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Prognostic Significance of the Initial Electrocardiographic Pattern in a First Acute Anterior Wall Myocardial Infarction*

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The availability of potent, but potentially dangerous, types of reperfusion therapy for acute myocardial infarction (AMI) has forced us to refine our tools for early and accurate diagnosis and for early risk stratification of patients with evolving AMI. The estimation of risk has to be made shortly after admission, when only the history, physical examination, and the ECG are available. This study was undertaken to compare in-hospital mortality with different patterns of the ECG obtained at admission in 147 consecutive patients with an evolving first AMI of the anterior wall. By using a new classification of the admission ECG, it was possible to divide the patients into 3 groups: (1) group A contained 12 patients with tall peaked T waves in the involved leads, without ST segment elevation; (2) group B comprised 77 patients with abnormal T waves and ST elevation, but without major changes in the terminal portion of the QRS complex; and (3) group C comprised 58 patients with abnormal T waves, ST elevation, and distortion of the terminal portion of the QRS. The mortality was 0, 3 percent, and 29 percent in groups A, B, and C, respectively ($\chi^2 = 22.91$; $p = 0$). By using a logistic regression model, it was found that the initial ECG pattern alone is a strong predictor of in-hospital mortality in patients with an evolving anterior wall AMI. The predicted probabilities of death in groups A, B, and C are 0.0016, 0.025, and 0.29, respectively. This simple classification of the initial ECG pattern in patients with a first AMI of the anterior wall may enable the differentiation of patients with low in-hospital mortality (groups A and B) and of those with an in-hospital mortality of almost 30 percent (group C).

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AMI = acute myocardial infarction; CK = creatine kinase; CK-MB = MB fraction of creatine kinase; rtPa = recombinant tissue-type plasminogen activator; VSD = ventricular septal defect

The availability of potent, but potentially dangerous, types of reperfusion therapy for acute myocardial infarction (AMI) has forced us to refine our tools for early and accurate diagnosis and for early risk stratification of patients with an evolving AMI. The estimation of risk needs to be made shortly after admission, when only the history, physical examination, and the ECG are available.

The ECG is simple and noninvasive and can be obtained at bedside, and its role in the diagnosis of AMI is well established;[1] however, the role of the ECG obtained at admission in predicting the prognosis and in risk stratification is less clear. In the early 1970s, it was found by epicardial and precordial mapping that the magnitude of ST segment elevation is a reflection of the extent of myocardial injury.[2-5] As a result, ST segment elevation was used to define subsets of patients who can benefit most from early thrombolysis[1,6,7] and even to monitor the effects of reperfusion therapy;[8-10] however, the magnitude of ST elevation is influenced not only by the extent and severity of the ischemia, but also by variations of the shape and size of the chest and by localization of the infarction.[11]

The purpose of this study is to correlate the different patterns of the admission ECG of patients with an evolving first anterior AMI to in-hospital mortality, in order to define a simple ECG tool that will help the clinician to estimate the risk of a patient with anterior AMI shortly after admission. Instead of using absolute measurements of ST elevation, we divided the patients into three groups according to the pattern of the admission ECG. We considered the relations between the T wave, the ST segment, and the terminal portion of the QRS complex.

Materials and Methods

Patients

We studied the records of all patients admitted to the coronary care unit from January 1988 to March 1991 who were in the early stages of an evolving first AMI involving the anterior wall. We studied only those patients who presented before inversion of the T wave or evolution of an abnormal Q wave had occurred. Patients with a history or ECG evidence of a previous AMI were excluded. Anterior AMI was diagnosed when the following criteria were met: prolonged chest pain of more than 30-min duration, suggestive of AMI; diagnostic increase and decrease of the serum creatine kinase (CK); and evolution of serial ECG changes in 2 or more adjacent precordial leads (tall peaked T waves that become inverted on subsequent recordings, ST elevation, and shortening of the R wave or evolution of an abnormal Q wave on subsequent recordings). The records of 228 patients were examined. Eighty-one patients were excluded from the study because the admission ECG showed inverted T waves (29 patients, 5 of them with abnormal Q waves), ST segment depression in the involved leads without ST elevation (9 patients), abnormal Q waves (31 patients), and bundle-branch

