Value of ST-segment elevation pattern in predicting infarct size and left ventricular function at discharge in patients with reperfused acute anterior myocardial infarction

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Background The implication of the shape of ST elevation in the acute phase of myocardial infarction (MI) remains unclear.

Methods and Results We examined the relation between the shape of ST elevation and infarct size in 77 patients who had a first acute anterior MI with successful reperfusion within 6 hours from symptom onset. A 12-lead electrocardiogram was recorded immediately before reperfusion confirmed by coronary angiography. The shape of ST elevation in lead V_3 was classified into 3 types: concave type (n = 24), straight type (n = 41), and convex type (n = 12). For concave type, straight type, and convex type, a median value of peak creatine kinase was 2287, 4371, and 5322 mU/mL, and left ventricular ejection fraction measured by left ventriculography at discharge (14 days after MI) was 58%, 48%, and 41% ($P < .05$; concave type versus the other 2 types), respectively. A multivariate logistic regression model demonstrated that the concave type of ST elevation was a strong predicting factor for preserved left ventricular function (left ventricular ejection fraction ≥50% at discharge; odds ratio 6.2, 95% confidence interval 1.6 to 20.8, $P = .019$).

Conclusions In patients with reperfused acute anterior MI, left ventricular function was excellent in patients with concave type, intermediate in those with straight type, and relatively poor in those with convex type ST elevation at discharge. This simple classification is useful for predicting left ventricular function at discharge. (Am Heart J 1999;137:522-7.)

The electrocardiogram is simple and noninvasive and can be recorded at bedside. Its role in the diagnosis of acute myocardial infarction (AMI) is well established. Although many studies have assessed infarct size on the basis of ST-segment measurements, such as the number of leads with or the magnitude of ST-segment elevation,[1,2] there is no report concerning the implications of the shape of ST-segment elevation. In the acute phase of AMI, the shape of ST-segment elevation might also reflect the severity of myocardial ischemia. We therefore proposed to clarify the clinical significance of the shape of ST-segment elevation in patients with anterior wall AMI.

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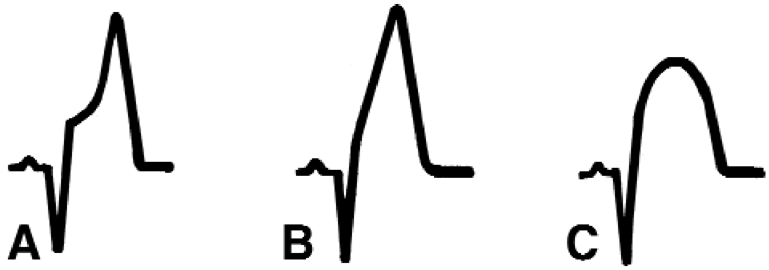
Methods

