Characteristic electrocardiographic pattern indicating a critical stenosis high in left anterior descending coronary artery in patients admitted because of impending myocardial infarction

In patients admitted to the hospital because of unstable angina, a subgroup can be recognized that is at high risk for the development of an extensive anterior wall myocardial infarction. These patients, who show characteristic ST-T segment changes in the precordial leads on or shortly after admission, have a critical stenosis high in the left anterior descending coronary artery. Of 145 patients consecutively admitted because of unstable angina, 26 (18%) showing this ECG pattern, suggesting that this finding is not rare. In spite of symptom control by nitroglycerin and beta blockade, 12 of 16 patients (75%) who were not operated on developed a usually extensive anterior wall infarction within a few weeks after admission. In view of these observations, urgent coronary angiography and, when possible, coronary revascularization should be done in patients with unstable angina who show this ECG pattern. (Am Heart J 103:730, 1982.)

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The management of patients admitted to the coronary care unit because of ischemic chest pain of recent onset or sudden exacerbation of chronic stable angina not resulting in immediate myocardial infarction has been a subject of intensive discussion in recent years. In most hospitals, the usual approach is to treat such patients medically with nitroglycerin and beta blockade. Calcium antagonists are given to those suspected of having Prinzmetal's angina. Only patients not responding within a few days to this type of management are considered candidates for coronary angiography to identify those who can and should be helped by coronary bypass surgery or coronary angioplasty.[1-3]

We believe that among patients at risk of an impending myocardial infarction, a subgroup can be recognized who do poorly with conservative management, even though initially they seem to respond well to treatment. This subgroup, for whom the value of more aggressive management should be evaluated, is described here.

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MATERIAL AND METHODS

Of 145 patients consecutively admitted because of an impending myocardial infarction, 26 had or developed within 24 hours after admission abnormal ST segments and negative T waves in the anterior chest leads without changes in the QRS complex. Impending myocardial infarction was defined as crescendo angina of recent onset, sudden worsening of stable angina, or crescendo postinfarction angina developing after an initial asymptomatic period.

As illustrated in Fig. 1, all 26 patients showed a typical pattern of the ST-T segment in leads V_2 and V_3 consisting of an isoelectric or minimally elevated (1 mm) takeoff of the ST segment from the QRS complex, a concave or straight ST segment passing into a negative T wave at an angle of 60 to 90 degrees, and a symmetrically inverted T wave.

Twenty-five of the 26 patients also had a typical pattern in lead V_1: an isoelectric or minimally elevated (1 mm) takeoff of the ST segment and a concave or straight ST segment passing into the first part of the T wave at an angle of approximately 135 degrees, followed by T wave inversion. In addition, 22 had an ST-T segment pattern in lead V_4, and sometimes V_5 and V_6, consisting of a takeoff of the ST segment from the QRS complex below the isoelectric line and a convex ST segment passing into a negative T wave at an angle of about 120 degrees with a deep symmetrically inverted T wave (Fig. 1, *B*).

In 13 patients this ECG pattern was present on admis-

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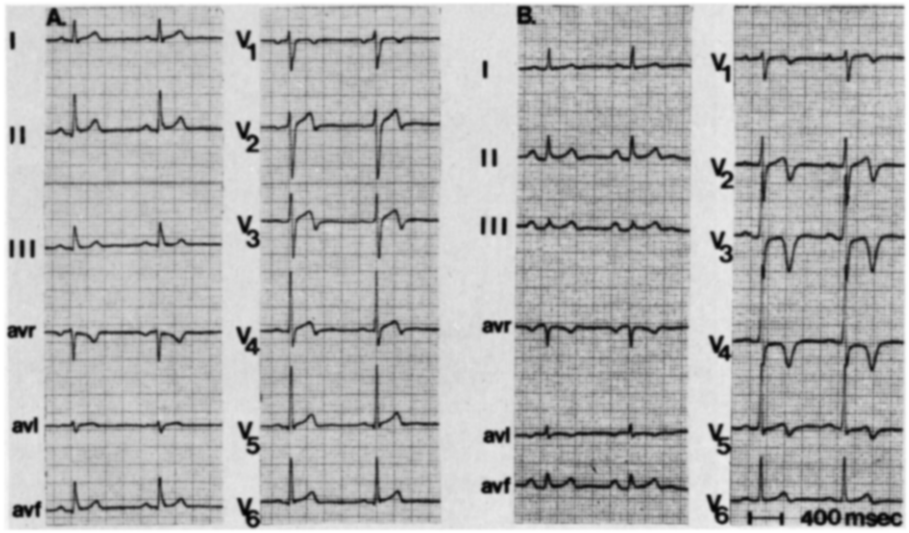

