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Expression of Polymorphonuclear Leukocyte Adhesion Molecules and Its Clinical Significance in Patients Treated With Percutaneous Transluminal Coronary Angioplasty

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Objectives. **This study evaluated the role of neutrophil adhesion molecules LFA-1 (CD11a/CD18), Mac-1 (CD11b/CD18) and p150,95 (CD11c/CD18) in patients undergoing percutaneous transluminal coronary angioplasty (PTCA).**

Background. **Several recent studies have suggested that cell adhesion molecules on both neutrophils and vascular endothelial cells play an important role in the process of tissue inflammation.**

Methods. **Thirty-eight patients (30 men, 8 women; mean [±SE] age 56 ± 5 years, range 38 to 76) with single-vessel coronary artery disease of the left anterior descending artery underwent coronary angioplasty. Peripheral blood was sampled at baseline before, immediately after and 12, 24, 48 and 144 h after PTCA. The expression of CD18, CD11a, CD11b and CD11c on the surface of polymorphonuclear leukocytes was examined by flow cytometry with monoclonal antibodies.**

Results. **In patients without subsequent restenosis, there was no change in mean channel fluorescence intensity (MFI) of CD18 at each sampling time. However, in the patients with restenosis, the MFI of CD18 significantly increased at 48 h after PTCA (from 57 ± 6 to 73 ± 8, p = 0.0008). The MFI of CD11b increased slightly at 48 h after PTCA in patients without restenosis (from 584 ± 121 to 735 ± 114, p = 0.037). In patients with restenosis, the MFI of CD11b was slightly increased at 24 h after PTCA (from 586 ± 122 to 768 ± 214, p = 0.018) and significantly increased at 48 h after PTCA (to 1,534 ± 268, p = 0.0006). The expression of CD11a and CD11c did not change at any sampling points after PTCA in either of the two patient groups. Percent change in the expression of CD18 at 48 h after PTCA (from baseline) and that of CD11b were correlated (r = 0.73, p = 0.0008) in patients with restenosis.**

Conclusions. **Inflammatory stimuli within the coronary vessels associated with coronary angioplasty may upregulate Mac-1 expression on the surface of polymorphonuclear leukocytes. This process may be more marked in patients who experience later restenosis. Thus, activation of neutrophil adhesion molecule Mac-1 at 48 h after PTCA may have value as a predictor of subsequent restenosis.**

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Polymorphonuclear leukocytes migrate across the vascular endothelium into the extravascular space in response to tissue injury and inflammation (1). Leukocyte adhesion to vascular endothelial cells is an important step in this process (2). It has been shown (3,4) that this adhesion is mediated by adhesion molecules, which are expressed on the cell surface. They induce various cell–cell interactions as receptor–ligand relations (3,4).

The neutrophil adhesion molecules include a family of heterodimic glycoproteins (called beta$_2$-integrins) possessing a common beta-subunit of CD18 associated noncovalently with separate alpha-subunits of CD11a, CD11b and CD11c, and designated as LFA-1, Mac-1 and p150,95, respectively (5–7). The adhesion molecules normally exist on the surface of neutrophils. However, inflammatory stimuli produce an increase in the cell surface expression of these molecules (8,9). Endothelial cell surface molecules, including C3bi, derived from the activation of the complement system, and intercellular adhesion molecule-1 (ICAM-1), interact with neutrophil CD18 adhesion-promoting receptor (5–7). The neutrophils adhere to endothelial cells and when activated can release a variety of mediators capable of promoting tissue injury.

Percutaneous transluminal coronary angioplasty (PTCA) is an established treatment for patients with coronary artery disease. Although PTCA has a high initial success rate, restenosis remains a major problem limiting the long-term efficacy of the procedure (10–12). The mechanism of restenosis has not been fully understood. Several investigators (13–15) have suggested that neutrophils might play a part in the mechanism of this restenosis. Coronary angioplasty induces neutrophil activation, which results in the release of various inflammatory mediators that may potentiate development of smooth muscle cell proliferation and resulting restenosis (13–15).