Patients

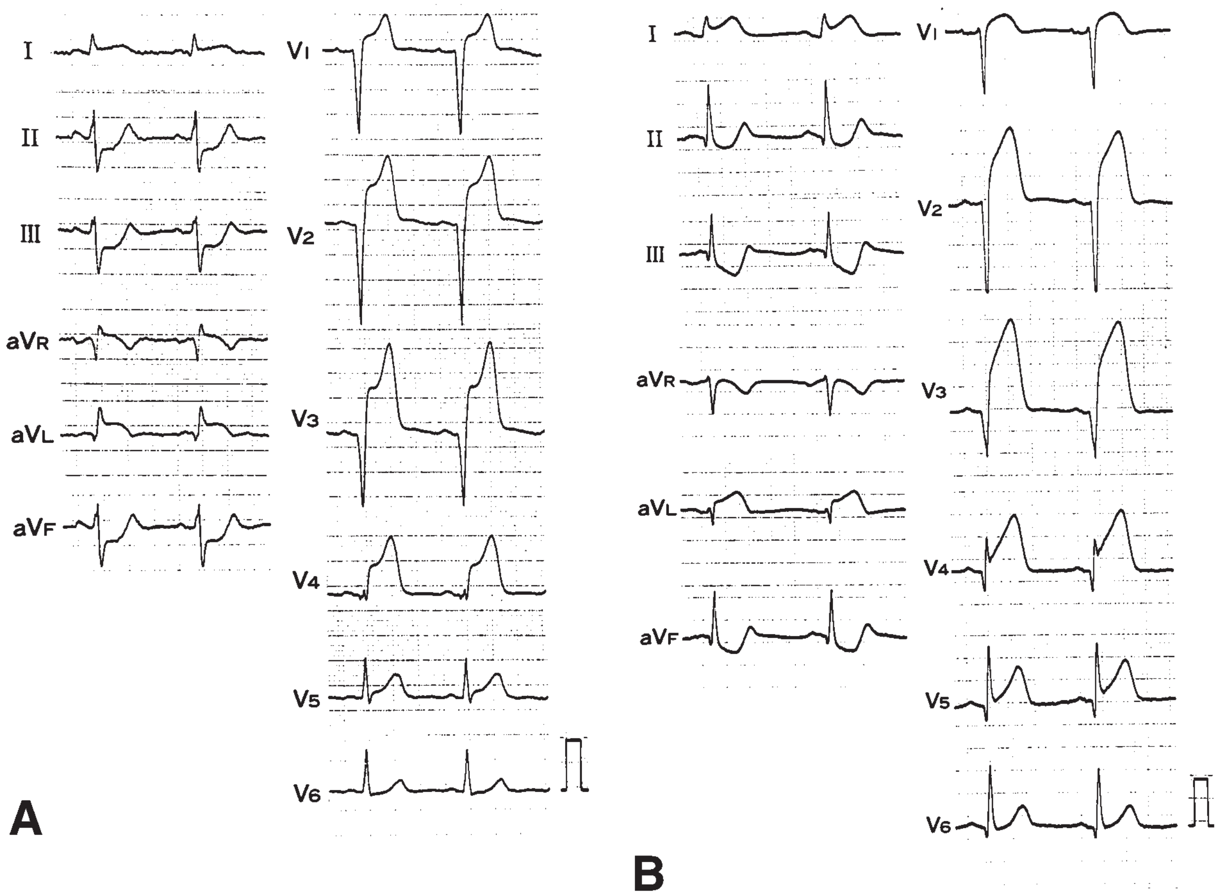
Between December 1990 and September 1996, 375 patients with anterior AMI were admitted to our coronary care unit. Seventy-seven patients (64 men and 13 women, 29 to 81 years [mean ± SD, 60 ± 11]) fulfilled the following inclusion criteria and were enrolled in our study: (1) first myocardial infarction, (2) complete occlusion (Thrombolysis in Myocardial Infarction [TIMI][3] grade 0) of the left anterior descending artery (LAD) confirmed by coronary angiography within 6 hours from the onset of symptoms, (3) successful reperfusion (TIMI grade 3 flow) of the LAD, and (4) patency of the LAD confirmed by follow-up coronary angiography performed at discharge (14 ± 4 hospital days). Patients were excluded from the study if they had (1) a history of myocardial infarction, (2) transient or permanent bundle block during the study period, (3) admission >6 hours from the onset of symptoms, (4) TIMI grade 1 to 3 flow of the LAD confirmed by the initial coronary angiography, (5) unsuccessful reperfusion (TIMI grade 0 to 2 flow), and (6) subsequent reocclusion of the LAD.

Figure 1



Schema of the shape of ST-segment elevation. **A,** Concave type. **B,** Straight type. **C,** Convex type.

Figure 2



Representative electrocardiograms of 3 types of ST elevation shape. **A**, Concave type, culprit lesion, segment 6. Time from symptom onset to reperfusion, 3.5 hours. LVEF 62% at discharge. **B**, Straight type, culprit lesion, segment 6. Time from symptom onset to reperfusion, 2.5 hours. LVEF 51% at discharge. **C**, Convex type, culprit lesion, segment 7. Time from symptom onset to reperfusion, 5.5 hours. LVEF 46% at discharge.

