Special Article

Percutaneous Coronary Angioscopy

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OVERVIEW

Morphologic changes in the coronary arteries of patients with ischemic heart disease were evaluated by angiography. Although a powerful diagnostic tool, angiography can show only the shadow of the luminal changes and therefore is an insufficient tool for diagnosis of pathological changes. Recent advances in fiberoptic technology now enable observation of the luminal changes even in small diameter vessels.

The fiberscope is now used for observation of experimental thrombosis and thrombolysis[1]; laser irradiation induced changes in cadaveric hearts and vessels[2]; luminal changes in peripheral vessels[3] and the pulmonary artery,[4] laser-induced changes in femoral arteries in patients with obstructive atherosclerosis[5]; thromboemboli in patients with pulmonary embolism[6]; cardiac chambers and valves in animals[7] and in various categories of heart disease in man,[8)-10] and for guidance of endomyocardial biopsy.[11),12] The angioscope is also used for observation of the coronary arteries during coronary artery bypass surgery.[13),14] Recently, the coronary artery has also been observed during cardiac catheterization.[15)-18] In this study, we describe percutaneous angioscopy of the coronary artery during routine cardiac catheterization or intervention.

APPLICATION OF CORONARY ANGIOSCOPY

Fiberscope

The fiberscopes used in this study were 1.6 French with 2,000 or 3,000 image glass fibers and 100 illumination fibers; 2.6 French with 3,000 image glass fibers and 150 illumination fibers; and 4.2 French with 3,000 image fibers and 200 illumination fibers (Olympus Corp. Ltd., Tokyo).

Guiding Balloon Catheter for Angioscopy of Proximal Coronary Segments

The guiding balloon catheters had 7 or 9 French external diameters of the Judkins or Amplatz type tip configuration, had a single lumen and a distal tip balloon diameter of 20.7 mm when fully inflated (Fig. 1, Clinical Supply Co., Gifu, Japan). Two to 3.5 ml of CO_2 were required to fully inflate the balloon.

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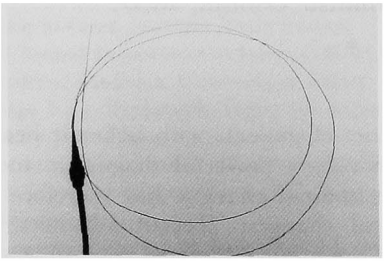

Fig. 1. A fiberscope 1.6 French in diameter.

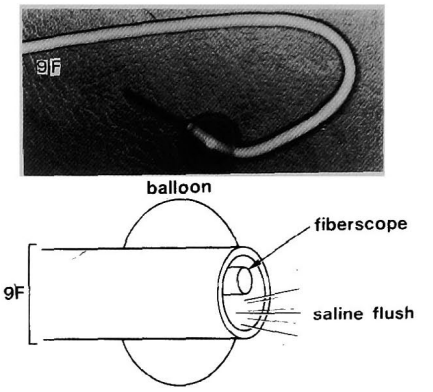

Fig. 2. A guiding balloon catheter 9 French in diameter and Judkins type tip configuration.

One of these guiding balloon catheters was selected according to the artery targeted for examination. The 7 and 9 French catheters were used to guide 2.6 and 4.2 French fiberscopes, respectively. This type of guiding balloon catheter was useful to obstruct the coronary ostium. The guiding balloon catheter was introduced through the sheath and advanced into the aoric root and then introduced into the ostium of the coronary artery. When necessary, the pressure was monitored from the distal lumen to identify whether the coronary artery was occluded. The balloon was inflated manually with CO_2. One of the fiberscopes was then advanced through the guiding catheter into the artery and warmed saline (heparin 10 IU/ml) was infused manually to displace the blood.

Guiding Balloon Catheters for Observation of Middle to Distal Coronary Segments

Although the above mentioned single lumen guiding balloon catheter is useful for observation of the proximal coronary segments, it is inadequate for observation of the middle-to-distal coronary segments. Therefore, we devised a 5 French guiding balloon catheter with 3 lumens, one for a 1.4 French fiberscope, one for a 0.014 or 0.018 inch guide wire, and one for saline flush. The catheter tip could be deflected for up to 35° by a deflector (Figs. 3 and 4). The guiding balloon catheter was introduced through a 9 French guiding catheter usually used for PTCA, and over the wire into the desired coronary segment. The balloon was inflated with CO_2 until catheter tip pressure dropped, and then warmed saline was infused manually for observation. When good coaxiality could not be obtained by the guide wire alone, the catheter tip was deflected until the fiberscope faced the lesion targeted for observation. Since the fiberscope was steerable, it could be advanced or pulled back for serial observation. This type of balloon guiding catheter could also be used for observation of the proximal coronary segments, although blood displacement was sometimes inadequate.

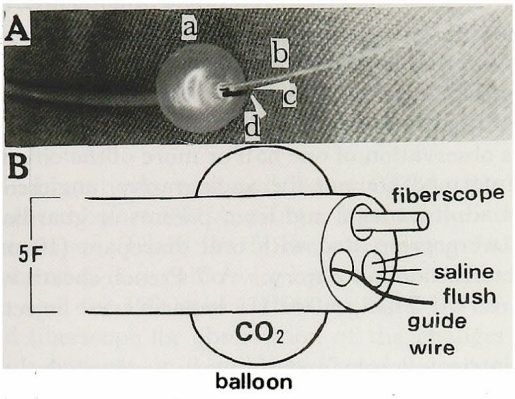

Fig. 3. A: three lumen guiding balloon catheter 5 French in diameter. a: balloon, b: 0.014 inch guide wire, c: flush lumen, d: fiberscope 1.6 French.
B: schematic representation of the catheter.

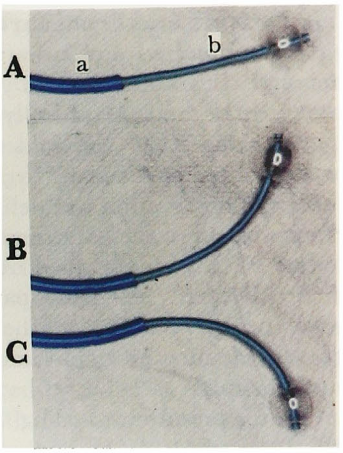

Fig. 4. The same catheter as that in Fig. 3.
A: before angulation. a: guiding catheter 9 French in diameter, b: guiding balloon catheter 5 French in diameter.
B and C: after angulation by deflector.

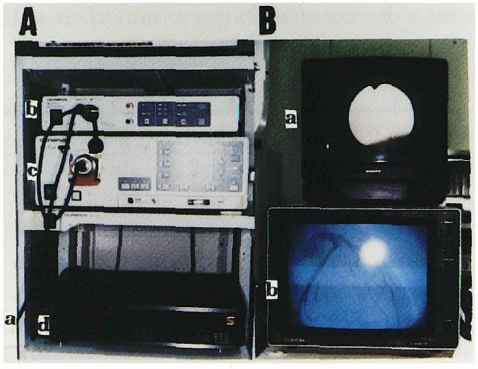

Fig. 5. A: angioscopy system. a: fiberscope, b: videoconverter, c: illumination source, d: videorecorder.
B: monitors. a: angioscopy monitor, b: angiography monitor.

Accompanying Equipment

In all these types of fiberscope, the fiberscope was connected to an illumination source. The obtained changes were transmitted via a CCD camera to a videoconverter and were recorded on 8, 16 or 24 mm videotapes, or on 16 mm color cinefilms at 25 frames/sec (Fig. 5). When necessary, the changes recorded on videotape could be printed out by color videoprinter (Sony Co. Ltd., Tokyo) for confirmation of the changes.

Patients and Procedures

One hundred and twenty-nine patients underwent coronary angioscopy (91 men and 38 women; 5 to 76 years old; 9 with chest pain without significant coronary stenosis angiographically, 61 with stable angina pectoris, 16 with unstable angina pectoris, 20 with old myocardial infarction, 8 with acute myocardial infarction, 10 after coronary bypass grafting, and 5 with Kawasaki disease (Table I). Successful observation was defined as observation of one half or more of the circumference of the targeted segment. Informed consent for angiography, angioscopy and/or PTCA was obtained from all adult patients and from parents or guardians of the children. All adult patients were pretreated with oral diazepam (10 mg) before being transferred to the catheterization laboratory. A 7 French sheath was introduced into the right femoral artery. Then, 5,000 IU heparin were injected intravenously.

