

Transient giant negative T wave in acute anterior myocardial infarction predicts R wave recovery and preservation of left ventricular function

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Abstract

Objective—To investigate the value of a giant negative T wave (≥ 1.0 mV) in pre-cordial leads of 12-lead electrocardiograms in the acute phase of Q wave myocardial infarction as a predictor of myocardial salvage.

Methods—Coronary angiographic and electrocardiographic findings, left ventricular ejection fraction in the chronic stage, and levels of cardiac enzymes were compared in patients with myocardial infarction with (group GNT, $n = 31$) and without (group N, $n = 20$) a giant negative T wave. GNT patients were divided into two subgroups according to the presence (GNT:R[+], $n = 10$) or absence (GNT:R[-], $n = 21$) of R wave recovery with an amplitude ≥ 0.1 mV in at least one lead that had shown Q waves.

Results—The maximum level of creatine kinase and the total creatine kinase were lower in group GNT compared with group N ($P < 0.05$). The left ventricular ejection fraction was higher in group GNT than in group N ($P < 0.05$). The maximum creatine kinase and total creatine kinase were lower in GNT:R(+) than in GNT:R(-) ($P < 0.01$). The left ventricular ejection fraction was higher in GNT:R(+) than in GNT:R(-) ($P < 0.01$). The frequency of R wave recovery was significantly higher when giant negative T waves appeared within 100 h of myocardial infarction or when the maximum potential was ≥ 1.4 mV. The appearance of a giant negative T wave ≥ 1.4 mV had a sensitivity of 90%, a specificity of 71.4%, a diagnostic accuracy of 77.4%, a positive predictive value of 60%, and a negative predictive value of 93.8% for prediction of R wave recovery.

Conclusions—The appearance of a giant negative T wave, especially within 100 h of the onset of myocardial infarction, with a maximum potential of ≥ 1.4 mV, may predict a reappearance of the R wave and a better left ventricular function in patients in the chronic stage of anterior myocardial infarction.

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Keywords: myocardial infarction; giant negative T wave; myocardial viability; left ventricular function

The location and extent of myocardial infarction and left ventricular function can be esti-

mated in patients who are in the chronic stage of myocardial infarction by the QRS complex on standard 12-lead electrocardiograms.¹⁻⁴ However, the value of the QRS complex alone in estimating the severity of myocardial infarction in the early phase is limited because the abnormal Q wave sometimes disappears over time, leading to recovery of the R wave.^{5,6}

Haines *et al* reported that the appearance of a new T wave inversion in patients with unstable angina was an important risk factor for subsequent myocardial infarction and cardiac death,⁷ but Matetzky *et al* recently reported that early inversion of T waves (< 24 h) in patients with acute myocardial infarction treated with thrombolytic drugs was associated with a better perfusion grade of the infarct related artery, better left ventricular function, and a more benign hospital course.⁸ However, the relationship between the amplitude of negative T waves and left ventricular function in patients with acute myocardial infarction with and without thrombolytic treatment has not been investigated. We examined the usefulness of early transient giant negative T waves (GNT) for predicting the extent of myocardial infarction, myocardial salvage, electrocardiographic improvement, and left ventricular function in the chronic stage in patients with acute anterior Q wave myocardial infarction.

Methods

PATIENTS

Of 369 patients with acute myocardial infarction admitted to the coronary care unit (CCU) of Hamamatsu Medical Centre, 31 patients showed a QS pattern on electrocardiograms performed in the acute stage that was associated with GNT during their hospital admission (group GNT, table 1). GNT was defined as a negative T wave with an amplitude ≥ 1.0 mV from baseline, TP segment.⁹ We excluded cases of reinfarction, subacute cases in whom it was not possible to obtain the maximum creatine kinase level, and cases of non-Q-wave

Table 1 Patient characteristics

	Group GNT	Group N
No of patients	31	20
Males/females	28/3	14/6
Age (years) (SD)	59.2 (8.3)	60.3 (7.1)
Number of chest leads showing QS (SD) (range)	3.2 (0.9) (2-4)	3.2 (1.2) (1-5)

Group GNT, patients who developed giant negative T wave after myocardial infarction; group N, patients with myocardial infarction not associated with GNT.

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myocardial infarction. We also excluded cases who did not undergo coronary angiography in the chronic stage (one month after onset of infarction). Echocardiography and left ventriculography performed in the chronic stage showed no significant asymmetrical septal hypertrophy or apical hypertrophy in any patient. Angiotensin converting enzyme inhibitors were not given in the acute phase of anterior myocardial infarction in the present study.