Fig. 1. ECG patterns in precordial leads of the patients reported. Pattern **A** was found in four patients; pattern **B**, in 22 patients. See text.

sion; in the remaining 13 it developed within 24 hours after admission. No pathologic Q waves or QS complexes were present or developed in the precordial leads. Patients with complete right bundle branch block, incomplete left bundle branch block, or criteria for probable or definite left or right ventricular hypertrophy were excluded. Also excluded were patients showing a loss in initial R wave voltage in lead V_1 or disappearance of Q waves in lead V_5 or V_6.

Serial enzyme values for creatinine phosphokinase (CPK), serum glutamic oxaloacetic transaminase (SGOT), and serum lactic dehydrogenase (SLDH) were determined in all patients every 8 hours for 3 consecutive days after admission. Twenty-two patients had normal serial enzyme values (CPK, SGOT, SLDH). Four patients showed a minor rise in serial enzyme levels, not exceeding twice the upper limit of normal.

The patients ranged in age from 38 to 81 years, with a mean of 58 years. There were 18 men and eight women. Seven patients had a history of hypertension, and three had suffered a previous myocardial infarction.

We divided our patients into two groups: group A (patients 1 to 9) had these ECG findings before the prognostic significance was realized; group B (patients 10 to 26) showed the same ECG abnormalities after the prognostic significance was suspected.

Coronary angiography was performed in multiple projections by using the Judkins technique. A stenosis in a coronary artery had to affect at least 70% of the luminal diameter in any view to be considered an important lesion. Abnormalities in left ventricular wall motion were assessed from the 30-degree right anterior oblique and the 60-degree left anterior oblique views. From these projections, the left ventricular silhouette was divided into seven segments (anterobasal, anteroseptal, anterolateral, apical, posterobasal, diaphragmatic, and posterolateral). The left ventricular ejection fraction was determined from the 30-degree right anterior oblique left ventriculogram. The catheterization variables were interpreted in conference by at least two of the same three experienced angiographers.

RESULTS

Case history. The tracings shown in Fig. 2 were obtained from a 45-year-old man who experienced ischemic chest pain (New York Heart Association class II) for 4 weeks before admission. Tracing *A* was recorded on admission. The maximal serum enzyme values were not diagnostic for acute myocardial infarction: CPK 106 U/L, SGOT 26 U/L, SLDH 343 U/L (upper limit of normal: CPK 200 U/L, SGOT 40 U/L, SLDH 400 U/L). The patient was treated with a beta-blocking agent and long-acting nitroglycerin and became symptom free. Tracing *B* was recorded 23 hours after admission at a time when the patient had no complaints. During the next 3 days, the ECG returned to "normal," and the patient remained symptom free and was mobilized. On the ninth day after admission, the patient had an attack on chest pain that did not respond to nitroglycerin (tracing *C*). He subsequently developed an extensive anterior wall infarction, complicated by severe pump failure, and died 12 hours later.

At autopsy, the normal-sized heart showed an extensive fresh anteroseptal infarction. At the bifurcation of the left coronary artery into the left anterior descending (LAD) and the circumflex branch, there was a complete occlusion by a fresh