After pressure recording, left ventriculography and coronary angiography, the sheath was replaced by an 8 or 9 French sheath. For observation of the proximal coronary artery, a 7 or 9 French guiding balloon catheter was introduced through the sheath into the coronary artery. Then, a 2.6 or 4.2 French fiberscope was introduced through the guiding catheter into the proximal coronary segments. During observation, the fiberscope was advanced or pulled back for serial observation (Fig. 6).

In other adult patients, the sheath was replaced by a 9 French sheath, through which a 9 French guiding catheter, which is used for PTCA, was introduced into the coronary artery, a 5 French guiding balloon catheter was introduced over a 0.014 inch guide wire into the coronary artery, and then a 1.4 French fiberscope

Table I. Subjects

129 patients; F 38, M 91; 5-76 y.o.	
chest pain alone	9
stable angina pectoris	61
unstable angina pectoris	16
old myocardial infarction	20
acute myocardial infarction	8
Kawasaki disease	5
CABG	10

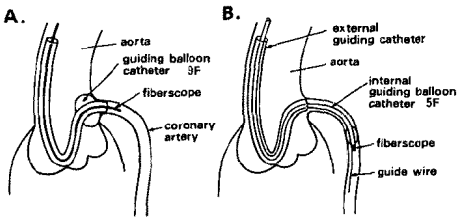

Fig. 6. Schematic representation of coronary angioscopy by preshaped guiding balloon catheter 9 French in diameter (A) and by three lumen guiding balloon catheter 5 French in diameter (B).

was introduced through one lumen of the 5 French guiding balloon catheter into the coronary artery for observation of the middle to distal coronary segments (Fig. 6). Usually, 200 μg nitroglycerin were injected into the coronary artery before introduction of the 5 French guiding balloon catheter to prevent coronary spasm. In adult patients who underwent observation of bypass grafts, a 9 French guiding catheter, which is used for PTCA, and a 5 French guiding balloon catheter were usually used.

In patients who underwent PTCA, the targeted lesion was angioscopically observed before PTCA, using a 5 French guiding balloon catheter and a 1.4 French fiberscope. Then, the 5 French guiding balloon catheter and fiberscope were replaced over a guide wire by a balloon catheter for PTCA. The balloon catheter used for PTCA was then replaced by the 5 French guiding balloon catheter and fiberscope for observation of the changes induced by PTCA. In contrast to adult patients, in 2 children (5 and 8 years old) with Kawasaki disease, 5–10 mg diazepam were injected intravenously in the catheterization laboratory, and a 7 French guiding balloon catheter was introduced into the coronary artery for observation of the coronary artery. In 3 other children with Kawasaki disease, an 8 French guiding catheter used for PTCA and a 4.6 French fiberscope were used for observation.

Clinical Results

Percutaneous coronary angioscopy was successful in 102 of 129 patients, namely, in all 9 with chest pain without significant coronary stenosis, 56 of 61 patients with stable angina pectoris with or without old myocardial infarction, 12 of 16 with unstable angina pectoris, 17 of 20 with old myocardial infarction, 5 of 8 with acute myocardial infarction, 8 of 10 after CABG and 4 of 5 with Kawasaki disease. Overall success rate was 86%. Among these patients, 29 patients with angina pectoris underwent coronary angioscopy before and after PTCA (Table II).

1. Angioscopic features of nonstenotic coronary artery

Figure 7 shows an angiogram of a left coronary artery in right oblique projection and angioscopic features of the main coronary artery (LMT) and its bifurcation to the circumflex artery (LCX) in a patient with chest pain without demonstrable angiographic coronary changes.

Table II. Success Rate

	n	(%)
chest pain	9/9	100
stable angina pectoris	56/61	90
unstable angina pectoris	12/16	75
old myocardial infarction	17/20	85
acute myocardial infarction	5/8	62
Kawasaki disease	4/5	80
CABG	8/10	80
Total	111/129	86

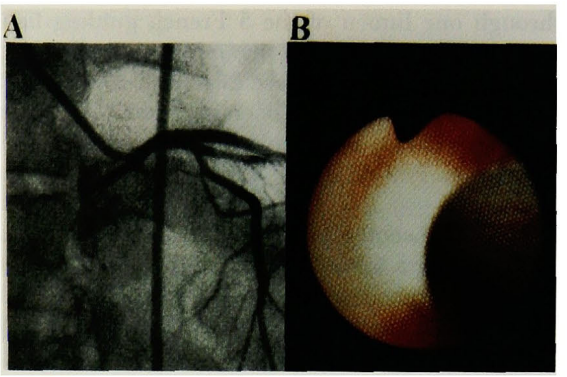

Fig. 7. A 32-year-old female with chest pain syndrome.
A: angiogram of left coronary artery. No significant stenosis.
B: angioscopic features of the left main trunk (LMT) and the ostium of the left circumflex artery (LCX), which corresponds to A. The luminal surface was light yellow.

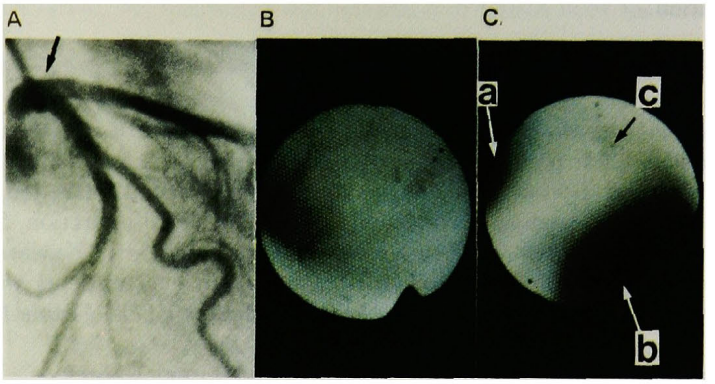

Fig. 8. A 58-year-old male with chest pain syndrome.
A: angiogram of the left coronary artery. B: angioscopic feature of the LMT. C: blunt bifurcation of the left anterior descending artery (LAD) and LCX (arrow corresponds to that in A). The luminal surface was white colored, suggesting fibrosis.

Angioscopically, the luminal surface was smooth and light yellow in color. In addition, the angle of bifurcation was sharp (Fig. 7). Similar changes were observed in 8 other patients with chest pain with ages below 40 years and with angiographically smooth coronary arteries. The coronary segments, especially the left anterior descending artery (LAD) collapsed or expanded in synchrony with each cardiac beat during saline infusion in these patients. Nonstenotic coronary segments were also observed in 43 other patients with angina pectoris or old myocardial infarction. Angiographically, 20 segments were somewhat uneven, 14 had corkscrew distal branches, and the remaining 9 had smooth luminal surfaces. Angioscopically, however, 14 segments were white colored (Fig. 8), 29 segments were yellow colored (Fig. 9), and 30 had spiral folds (Fig. 10).

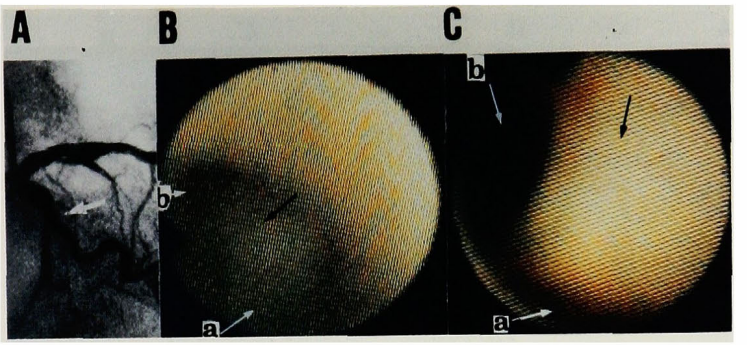

Fig. 9. A 50-year-old female with chest pain without demonstrable angiographic change except corkscrew changes.

A: angiogram of left coronary artery. B, C: angioscopic features of LCX and its bifurcation to obtrude marginal branch (arrows). The luminal surface was yellow in color and had spiral folds, suggesting fat deposition.