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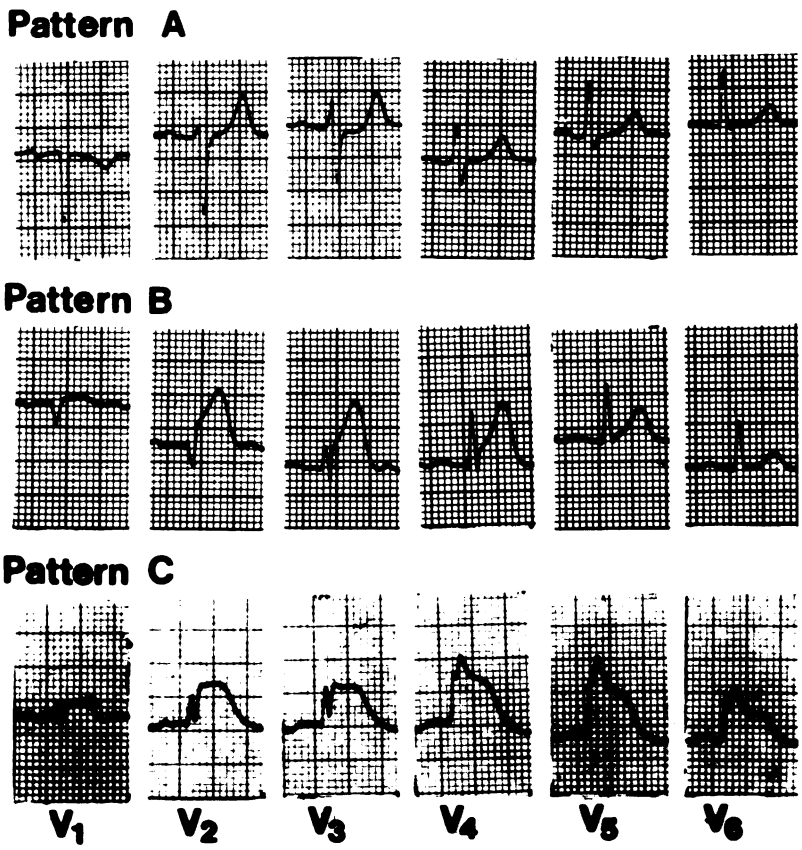

FIGURE 1. Initial ECG patterns. Examples of different patterns are demonstrated in three different patients with anterior AMI. Pattern A, tall symmetric abnormal T waves in involved leads (V_2 to V_3), without ST elevation or major changes in terminal portion of QRS complex; pattern B, abnormal T waves and ST elevation (>0.1 mV) in leads V_1 to V_5, without major changes in terminal portion of QRS; and pattern C, abnormal T waves and ST elevation (>0.1 mV), accompanied by distortion of terminal portion of QRS complex (disappearance of S wave in leads V_1 to V_3 and emergence of J point at level above lower half of R wave in leads V_4 to V_6).

block (17 patients). The studied group consisted of 147 patients (111 men and 36 women) aged 37 to 86 years (mean, 64 years); 98 were treated with thrombolytic therapy (87 with streptokinase [750,000 to 3,000,000 units in 1 h] and 11 with recombinant tissue-type plasminogen activator [rtPa; 100 mg in 1 h]). All of the patients were treated with intravenous heparin (1,000 units/h) and isosorbide dinitrate (0.03 to 0.07 mg/min).