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Acronyms and Abbreviations

ICAM-1	=	intercellular adhesion molecule-1
IL-1	=	interleukin-1
MFI	=	mean channel fluorescence intensity
PTCA	=	percutaneous transluminal coronary angioplasty
TNF-alpha	=	tumor necrosis factor-alpha

The present study sought to determine the role of leukocyte adhesion molecules LFA-1 (CD11a/CD18), Mac-1 (CD11b/CD18) and p150,95 (CD11c/CD18) in patients undergoing PTCA.

Methods

Patients. Thirty-eight patients (30 men, 8 women; mean [±SEM] age 56 ± 5 years, range 38 to 76) who underwent initial elective PTCA were enrolled in the study. They all had isolated atherosclerotic coronary artery disease (≥75% diameter stenosis) of the proximal left anterior descending artery. All patients had clinically stable angina pectoris without previous myocardial infarction and had evidence of ischemia evaluated by exercise stress electrocardiography and thallium-201 myocardial scintigraphy. All patients received the standard medication for angina, including 40 mg of isosorbide dinitrate, 40 mg of nifedipine, 81 mg of aspirin and 75 mg of dipyridamole daily, and none of these drugs was discontinued before PTCA. Exclusion criteria included receipt of other cardioactive drugs and the presence of other cardiac or noncardiac complications that could affect our analysis. Seven healthy volunteers (five men, two women; mean age 49 ± 7 years, range 32 to 72) were also studied as control subjects. The study protocol was approved by the Dokkyo University Institutional Review Board, and written informed consent was obtained from each patient.

Percutaneous transluminal coronary angioplasty. Coronary angioplasty was performed using the standard Judkins technique and a movable guide wire system through the femoral artery. An 8F guiding catheter (USCI, Inc.) was positioned in the coronary ostium, and control coronary angiograms were obtained. All patients received premedication with 5,000 U of intravenous heparin and 0.1 mg of intracoronary nitroglycerin before angiography. The dilation procedure was performed with multiple balloon inflations using steerable nonperfusion balloon dilation catheters (USCI, Inc.) ranging in diameter from 2.5 to 3.5 mm when inflated. Optimal balloon sizes were chosen on the basis of estimates of reference diameter of normal segments adjacent to the lesion. Each balloon inflation was maintained for 90 s at a pressure range from 6 to 12 atm. A nonionic iodinated contrast agent was used during the procedure (Iopamidole, Schering AG) in all patients. After PTCA, all patients received 500 U/h of intravenous heparin for 24 h. Any oral medications were not changed until follow-up angiography. Follow-up angiography was recommended to all patients at 6 months after PTCA and was performed earlier if there were clinical indications. Coronary lesions were assessed angiographically before and immediately after PTCA and at follow-up coronary angiography. The method used, caliper measurements in multiple projections, adequately demonstrated the lesions. Primary success of angioplasty was defined as a 20% increase in lumen diameter and a residual diameter stenosis <50%. For purposes of follow-up angiography, restenosis was defined as >50% diameter stenosis.

Flow cytometric analysis of leukocyte adhesion molecules. In each patient, peripheral blood was sampled at baseline before, immediately after and 12, 24, 48 and 144 h after PTCA. Blood samples were also obtained from the healthy volunteers. The expression of CD18, CD11a, CD11b and CD11c on the surface of polymorphonuclear leukocytes was analyzed by flow cytometry with monoclonal antibodies. Blood was immediately collected in a tube containing acid citrate dextrose (ACD). Two-color immunofluorescence staining (16) was performed using fluorescein isothiocyanate (FITC) (17) conjugated anti-CD18 (IOT18, Immunotech, Inc.) and anti-CD11a (IOT16, Immunotech, Inc.) and phycoerythrin (PE) (18) conjugated anti-CD11b (Lew 15, Becton Dickinson) and anti-CD11c (LewM5, Becton Dickinson). After hemolysis was completed by the lysing solution, cells were fixed in a paraformaldehyde solution with phosphate-buffered saline (PBS). The staining process was performed according to the National Committee for Clinical Laboratory Standards guidelines for flow cytometry (19). Two-color flow cytometric analysis was then performed using a FACScan laser flow cytometry system (Becton Dickinson) within 2 h. We collected the data from 10,000 cells/test and analyzed the scatter signals and fluorescence intensity. The light-scattering properties projected on a scattergram could distinguish the polymorphonuclear leukocyte cluster from other leukocyte clusters (20). Fluorescence intensity was expressed on a cytohistogram where the region of interest was limited to the polymorphonuclear leukocyte cluster for CD18, CD11a, CD11b, and CD11c each. Mean channel fluorescence intensity (MFI) (21) was calculated as the index of the expression of each adhesion molecule.