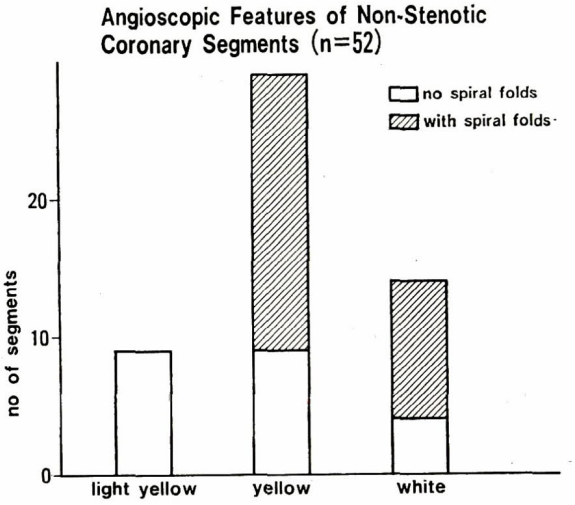

Fig. 10. Angioscopic features of nonstenotic coronary artery.

2. Angioscopic features of stenotic coronary segments

Angioscopically, the stenotic coronary segments were composed of regular plaque (smooth surfaced) and complex plaque (irregular with or without ulcers, bleeding, thrombus and/or dissection).

Figure 11 represents an angiogram of the LMT and angioscopic features of the same segment. Angiographically, this LMT had a smooth concentric stenosis which extended to the LAD and LCX. Angioscopically, the segment was composed of white and smooth plaque (regular plaque), and the blood flow into the residual lumen could be observed during diastole. Such white colored regular plaques could be observed in 17 of 90 segments (Fig. 12).

Figure 13 shows angiographically smooth eccentric stenosis in the proximal

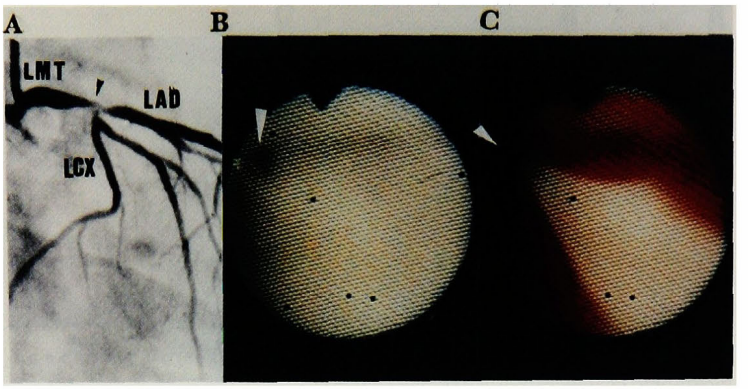

Fig. 11. A 50-year-old male with stable angina pectoris.

A: angiogram of the left coronary artery. Smooth concentric stenosis of LMT, LAD and LCX. B: angioscopic feature of the stenotic segment of LMT which corresponds to the arrow in A. Smooth stenosis with white (fibrous) plaque. Arrow: stenotic segment. C: blood stream into the stenotic segment immediately after deflation of the balloon.

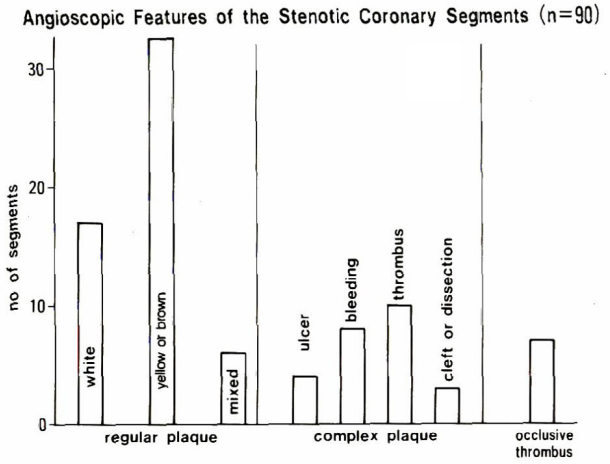

Fig. 12. Angioscopic features of stenotic coronary artery.

LAD. Angioscopically, this segment was composed of smooth yellow plaque (artheromatous or xanthomatous). Such yellow regular plaque was observed in 27 segments. Also, regular and brown colored plaque was observed in 6 segments (Figs. 12, 14). In addition to these plaques, regular plaque, with yellow and white portions distributed in mosaic fashion, was observed in 6 of 90 segments (Fig. 12). Different from these regular plaques, complex plaques were also observed in 18 of 90 segments; namely, irregular plaque alone comprising the stenotic segment (Figs. 15A, 16), irregular plaque with ulcer (Fig. 17), and irregular plaque with dissection and/or bleeding or thrombus (Figs. 15B and 12). These complex plaques were

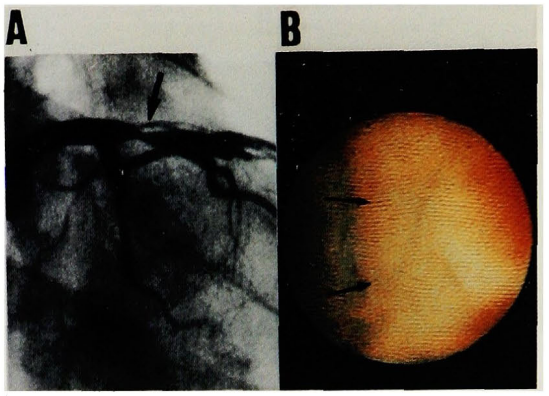

Fig. 13. A 62-year-old male with stable angina pectoris.
A: angiogram of left coronary artery. Smooth concentric stenosis (arrow). B: angioscopic feature of the same segment. Stenosis with smooth and yellow (atheromatous) plaque (arrows).

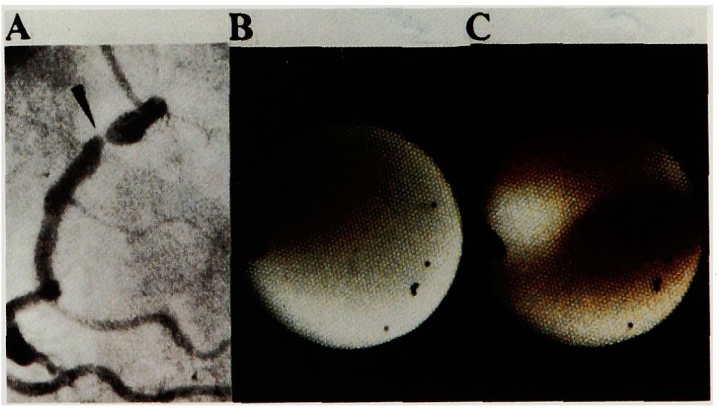

Fig. 14. A 62-year-old female with stable angina pectoris.
A: concentric stenosis of right coronary artery (RCA). B: angioscopic features of the stenotic segment corresponding to the arrow in A. Stenosis with a smooth brown plaque. C: closer observation of the same segment.

observed more frequently in patients with unstable angina pectoris (Fig. 18). Occlusive thrombus was also observed in all 5 patients with acute myocardial infarction and in 2 of 12 patients with unstable angina pectoris (Figs. 18 and 19).

The thrombus was red and white in mosaic fashion indicating a fresh mixed thrombus in 4 patients. In the remaining 3 patients, the thrombi were white colored, indicating platelets and/or fibrin thrombi. Although the thrombi were detected, it was impossible to differentiate these two kinds of thrombi by angiography. Different from these two types of thrombi, a doughnutlike thin mural thrombus surrounded the inlet of a stenotic segment which was composed of a white and smooth plaque in a patient with unstable angina pectoris (Fig. 20). Although the plaque

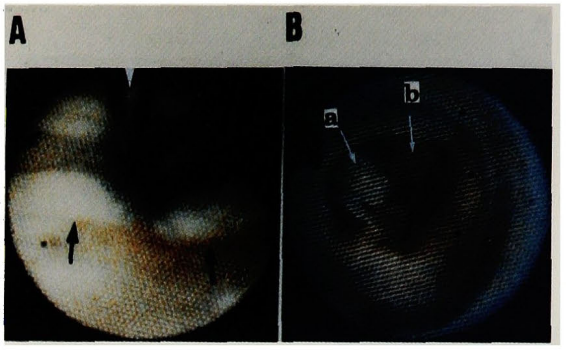

Fig. 15. Complex plaques.
A: a 61-year-old male with unstable angina pectoris. Ruptured and brown colored plaques in the middle segment of the right coronary artery. B: a 58-year-old male with unstable angina pectoris. Intimal flap (a) and thrombi (b) in the middle segment of RCA.