Figure 2 cont'd

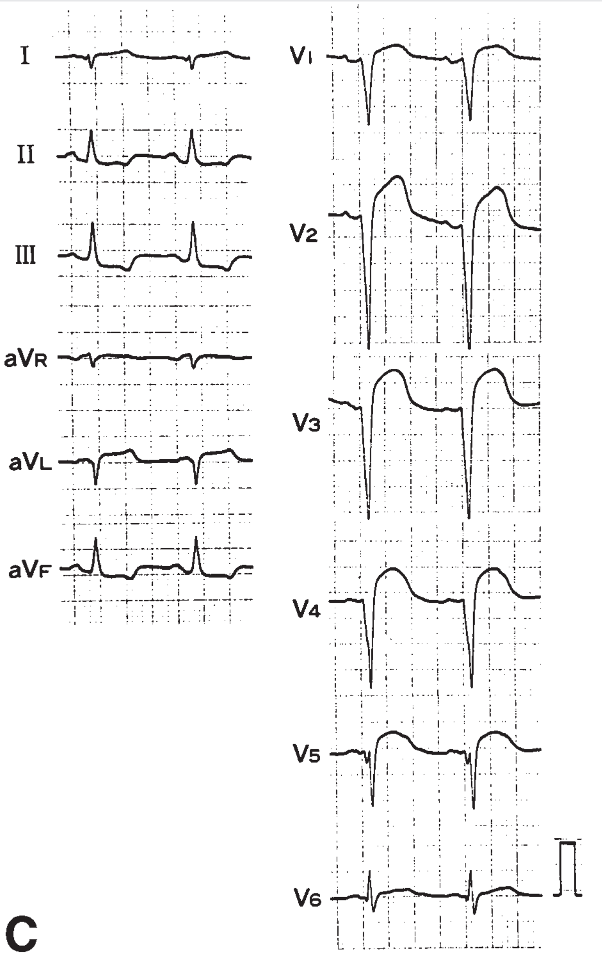
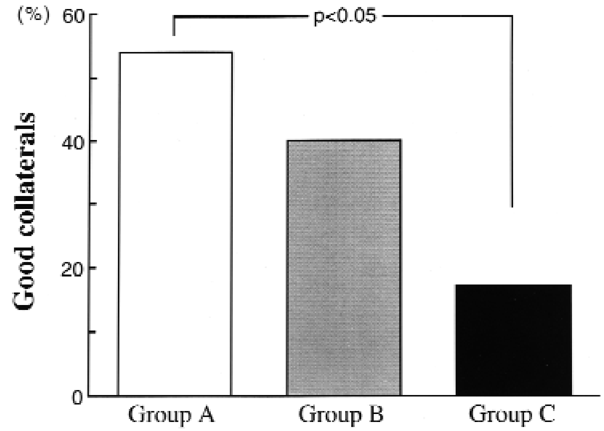


Figure 3



Comparison of good collateral circulation in acute phase. "Good collaterals" were more frequent in patients with concave type ST elevation than in those with convex type.

Definitions

Anterior AMI was defined by typical chest pain for >30 minutes, ST-segment elevation of at least 0.1 mV in 2 contiguous precordial leads, and the typical increase in a serum creatine kinase.

Methods of reperfusion

Coronary angiography was performed during the acute phase and at discharge. The grade of collateral filling in the LAD was evaluated according to the criteria of Rentrop et al[4] (0, no visible filling of any collateral channel; 1, filling only of side branches without visualization of the epicardial segment; 2, partial filling of the epicardial segment; and 3, complete filling of the epicardial segment). A good collateral channel was defined as grade 2 or 3 and a poor collateral channel as 0 or 1. Reperfusion was defined as establishment of TIMI grade 3 coronary flow, which was attained by thrombolysis in 38 patients and by direct coronary angioplasty in 39 patients.