Electrocardiographic Evaluation

Definition of the initial ECG pattern (Fig 1) was as follows: (1) group A, tall symmetric abnormal T waves in the involved leads, without ST elevation or major changes in the terminal portion of the QRS; (2) group B, abnormal T waves and ST elevation (>0.1 mV) in 2 or more adjacent leads, without major changes in the morphology of the terminal portion of the QRS; and (3) group C, abnormal T waves and ST elevation (>0.1 mV), accompanied by distortion of the terminal portion of the QRS complex in 2 or more adjacent leads (emergence of the J point at a level above the lower half of the R wave or disappearance of the S wave in leads with an Rs configuration).[12]

All of the admission ECGs done in the emergency room and on arrival to the coronary care unit were evaluated by two cardiologists separately. In case of disagreement, a third examiner was consulted. The ST elevation was measured manually to the nearest 0.05 mV in each lead at 0.08 s from the J point. The number of leads with ST elevation (>1 mm in limb leads and >2 mm in precordial leads) was recorded.[13] The patients were divided into three groups according to the definitions mentioned previously.

Clinical Evaluation

We studied the charts of the patients for clinical data such as age, sex, history of diabetes mellitus, hypertension, and angina pectoris, Killip functional class on admission, thrombolytic therapy, and death during the index admission.

Statistical Analysis

The χ^2 test was applied to see if there is a difference in the in-hospital mortality among the three groups of initial ECG patterns. We used the Spearman correlation coefficient to measure the strength of association between in-hospital mortality (1 = death; 2 = survival) and each of the following parameters: age; sex; Killip functional class on admission; thrombolytic therapy; number of leads with ST elevation; and the three initial ECG patterns.

A logistic regression model was fitted, using the "SAS Procedure Logistic for P.C.," to evaluate the prediction of in-hospital mortality for each subgroup of the parameters. Decisions concerning potential explanatory variables, to be included in the model, were based on the p value of the Wald χ^2 statistic. The dependent or response variable was in-hospital mortality (denoted for convenience by 1 = death and 2 = survival). The potential prognostic factors to be included in the model were the initial ECG pattern (1 to 3), the number of leads with ST elevation, Killip functional class, age, and sex. The estimates of the logistic regression model were used to calculate the predicted probabilities of death in the different groups of initial ECG patterns.

RESULTS

One hundred forty-seven patients were enrolled in the study. There were 12, 77, and 58 patients included in initial ECG pattern groups A, B, and C, respectively. Ninety-nine patients received thrombolytic therapy: 3 (25 percent), 53 (69 percent), and 42 (72 percent) in groups A, B, and C, respectively. Nineteen patients died during hospitalization (in-hospital mortality of 13 percent). The age, sex, initial ECG pattern, time of death after admission, and the presumed cause of death are shown in Table 1. Most of the patients

Table 1—*Data From 19 Patients Who Died During Hospitalization*

Age, Sex	Initial ECG Pattern	Time of Death after Admission	Cause of Death
73, F	B	12 d	After operation for VSD
86, F	B	8 h	Cardiogenic shock
80, M	C	10 h	Cardiogenic shock
69, F	C	25 h	Cardiogenic shock
63, M	C	30 h	Cardiogenic shock
70, F	C	8 h	Cardiogenic shock
75, M	C	5 h	Cardiogenic shock (after rescue PTCA*)
74, F	C	6 h	Cardiogenic shock
75, M	C	2 h	Cardiogenic shock
63, M	C	5 h	Cardiogenic shock
75, F	C	3 h	Arrhythmia
75, F	C	24 h	Cardiogenic shock
80, M	C	8 h	Cardiogenic shock
66, M	C	10 h	Cardiogenic shock
69, F	C	18 h	Cardiogenic shock
70, M	C	21 d	Reinfarction
68, F	C	13 d	Cardiogenic shock
67, M	C	2 h	Cardiogenic shock
81, F	C	2 d	Cardiogenic shock

*PTCA, Percutaneous transluminal coronary angioplasty.

who died did so during the first hours after admission. The cause of death was pump failure in 17 patients, one of them after reinfarction on the 21st day. One patient died after operation for a ventricular septal defect (VSD) on the 12th day, and one died because of ventricular fibrillation. In all of the patients, the ECG pattern was stable from arrival at the emergency room until the initiation of specific therapy (approximately 15 to 30 min later).