Data analysis. Coronary angiograms were assessed by two independent observers (T.I., Y.S.). Each observer measured the severity of stenosis using the same technique, and the mean value was recorded. There was a 1.8 ± 5.7% difference between the two observers on 30 randomly selected lesions, excluding those of the study patients. Serial changes in the MFI of CD18, CD11a, CD11b and CD11c were each analyzed using repeated measures analysis of variance in patients with and without restenosis for intragroup and intergroup comparisons. Comparisons of the values between the two patient groups and the control subjects were performed using one-way analysis of variance. The chi-square test or unpaired *t* test was used for intergroup comparisons of baseline characteristics. Correlation between percent increase in the MFI of CD18 and that of CD11b was determined with linear regression in each patient group. To predict the occurrence of restenosis, the sensitivity of increases in the MFI of CD18 or CD11b, or both, was

Table 1. Clinical Characteristics of 38 Study Patients

	Pts Without Restenosis (n = 24)	Pts With Restenosis (n = 14)	p Value
Age	55 ± 4	57 ± 3	0.366
Men/women (no.)	19/5	11/3	0.284
Leukocyte count (/μl)	6,760 ± 360	6,270 ± 290	0.226
Platelet count (×10⁴/μl)	28.5 ± 4.6	30.2 ± 5.8	0.183
PT (s)	11.2 ± 0.3	11.3 ± 0.2	0.676
APTT (s)	31.6 ± 0.6	31.9 ± 0.5	0.720
Coronary risk factors			
Cigarette smoking	21 (88%)	12 (86%)	0.624
Family history	7 (29%)	4 (28%)	0.641
Diabetes mellitus	4 (17%)	2 (14%)	0.528
Systemic hypertension	7 (29%)	4 (28%)	0.725
Total cholesterol (mg/dl)			
Before PTCA	207 ± 9	214 ± 12	0.465
At follow-up study	197 ± 8	199 ± 14	0.673
HDL cholesterol (mg/dl)			
Before PTCA	37 ± 2	36 ± 2	0.322
At follow-up study	39 ± 4	39 ± 3	0.864
Taking lipid-lowering drugs	4 (17%)	2 (14%)	0.464

Data presented are mean ± SE or number (%) of patients (Pts). APTT = activated partial thromboplastin time; HDL = high density lipoprotein; PT = prothrombin time; PTCA = percutaneous transluminal coronary angioplasty.

determined as true positive/(true positive + false negative), specificity as true negative/(true negative + false positive), positive predictive values as true positive/(true positive + false positive) and negative predictive values as true negative/(true negative + false negative). Results are expressed as mean value ± SE; $p < 0.05$ was considered significant.

Results

Results of angioplasty. Balloon inflations ranged from three to eight (mean 4.2 ± 0.3), and PTCA was initially successful in all patients. No patient experienced either abrupt coronary occlusion or major coronary dissection. However, restenosis was seen in 14 patients at follow-up angiography. Comparison of 24 patients without restenosis and 14 with restenosis revealed no significant differences in age, gender, leukocyte counts, platelet counts and blood coagulation activity before PTCA. There were also no significant differences among the patients with regard to coronary risk factors, such as smoking habits, family history, diabetes mellitus, hypertension and hyperlipidemia (Table 1). Characteristics of coronary lesions, including reference diameter, American College of Cardiology/American Heart Association classification of lesion type, American Heart Association classification of lesion location and severity of stenosis before and immediately after PTCA, were similar in patients with and without restenosis. Furthermore, there were no significant differences between patients with and without restenosis with regard to the angioplasty procedure itself (balloon size, number of inflations, inflation pressures, duration of inflations, duration of the procedure and amount of contrast medium used). In patients with restenosis, time to follow-up study after PTCA was 4.8 ± 1.1 months, possibly indicating the interval after PTCA when restenosis was first clinically demonstrable, whereas it was 6.6 ± 0.4 months ($p = 0.045$) in patients without restenosis (Table 2).

