laboratory occurs more frequently in emergency PTCA than in elective PTCA (13, 14, 16). We studied factors responsible for acute restenosis in emergency PTCA using univariate and multivariate analysis.

Methods

Patients. From April 21, 1984 through November 1, 1987, 50 patients with acute myocardial infarction (AMI) underwent emergency PTCA in our hospital. The diagnosis of AMI was established by the symptom of typical severe chest pain associated with more than 2.0 mm ST segment elevation in 2 or more conventional electrocardiographic leads. Patients with symptoms which began more than 4 h before admission to our hospital were excluded from this study. Other exclusion criteria were: age more than 80 years, cardiogenic shock, recent cerebrovascular accidents and disorders associated with high risk of bleeding.

Cardiac catheterization. Before cardiac catheterization, all patients were given 100 U/kg body weight of heparin intravenously. Coronary angiography was performed in multiple views by the standard percutaneous transluminal method with a femoral approach. Initially, selective arteriography of a coronary artery assessed electrocardiographically not to be responsible for the AMI was performed to determine the angiographic extent of collateral vessels. Then, arteriography of the infarct-related artery was conducted. Prior to emergency PTCA, 0.2 mg of nitroglycerin was administered into the infarct-related coronary artery to rule out and prevent coronary artery spasm.

Emergency PTCA. We started to prepare the equipment for PTCA regardless of whether the coronary artery responsible for the AMI was totally or subtotally occluded. During the preparation for emergency PTCA, patients were randomly administered 0-120,000 units of urokinase into the occluded artery with or without an additional 240,000-600,000 units of urokinase at the rate of 16,000 units per min to examine the effect of pre-operation administration of a thrombolytic agent on acute restenosis. Emergency PTCA was attempted according to standard methods with a flexible, movable guide wire (0.014-0.016 inch flexible steerable wire, USCI, Galway, Ireland, or 0.018 inch high torque floppy wire, Advanced Cardiovascular Systems Inc., Temecula, CA, USA) and with a balloon catheter (2.0-4.0 mm balloon diameter, Simpson-Robert or Simpson Ultra-Low Profile balloon catheter, Advanced Cardiovascular System Inc.). After arteriography of the infarct-related artery, the guide wire was gently pushed into the occlusion site, and if no resistance was met, it was gently advanced through the occlusion site. Then the balloon catheter was introduced and positioned at the occluded lesion. The balloon was inflated incrementally starting with low pressures and increasing to higher pressures to achieve gradual revascularization of the occluded site. The pressure level which just diminished the defect on the balloon by the stenosis was maintained for 60 sec. After the termination of balloon inflation, the balloon catheter was withdrawn into the guiding catheter while the guide wire was left in the artery across the stenosis. Immediately thereafter, arteriography was performed to evaluate revascularization. If 50% or more luminal reduction of the diameter of the lesion was still visualized, we immediately performed additional PTCA using the same size or 0.5 mm larger balloon cath-

eter with the same or slightly higher pressure. When revascularization to less than 50% stenosis was achieved, the arteriography was performed 5 min later to determine the acute restenosis defined later. If the lesion remained at more than 50% stenosis, we repeated PTCA until the stenosis was reduced to less than 50% narrowing. If the arteriogram 5 min after the termination of balloon inflation revealed the stenosis remained less than 50% stenosis, we waited another 10 min to be sure revascularization was stable. Optimal revascularization depended on the charac-

Table 1 Score of acute restenosis, entry factors for univariate and multivariate analysis and characteristics of the 47 patients

	*Score, Definition	No (%)
Acute restenosis	0, —	26 (55)
	1, Once	13 (28)
	2, Twice	5 (11)
	3, ≧Three times	3 (6)