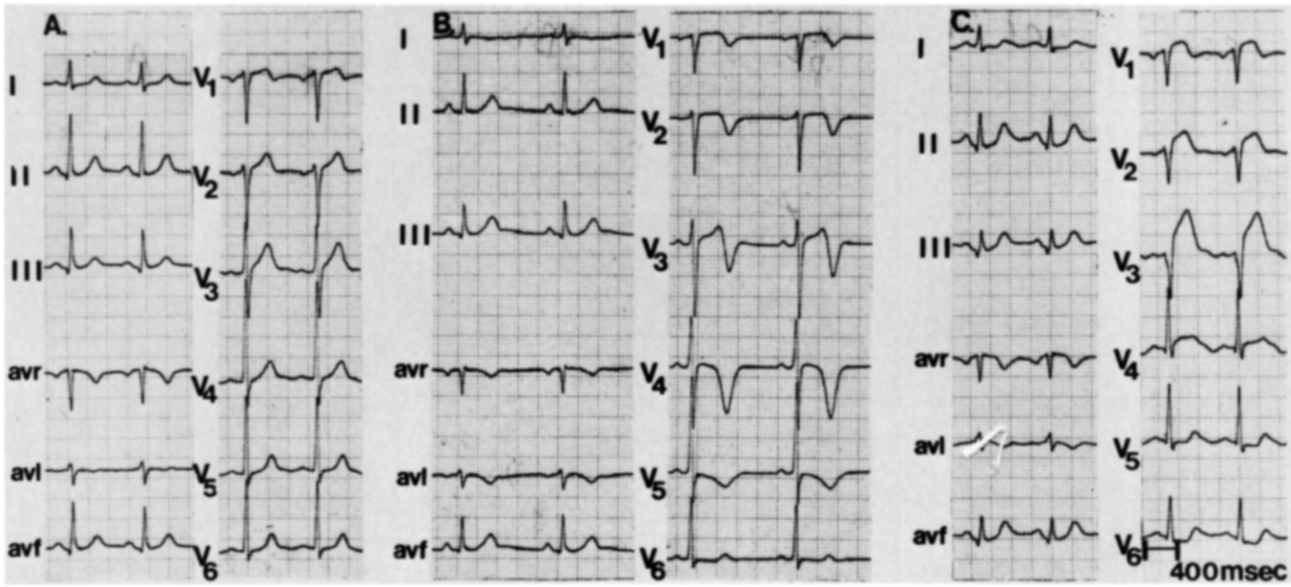

Fig. 2. ECG patterns from patient 2. **A,** ECG recorded on admission. **B,** ECG recorded 23 hours later. The patient was without pain in the interval between tracings *A* and *B*. Four days after admission, the tracings were like those in **A**. **C,** ECG made on day 9 following admission. At that time, the patient suffered from severe chest pain and did not respond to nitroglycerin. He died from progressive pump failure 12 hours later.

thrombus, seated on a severely narrowed arteriosclerotic artery. The right coronary artery showed no significant stenoses.

Clinical data. All 26 patients fulfilled the criteria for unstable angina (Table I). Eighteen patients had crescendo angina of recent onset (range 1 day to 4 weeks; mean 16 days). Five patients had sudden worsening of previously stable angina. The remaining three had developed crescendo postinfarction angina after an initial asymptomatic period; their infarctions had occurred 5 weeks, 7 months, and 3 years, respectively, before this admission. In all 26 patients, chest pain was alleviated with drug therapy: 25 were administered long-acting nitroglycerin and a beta-blocking agent; one patient, with a typical history of Prinzmetal's angina, received a calcium antagonist.

The prognostic significance of the ECG pattern was not initially recognized, which may, in part, explain why eight of the first nine patients (group A) developed a myocardial infarction. In all, 12 patients (eight in group A and four in group B) developed a myocardial infarction (Table II), 11 within 39 days (range 4 to 38, mean 21 days) and one patient 307 days after the onset of complaints of impending infarction. The maximal SGOT value ranged in nine patients from 56 to 607 U/L (mean 315 U/L). Two patients died within 12 hours. One patient's ECG showed an anteroseptal infarction on the first outpatient clinic visit 23 days after admission for an impending infarction. Enzyme values were normal at that time. Table II gives data on the size of the infarctions (the maximal SGOT value) and on complications.

In addition to the two patients (patients 2 and 6) who died of congestive heart failure within 12 hours after infarction, one patient died 6 weeks after infarction, following aneurysmectomy performed because of intractable ventricular tachycardia.

Catheterization findings. Following our experience with the first nine patients, we performed early cardiac catheterization and coronary angiography in 10 of the next 17 patients within 1 to 8 days (mean 4 days) after admission. Two patients were considered too old for the procedure, and five patients refused catheterization. Including three of the first nine patients, a total of 13 catheterizations were done.