Electrocardiographic analysis

A 12-lead electrocardiogram was recorded immediately before reperfusion confirmed by coronary angiography at a paper speed of 25 mm/s and an amplification of 10 mm/mV. The isoelectric line was defined as the level of the preceding TP segment. ST-segment elevation was measured at the J point, and the sum of ST-segment elevation was calculated by summing the degree of ST-segment elevation in precordial leads. The number of precordial leads with abnormal Q waves was calculated. We evaluated and classified the shapes of ST elevation in lead V_3 into 3 types (Figs 1 and 2): concave type, ST-T segment rises with downward convexity; straight type, ST-T segment rises obliquely like an inclined plane; and convex type, ST-T segment rises with an upward convexity.[5] Electrocardiograms were separately evaluated by 2 independent observers without knowledge of the patient's data. In cases of disagreement, a third observer established consensus.

Cardiac enzyme study

Blood samples were obtained on admission and at 3-hour intervals during the first 24 hours, at 6-hour intervals for the next 2 days, and then daily until discharge. Serum creatine kinase activity was measured by the method of Rosalki.[6]

Analysis of left ventricular function

Left ventricular function was evaluated by cineventriculography performed during cardiac catheterization just before hospital discharge. The left ventricular ejection fraction (LVEF) was determined by the area-length method.[7] The regional wall motion in the territory of the LAD was assessed with the centerline method and expressed as SD/chords.[8]

Table I. Patient characteristics

	Group A (n = 24)	Group B (n = 41)	Group C (n = 12)
Age (y)	56 ± 13	60 ± 10	55 ± 9
Men (%)	21 (88%)	32 (78%)	11 (92%)
Systolic blood pressure on admission (mm Hg)	145 ± 23	144 ± 29	148 ± 27
Diastolic blood pressure on admission (mm Hg)	89 ± 17	85 ± 19	82 ± 22
Heart rate on admission (beats/min)	85 ± 18	86 ± 15	82 ± 15
Thrombolysis (%)	14 (58%)	17 (41%)	7 (58%)
Culprit lesion (segment 6/7)	16/8	28/13	7/5
Time to reperfusion (h)	3.6 ± 1.5	3.8 ± 1.5	4.3 ± 1.5
Previous angina (%)	18 (75%)†	25 (61%)	5 (42%)
∑ST before reperfusion (mV)	1.4 ± 1.1	1.8 ± 1.2	2.2 ± 1.0
nQ before reperfusion	2.0 ± 1.9†	2.3 ± 1.4†	4.0 ± 1.6

∑*ST*, Sum of ST-segment elevation in precordial leads; *nQ*, number of precordial leads with abnormal Q waves.
**P* < .05 vs group B.
†*P* < .05 vs group C.

Table II. Infarct size and left ventricular function at discharge

	Group A (n = 24)	Group B (n = 41)	Group C (n = 12)
Peak creatine kinase (mU/mL)	2287 (1689, 3702)*†	4371 (3155, 6455)	5322 (3779, 6696)
Time to peak creatine kinase (h)	10 (7.5, 13.6)	9.5 (7, 12.6)	9.5 (7, 13.5)
LVEF (%)	58 (51.64)*†	48 (41,54)†	41 (34, 49)
Regional wall motion (SD/chords)	−1.2 (−2.0, −0.9)*†	−2.6 (−3.0, −2.1)†	−3.0 (−3.2, −2.8)

Values followed by numbers in parentheses are medians, with 25th and 75th percentiles shown in parentheses.
**P* < .05 vs group B.
†*P* < .05 vs group C.

