Value of the Electrocardiogram in Diagnosing the Number of Severely Narrowed Coronary Arteries in Rest Angina Pectoris

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The aim of this study was to assess the value of the electrocardiogram recorded during chest pain for identifying high-risk patients with 3-vessel or left main stem coronary artery disease (CAD). Therefore, the number of leads with abnormal ST segments, the amount of ST-segment deviation, and specific combinations of leads with abnormal ST segments were correlated with the number of coronary arteries with proximal narrowing of >70%. Electrocardiograms recorded during chest pain were compared with one from a symptom-free episode. In this retrospective analysis, 113 consecutive patients were included. One-vessel CAD was present in 47 patients, 2-vessel CAD in 22, 3-vessel CAD in 24 and left main CAD in 20. Stratification was performed according to the presence of an old myocardial infarction. The number of leads with ST-segment deviations, and the amount of ST-segment deviation in the electrocardiogram obtained during chest pain at rest showed a positive correlation with the number of diseased coronary arteries. These findings were more marked when the absolute shifts from baseline were considered, because ST-segment abnormalities could be present also in the electrocardiogram obtained during the symptom-free episode. Left main and 3-vessel CAD showed a frequent combination of leads with abnormal ST segments: ST-segment depression in leads I, II and V_4–V_6, and ST-segment elevation in lead aVR. The negative predictive and positive accuracy of this pattern were 78 and 62%, respectively. When the total amount of ST-segment changes was >12 mm, the positive predictive accuracy for 3-vessel or left main stem CAD increased to 86%. The findings show that the electrocardiogram during chest pain at rest is of great value in diagnosing the number of diseased coronary arteries in patients with rest angina.

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The challenge when confronted with the patient with acute reversible myocardial ischemia is to identify the amount of myocardium at risk. Critical stenoses in the proximal part of the left anterior descending branch,[1] severe 3-vessel coronary artery disease (CAD)[2,3] and left main stem stenosis[4] have all been recognized as clinical conditions complicated by a high incidence of large infarction, pump failure, arrhythmias and sudden death. Because many effective treatment modes are available currently,[5,6] early recognition of those circumstances is crucial for appropriate management. The electrocardiogram is an inexpensive tool that is easily available in any patient admitted because of myocardial ischemia. The aim of this study was to assess the value of the electrocardiogram in diagnosing the extent of CAD in patients with transient reversible myocardial ischemia at rest.

METHODS

Patients were selected with a 12-lead electrocardiogram recorded during transient chest pain at rest, and ≥1 severe stenosis in either the main stem, proximal right coronary artery, left anterior descending branch proximal to the first diagonal branch, or proximal circumflex branch, or a combination, as assessed by coronary angiography during the same admission. A stenosis was considered significant when the reduction in diameter in any projection was ≥70% of the adjacent normal diameter of the coronary artery. Patients with previous coronary revascularization, acute myocardial infarction (plasma aspartate aminotransferase increase greater than twice the upper level of normal) or left bundle branch block were excluded from the study. The electrocardiogram with the most marked abnormalities during chest pain at rest was analyzed by measuring the ST-segment deviation 80 ms after the J point, using the PQ segment as the isoelectric line. These electrocardiograms were also compared with those recorded during an episode without chest pain. The number of leads showing ST-segment changes, and the amount of ST-segment deviation were scored, and the findings were analyzed in relation to location and number of proximal lesions in the coronary arteries. Statistical analysis was performed using chi-square, paired *t* test or 1-way analysis of variance followed by Bonferroni's *t* test.

RESULTS

Patient selection and characteristics: One hundred thirteen patients fulfilled the entry criteria. In these patients with transient chest pain at rest, 1-vessel CAD was present in 47, 2-vessel CAD in 22, 3-vessel CAD in 24,

TABLE I Characteristics of 113 Patients with Transient Chest Pain at Rest in Relation to the Number of Severely Narrowed Coronary Arteries

	1 VD (%)	2 VD (%)	3 VD (%)	LMS (%)	p Value
Number of patients	47	22	24	20	
Age (years)	59 ± 8	61 ± 7	63 ± 7	67 ± 9	<0.001
Men	31 (66)	15 (68)	16 (67)	15 (75)	NS
Duration of symptomatic CAD (weeks)	6 ± 9	240 ± 250*	340 ± 79*	155 ± 221*	<0.001
Collateral circulation	15 (32)	10 (45)	19 (79)	17 (85)	<0.001
Old MI	2 (9)	7 (32)	19 (46)	8 (35)	NS

*Versus 1-vessel CAD.
CAD = coronary artery disease; LMS = left main stem disease; MI = myocardial infarction; VD = vessel disease.