Twelve patients—three in group A and nine in group B—had coronary artery disease. Of those in group A, two had already suffered a myocardial infarction and one patient was catheterized after the significance of the ECG pattern was realized. The two in group A (patients 1 and 3) who had suffered a myocardial infarction and were catheterized showed a complete occlusion of the LAD artery proximal to the first septal branch. One patient in group B (patient 12), whose ECG was like that in Fig. 1, *B*, had normal coronary arteries and a prolapse of the posterior leaflet of the mitral valve. The hemodynamic and angiographic findings in the one patient

Table I. Characteristics of the 26 patients studied

			Past medical history			*Clinical course*		
Patient	*Sex*	*Age (yr)*	*HT*	*Previous MI (location)*	*Onset or exacerbation of chest pain (wk)*	*AMI*	*Cath*	*CABG*
1	M	67	+	−	1	+	+	
2	M	45	−	−	4	+→†		
3	F	68	+	−	½	+→†	+	
4	M	61	−	−	4		+	+
5	F	81	−	−	5	+		
6	M	75	−	−	2.5	+→†		
7	M	69	−	−	2.5	+		
8	M	43	+	−	0.5	+		
9	M	65	−	−	1	+		
10	M	43	+	Anterior	< 6		+	+
11	F	64	+	−	0.5		−(r)	
12	F	58	−	−	4		+	−
13	F	54	−	−	2		+	+
14	M	41	−	−	2		+	+
15	M	49	−	−	2		+	+
16	F	59	−	−	4		+	+
17	F	38	−	−	0.33		+	+
18	M	60	−	Inferior	1.5		−(r)	
19	M	70	−	−	1.5	+	−(a)	
20	M	63	−	−	4	+	−(r)	
21	F	69	+	−	2		−(a)	
22	M	44	+	−	2		+	+
23	M	60	−	−	0.14	+	−(r)	
24	M	54	−	−	4		+	
25	M	55	−	−	3		+	+
26	M	44	−	Inferior	0.33	+	−(r)	

AMI, Acute myocardial infarction; *CABG*, coronary artery bypass graft; *Cath*, cardiac catheterization; *HT*, hypertension; *MI*, myocardial infarction; *(a)*, age; *(r)*, refused.
+ = present; −= absent; † = death.

in group A who had not developed myocardial infarction and the 10 patients in group B are given in Table III. As shown, in all patients with coronary artery disease, a significant stenosis (≥ 90%) was present in the LAD artery. In seven, the stenosis was located proximal to the first septal branch, and in three, between the first and second septal branches. In all 10 patients the ejection fraction was normal or near normal. Except in two patients, the left ventricular end-diastolic pressure was normal. Hypokinetic segmental wall motion in the area supplied by the LAD branch was seen in all 10 patients. No complications occurred during catheterization.

Of the 11 patients without myocardial infarction studied by coronary angiography, nine underwent coronary bypass surgery 17 to 56 days (average 33 days) after the onset of complaints and 2 to 28 days (average 14 days) after admission to the hospital. All patients received grafts to the LAD artery. In four patients two vessels, in two patients three, and in one patient four vessels were bypassed. All patients became symptom free. The mean follow-up period was 7.5 months. Postoperatively, seven patients showed a normal ST-T segment in the precordial leads, and two patients had negative T waves in the precordial leads. The abnormal ST-T segments (Fig. 1) disappeared in all cases. One patient will be operated on shortly.

Duration of ST-T segment characteristics. Nine of the 12 patients who developed a myocardial infarction showed the reported ST-T segment abnormalities during the last days preceding infarction. Of the nine patients operated on, three still had the same abnormalities the day before surgery, five had nonspecific ST-T segment changes, and one patient's ECG was normal. Of the three patients in group B who did not develop a myocardial infarction and who were not catheterized, two still exhibited the ST-T segment abnormalities 3 and 9 months, respectively, after admission. In the patient with a history of Prinzmetal's angina, the ECG became normal after treatment with a calcium antagonist.