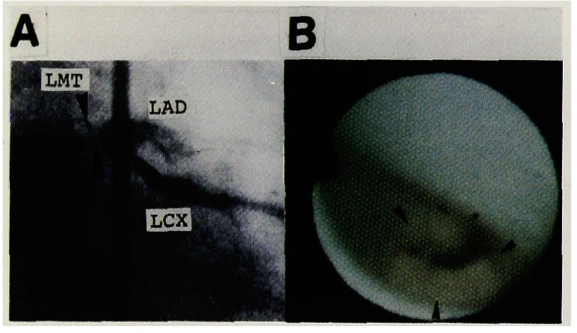

Fig. 16. A 70-year-old male with unstable angina pectoris.
A: stenotic LMT (arrows). B: irregular plaque surrounding the inlet of stenotic segment (arrows).

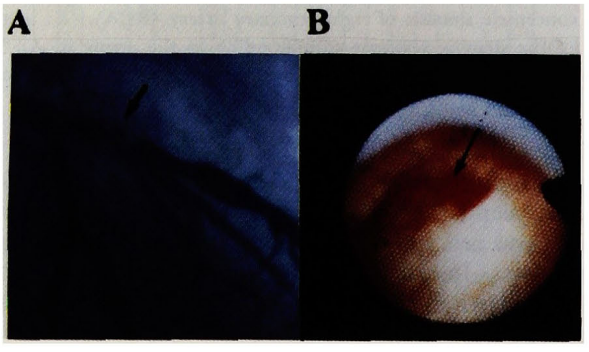

Fig. 17. Coronary ulcer. A 67-year-old male one month after the onset of acute myocardial infarction. A: angiogram of LAD showing ulcer in the stenotic segment. B: angioscopic feature of the aneurysm.

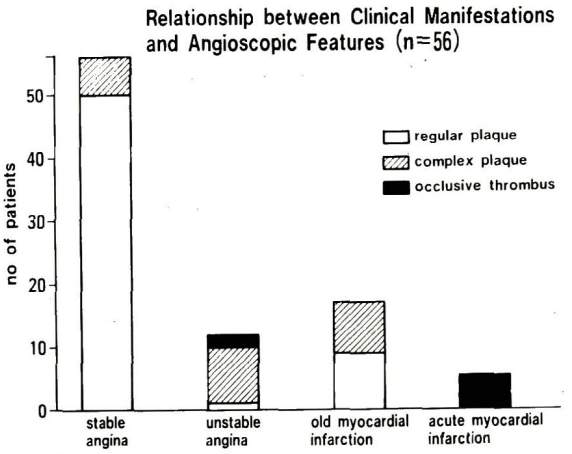

Fig. 18. Relationship between angioscopic features and clinical manifestations.

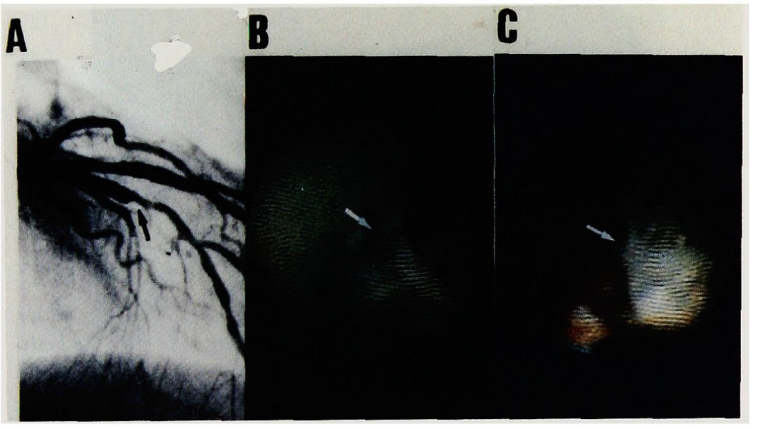

Fig. 19. A 71-year-old male with acute myocardial infarction.
A: angiogram of left coronary artery. Arrow indicates stenotic segment.
B and C: angioscopic features of the same segment. Arrows indicate mixed thrombi. White portions were composed of fibrin.

itself was regular, it was classified as a complex plaque since it accompanied the thrombus.

3. Angioscopic features of saphenous vein graft

Three to 12 months after coronary bypass surgery, angioscopy of the grafted saphenous vein was performed in 10 patients. A significant stenosis was angiographically observed in 2. Both portions anastomosed to the aorta and to the native coronary artery were observed in all segments. The angiographically stenotic segment was composed of white plaque in 1 and organized thrombus in 2 patients (Figs. 21 and 22).

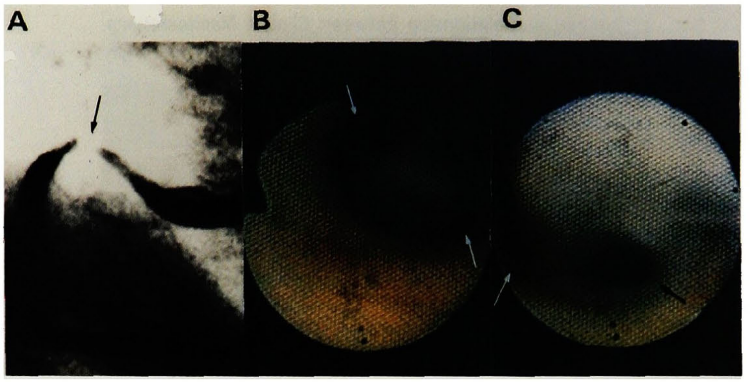

Fig. 20. A 68-year-old female with unstable angina pectoris.
A: angiogram of RCA. B: a doughnut-like thrombus proximal to the stenotic segment (white arrows). C: stenotic segment composed of white regular plaque.

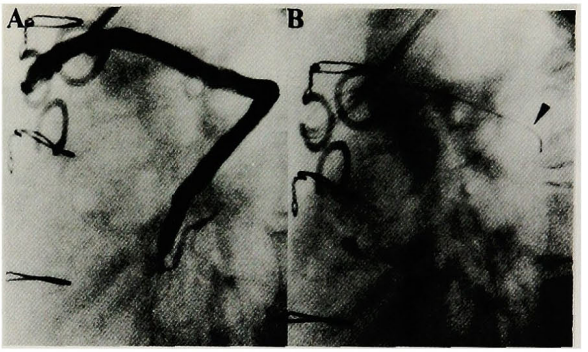

Fig. 21. Angioscopy of a saphenous vein graft one year after the grafting.
A: angiogram of the bypass graft to LAD. No obvious stenosis. B: during angioscopy. Arrow: fiberscope.

4. Angioscopic changes induced by PTCA

Twenty-nine patients (18 with angina pectoris alone and 11 with angina pectoris and old myocardial infarction) underwent coronary angioplasty and angioscopy. Before PTCA, the target lesion was composed of regular plaque in 24 and complex plaque in 5 segments. Figures 23 and 24 show, respectively, the angiographic and angioscopic changes in the stenotic distal segment of the right coronary artery (RCA) in a patient with stable angina pectoris. Angiographically, the stenotic segment was eccentric but smooth surfaced. The segment was successfully dilated with residual stenosis of less than 25%. Angioscopically, the plaque was light yellow and relatively smooth before PTCA and the plaque was smoothly compressed by PTCA.

In a patient with stable angina pectoris, the stenotic proximal LAD was eccentric but smooth angiographically. The segment was dilated smoothly, at least

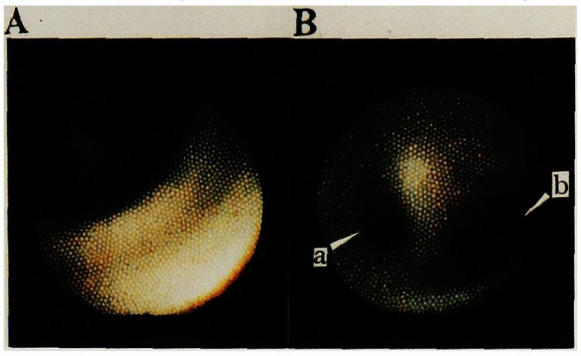

Fig. 22. The same bypass graft.
A: saphenous vein graft was yellow colored and smooth. B: yellow and smooth anastomosed portions. a: ostium to proximal LAD, b: ostium to distal LAD.