Statistical analysis

Data are expressed as mean ± SD. The unpaired 2-tailed Student's *t* test was used to analyze differences in continuous variables, and the chi-square test was used to analyze categorical variables. A multivariate logistic regression analysis included preserved left ventricular function (LVEF ≥50% at discharge) as the dependent variable and age, sex, method of reperfusion therapy, site of the culprit lesion, time from symptom onset to reperfusion, previous angina, collateral circulation, systolic blood pressure, heart rate on admission, the sum of ST-segment elevation, the number of precordial leads with abnormal Q waves before reperfusion, and the shape of ST-segment elevation as independent variables was performed. Odds ratios and 95% confidence intervals (CI) were calculated. A probability value <.05 was considered to indicate a statistically significant difference.

Results

Patient characteristics

Patients were classified into 3 groups according to the shape of ST elevation as defined. In 68 (88%) of 77 patients, the same judgment of ST-elevation pattern was made by 2 observers. In the other 9 (12%) patients, the judgment disagreed whether the ST-elevation pattern was concave type or straight type, and consensus was established with the third observer. There was no case in which the observers were irresolute between convex type or the other 2 types. Twenty-four patients (group A) had concave type ST elevation, 41 patients (group B), straight type, and 12 patients (group C), convex type (Figures 1 and 2). There were no differences among the 3 groups with regard to age, sex, systolic and diastolic blood pressures on admission, heart rate on admission, method of reperfusion therapy, site of the culprit lesion, and time from symptom onset to reperfusion (Table I).

Patients in group A had higher rates of previous angina and good collateral circulation than those in group C (Table I and Fig 3). The sum of ST-segment elevation before reperfusion was slightly but not significantly lower in group A than in the other 2 groups. The number of precordial leads with abnormal Q waves was significantly smaller in groups A and B than in group C (Table I).

Infarct size and left ventricular function

Peak creatine kinase was significantly lower in group A than in groups B and C. LVEF and regional

Table III. Factors associated with preserved left ventricular function (LVEF ≥50% at discharge) in multivariate analysis

Variable	Odds ratio (95% CI)	*P* value
Age	1.0 (0.9-1.02)	.154
Sex	0.2 (0.03-1.5)	.122
Method of reperfusion	0.3 (0.08-1.3)	.107
Culprit lesion	1.9 (0.5-7.7)	.372
Time to reperfusion	0.7 (0.4-1.1)	.157
Previous angina	3.8 (0.9-16.1)	.076
Collateral circulation	4.0 (0.96-16.9)	.057
Systolic blood pressure on admission	1.0 (0.99-1.1)	.083
Heart rate on admission	1.0 (0.9-1.03)	.397
Electrocardiographic findings before reperfusion		
∑ST	0.5 (0.3-0.99)	.047
nQ	0.7 (0.5-1.1)	.121
ST elevation pattern	6.2 (1.6-20.8)	.019

∑ST, Sum of ST-segment elevation in precordial leads; *nQ*, number of precordial leads with abnormal Q waves.

wall motion of the anterior wall (SD/chords) were best in group A among the 3 groups (Table II). There was no difference in the median time to predischarge cardiac catheterization among groups A, B, and C (14.8 days, 14.2 days, and 15.3 days).

Preserved left ventricular function at discharge: Multivariate analysis

Multivariate analysis found the sum of ST-segment elevation and concave type ST-segment elevation to be independently associated with preserved left ventricular function (LVEF ≥50% at discharge). The odds ratio for the sum of ST-segment elevation was 0.5 (95% CI 0.3 to 0.99, $P = .047$), and concave type ST-segment elevation was 6.2 (95% CI 1.6 to 20.8, $P = .019$) (Table III).