Table II. Characteristics of 12 patients who developed acute myocardial infarction

Patient	Time between admission and infarction (days)	Time from onset of complaints to infarction (days)	Maximum SGOT (U/L)	Complications	Autopsy
1	7	14	358	CRBBB, pericarditis, CHF, AF	
2	9	37	?	VT, CHF, †	Complete occlusion bifurcation, LCA
3	8	11	390	CRBBB, CHF, VT, aneurysmectomy, †	
5	1	36	56		
6	22	39	?	CHF, †	Complete occlusion proximal LAD
7	290	307	420	AF	
8	5	8	350		
9	5	12	131		
19	23	33	?		
20	3	31	607	Pericarditis, CHF, AF	
23	9	10	328		
26	2	4	194		

AF, Atrial fibrillation; *CHF*, congestive heart failure; *CRBBB*, complete right bundle branch block; *LAD*, left anterior descending coronary artery; *LCA*, left coronary artery; *SGOT*, serum glutamic oxaloacetic transaminase; *VT*, ventricular tachycardia.
† = death.

Table III. Hemodynamic and angiographic findings in one patient from group A and 10 patients from group B

Patient	LVEDP (mm Hg)	Ejection fraction (%)	Areas of hypokinetic wall motion	Stenosis (≥90%)
4	18	70	AP, AL	LAD
10	20	59	AS, AP, AL	LAD, RCA
12*	14	71	—	—
13	6	62	AP, AL	LAD
14	8	65	AP, AL	LAD
15	12	73	AP	LAD
16	12	71	AP	LAD, RCA
17	10	71	AP	LAD, Circ
22	8	54	AS, AP, AL	LAD, Circ, RCA
24	10	74	AP	LAD
25	8	77	AP	LAD

AL, Anterolateral; *AP*, apical; *AS*, anteroseptal; *Circ*, circumflex coronary artery; *LAD*, left anterior descending coronary artery; *LVEDP*, left ventricular end-diastolic pressure; *RCA*, right coronary artery.
*Prolapsed mitral valve.

The ST-T abnormalities in the patient with mitral valve prolapse were still present on an outpatient clinic visit 10 months after admission.

DISCUSSION

Our study indicates that certain ST segment and T wave abnormalities in the anterior chest leads, in the setting of an impending myocardial infarction, are suggestive of extensive ischemia of the anterior wall, most likely caused by a critical lesion in the proximal portion of the LAD artery. Twenty-six of 145 (18%) patients consecutively admitted because of recent onset or exacerbation of chronic stable angina exhibited these ECG changes, indicating that this is not a rare finding. Our observations suggest that this group of patients is at high risk for the subsequent development of an extensive myocardial infarction of the anterior wall. Twelve of the 16 patients not investigated by coronary angiography developed a usually extensive anterior wall infarction. In 11, the myocardial infarction occurred within 1 to 23 days (mean 8.5 days) after admission. Of interest is the difference between the time from admission to infarction in the 11 patients who

suffered a myocardial infarction (mean 8.5 days) and the interval from admission to bypass surgery in the nine patients who were operated on (mean 14 days). One possible explanation for the lack of infarction in the latter group could be the restriction in physical activities imposed on them following catheterization.

Patients showing the type of ST-T segment abnormalities described usually are classified as having either nontransmural or subendocardial ischemia (in the absence of enzyme changes) or a subendocardial infarction of the anterior wall (in the presence of an enzyme rise). In recent years, it has been stressed that the 1-year prognosis of patients with subendocardial infarction is no different from that of patients with a transmural infarction.[4-7] Our data suggest that the poor prognosis of patients with subendocardial infarction may be the result of the inclusion in those series of the type of patients described here. In our patients, the control of symptoms by drug therapy was not indicative of a more benign course. With regard to the ST-T segment abnormalities, we could not identify a particular sign having prognostic significance, such as the degree of the ST segment elevation in lead V_2, the shape of the ST segment in leads V_2 and V_3, the depth of the inverted T waves, or the duration of the ST-T segment abnormalities.

We do not have an explanation for the mechanism of these ST-T segment abnormalities. Although the possibility of a subendocardial infarction cannot be excluded, perhaps the ECG manifestations of persistent myocardial abnormalities may be the consequence of brief periods of severe ischemia not associated with necrosis.[8,9] As would be expected, the ECG changes do not predict the presence or absence of significant stenoses in other coronary arteries.