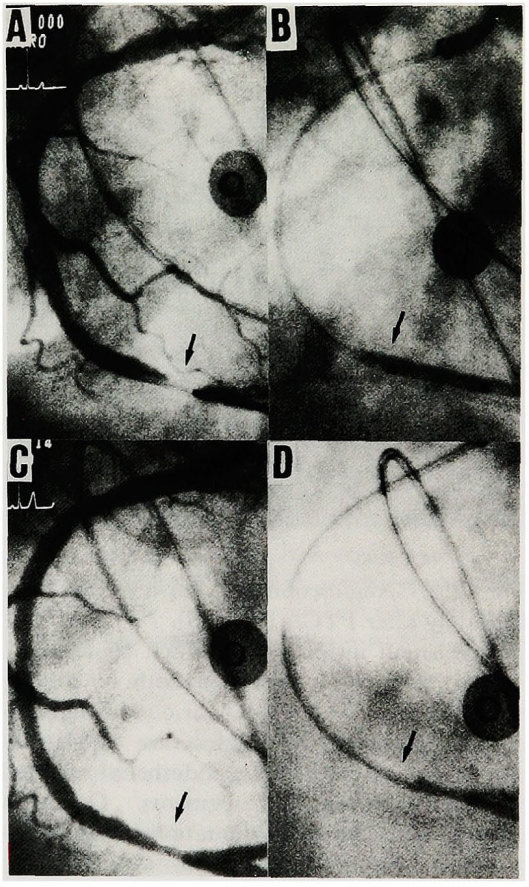

Fig. 23. A 60-year-old female with stable angina pectoris. Angiograms showing process of PTCA to distal segment of RCA.
A: smooth eccentric stenosis before PTCA (arrow). B: during PTCA. Arrow: balloon. C: dilatation of the stenotic segment (arrow). D: during angioscopy. Arrow: guiding balloon catheter.

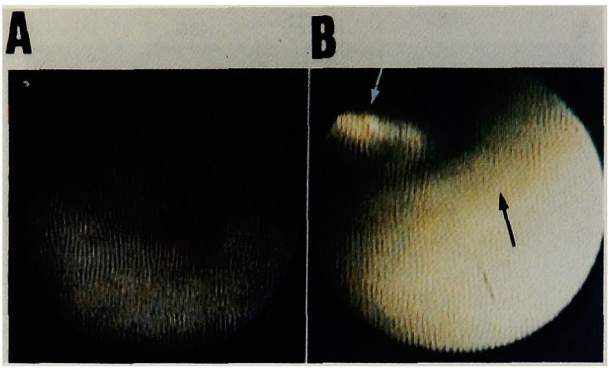

Fig. 24. The same patient as that in Fig. 23. Angioscopic feature of the stenotic segment before (A) and after PTCA (B).

A: irregular light yellow plaque before PTCA. B: smooth compression of the plaque after PTCA (black arrow). White arrow: 0.014 inch guide wire.

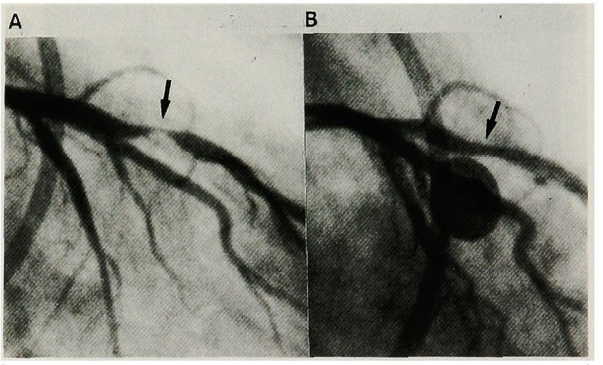

Fig. 25. A 70-year-old male with stable angina pectoris.

A: angiogram showing smooth eccentric stenosis in the middle segment of LAD (arrow).

angiographically (Fig. 25). Angioscopically, however, at least 3 intimal flaps were identified immediately after PTCA (Fig. 26).

In addition to these small intimal flaps which could not be detected angiographically, large intimal flaps were identified both by angiography and angioscopy in 2 other patients (Fig. 27). Thus, various changes were observed after PTCA, including cleft or dissection in 12; fracture of plaque, namely irregular compression with multiple small flaps in 5; endothelial exfoliation in 26; intimal bleeding in 13 and thin mural thrombi in 7 segments. On the other hand, plaques were smoothly compressed with successful dilatation in the other 10 segments (Fig. 28).

5. Relationship between angioscopic changes of the plaques before and after PTCA

Cleft and dissection were produced by PTCA in white plaques more frequently

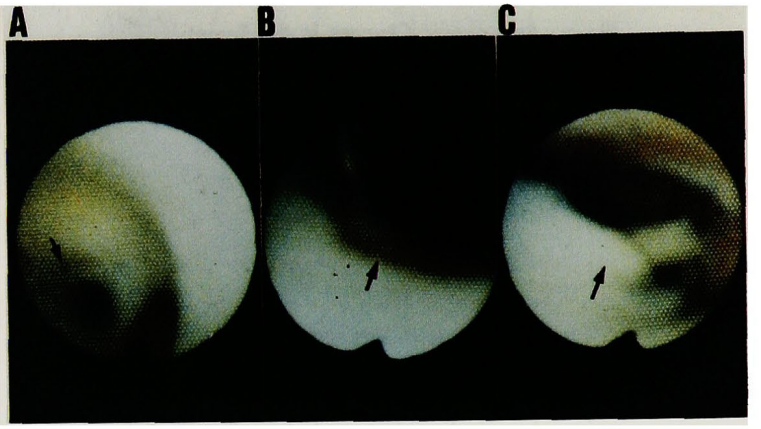

Fig. 26. The same patient as that in Fig. 29.
A: stenosis with smooth and yellow colored plaque (arrow). B: dilated by PTCA (arrow). C: intimal dissection (arrow).

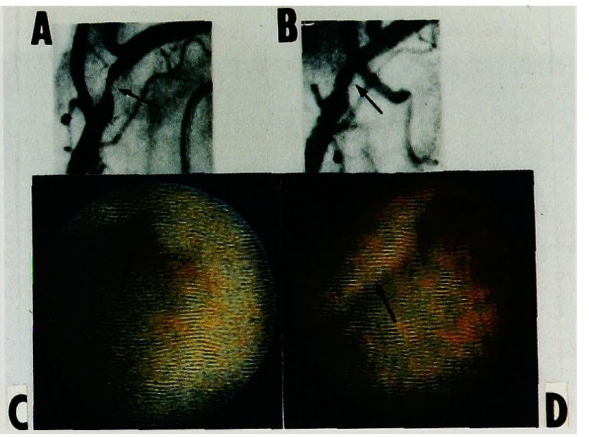

Fig. 27. A 62-year-old male with stable angina pectoris.
A and B: before and after PTCA of the middle segment of right coronary artery, respectively (arrow). C: cleft in the light yellow plaque (arrow) after PTCA. D: intimal flap fluttering in synchrony with each cardiac beat (arrow).

than in yellow or brown ones, while yellow or brown plaques were smoothly dilated more frequently than white plaque (Fig. 29).

6. Angioscopic features of recoil after PTCA

Figures 30 and 31 show angiographic and angioscopic changes after PTCA. Angioscopically, the multiple intimal flaps were produced by PTCA, but they were compressed on the luminal surface immediately after PTCA. Ten min after, however, haziness appeared angiographically and separation of flaps occurred angioscopically. Anginal attacks also occurred. Repeated PTCA resulted in

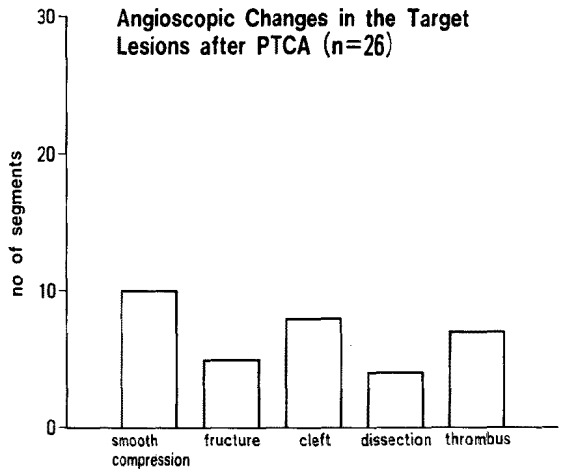

Fig. 28. PTCA-induced angioscopic changes in the target lesions.