Discussion

Previous studies assessing whether the admission electrocardiogram can be used to predict infarct size have focused on the number of leads with or the magnitude of ST-segment elevation. Aldrich et al[1] developed a formula relating the number of leads with ST elevation to infarct size in anterior AMI. However, Yusuf et al[9] found only a weak correlation between the number of leads with ST elevation and infarct size. Hackworthy et al[2] reported a direct relation between the sum of ST elevation in a standard 12-lead eletrocardiogram and infarct size; however, other investigators found no such correlation.[10] Because these studies were performed in the prethrombolytic era, they might not be adaptable in patients receiving thrombolytic therapy. Recently, many studies have shown that the electrocardiogram may be unreliable in assessing infarct size after reperfusion therapy.[11,12] Juergens et al[13] showed that the 32-point QRS score on day 7, but not in the acute phase, was useful in estimating infarct size after thrombolytic therapy. Birnbaum et al[14] reported that distortion of the terminal portion of the QRS complex on the admission electrocardiogram is independently associated with mortality rate in patients with AMI who received thrombolytic therapy. However, they studied only patients in the very early stages of AMI who were seen before evolution of an abnormal Q wave.

To our knowledge, there is no report concerning the shape of ST-segment elevation in the acute phase of AMI. Because Ben-gal et al[15] recently reported the anatomic significance of ST-segment elevation in leads V_1 and V_2 during anterior AMI was questionable, we selected lead V_3 to evaluate the shape of ST-segment elevation. We have retrospectively classified the shape of ST-segment elevation into 3 types: concave type, straight type, and convex type. To clarify its clinical significance, we selected homogeneous patients and examined the relation between this variable and infarct size.

Our study demonstrated that the shape of ST elevation before reperfusion was associated with infarct size and left ventricular function at discharge in patients with successful reperfusion. Patients with concave type ST elevation had high rates of collaterals and previous angina, low peak creatine kinase activity, and well-preserved left ventricular function. In contrast, patients with convex type ST elevation had poor collaterals, a high number of abnormal Q waves before reperfusion, high peak creatine kinase activity, and left ventricular dysfunction. Kloner et al[16] showed that patients with previous angina before infarction had a smaller infarct size as assessed by creatine kinase activity than those without it and attributed this difference to ischemic preconditioning. Some studies have found that patients with previous angina have more collaterals, suggesting that preservation of left ventricular function is a secondary consequence of increased collateral perfusion.[17] Therefore, the limited myocardial damage and small infarct size in patients with concave type ST elevation may be ascribed to both ischemic preconditioning and collateral channels. In contrast, patients with convex type ST elevation are likely to have extensive myocardial damage before reperfusion and a large infarct size. In straight type ST elevation, clinical characteristics and left ventricular function at discharge are intermediate between those of concave type and those of convex type. Moreover, multivariable logistic regression analysis confirmed that concave type ST elevation was an independent predictor of well-preserved left ventricular function at discharge. It is important to be able to predict outcome in patients with evolving AMI. Ideally, such assessment should be simple, quick, and noninvasive. In this respect, it should be emphasized that the shape of ST-segment elevation may be helpful for making decisions regarding therapeutic strategy in the early stage of AMI.

The underlying mechanisms for the different shapes of ST-segment elevation in the acute phase of AMI are not clear. It has been reported that transmembrane potential markedly changed during the early stage of myocardial ischemia; ischemia shortened action potential duration and decreased its amplitude, upstroke velocity, and resting potential.[18] Because such action potentiates waveform changes, which include alterations in slope of phases 2 and 3, may affect the shape of ST-segment elevation, it is plausible that the shape of ST elevation may reflect the severity of myocardial injury. Hence, concave type ST elevation, which is similar to the normal configuration of ST-T segment, is likely to reflect less myocardial damage.

Study limitations

We used very strict entry criteria. This is a small study of patients with a first anterior AMI in whom both total occlusion of the LAD and successful reperfusion without subsequent reocclusion were confirmed. Further study with a larger number of patients is needed to elucidate the mechanism underlying this ST-elevation pattern and to verify our results.

Conclusions

In patients with reperfused AMI, left ventricular function was excellent in patients with concave type ST elevation before reperfusion, intermediate in those with straight type, and relatively poor in those with convex type at discharge. This simple classification of the shape of ST-segment elevation is useful in predicting left ventricular function at discharge.

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