TABLE II ST-Segment Changes and Number of Abnormal Leads in Relation to the Number of Severely Narrowed Coronary Arteries

	1 VD	2 VD	3 VD	LMS	p Value <0.05
ST-segment changes					
No old MI					
Absolute changes	8 ± 5	8 ± 7	13 ± 4	18 ± 6	1) 2) 4)
Relative changes	7 ± 5	6 ± 6	10 ± 4	15 ± 6	1) 2)
p value	<0.01	<0.01	<0.01	<0.01	
Old MI					
Absolute changes	2 ± 2	9 ± 5	12 ± 8	19 ± 7	1)
Relative changes	3 ± 3	5 ± 4	9 ± 6	16 ± 8	1) 2)
p value	NS	<0.05	<0.05	<0.05	
Number of abnormal leads					
No old MI					
Absolute changes	7 ± 2	7 ± 3	10 ± 1	11 ± 1	1) 2) 4) 5)
Relative changes	7 ± 3	6 ± 3	10 ± 2	10 ± 1	1) 2) 4) 5)
p value	NS	<0.05	<0.05	NS	
Old MI					
Absolute changes	3 ± 3	9 ± 3	9 ± 1	11 ± 0	1) 4) 6)
Relative changes	4 ± 3	6 ± 3	9 ± 2	11 ± 1	1) 2) 4)
p value	NS	<0.01	NS	<0.05	

1) = LMS versus 1 VD; 2) = LMS versus 2 VD; 3) = LMS versus 3 VD; 4) = 3 VD versus 1 VD; 5) = 3 VD versus 2 VD; 6) = 2 VD versus 1 VD.
Abbreviations as in Table I.

and left main CAD in 20. Of patients with 1-vessel CAD, 9 had right CAD, 10 circumflex and 28 left anterior descending narrowing. Of patients with 2-vessel CAD, 2 had right/circumflex CAD, 14 left anterior descending/right and 6 left anterior descending/circumflex. Of patients with left main CAD, additional 1-vessel CAD was present in 2 (right coronary artery), 2-vessel CAD in 5, and 3-vessel CAD in 12. Only 1 patient had no other coronary artery involved.

Other baseline variables are listed in Table I. The extent of CAD was positively correlated with older age and the presence of collateral circulation. Statistically significant differences between single and multivessel CAD were also present in relation to duration of symptomatic CAD, and the presence of an old infarction on the electrocardiogram. No statistically significant correlation was found between the extent of CAD and gender.

Electrocardiographic findings: The electrocardiograms obtained during chest pain showed sinus rhythm, except in 4 patients with atrial fibrillation; none of the latter was using digitalis. In 1 patient, 2:1 atrioventricular block was present, and in another, a ventricular bigeminy. The latter patient could be included in the study, because no postextrasystolic ST-segment changes were observed. Q waves due to old myocardial infarction were found in 4 of 47 patients (9%) with 1-vessel CAD, 7 of 22 (32%) with 2-vessel CAD, 11 of 24 (46%) with 3-vessel CAD and 7 of 20 (35%) with left main CAD. Old inferior infarction was present in 24 patients and old anterior infarction in the remaining ones. No patient presented with an extensive infarction, as suggested by the absence of predominant QS patterns.

The relation between the extent of coronary artery disease, the number of abnormal leads, and the sum of ST-segment changes: Table II shows the ST-segment changes and number of abnormal leads classified regarding the presence of an old myocardial infarction and changes from baseline (absolute changes) or changes in comparison with the electrocardiogram obtained outside the episode of chest pain (relative changes). The following observations were made: (1) The higher the number of coronary arteries involved, the more ST-segment changes and the greater the number of abnormal leads were present. (2) ST-segment changes were more marked and the number of abnormal leads was higher when compared with baseline than when compared with the electrocardiogram obtained during the ischemic-free episode. This finding is explained by preexisting ST-segment abnormalities. (3) ST-segment changes and the number of leads were not different when an old myocardial infarction was visible on the electrocardiogram.