There was no significant difference between the mortality of patients with a previous history of diabetes mellitus, hypertension, and angina pectoris and patients without such a history. The mortality in 48 patients who did not receive thrombolytic therapy was 19 percent (9 patients). Ten of the 99 patients who received thrombolytic therapy died, but the difference is not significant ($\chi^2 = 2.15$; $p = 0.14$). The mortality in groups A, B, and C was 0, 3 percent (2 patients), and 29 percent (17 patients), respectively. The mortality among the patients who received thrombolytic therapy in groups A, B, and C was 0, 2 percent (1 patient), and 21 percent (9 patients), respectively. The relationship between mortality and the ECG patterns was statistically significant ($p = 0$) (Table 2).

Table 2—*Mortality by Initial ECG Pattern**

ECG Pattern	Died	Survived	Total	Mortality, %
Group A	0	12	12	0
Group B	2	75	77	3
Group C	17	41	58	29
Total	19	128	147	13

*$\chi^2 = 22.91$; $p = 0.00$.

Table 3—*Correlation Coefficients and Significance Between Several Parameters and Mortality**

Variable	Correlation Coefficient	Significance
Initial ECG pattern	−0.38	0.0001
Age	−0.29	0.0003
Sex	−0.25	0.0021
Number of leads	−0.24	0.0029
Killip class	−0.16	0.0571
Thrombolysis	+0.12	0.1447

*Death was defined as 1 and survival as 2. That is cause for negative value in most of correlations.

Table 3 shows the correlation coefficient and the p value of each parameter and the in-hospital mortality. The initial ECG pattern was the most significant parameter (correlation coefficient = −0.38; $p = 0.0001$). Other variables (age, sex, number of leads with ST elevation, and Killip class at presentation) were also statistically significant.

In a preliminary step for prediction of in-hospital mortality, we included in the logistic regression model the following prognostic factors: age; sex; Killip functional class; number of leads with ST elevation; and the initial ECG pattern.

Neither the Killip class nor the number of leads with ST elevation was statistically significant (Table 4). When the initial ECG pattern was included in the model, the contribution of the other prognostic factors was very small, so in our final logistic regression model, the only explanatory variable included was the initial ECG pattern. The odds ratio between the initial ECG patterns B and A is 15.6. The odds ratio between the initial ECG patterns C and B is 11.6, while the odds ratio between patterns C and A comes up to 181 (Table 5). Thus, for a patient presenting with ECG pattern A, the predicted probability of death is 0.0016. For a patient with pattern B, the predicted probability of death is 0.025, and for a patient with pattern C, the probability is 0.29 (Table 6).

Discussion

In this study, we attempted to correlate the different

Table 4—*Estimated Parameters From Multivariate Logistic Regression With In-Hospital Mortality as Dependent Variable*

Variable	Parameter Estimate (β)	Standard Error of β	p Value*
Intercept	−16.1187	3.4766	0.0001
Initial ECG pattern	2.6623	0.8941	0.0029
Age	0.0652	3.6681	0.0555
Sex	1.5138	5.3838	0.0203
Number of leads	0.0219	0.0122	0.9121
Killip class	0.3357	1.1693	0.2795

*p value was based on Wald χ^2 statistic.

Table 5—*Estimated Parameters from Logistic Regression With In-Hospital Mortality as Dependent Variable and Only ECG Pattern as Predictor Variable*

Data	Variable	
	Intercept	ECG Pattern
Parameter estimate (β)	−9.1768	2.766
Standard error of β	2.1993	0.7632
p value*	0.0001	0.0003

*p value is based on Wald χ^2 statistic.

patterns of the ECG on admission in patients having evolving anterior AMI with the in-hospital mortality.