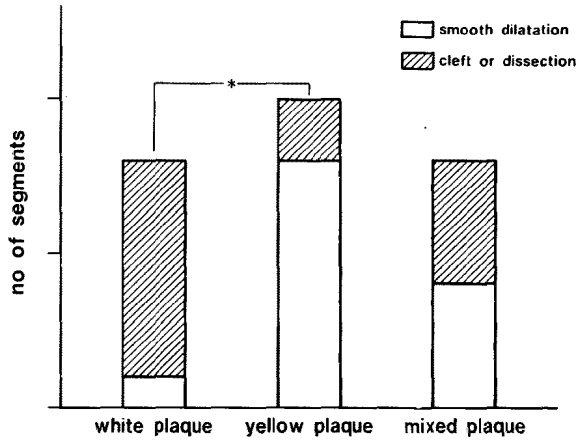

Fig. 29. Relationship between the angioscopic changes before and those after PTCA.

remodeling and disappearance of haziness and attacks. Similar changes were observed in 2 other patients. In 1 patient, compressed yellow plaque was swollen within 10 min of observation.

7. Identification of the PTCA-induced changes by angioscopy and angiography

Even small changes such as endothelial exfoliation, bleeding and thin mural thrombi were frequently observed by angioscopy. However, they were never identified by angiography (Fig. 32).

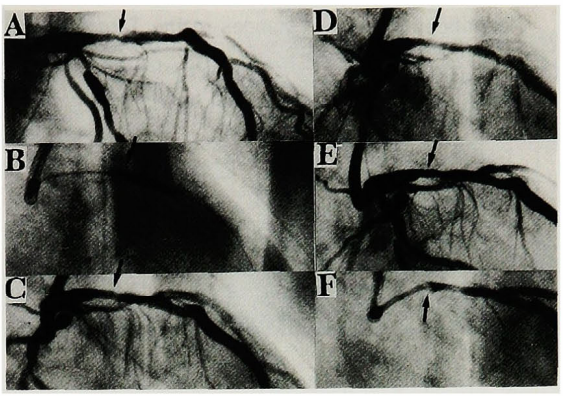

Fig. 30. A 65-year-old male with stable angina pectoris. Angiograms of LAD showing process of PTCA.

A: concentric stenosis before PTCA. B: during PTCA. C: dilatation after PTCA. D: haziness 10 min after PTCA (arrow). E: disappearance of haziness after repeat PTCA. F: during angioscopy.

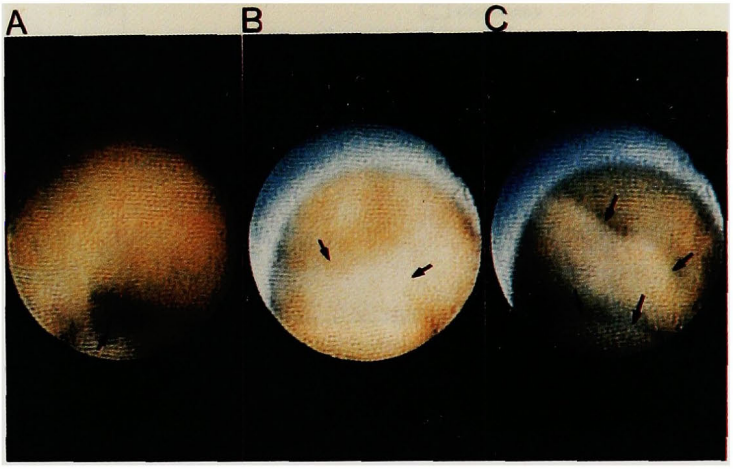

Fig. 31. The same patient as that in Fig. 30.

A: stenotic segment with complex plaque. B: immediately after PTCA. Intimal flaps were compressed onto the wall (arrows). C: 10 min after PTCA. Peeling back of the flaps due to recoil (arrows), resulting in acute occlusion and anginal attack.

8. PTCA-induced changes in the coronary segments proximal to the targeted lesions

Figure 33 shows smooth compression and bleeding in a segment proximal to the targeted lesion. Figure 34A shows endothelial exfoliation in a segment proximal to the targeted lesion and 34B shows a thrombus on the guide wire. Thus, mechanically induced changes such as endothelial exfoliation, bleeding, thrombus formation, intimal compression or rarely dissection were observed angioscopically

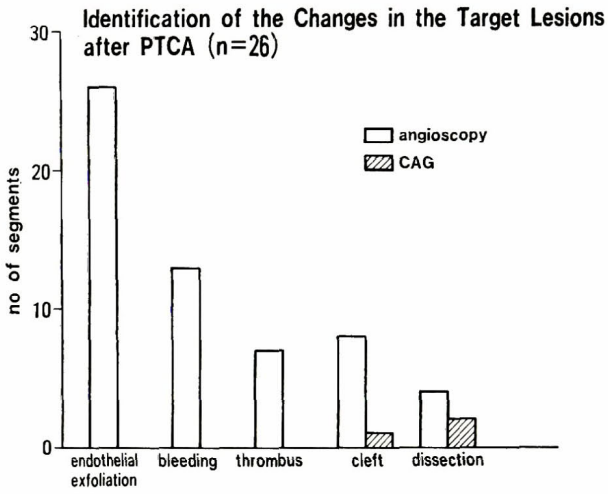

Fig. 32. Identification of PTCA induced luminal changes by angiography and angioscopy.

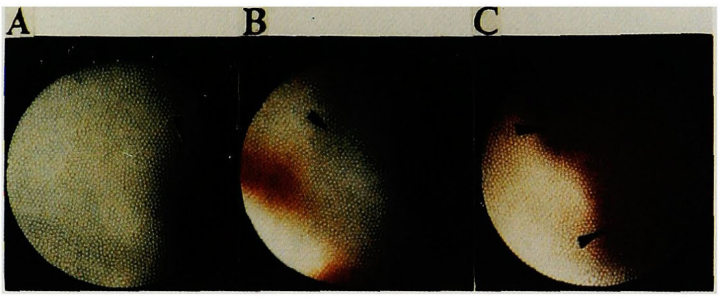

Fig. 33. A coronary segment proximal to the target lesion after PTCA. A: smooth and white segment proximal to the target lesion before PTCA. B: compression and bleeding in the same segment after PTCA (arrow). C: thrombus formation on compressed portion.

in many patients. However, they could be identified by angiography in only one patient (Fig. 35).

9. Angioscopic changes seen chronically in the coronary segment dilated by PTCA

Percutaneous coronary angioscopy was performed 1 to 12 months after PTCA in 9 patients. Figure 36 shows angioscopic and angiographic changes in a coronary segment before, immediately after and 12 months after PTCA. Immediately after PTCA, fracture of a white plaque with multiple flaps and mural thrombi was observed. Twelve months later, however, these changes disappeared and the dilated segment was smooth and brown in color, and reflected illumination resembling polished German silver. The dilated segment was smoothly reconstructed in 7 (Fig. 37A) while irregular changes remained in 2 patients (Fig. 37B).

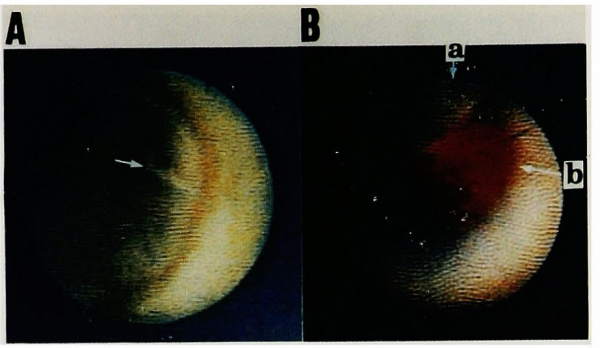

Fig. 34. A: nonstenotic segment of LAD proximal to targeted lesion. Arrow: endothelial exfoliation. B: thrombus on guide-wire observed during PTCA. a: 0.014 inch guide wire, b: fresh thrombus on wire.