In one patient (patient 12) ECG abnormalities were present in the absence of coronary artery disease. Table III shows that a normal or near normal ejection fraction was found in patients with a critical LAD lesion who underwent catheterization and did not develop myocardial infarction. Only two of these had a left ventricular end-diastolic pressure of more than 14 mm Hg. All 10 had areas of hypokinesis (but not akinesis or dyskinesis) in the anterior wall. Nitroglycerin was not routinely given during the catheterization. Because not all the patients were recatheterized after surgery, information about the reversibility of these wall-motion abnormalities is not available.

Conclusions. It is of importance that the time course between complaints, ST-T segment abnormalities, and subsequent myocardial infarction allows early coronary angiography in the majority of patients showing these ECG abnormalities. We conclude that in patients admitted with chest pain and with the ECG pattern described who have no or slight myocardial damage as reflected by enzyme values, urgent coronary angiography should be performed to identify candidates for early revascularization. The morbidity and mortality of cardiac catheterization and surgery can be expected to be less than that of an extensive myocardial infarction of the anterior wall.[10] The long-term benefit of bypass surgery in these patients needs further evaluation.

REFERENCES

1. Plotnick GD, Conti CR: Unstable angina: Angiography, short- and long-term morbidity, mortality and symptomatic status of medically treated patients. Am J Med **63**:870, 1977.
2. National Cooperative Study Group: Unstable angina pectoris: National cooperative study group to compare surgical and medical therapy. II. In-hospital experience and initial follow up results in patients with one-, two- and three-vessel disease. Am J Cardiol **42**:839, 1978.
3. Kolibask AJ, Goodenow JS, Busk CA, Tetalman MR, Lewis RP: Improvement of myocardial perfusion and left ventricular function after coronary artery bypass grafting in patients with unstable angina. Circulation **59**:66, 1979.
4. Rigo P, Murray M, Taylor DR, Weisfeldt ML, Strauss HW, Pitt B: Hemodynamic and prognostic findings in patients with transmural and non-transmural infarction. Circulation **51**:1064, 1975.
5. Madias JE, Gorlin R: The myth of "mild" myocardial infarction. Ann Intern Med **86**:347, 1977.
6. Madigan NP, Rutlerford BD, Frye RL: The clinical course, early prognosis and coronary anatomy of subendocardial infarction. Am J Med **60**:634, 1976.
7. Szklo M, Goldberg R, Kennedy HL, Tonascia JA: Survival of patients with nontransmural myocardial infarction: A population-based study. Am J Cardiol **42**:648, 1978.
8. Kloner RA, DeBoer LWV, Darsee JR, Ingwal JS, Braunwald E: Persistent myocardial abnormalities following brief periods of temporary coronary occlusion not associated with necrosis. Circulation **62**:(suppl III):80, 1980.
9. DeBoer LWV, Kloner RA, Ingwal JS, Hale S, Dinello A, Braunwald E: ATP resynthesis and purine metabolism after brief ischemia and prolonged reperfusion. Circulation **62**(suppl III):176, 1980.
10. Kennedy JW, Kaiser GC, Fisher LD, Maynard C, Fritz JK, Myers W, Mudd JG, Ryan TJ, Coggin J: Multivariate discriminant analysis of the clinical and angiographic predictors of operative mortality from the Collaborative Study in Coronary Artery Surgery (CASS). J Thorac Cardiovasc Surg **80**:876, 1980.

DISCUSSION

Dr. Gold: Have you been able to see a coronary intraluminal filling defect either proximal or distal to the lesion in this group of patients?

Dr. Wellens: If you are asking whether there was evidence for thrombus formation in these patients, the answer is no. We could not identify an intraluminal filling defect close to the stenosis.

Dr. Gold: I would agree that this ECG pattern indicates a need for emergency angiography. However, we have found in postmortem examinations that a large percent-

age of patients who died of an infarct before the days of revascularization had a plaque hemorrhage with a mural thrombus visible in the vessel. And in two of 20 patients, we were actually able to see the thrombus during a postmortem angiogram.