The severity of the electrocardiographic abnormalities in relation to the number of abnormal coronary arteries is shown in Figures 1 to 4. Figure 1 shows a typical example of an electrocardiogram recorded during chest pain in left main stem CAD. The most obvious findings are the marked but reversible ST-segment

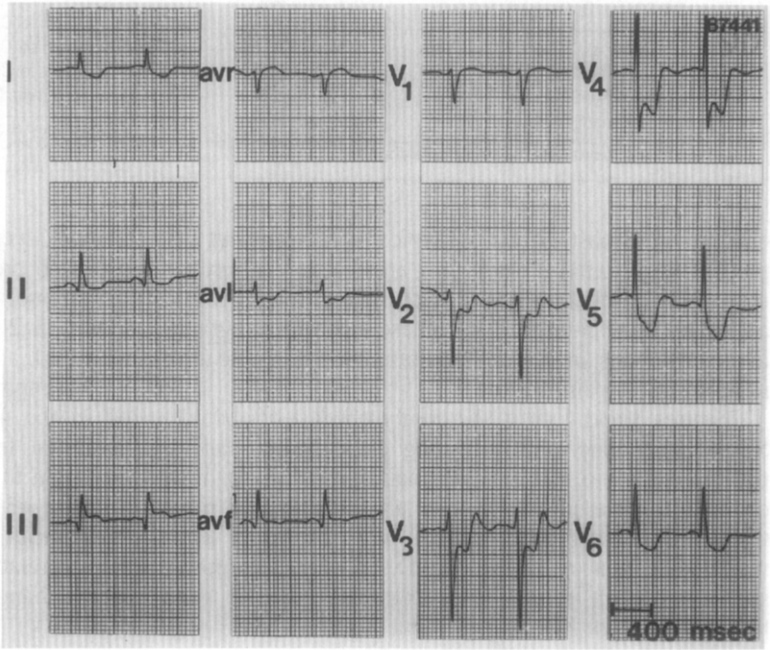

FIGURE 1. Typical example of ischemia due to left main disease. Note severe ST-segment changes in almost all leads, with ST depression in leads I, II and V_4–V_6, and ST elevation in aVR. Sum of ST-segment changes in all leads is 30 mm.

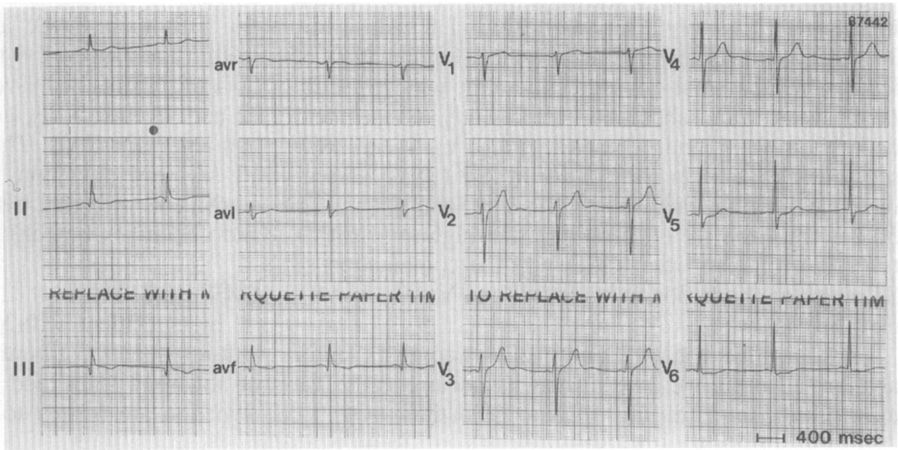

FIGURE 2. Electrocardiogram recorded in same patient after disappearance of chest pain. Most ST-T-segment abnormalities have subsided. Small old inferior wall infarction is present.