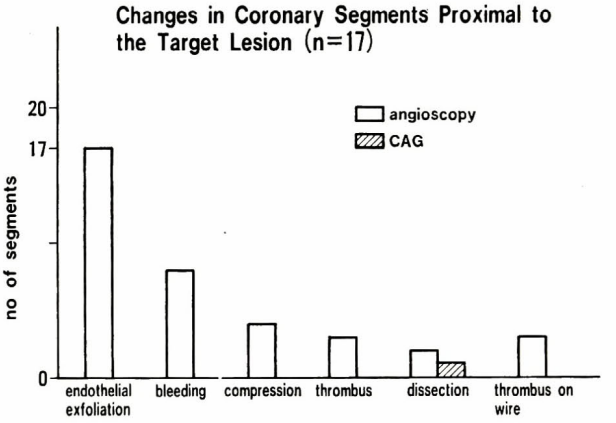

Fig. 35. Changes in the coronary segments proximal to the targeted lesions after PTCA.

Smooth or irregular surfaces, and white, yellow or brown coloration seen in the chronic stage were not related to the changes noted before PTCA nor to those seen immediately after PTCA (Fig. 35). The dilated segment reflected illumination in a manner similar to polished metal irrespective of the types of changes.

10. Complications

Unfortunately, acute myocardial infarction occurred during coronary angioscopy in 2 patients; immediately after observation beyond the stenotic segment in 1 patient with unstable angina pectoris and during observation of thrombus in a patient with Kawasaki disease. Depression or elevation of the ST segment and appearance of giant negative T waves on the electrocardiogram occurred frequently (Fig. 36). They disappeared immediately after deflation of the balloon of the guiding catheter. Neither signs and symptoms suggesting systemic embolism nor bleeding at the punctured inguinal region occurred in any patient.

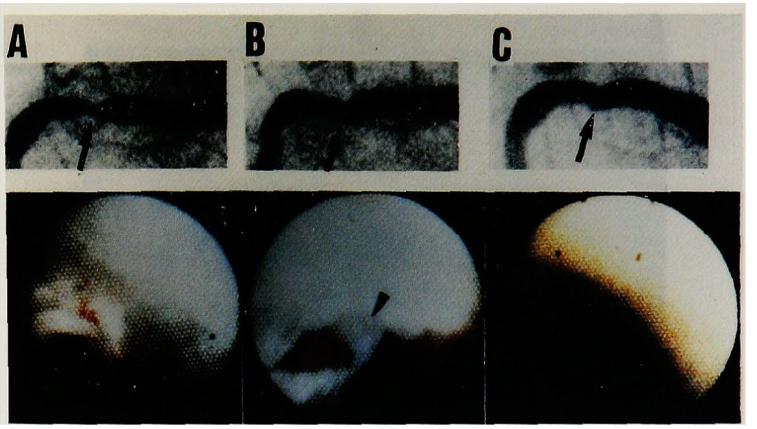

Fig. 36. A 62-year-old female with stable angina pectoris.
A: angiographically concentric stenosis (arrow) and angioscopically white and irregular stenosis before PTCA. B: angiographically a flap in the dilated segment (arrow) and angioscopically multiple intimal flaps and thrombi in the dilated segment (arrow). C: one year after PTCA. Angiographically no significant restenosis (arrow) and angioscopically smooth and yellow surface.

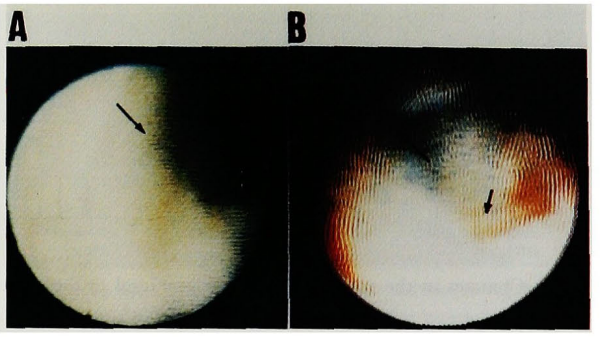

Fig. 37. A: a 73-year-old male with stable angina pectoris. Middle segment of LAD one month after successful PTCA. Smooth, white or light yellow surface of the dilated segment, reflecting the illumination, simulating polished German silver (arrow). B: a 69-year-old female with stable angina pectoris. Middle segment of LAD 3 months after PTCA. Clefts observed immediately after PTCA remained, although their surfaces became relatively smooth and reflected illuminations (arrows).

Comments

The results of this study indicate that percutaneous fiberoptic angioscopy of the coronary artery using a guiding balloon catheter is feasible and useful for macroscopic pathological diagnosis of the coronary luminal changes and for evaluation of interventional treatment.

In a preliminary study, we used a guiding catheter without a balloon for percutaneous coronary angioscopy in which a power injector was required to in-

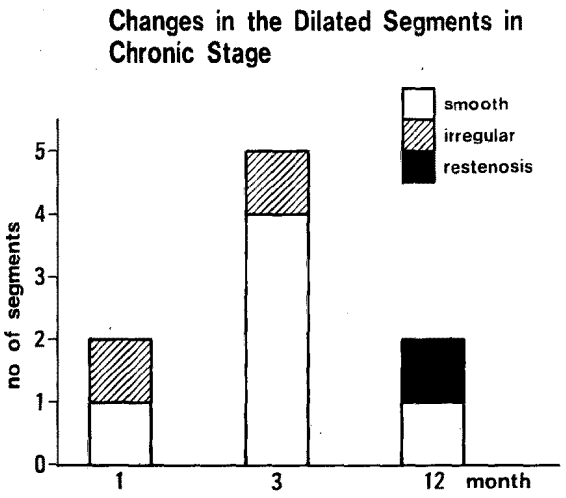

Fig. 38. Angioscopic features of the dilated coronary segments in the chronic stage.

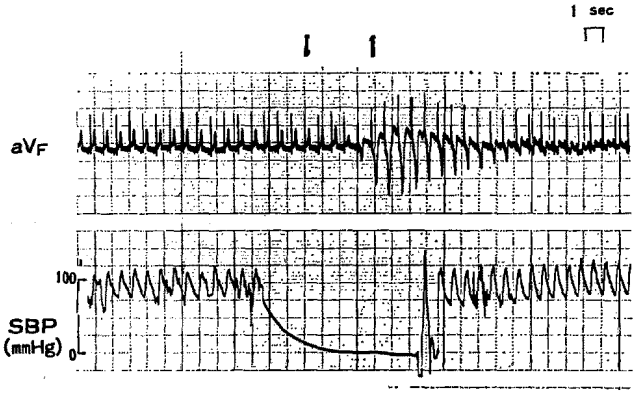

Fig. 39. Appearance of ST-segment depression, and wide and negative T waves during saline infusion into the right coronary artery. A 9 French guiding balloon catheter was used for angioscopy.

ject a large amount of saline for displacement of the blood.[16] Also, a fiberscope with a steerable guide wire was required to obtain good coaxiality.[19] Compared to these previously used systems, the guiding balloon catheters used in this study effectively stopped blood flow and minimized the saline required for displacement of the blood. Furthermore, a 5 French guiding balloon catheter with a tip deflector was useful in obtaining good coaxiality. The overall success rate was higher than those previously reported. By using new fiberscopes with an increased number of glass or quartz fibers, color quality became more accurate and resolving power was much increased.

In this study, the coronary luminal surface was smooth and light yellow in

color, and the luminal diameter changed in synchrony with each cardiac beat, indicating that the vessel wall was thin and soft.

Bifurcations to distal branches were sharply edged in young patients and without demonstrable changes. Therefore, such angioscopic features are considered to reflect the normal coronary luminal surface. In more aged patients, especially in those angiographically exhibiting a corkscrew coronary artery or uneven luminal wall but without obvious stenosis, the luminal surface was angioscopically yellow or white in color, the diameter did not change in synchrony with the cardiac cycle, and spiral folds and bluntly edged bifurcations were frequently observed, suggesting thickening of the wall. The yellow coloration may indicate diffuse but thin deposition of fat and white coloration may indicate fibrous thickening. The spiral folds observed in this study were also observed in nonstenotic coronary segments in patients with ischemic heart disease as was reported before.[16]

The plaques which composed the stenotic segments were angioscopically classified into smooth and irregular plaques. The smooth plaques were further divided into smooth white, smooth yellow or brown, and smooth with yellow and white portions distributed in a mosaic fashion. The irregular plaques were classified into those with or without bleeding, thrombus, ulcer, and/or dissection. The former and latter groups were respectively called "regular" and "complex" plaques according to Sherman.[13] Taking into consideration the coronary luminal changes observed during autopsy, the white plaques were probably composed of thick fibrous tissues with or without atheromatous tissue beneath them. Yellow or brown plaques were probably due to atheroma with thin fibrous caps. Ramee et al[22] observed thrombus on plaque and dissection of plaque, namely complex plaques, more frequently in patients with unstable angina than in those with stable angina pectoris. Also, complex plaques were observed in the majority of patients with unstable angina pectoris in this study.