Expression of leukocyte adhesion molecules. Serial changes in adhesion molecule expression in patients with and without restenosis compared with control values are shown in Figure 1. The MFI for CD18 at each sampling time did not change immediately or 12, 24 or 48 h after PTCA from baseline values in patients without restenosis. However, in patients with restenosis, it significantly increased at 48 h after PTCA (from 57 ± 6 to 73 ± 8, $p = 0.0008$). The MFI for CD11b increased slightly at 48 h after PTCA even in patients without restenosis (from 584 ± 121 to 735 ± 114, $p = 0.037$). In the restenosis group, the MFI for CD11b increased slightly at 24 h after PTCA (from 586 ± 122 to 768 ± 214, $p = 0.018$) and increased significantly at 48 h after PTCA (to 1,534 ± 268, $p = 0.0006$). The expression of CD11a and CD11c in both patient groups did not change at any sampling time. A comparison of patients with and without restenosis at each sampling time reveals that there were no significant differences in MFI values, except that for CD11b at 48 h after PTCA, which was slightly higher ($p = 0.021$) in patients with restenosis. A comparison of each patient group versus control values shows no significant difference, except for the MFI for CD18 ($p = 0.046$) and CD11b ($p = 0.009$) at 48 h after PTCA, which were higher in patients with restenosis.

Figure 2 shows a correlation between the percent change in expression at 48 h after PTCA from the baseline value of CD18 and CD11b in each patient. Both changes were correlated in patients with ($r = 0.73$, $p = 0.0008$) but not in those without ($r = 0.17$, $p = 0.382$) restenosis. This relation also showed that the increase in expression of both CD18 and CD11b at 48 h

Table 2. Profiles of Coronary Lesions and Angioplasty Procedure in 38 Study Patients

	Pts Without Restenosis (n = 24)	Pts With Restenosis (n = 14)	p Value
Reference diameter (mm)	2.82 ± 0.07	2.79 ± 0.06	0.322
ACC/AHA lesion type (A/B)	14/10	8/6	0.283
AHA lesion location (seg 6/seg 7)	10/14	7/7	0.128
% diameter stenosis			
Pre-PTCA	86.9 ± 3.4	85.2 ± 2.8	0.267
Post-PTCA	14.0 ± 2.5	15.6 ± 3.2	0.324
Follow-up study	36.5 ± 4.2	64.8 ± 8.6	0.0003
Final balloon size (mm)	2.91 ± 0.07	2.89 ± 0.08	0.362
No. of inflation trials (times)	4.1 ± 0.3	4.2 ± 0.4	0.456
Peak inflation pressure (atm)	11.2 ± 0.3	11.1 ± 0.2	0.867
Duration of total inflations (s)	368 ± 27	382 ± 36	0.572
Duration of all procedures (min)	56 ± 3	59 ± 3	0.120
Amount of contrast medium (ml)	148 ± 7	152 ± 9	0.261
Follow-up term (mo)	6.6 ± 0.4	4.8 ± 1.1	0.045

Data presented are mean value ± SE or number of lesions. ACC = American College of Cardiology; AHA = American Heart Association; seg = segment; other abbreviations as in Table 1.