Previous Studies

Previous studies concerning the ability of the admission ECG to predict either infarct size or prognosis have concentrated on absolute ST segment measurements. Cohen et al[14] found that the number of leads with ST elevation observed during angioplasty of the left coronary artery correlated with the angiographic estimate of the size of the ischemic hypocontractile zone. Aldrich et al[8] found a formula relating the number of leads with ST elevation at the J point to the infarct size in anterior AMI, with the validity of the formula proven in a prospective study.[15] Mauri et al,[13] by assessing the patients enrolled in the Gruppo Italiano Per Lo Studio della Streptochimasi Nell'infarcto Miocardico (GISSI) trial, found that the mortality of patients with an anterior AMI increased from 8 percent in patients with ST elevation in 2 to 3 leads to 23.8 percent in those with 8 to 9 involved leads; however, Murray et al[16] found only a weak correlation between the number of leads with ST elevation (measured by precordial 35-lead maps) and infarct size (estimated by imaging with ^{99m}Tc-labeled stannous pyrophosphate [^{99m}Tc-PYP]). Yusuf et al[11] and Nielsen[17] did not find any correlation between the number of leads with ST elevation and cumulative CK-MB[11] or mortality.[17]

Estimation of the magnitude of ST elevation has been correlated with mortality. Nielsen[17] found that the death rate of patients with "major ST elevation" was 23 percent, while in patients with "minor ST elevation," the mortality was 6 percent ($p<0.005$). Marik et al[18] stated that the mortality in 42 patients with maximal ST elevation of 0 to 1 mm in a single lead was 0, while this value rose to 54 percent in 70 patients with an ST elevation of 5 mm or more in a single lead.

Table 6—*Estimated Probabilities* of Death in Relation to ECG Pattern*

ECG Pattern	Predicted Probability of Mortality	95% Confidence Limits
Group A	0.0016	0.0001-0.027
Group B	0.025	0.006-0.95
Group C	0.29	0.19-0.42

*Probabilities were calculated based on logistic regression estimates.

The sum of ST elevations, measured by 35-lead precordial mapping[11,19,20] or in a standard 12-lead ECG[7,21,22] has been correlated with infarct size and also with mortality;[22] however, other investigators did not find such a correlation.[4,16,23,24] In a recent study,[25] only a weak correlation between the sum of ST elevations and the myocardial area at risk assessed by ^{99m}Tc-sestamibi imaging, was found.

Present Study

We have studied the initial ECG patterns (the terminal portion of the QRS, the ST segment, and the T wave) in patients presenting in the early stages of an evolving anterior AMI, before inversion of the T wave and before appearance of an abnormal Q wave. We found that it is possible to recognize three different patterns of the admission ECG (Fig 1).[12] The first pattern is characterized by tall peaked abnormal T wave in the involved leads, without ST elevation or major changes in the terminal portion of the QRS. Recently, we described a subgroup of patients with anterior AMI compatible with this pattern.[26] In this subgroup, there is a high incidence of total or near total obstruction of the left anterior descending coronary artery and retrograde filling of the artery by collateral vessels. In these patients the prognosis is relatively good. The second pattern is recognized by abnormal T waves and ST elevation (>0.1 mV) in 2 or more leads, without major changes in the morphology of the terminal portion of the QRS. The third pattern is characterized by abnormal T waves and ST elevation accompanied by distortion of the terminal portion of the QRS. Recently, changes in the terminal portion of the QRS were described early in the course of AMI,[27] but the prognostic significance of these changes have never been previously studied.

We found this classification to be simple and highly reproducible. The ECG pattern was stable in all of our patients from arrival in the emergency room until the initiation of reperfusion therapy.

The in-hospital mortality in our patients was 13 percent and is comparable with other series of patients with first anterior AMIs.[13,18,28-30] In-hospital mortality in groups A, B, and C was 0, 3 percent and 29 percent, respectively. The correlation between the initial ECG pattern and mortality is highly significant (correlation

coefficient = 0.38; p = 0.0001). The number of leads with ST elevation also had a good correlation with in-hospital mortality, but the correlation coefficient was less than that of the ECG pattern (Table 3).