Recurrent luminal obstruction with thrombi may be the mechanism of recurrent anginal attacks in patients with unstable angina pectoris and sustained obstruction with thrombi may lead to acute myocardial infarction. In a patient with unstable angina, a doughnut-like thin thrombus surrounded the inlet of a smooth stenosis, namely regular plaque. Probably, recurrent occlusion of the stenotic segment by the detached thrombus resulted in recurrent attacks.

Luminal changes in the grafted saphenous vein were also observed in several patients. Percutaneous angioscopy may be useful for observation of the process of saphenous vein obstruction which not infrequently occurs in a certain group of patients.

The coronary luminal changes in patients with Kawasaki disease were observed first by Uchida et al.[20] In one such patient the luminal surface of the aneurysm was white and uneven, suggesting fibrosis without fat deposition. In Kawasaki disease, thrombi frequently formed in the aneurysm and their shadows were hitherto observed by echocardiography or angiography. In this study, a giant mixed thrombus was identified by angioscopy. In this category of disease, the coronary aneurysm is gradually narrowed and finally changes to stenosis or obstruction. Hitherto, it had been suggested that the thrombus becomes organized, resulting in stenosis or obstruction. In this study, the stenotic or occluded segment was white, suggesting that excessive fibrosis resulted in stenosis or obstruc-

tion.

PTCA was performed in 29 patients, 24 with stable and 5 with unstable angina pectoris. Various types of changes were observed by angioscopy immediately after PTCA as were seen during in vitro experiments using removed human coronary artery.[21] The stenotic segments were smoothly dilated in 10 segments. In these patients, smooth compression of the plaque could be identified by angioscopy. Such smooth dilatation was more frequently observed in yellow or brown plaques. On the other hand, dissection and cleft were more frequently observed in white plaques. Probably, white plaques were mainly composed of fibrous tissues and were less distensible, and therefore were more easily split by balloon distension, resulting in cleft or dissection.

Although large changes induced by PTCA, such as dissection, were detected by angiography, small changes such as mural thrombi, endothelial exfoliation and bleeding could not be detected by angiography, indicating that angioscopy is more suitable for detection of such small changes. In addition to the changes in the target lesions, mechanically induced changes were also observed in the segments proximal to the target lesions. Whether these unwanted lesions accelerate atherosclerosis or result in acute occlusion remains to be elucidated. In the chronic stage, the segments dilated by PTCA were either smoothly or not smoothly repaired. However, the relationship between the plaque character before PTCA or changes immediately after PTCA with those seen in the chronic stage was not obvious in this small group of patients. The luminal surface of the dilated segment reflected illumination, resembling polished German silver, irrespective of the smoothness of the surface. This change was characteristic of dilated segments. The shape and arrangement of the regenerated endothelial cells or the structure of the regenerated subendothelial tissues may have been different from those seen before PTCA. Unfortunately, acute myocardial infarction occurred in 2 patients during coronary angioscopy. Therefore, angioscopic observation should be performed carefully. During infusion of saline, electrocardiographic changes such as ST-segment changes or giant negative T waves occurred in all patients. However, the changes disappeared spontaneously in all but the above mentioned 2 patients.

In this study, the overall success rate of percutaneous coronary angioscopy was around 86%, despite the use of improved guiding catheters. Further improvement of the angioscope system is required to increase the success rate.

In the near future, coronary angioscopy will be able to be used to select the target lesion and to guide the micromachines used to treat the lesions. Also, the angioscope incorporated in the ultrasonic catheter can be used for diagnosis of changes of not only the coronary luminal surface but also of wall structures.

References

1. Uchida Y, Masuo M, Tomaru T, Kato S, Sugimoto T: Fiberoptic observation of thrombosis and thrombolysis in isolated human coronary arteries. Am Heart J **112**: 691, 1986
2. Abela GS, Fenech A, Crae F, et al: Hot-tip: another method of laser vascular recanalization. Laser Surg Med **5**: 327, 1985
3. Uchida Y, Hasegawa K, Kawamura K, Shibuya I, Kawashima M, Mukai H: Percutaneous transluminal angioscopy of the right heart. J Jpn Coll Angiol **30**: 319, 1990
4. Uchida Y, Tomaru T, Kato S: Percutaneous pulmonary angioscopy using a guiding balloon

catheter. Clin Cardiol **9**: 61, 1988
5. Uchida Y, Oshima T, Fujimori Y, Hirose J: Angioscopic comparative study of the arterial luminal changes induced by percutaneous balloon angioplasty, laser-angioplasty and laser-assisted balloon angioplasty. J Jpn Coll Angiol **30**: 517, 1990
6. Shure S, Gregoratos G, Mose MM: Angioscopy is useful in evaluation of chronic pulmonary arterial obstruction. Circulation **70** (suppl II): 182, 1984
7. Uchida Y, Tomaru T, Nakamura F, Sugimoto T: Fiberoptic angioscopy of cardiac chambers, valves and great vessels using a guiding balloon catheter in dogs. Am Heart J **115**: 1297, 1988
8. Uchida Y, Oshima T, Shibuya I: Percutaneous angioscopy of the right side of heart in humans. Cardiovasc World Report **1**: 13, 1989
9. Uchida Y, Nakamura F, Oshima T, Fumitaka Y, Hirose J: Percutaneous fiberoptic angioscopy of the left ventricle in patients with dilated cardiomyopathy and acute myocarditis. Am Heart J **120**: 677, 1990
10. Uchida Y, Oshima T, Fujimori Y, Hirose J: Percutaneous angioscopy of cardiac valves. Am Heart J **121**: 1791, 1991
11. Uchida Y, Nakamura F, Tsukamoto M, You Sei, Kido H, Sugimoto T: Percutaneous ventricular endomyocardial biopsy with angioscopic guidance. Am Heart J **118**: 1039, 1989
12. Uchida Y, Oshima T, Fujimori Y: Percutaneous ventricular endomyocardial biopsy with angioscopic guidance in dilated cardiomyopathy. Am Heart J **119**: 944, 1990
13. Sherman CT, Litvak F, Grundfest WS: Demonstration of thrombus and complex atheroma by in vivo angioscopy in patients with unstable angina pectoris. New Engl Med **315**: 913, 1986
14. Swaptom TA: Intraoperative angioscopy of saphenous vein and coronary arteries. J Thorac Cardiovasc Surg **9**: 339, 1987
15. Spears JR, Spokojny AM, Marais HJ: Coronary angioscopy during cardiac catheterization. J Am Coll Cardiol **6**: 93, 1985
16. Uchida Y, Tomaru T, Nakamura F, Furuse A, Hasegawa K: Percutaneous coronary angioscopy in patients with ischemic heart disease. Am Heart J **114**: 1216, 1987
17. Uchida Y, Hasegawa K, Kawamura K, Shibuya I: Angioscopic observation of the coronary luminal changes induced by PTCA. Am Heart J **117**: 4, 1987
18. Mizuno K, Arakawa K, Shibuya T: A serial observation of coronary thrombosis in vivo by a new angioscope. J Am Coll Cardiol **11**: 30A, 1988
19. Uchida Y: Percutaneous coronary angioscopy using a fiberscope with a steerable guide wire. Am Heart J **117**: 1153, 1989
20. Uchida Y:Abnormal vascular activity observed by angioscopy. Clin Sci **25**: 1485, 1989
21. Uchida Y: A fiberoptic observation of coronary luminal changes caused by angioplasty. Circulation **72**: 218, 1985
22. Ramee SR, White CJ, Collins TJ, Mesa JE, Murgo JP: Percutaneous angioscopy during coronary angioplasty using a steerable microangioscope. J Am Coll Cardiol **17**: 100 1991