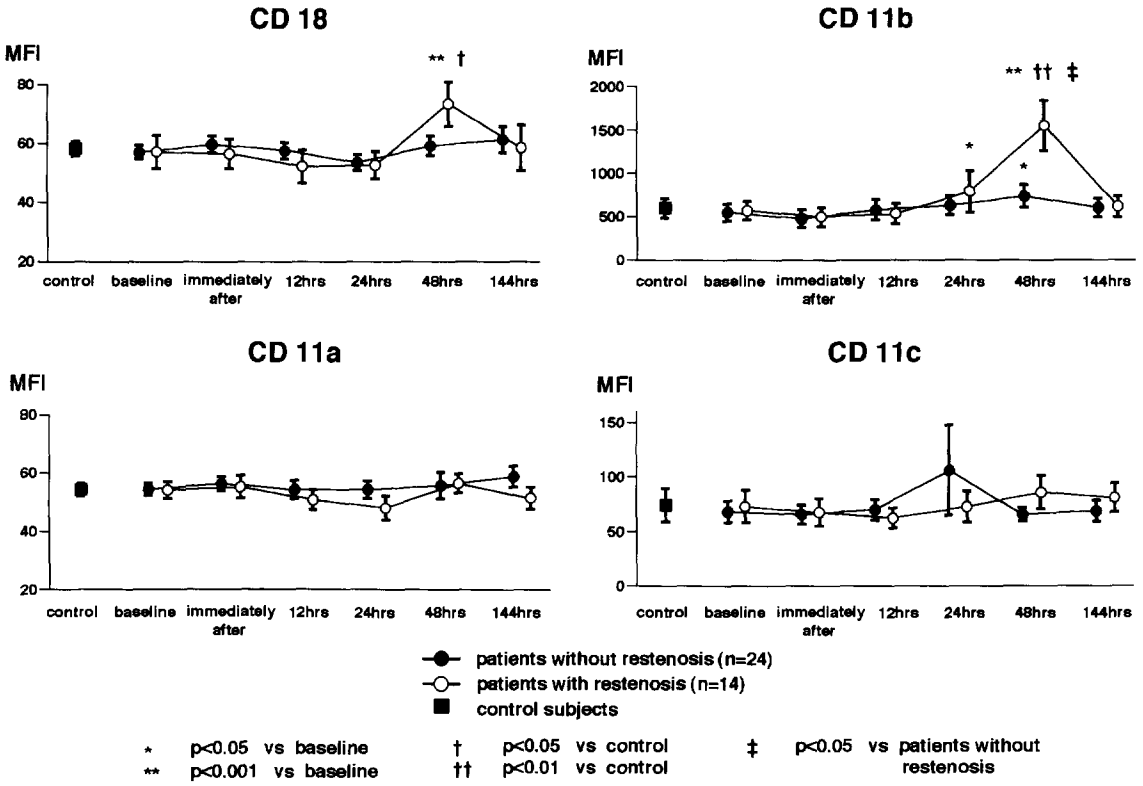
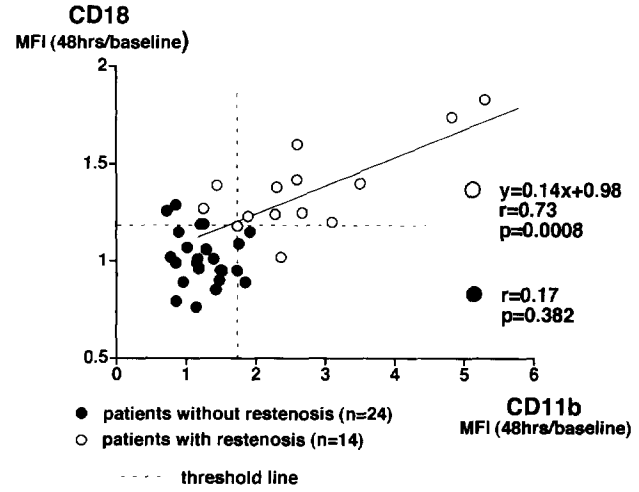


Figure 1. Serial changes of each leukocyte adhesion molecule expression evaluated separately in patients with and without restenosis compared with control values. See Results for details.

was greater in patients with restenosis. In our analysis of percent change in CD18 at 48 h after PTCA, a threshold value of 1.2 had a sensitivity of 86%, a specificity of 83%, a positive predictive value of 75% and a negative predictive value of 91%. For analysis of the percent change in CD11b, a threshold value of 1.7 had a sensitivity of 79%, a specificity of 88%, a positive predictive value of 79% and a negative predictive value of 88%. Furthermore, for both a >1.2-fold increase in expression of CD18 and a >1.7-fold increase in that of CD11b, the sensitivity, specificity and positive and negative predictive values were 71%, 100%, 100% and 86%, respectively.

Figure 2. Correlation between percent change in adhesion molecule expression at 48 h after PTCA from baseline value of CD18 and CD11b in each patient. See Results for details.