Entry factors	Score, Definition	No (%)	Entry factors	Score, Definition	No (%)
1. Sex	0, Female	9 (19)	9. Dissection	0, —	32 (68)
	1, Male	38 (81)		1, Intraluminal filling defect or faint, fine extravasation of contrast material	6 (13)
2. Age	0, <50	4 (9)		2, Clear extravasation of contrast material or linear luminal density or luminal staining	9 (19)
	1, 50≦ <60	18 (38)			
	2, 60≦ <70	14 (30)			
	3, 70≦	11 (23)			
3. Onset time	0, Daytime (8:00 AM -10:00 PM)	28 (60)	10. Collateral vessels	0, —	35 (74)
	1, Night (10:00 PM -8:00 AM)	19 (40)		1, Poor	9 (19)
				2, Well	3 (6)
4. Time from onset to PTCA (T) (min)	0, T≦120	5 (11)	11. Balloon/artery diameter ratio (R)	0, 1.00≦R	11 (23)
	1, 120<T≦180	8 (17)		1, 0.90≦R<1.00	5 (11)
	2, 180<T≦240	14 (30)		2, 0.80≦R<0.90	7 (15)
	3, 240<T≦300	15 (32)		3, 0.70≦R<0.80	20 (43)
	4, 300<T≦360	5 (11)		4, R<0.70	4 (8)
5. Lesion location	0, in LCA	31 (66)	12. Urokinase administration (units)	0, 0-120,000	19 (40)
	1, in RCA	16 (34)		1, 240,000-360,000	19 (40)
				3, 480,000-600,000	9 (19)
6. Angle	0, <30 degrees	23 (49)	13. Systolic blood pressure during PTCA (mmHg) (P)	0, 120≦P	15 (32)
	1, ≧30 degrees	24 (51)		1, 110≦P<120	8 (17)
				2, 100≦P<110	13 (28)
7. Involvement of branch	0, —	23 (49)		3, 90≦P<100	8 (17)
	1, +	24 (51)		4, P< 90	3 (6)
			14. Extent of coronary arterial disease	0, 1 Vessel	32 (68)
8. Occlusion	0, Subtotal	29 (62)		1, 2 Vessels	12 (26)
	1, Total	18 (38)		2, 3 Vessels	3 (6)

Abbreviations: LCA, left coronary artery; RCA, right coronary artery; No, number of patients.

teristics of the lesion and the patient's hemodynamical condition. After the termination of PTCA, all patients were transfered to the coronary care unit and were given 50 units/kg body weight of heparin every 4 h for 4 days. Aspirin and dipyridamol were also administered orally.

Angiographic study of the coronary artery to determine the patency of the revascularized coronary artery was performed from 30 to 40 days after the emergency PTCA.

The stenosis was determined by visual evaluation from at least two angles of view and was expressed as percent luminal reduction. We defined acute restenosis as a lesion which was revascularized to less than 50% luminar reduction and narrowed again to more than 75% luminar reduction 5 min after the termination of balloon inflation. Acute restenosis was judged by two cardiologists who had more than 300 experiances with coronary angiography. The factors influencing acute restenosis studied herein were scored and assessed for each patient (Table 1). An occluded lesion curving more than 30 degrees in either or both the RAO and LAO views was defined as a curved stenosis. A stenosis involving a branch artery was defined as a branching lesion. Diameters of the inflated balloon and of infarct-related artery just proximal to the lesion were measured on a cineangiofilm projector, and the mean balloon/artery ratio from the RAO and LAO views was used for analysis. When we changed balloon size, the diameter of the balloon which was used just prior to the acute restenosis was used for calculation of the ratio.

Data analysis. For univariate analysis, we used chi-square tests for discrete variables and *t*-tests of correlation coefficients by simple regression analysis for continuous data. For multivariate analysis, with the prevalence rate of the acute restenosis as a dependent variable and 14 scored characteristics as independent variables, (Table 1), a stepwise linear multiple regression analysis was used to determine factors significantly affecting acute restenosis. For a rough comparison of the strength of the influence of the factors on restenosis, we calculated a standardized regression coefficients using standardized score which was subtracted averaged score from each score divided by the standard deviation of each factor. A multivariate normal distribution of the data was determined using probability plots. Multicolinearities of the factors were judged by variance inflation factors. A p value of <0.05 was considered significant.

Results

Baseline characteristics. Both the guide wire and balloon catheter could be passed across the totally or subtotally occluded artery, and the balloon could be inflated in 47 of 50 patients. In one patient, the lesion could not be crossed by the guide wire because the artery was too winding. In the other 2 patients, only the guide wire passed the lesion, but balloon catheter could not be inserted across the lesion because PTCA guiding catheter went away from coronary orifice due to the stenosis being too rigid. These 3 patients were excluded from the study on acute restenosis. The 47 patients were from 38 to 79 years old (mean, 61 years old) and consisted of 38 men and 9 women. The time from the onset of typical severe chest pain to admission to our hospital was less than 4 h (mean, 117 min). The site of AMI was anterior, including localized anterior, anteroseptal, anterolateral, anteroseptallateral, in 32 patients (68%), and inferior in 15 patients (32%). Serum creatinine phosphokinase activity was still within the normal range in all 47 patients.