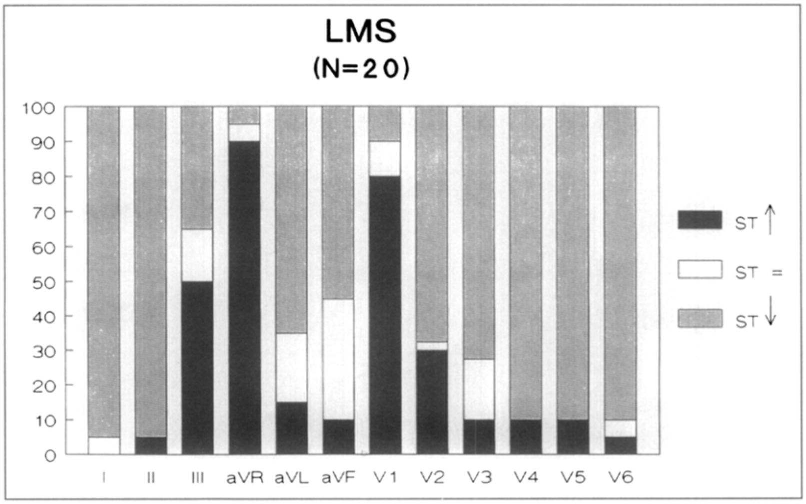

FIGURE 3. Frequency of ST-segment elevation or depression, or no change (ST =) in patients with left main stem disease (LMS). Note frequent occurrence of ST depression in leads I, II and V_4–V_6, and ST elevation in aVR and V_1.

TABLE III The Distribution of the "Left Main" Electrocardiographic Pattern in Relation to the Number of Diseased Coronary Arteries

Number of Coronary Arteries Narrowed >70% in Diameter	ECG Pattern Present (%)
1-vessel CAD	10/47 (21)
2-vessel CAD	8/22 (36)
3-vessel CAD	12/24 (50)
Left main CAD	18/20 (90)

CAD = coronary artery disease; ECG = electrocardiographic.

TABLE IV The "Left Main" Electrocardiographic Pattern in Relation to the Sum of ST-Segment Changes, and the Number of Severely Narrowed Coronary Arteries

Sum of ST Changes (mm)	<8 (n = 6)	8–12 (n = 20)	12–18 (n = 13)	>18 (n = 9)
1-vessel CAD (%)	4 (67)	5 (25)	1 (8)	0 (0)
2-vessel CAD (%)	1 (16)	5 (25)	1 (8)	1 (11)*
3-vessel CAD (%)	1 (16)	5 (25)	6 (46)	0 (0)
Left main CAD (%)	0 (0)	5 (25)	5 (38)	8 (89)

*Left main equivalent.
CAD = coronary artery disease.

changes in almost all leads. Typically, ST-segment depressions are found in leads I, II and V_4 to V_6. Furthermore, ST-segment elevation is present in leads III and aVR, and also slightly in V_1. These electrocardiographic abnormalities are for an important part reversible after relief of chest pain (Figure 2).

Figures 3 and 4 show the combined data of absolute ST-segment abnormalities during chest pain in all 44 patients with 3-vessel and left main CAD. ST-segment changes are present in virtually all leads. In left main CAD, the percentage of patients with abnormal leads was higher than in 3-vessel CAD. ST-segment depression was present in most leads except aVR and V_1 (and to a lesser extent III), which frequently showed ST-segment elevation.

Electrocardiographic pattern, frequently occurring in left main coronary artery disease: In left main CAD, 18 of 20 patients (90%) had a typical combination of leads with abnormal ST-segments; although frequently more leads were abnormal, consistently, ST-segment depression was found in leads I, II and V_4–V_6 and ST-segment elevation in aVR. Less frequent was ST-segment elevation in leads V_1 (n = 17; 85%) and III (n = 10; 50%). Thus, the set of leads with the highest sensitivity (90%) for main stem CAD was the combination of ST-segment depression in leads I, II and V_4–V_6, and ST elevation in aVR.

To assess the statistical power of this combination of abonormal leads, we investigated its occurrence in the electrocardiograms during ischemia in patients with 1-, 2- and 3-vessel CAD (Table III). A similar combination was also present in 10 of 47 electrocardiograms (21%) in 1-vessel CAD (6 with circumflex CAD), 8 of 22 (36%) in 2-vessel CAD, and 12 of 24 (50%) in 3-vessel CAD.

To improve the predictive value, we also investigated in the 48 patients with the aforementioned set of abnormal leads the value of the sum of ST-segment deviation in all leads.

Sum of ST-segment deviation in all leads in the "left main electrocardiogram": As expected, a positive correlation was found between the sum of ST-segment changes and the number of coronary arteries (Table IV). No patient showing the described abnormalities in leads I, II, aVR and V_4–V_6, but with a total amount of ST-segment change in all leads of <8 mm had left main CAD, and only 1 had 3-vessel CAD. Within the range of 8 to 12 mm ST-segment changes, 50% of patients had 3-vessel or left main CAD, between 12 and 18 mm, 84%, and >18 mm, 89%, all of whom had left main CAD. The only other case with >18 mm ST-segment deviation was a patient with left main equivalent (proximal stenoses in left anterior descending and circumflex branch).