Mortality in Relation to Clinical Data

Our data demonstrate that age and female sex are associated with increased mortality (Table 3). This is in agreement with other studies.[18,29-36]

Our data do not support an association between a history of previous angina pectoris, hypertension, and diabetes mellitus and mortality. Evidence of heart failure or hypotension, as classified by Killip and Kimball,[37] has a strong association with mortality.[18,20,30,33,38-40] Our data are in concordance with those studies (Table 3). The mortality in 99 patients who received thrombolytic therapy was 10 percent versus 19 percent in 48 patients who were treated conservatively. Even though the two groups are not comparable because of selection bias (there was no randomization between the two groups; those patients who survived cardiopulmonary resuscitation and most of the patients with no ST elevation were not treated by thrombolysis), the relationship between thrombolysis and in-hospital mortality was not statistically significant ($\chi^2 = 2.15$; p = 0.14).

Multivariant Regression Analysis

Among the different parameters that were examined, the initial ECG pattern seems to be the one with the strongest association with mortality. Correlations of in-hospital mortality with age, sex, Killip functional class on admission, and the number of leads with ST elevation were also significant. When we separated the effect of the ECG pattern on the in-hospital mortality from the additional effects produced by age and sex, the odds ratio was almost unchanged.

The ECG is thus a simple and an immediately available noninvasive tool that can help the clinician in the diagnosis and risk stratification of patients with AMI, shortly after admission. By using simple ECG criteria, such as the initial ECG pattern, we were able to divide patients shortly after admission into three subgroups that differ significantly in the risk of death, from negligible mortality to almost 30 percent.

Electrophysiologic Explanation of Initial Pattern

It is accepted that ST elevation during myocardial ischemia is caused by a "current of injury" between the normal region and the ischemic zone.[41,42] ST elevation is a manifestation of segmental damage. Good correlation was found between regional wall motion abnormalities and ST elevation during coronary angioplasty[14] and between the grade of collateral flow during transient coronary occlusion during angioplasty and the sum of ST elevation.[43,44]

Distortion of the QRS complex during myocardial ischemia is caused by alterations in the conduction velocity of the activation wave in the Purkinje fibers as it travels through the ischemic region.[45] The delayed conduction decreases the degree of cancellation and, by so doing, increases the amplitude of the R wave and causes disappearance of the S wave. The Purkinje system is less sensitive to ischemia than the contracting myocardial cells.[46,47] For an alteration in the terminal portion of the QRS to occur, there must be a more severe degree of ischemia that would injure the Purkinje system.[45]

From these data, it can be concluded that in patients in group A, probably because of a good collateral circulation, the ischemia is not severe enough to cause an "injury current." The damage is minimal, and the prognosis is good.[26] One may postulate that in group B the ischemia is more severe, causing an "injury current," but the Purkinje fibers are not injured enough to cause major changes in the terminal portion of the QRS. Group C is characterized by ST elevation, accompanied by alteration of the terminal portion of the QRS. This may be because of a lack of collateral circulation, causing an even more severe degree of myocardial ischemia that affects the Purkinje system, and this may explain the increased mortality in group C.

Limitations

This is a historical prospective study of patients with a confirmed first anterior AMI. There was no randomization between patients who received thrombolytic therapy and those who did not. There is a need for a larger prospective study to verify our results and to examine, by randomized study, the role of more aggressive reperfusion measures in patients with AMI presenting with initial ECG pattern C.

Clinical Implication

It is most important to estimate the prognosis of a patient with an evolving AMI shortly after admission, because a potential poor prognosis would justify more aggressive reperfusion measures such as "primary" or "salvage" angioplasty or emergency coronary artery bypass grafting following angiography, especially in cases where thrombolytic therapy is contraindicated. By using the admission ECG, we were able to differentiate between three subgroups of patients with a first anterior AMI. The in-hospital mortality differs significantly among these subgroups. Categorizing the admission ECG according to the three patterns may aid the clinician in risk stratification before other data such as left ventricular ejection fraction and serial CK-MB serum levels are available.

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