We compared angiographic and electrocardiographic indices, the left ventricular ejection fraction, and serum levels of enzymes in the 31 patients in group GNT (all patients had anterior myocardial infarction), and in 20 patients with anterior myocardial infarction who were admitted to the hospital during the same period and who fulfilled the same criteria as group GNT, except for the presence of GNT (group N, table 1). We also analysed differences between GNT patients who showed R wave recovery before discharge about one month after admission (GNT-R[+]) and GNT patients who did not show R wave recovery (GNT-R[-]). R wave recovery was defined as the appearance and persistence of an R wave with an amplitude ≥ 0.1 mV in at least one lead that had shown a QS pattern during the hospital admission.

Cardiac catheterisation

Coronary angiography was performed by the brachial or femoral approach. Left ventriculography was performed during the chronic stage of myocardial infarction. The segments of the coronary artery responsible for the infarction were identified according to the reporting system of the American Heart Association.¹⁰ The per cent diameter stenosis of the infarct related artery was quantitatively calculated by comparing the narrowest diameter of the stenosis in both right and left anterior oblique projections to the normal adjacent diameter of the artery. The left ventricular ejection fraction was calculated from ventriculographic data by the area-length method of Sandler and Dodge.¹¹

Table 2 Comparison of GNT and N groups. Values are mean (SD) or no (%)

	Group GNT (n = 31)	Group N (n = 20)
Reperfusion treatment in the acute phase		
CT	20 (65%)	15 (75%)
PTCA	3 (10%)	4 (20%)
TOTAL	23 (75%)	19 (95%)
Infarct related coronary artery		
LAD segment 6	16	11
segment 7	13	8
segment 8	1	1
Unknown	1	0
Stenosis of responsible lesion (%)	58.4 (27.1)	69.1 (28.3)
Max CK (IU/l)	2085 (1268)	2984 (1819)*
Max CK time (h)	13.8 (5.7)	14.4 (5.2)
Total CK (IU/ml)	1203 (745)	1747 (1088)*
LVEF (%)	56.5 (10.4)	47.9 (14.4)†

Group GNT, myocardial infarction followed by giant negative T wave; group N, myocardial infarction without GNT; GNT, giant negative T waves; CT, coronary thrombolytic therapy; PTCA, percutaneous transluminal coronary angioplasty; LAD, left anterior descending coronary artery; CK, creatine kinase; Max CK time, time from the onset of infarction to the maximum creatine kinase value; LVEF, left ventricular ejection fraction determined by left ventriculography. *P < 0.05, †P < 0.02 v GNT.

Electrocardiography

Electrocardiograms were obtained every 4 h for the first 48 h after admission, once daily for the next 3 d, and twice weekly thereafter. The positions of electrodes on the chest were marked to ensure reproducibility. The appearance and disappearance of GNT were determined from electrocardiographic findings. Disappearance of the GNT was defined as a decrease in the potential to below 1.0 mV in all leads showing a GNT. The highest GNT potential recorded during the period of observation was defined as the maximum potential.

Creatine kinase (CK)

Blood samples were obtained every 4 h after admission for 48 h and then twice daily for one week for determinations of the maximum CK value and the time until the maximum CK. The size of the infarction was determined enzymatically on the basis of the disappearance rate of CK from the serum, by a previously described method.^{12,13} The enzymatic determination of the size of infarction is expressed as the total CK.

STATISTICAL ANALYSIS

Data are expressed as the mean (SD). Data were analysed by the unpaired *t* test and discriminant analysis. The sensitivity (true positive/[true positive + false negative]), the specificity (true negative/[true negative + false positive]), the positive predictive value (true positive/[true positive + false positive]), the negative predictive value (true negative/[false negative + true negative]), and the diagnostic accuracy ([true positive + true negative]/total group) of variables are expressed as percentages. A probability value less than 0.05 was considered statistically significant.

Results

COMPARISON OF GROUPS GNT AND N

R wave recovery was observed in 10 of 31 patients in the group GNT (32%) and in two of 20 patients in the group N (10%) (P < 0.02). The percentage of patients who received reperfusion treatment during the acute stage was slightly, but not significantly, higher in group N than in group GNT (table 2). Infarct related lesions involved the left anterior descending artery in both groups. There was no significant difference between groups on the basis of the segment of the coronary artery responsible for infarction. The maximum CK value and total CK were lower in GNT than in N (P < 0.05). The left ventricular ejection fraction was higher in group GNT than in N (P < 0.02). Figure 1 shows the serial electrocardiograms obtained in a representative GNT patient.