Discussion

In our study, only patients with single-vessel coronary artery disease of the proximal left anterior descending artery were selected for inclusion. All patients had stable angina and no previous myocardial infarction, and all were given identical medications during the postprocedural period. We demonstrated that the expression of CD18 and CD11b on the surface of polymorphonuclear leukocytes sampled from peripheral blood increased at 48 h after PTCA, whereas expression of CD11a and CD11c did not. Increases in the expression of CD18 and CD11b at 48 h after PTCA were more prominent in patients with restenosis group despite the finding that baseline characteristics (including invasive procedure, coronary risk factors and leukocyte count) were similar between patients with and without restenosis. Furthermore, the relation between both increases in CD18 and CD11b shown in the restenosis group indicates that the increase in CD18 expression might correspond to the increase in Mac-1. These results suggest that the repeated balloon inflations during PTCA resulted in an upregulation of Mac-1 on the surface of

polymorphonuclear leukocytes at 48 h after PTCA that might be related to the development of restenosis. Moreover, the upregulation of Mac-1 at 48 h after PTCA had a high predictive value for subsequent restenosis.

Expression of neutrophil adhesion molecules as a marker for inflammation. It is widely recognized that adhesion molecules CD18, CD11a, CD11b and CD11c are expressed on the surface of circulatory neutrophils even under normal conditions and can be upregulated severalfold by inflammatory stimuli using various cytokines, including tumor necrosis factor-alpha (TNF-alpha), interleukin-1 (IL-1) or endotoxins (8,9). In our study, no significant differences were seen in MFI values of the adhesion molecules in patients with and without restenosis at any time point or in these patients compared with control subjects, except for the values of CD18 and CD11b at 48 h after PTCA. These values showed large individual variations not only in the patient groups but also among the control subjects. However, serial changes in an individual are suggestive of greater significance, and the findings that the values of CD18 and CD11b increased at 48 h after PTCA in patients with restenosis might be of value.

Recently, neutrophil adhesion molecules LFA-1, Mac-1 or p150,95, alone or in combination, have been postulated to play a role in myocardial reperfusion injury (22–27). Endothelial injury secondary to ischemia and reperfusion promotes neutrophil adherence to the endothelial cell surface of the postcapillary venules. However, these phenomena have been recognized mainly in experimental studies with animals, and the role of adhesion molecules in the human heart remains controversial. Our data suggest that leukocyte adhesion molecules may also have a significant impact on the human heart.

Restenosis after coronary angioplasty. Restenosis is the major limitation to the long-term success of PTCA. Restenosis occurs within several months of the procedure in approximately one-third of patients (10–12). The pathophysiology of restenosis has been controversial, but several histopathologic studies indicate that intimal proliferation of smooth muscle cells is a major mechanism (28). Traumatic injury of the vessel wall during angioplasty probably triggers a series of cellular and subcellular events that may ultimately lead to myointimal proliferation and restenosis. Although the exact mechanism by which this occurs is unknown, several factors may enhance smooth muscle cell growth and therefore play a role in the development of restenosis. These include platelet deposition, mechanical stretching of the media; inflammation of the vessel wall; the activity of growth factors, such as platelet-derived growth factor (PDGF) and basic fibroblast growth factor (bFGF); vasoactive substances, such as serotonin and thromboxane A_2; wall shear stress; alterations in vessel geometry; and other, still unknown factors (29,30). Leukocyte function has recently been singled out for its role in smooth muscle cell proliferation. In addition to production of various growth factors by macrophages (31), activated neutrophils have been also implicated in platelet activation and smooth muscle cell proliferation (13–15,32).

Role of neutrophils in mechanism of restenosis. Coronary angioplasty induces neutrophil activation, which results in the release of a variety of inflammatory mediators, for example, granulocyte proteases, such as elastase, and superoxide anion (14,15). The release of proteolytic enzymes and the generation of oxygen free radicals may aggravate the endothelial damage and further stimulate platelets. This process has potential implications in the subsequent development of smooth muscle cell proliferation and resulting restenosis. During the process of neutrophil activation, the adhesion of neutrophils to vascular endothelial cells is an important physiologic interaction. Thus, it is suggested that the adhesion molecules on the surface of both neutrophils and endothelial cells may play a role in the mechanisms of restenosis.