Dr. Wellens: Patients who are operated on do very well. In fact, in eight of the 10 the ECG showed complete normalization. In the other two, there were persistent ST segment abnormalities in the sense of T wave negativity. We have not, however, restudied them by angiography.

Dr. Swan: It is important to recognize this group as a serious subset in the clinical presentation of acute infarction. But there is an even more pressing reason to take these patients promptly to the angiographic laboratory if there is any suggestion that symptom relief is not accompanied by immediate normalization of the ECG. We have had the same experience as you have described, but we have also found that several patients have single-vessel disease high in the anterior descending coronary artery. A recent patient underwent transluminal angioplasty by the technique of Gruntzig and immediately became symptom free. The ST segments were slightly elevated in leads V_1, V_2, and V_3. They normalized, and he completed a stress test about 5 days later and left the hospital in excellent condition.

Dr. Wellens: I agree completely. Five of our 10 patients could have been helped by coronary angioplasty.

Dr. Conti: Your data make a good case for angiographic study of patients admitted to the hospital primarily for the management of chest pain—to pick out those whom Dr. Gold and Dr. Swan are concerned about, for whom we could perform angioplasty or do streptokinase infusion. In the unstable angina study performed for the National Heart, Lung and Blood Institute (NHLBI), about 27% had ST segment elevations associated with chest pain on admission to the hospital. I don't know exactly how many were in the anterior precordial leads, but a fair number were. If we analyze the data in terms of medical and surgical therapy, the results for the subset of patients with St segment elevation are not significantly different from those for the entire group. There was about an 8% to 10% incidence of in-hospital myocardial infarction in the medical group and a higher incidence among those who underwent emergency surgery. The long-term myocardial infarction rate is also similar to the overall group. I suspect that the NHLBI patients were not precisely the same as your group. We required only transient, not permanent, ECG changes with pain. Also, we excluded patients with any significant cardiac enzyme changes. We were concerned that myocardial infarction was present whenever ECG changes were accompanied by *any* enzyme elevation. I agree with you, however, that these patients should be evaluated to define the anatomic derangement. I suspect that a high incidence of multiple-vessel disease will be found in this group, and perhaps even a high incidence of left main coronary artery stenosis, but that is just speculation. Another point is that among the 228 patients with unstable angina studied, 208 had significant LAD disease. When that subset is analyzed and compared with the entire group, the prognosis is not much different with either medical or surgical therapy, at least for the short term.

Dr. Wellens: One of our duties regarding patients admitted because of an impending myocardial infarction is to recognize those at a very high risk of developing an extensive infarction. I believe that by using the ECG pattern, we can define a subset of people with a proximal LAD lesion, with a 75% chance of losing 35% of their myocardium within 2 weeks, and I believe that they should be distinguished from patients who develop ST segment elevations or depressions during pain. The pattern that I described develops *after* the pain, and it remains. ECGs can be done everywhere and provide an easy way to recognize a very high-risk group.

Dr. Mason: You have implied that surgery benefits these patients and prevents death and myocardial infarction. Do you think that this represents the latest evidence that coronary bypass grafting prevents myocardial infarction and death in patients with single-vessel disease, or alternatively, is it possible that there is a difference between group A and group B patients?

Dr. Wellens: I think that we are dealing with a group of patients who have a very high incidence of myocardial infarction if they are not revascularized. Twelve of the 16 who did not undergo bypass surgery developed a usually extensive anterior wall infarction within a few weeks, but none of those who were operated on suffered a myocardial infarction. Our data suggest that, at least for the short term, revascularization is indicated these patients. Obviously, more information is required concerning long-term follow-up.

Dr. Zipes: Folts et al. (Circulation **54**:365, 1976) have made an interesting observation about partially stenosed coronary arteries, showing that the flow distal to the partial occlusion waxes and wanes, probably because platelet clots intermittently plug up the vessel and then break off and restore flow. I wonder whether coronary angiography done at an appropriate time could show such an occlusion due to a space-occupying lesion (i.e., a platelet plug). If the injection is forceful enough, it could push the clots downstream, and the stenosis would no longer be present. Perhaps that waxing and waning could account for some of the clinical course that you have observed.