Angioplasty. The infarct related artery was the left anterior descending coronary artery in 29 (61%), left circumflex in 2 (4%), and right coronary artery (RCA) in 16 (34%). Acute restenosis occurred at least once in 21 of the 47 patients (44%). Table 2 shows the results of univariate analysis of the factors influencing acute restenosis. Acute restenosis was demonstrated in 10 of 15 lesions (67%) which showed dissection, and in 12 of 24 curved lesions (50%). The restenosis rate was frequent in RCA lesions (11 of 15; 73%). On the other hand, acute

Table 2 The results of univariate analysis

Factors	Significance	p Value
1. Sex	NS[a]	
2. Age	NS	
3. Onset time	NS	
4. Onset-PTCA time	NS	
5. Legion; location	Significant	$p < 0.01$
6. ; curved	NS	$(0.05 < p < 0.10)$
7. ; involvement of branch	NS	
8. ; occlusion	NS	
9. Dissection	Significant	$0 < 0.01$
10. Collateral vessels	NS	
11. Balloon/artery diameter ratio	Significant	$p < 0.01$
12. Urokinase administration	Significant	$p < 0.05$
13. Systolic blood pressure during PTCA	NS	
14. Extent of coronary arterial disease	NS	

a: Not significant.

Table 3 Results of stepwise linear multiple regression analysis

Factors	Regression coefficient	Standardized regression coefficient	Partial correlation coefficient	VIF[a]
Dissection	0.47	0.41	0.53 ($p < 0.001$)	1.01
Location	0.60	0.32	0.41 ($p < 0.005$)	1.16
Urokinase administration	−0.36	−0.29	0.40 ($p < 0.01$)	1.02
Curved Lesion	0.51	0.28	0.40 ($p < 0.01$)	1.02
Balloon/artery diameter ratio	0.18	0.27	0.36 ($p < 0.02$)	1.14
constant	−0.11			
Multiple correlation coefficient = 0.76 ($p < 0.01$)				

a: Variance inflation factor.

restenosis occurred only in 11 of 32 patients (34%) with left coronary artery (LCA) lesions. The restenosis rate was 58% (11 of 19) in patients administered less than 120,000 units of urokinase in contrast with 35% (10 of 28) in patients administered more than 240,000 units. A balloon in which balloon/artery diameter ratio of less than 0.80 resulted in acute restenosis in 16 of 24 patients (71%) while restenosis was demonstrated in only 5 of 23 patients (22%) when the ratio was bigger than 0.80.

A significant correlation with other factors to acute restenosis was not obtained in this study.

Multivariate analysis. Table 3 shows the result of the stepwise linear multiple regression analysis. The factors which significantly contributed to the acute restenosis were angiographic evidence of dissection, lesion in the RCA, lack of or insufficient urokinase administration preceding emergency PTCA, curved lesion and relatively small balloon/artery diameter ratio. The ranking of the strength of the factors was: dissection > lesion in the RCA > lack of or insufficient urokinase administration > curved lesion > small balloon/artery diameter ratio. Distribution of scores of the factors fitted multivariate normal fashion as judged by prob-

ability plots. No multicollinearities were obtained by variance inflation factors.

Post-PTCA angiographic study. In all of the patients without acute restenosis, the infarct-related artery remained patent 30-40 days after the emergency PTCA. However, reocclusion of the treated artery was recognized in 5 of 21 patients (19%) with acute restenosis. In 2 of 3 patients (67%) who suffered from restenosis more than 3 times, the artery was occluded. Acute restenosis was significantly correlated with late reocclusion by chi-square test ($p < 0.05$).

Complications. No major complications such as perforation or rupture of coronary artery occurred in our series of emergency PTCA.

Discussion

The major finding of this study was that acute restenosis led to a decrease in long-term of patency of the affected artery after emergency PTCA. Factors which significantly affected acute restenosis were: angiographic evidence of dissection, lesion in the RCA, lack of or insufficient thrombolytic agent administration preceding emergency PTCA, curved lesion, and relatively small balloon/artery diameter ratio.

Initial success rate. When initial success was defined as revascularization to less than 50% stenosis, at least once, by inflation of the balloon, the rate of initial success was 94% (47 of 50 patients). This rate was not different between totally (95%) and subtotally (94%) occluded arteries. Advancing the guide wire through the stenotic site to the distal part of the coronary artery was usually easy. Approximately 80% of the totally occluded sites were crossed in a few minutes. When we met resistance at the lesion, changing direction of the guide wire allowed passage across the stenosis in most cases. Changing of the tip curvature of the guide wire, however, was needed for crossing in 7 cases, and changing type of guide wire was helpful in one case. These results suggest that the guide wire can safely be passed across an occlusion site without resistance even if the lesion is totally occluded. Our initial success rate compared favorably with previous reports (6-16), and suggested that emergency PTCA could reestablish coronary blood flow more rapidly than thrombolytic therapy.