Two possible mechanisms explain how PTCA induces the upregulation of Mac-1: 1) This process may result from ischemia–reperfusion cycles induced by repeated balloon inflations; 2) the traumatic vascular injury by balloon inflation may result in this upregulation. Although neutrophil activation may be triggered by 15 min of ischemia followed by reperfusion (22), it is not known whether repeated but shorter bouts of ischemia followed by restoration of flow, as occurs during PTCA, could have the same effects. Mazzone et al. (33) observed increased expression of adhesion molecules CD18 and CD11b on the surface of neutrophils taken from the coronary sinus in patients with unstable angina. They speculated that plaque rupture and subsequent inflammation associated with considerable coronary vascular damage in unstable angina might increase the expression of these molecules. In line with their suggestion, the traumatic vascular injury may be the more important factor. In our study, it would appear that inflammatory stimuli within the coronary vessels attributable to coronary angioplasty may upregulate Mac-1 expression on the surface of polymorphonuclear leukocytes. Therefore, the upregulation of Mac-1 may be an indicator of injury or inflammation within the vessel.

Ikeda et al. (34) observed that neutrophil surface expression of CD11b in the coronary sinus blood increased immediately after PTCA. In that report, however, the expression was evaluated immediately after PTCA only, whereas our study showed an increase at 48 h after PTCA. We cannot explain why upregulation occurred only at 48 h after the procedure. We believe that the magnitude of inflammatory stimuli may be related to the duration of leukocyte activation and that ex vivo stimuli using cytokines or endotoxins produced immediate upregulation of Mac-1 on the surface of leukocytes. In contrast, Tanaka et al. (35) observed the expression of ICAM-1, a counterreceptor of LFA-1 and Mac-1, on the endothelial cell surface of rabbit aorta 48 h after balloon injury. Prescott et al. (32) observed that neutrophils adhered to endothelium at 48 h after inducing leukocyte migration by the implantation of an endotoxin-soaked cotton thread in the adventitia of the rat femoral artery. If the nature of inflammatory stimuli produced by PTCA angioplasty in humans is similar to that seen in those experiments, our results at 48 h may be understandable. In addition, in view of the short life expectancy of the polymor-

phonuclear leukocyte, it is likely that PTCA creates a persistent proinflammatory surface within the artery that can stimulate leukocyte expression of Mac-1 for 2 days or that the section of artery traumatized by the balloon inflations begins to secrete cytokines such as TNF-alpha or IL-1 ~24 to 36 h after the procedure, which can upregulate surface expression of Mac-1. The same cytokines that stimulate expression of the leukocyte adhesion molecules may also stimulate smooth muscle cell proliferation (36).

In contrast, the study by Ikeda et al. (34) did not indicate a direct relation between CD11b expression and the progression of restenosis. To our knowledge, our study is the first to demonstrate that the upregulation of Mac-1 is significantly greater in patients with than without restenosis. Although our study does not necessarily prove that this upregulation has a direct role in the mechanism of restenosis, it does suggest some relation between this finding and the pathogenesis of restenosis. Moreover, our results also suggest that activation of the polymorphonuclear leukocyte Mac-1 at 48 h after PTCA may have value as a predictor of subsequent restenosis.

Potential limitations. Our study has several possible limitations. Although we showed that the observed increase in CD18 and CD11b had high predictive values for the occurrence of restenosis, these data were analyzed only retrospectively. Another prospective trial to validate this prediction should be considered. In our study, coronary lesions were assessed angiographically using only caliper measurements. In light of recent progression of quantitative coronary angiographic analysis, we would need to interpret the relation between leukocyte function and quantitative coronary angiographic data.

In addition, the expression of leukocyte adhesion molecules in our study may have been modified by invasive procedures, such as arterial puncture or coronary artery catheterization. The introduction of infusion materials, such as contrast medium (37) or heparin (38), might also influence leukocyte function. However, there may still be significance in the finding that serial patterns for the expression of CD18 and CD11b were different in patient groups with and without restenosis because these groups were similar in terms of the invasive procedures performed, amount of contrast medium used and dose and duration of heparin.

Clinical implications. Our study demonstrated that the expression of CD18 and CD11b on the surface of polymorphonuclear leukocytes sampled from peripheral blood increased at 48 h after PTCA. Inflammatory stimuli within the coronary vessels, which may be attributable to repeated short-term ischemia–reperfusion cycles or traumatic vascular injury associated with the angioplasty, or both, may upregulate Mac-1 on the surface of polymorphonuclear leukocytes. This process may be more pronounced in patients who experience later restenosis. Thus, the upregulation of polymorphonuclear leukocyte Mac-1 at 48 h after PTCA may have value as a predictor of restenosis.

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