DISCUSSION

In agreement with previous studies,[7] it was found that in patients with transient angina at rest, the number of abnormal leads, and the total amount of ST-segment deviation are related to the number of narrowed coro-

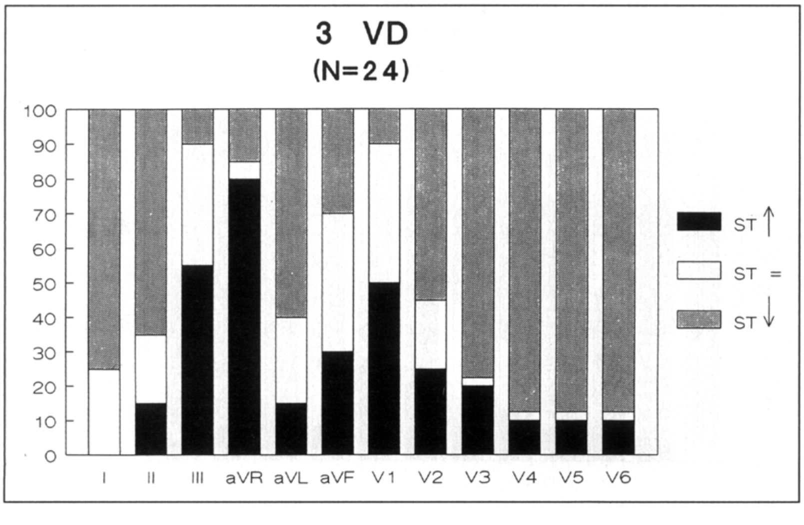

FIGURE 4. Frequency of ST-segment elevation or depression, or no change (ST =) in patients with 3-vessel disease (3 VD).

nary arteries. A useful finding in this study is the combination of leads with ST-segment abnormalities to diagnose multivessel (especially 3-vessel) and left main CAD. In these patients, severe ST-segment depressions in leads I, II and V_4–V_6, and ST-segment elevation in aVR were frequently present during chest pain. The sensitivity of this electrocardiographic pattern was highest in left main CAD. Lead aVR, which is frequently ignored by most electrocardiographers, was also found to be useful.

The occurrence of generalized ST-segment depressions in 3-vessel and left main CAD has also been observed by other investigators[2,3]; also as in the present study, more frequent prior myocardial infarction, a larger episode of preceding angina, and a worse prognosis were found.[3,8] Although the sensitivity of this combination of abnormal leads was high in left main CAD, specificity was less, resulting in relatively low predictive accuracy. This is to be expected because 2- and 3-vessel CAD may cause ischemia in the same part of the left ventricle. Consequently, the accuracy of this electrocardiographic pattern to predict multivessel CAD was high (79%). One-vessel CAD, especially circumflex, may mimic this picture. Therefore, to differentiate further between 2- and 3-vessel, and left main CAD, the value of the amount of ST-segment deviation in all leads was assessed. A high ST-segment deviation score (>12 mm) is highly suggestive for left main or 3-vessel CAD. The reverse was also true: the absence of this lead pattern made 3-vessel or left main CAD unlikely.

Exercise testing has frequently been used to estimate the severity of CAD in patients with angina pectoris,[9–22] and a strongly positive exercise test is related to increased risk for future cardiac events. The data show that the rest electrocardiogram obtained during chest pain is useful for this purpose also.

Clinical implications: In patients admitted to the hospital because of transient chest pain at rest who do not develop myocardial infarction, it is important to recognize the subset in whom a large area of myocardium is jeopardized. These patients are especially at risk to develop severe complications, and should have priority for coronary angiography and interventions. The findings indicate that recording the 12-lead electrocardiogram during chest pain can identify these patients. This will not only be of benefit to the patient, but will also be cost effective.

The findings also indicate the necessity of instructing coronary care unit personnel to record electrocardiograms immediately when the patient complains of chest pain and before administering antianginal medication.

Study limitations: This study was retrospective, including only patients with documented chest pain at rest in whom coronary angiography was performed during the same admission. We restricted the study group to patients with transient ischemia at rest. Patients with acute myocardial infarction or only effort angina were excluded, as well as those with previous coronary bypass surgery. Currently, we are performing a prospective study to further evaluate the value of the present findings.

Finally, it should be emphasized that the described electrocardiographic abnormalities were recorded during chest pain. Therefore, similar electrocardiographic findings recorded without the presence of angina should be interpreted with caution.

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