There are no reports concerning acute restenosis in emergency PTCA. The rate of acute restenosis in emergency PTCA studied here was higher than that reported for elective PTCA (17). Previous reports of higher reocclusion rate in the catheterization laboratory in emergency PTCA are consistent with our results (13, 14, 16).

Factors influencing acute restenosis. Emergency PTCA must be performed in a short time, because of the hemodynamic instability of patients with AMI. Acute high grade restenosis progresses to total occlusion within several minutes, resulting in interruption of blood flow to infarcting myocardium. When acute restenosis occurred, an additional PTCA procedure was needed, and more time was required to establish stable recanalization. Furthermore, repeating the restenosis led to disappointing result in terms of long-term patency of the artery. To define the factors which affects acute restenosis could shorten the time required for emergency PTCA and improve long-term patency.

Dissection and angularity of the lesion correlated significantly with acute restenosis in this study. Dissection occurred more frequently in emergency PTCA than elective PTCA (18). These results suggest that the lesion might be more fragile in AMI as "active disease" than in patients with stable angina who underwent elective PTCA. The

reason why there was a higher incidence of acute restenosis in the RCA than in the LCA was obscure. The difference in hydrodynamical stress on the arterial wall and altered characteristics of atherosclerotic formation of the RCA from the LCA might play a role in the higher incidence of restenosis (19, 20).

Of the factors which correlated significantly with acute restenosis, size of balloon and administration of thrombolytic agent can be controlled by the physician. Our result that a thrombolytic agent improved short-term results of emergency PTCA should be emphasized. The thrombolytic agent can be administered during the preparation for the PTCA without loss of time. Emergency PTCA can restore blood flow to infarct-area, while high risk of thrombus formation at the occluded site still remained unchanged. The method for revascularization does not modify the coagulability of the blood and the endothelium of the injured vessel remains exposed to the threat of thrombosis. Thus, preventing thrombosis with a thrombolytic agent may aid in obtaining a satisfactory short-term result in emergency PTCA. Urokinase administered before PTCA was effective in reducing acute restenosis in this study. Previous reports of no adverse effects of thrombolytic therapy on the performance of emergency PTCA are consistent with this result (6, 9-11, 13, 14, 16). Higher thrombus formation activity in patients with AMI might play a role in acute restenosis. It was indicated that thrombolytic therapy prior to PTCA could reduce acute restenosis due to reformation of a thrombus in the lesion.

The use of balloon smaller than the artery was frequently associated with acute restenosis. A previous experimental study demonstrated that angioplasty within the true elastic limits of the artery results in delayed collapse of the dilated artery (21). Insufficient dilation within the elastic limits by a smaller balloon would explain the correlation between inflated balloon/artery diameter ratio and acute restenosis. The report of a small balloon/artery diameter ratio resulting in a higher rate of late restenosis in elective PTCA seems consistent with our results (22).

Although we observed a high incidence of acute restenosis when a relatively small balloon was used, a balloon as large as a totally occluded artery can not be recommended to for use, because the risk of rupture and large dissection might increase. An optimally sized balloon must be used and sufficient dilation of the stenosis must be achieved after the coronary arteriogram can be viewed distal to the occluded site.

Late reocclusion. The infarct-related artery was patent in 42 of the 47 patients (89%) 30-40 days after the emergency PTCA. Previous studies indicated approximately the same rate as in our study (6-8, 13-16). A higher rate of late reocclusion was found in patients with acute restenosis in emergency PTCA. No reports are available concerning the relationship between the acute restenosis and long-term patency. Lesions with acute restenosis might be more fragile, complex and unstable than those without restenosis. This might explain the finding that acute restenosis increased the rate of late reocclusion.

Conclusion. Our results indicated that emergency PTCA could be effective in recanalization and revascularization of an occluded artery responsible for AMI. PTCA provides more rapid and stable coronary reflow than thrombolytic therapy without major complications. In these circumstances, emergency PTCA would be the most effective procedure for rapidly restoring coronary blood flow in AMI.

Although PTCA is effective in patients with AMI, long-term patency is not complete. The data presented herein may be useful in

identifying patients with a high or low risk of the acute restenosis in emergency PTCA. Furthermore, this study indicates that it is important to administer thrombolytic agent prior to emergency PTCA and to use a balloon of a adequate size.

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