PATIENTS WITH AND WITHOUT R WAVE RECOVERY IN GROUP GNT

A QS pattern was observed during the acute phase of myocardial infarction in two to four leads (mean, 2.6) in the 10 patients in GNT who showed R wave recovery. R wave recovery was observed in an average of 1.8 of these

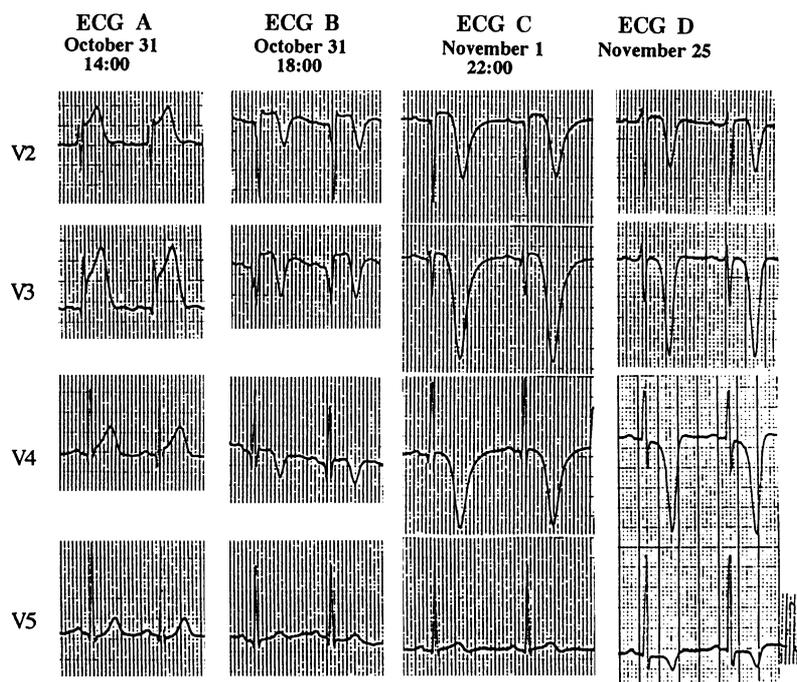
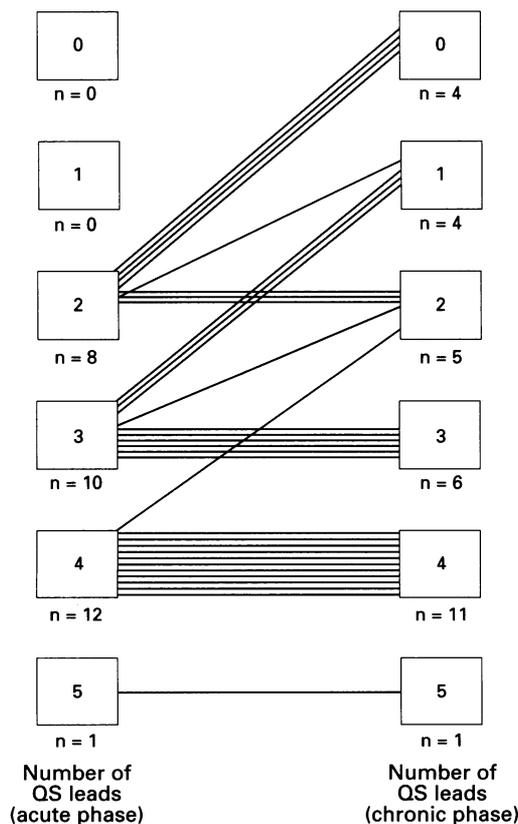


Figure 1 Serial electrocardiograms obtained in a 60 year old man who developed unstable angina in early October. At 11:00 on October 31, he developed an acute myocardial infarction associated with a sensation of chest oppression. He was admitted to the CCU of our hospital at 13:50. He received 960 000 U of urokinase intravenously. His maximum serum creatine kinase value was 501 IU/l 9 h after the onset of myocardial infarction. (A) ECG recorded on admission at 14:00 on October 31; (B) ECG recorded at 18:00 on October 31 showed a QS pattern in leads V1 and V2; (C) ECG recorded 35 h after onset showed a giant negative T wave in precordial leads; (D) ECG recorded on November 25 showed R wave recovery. Coronary angiography performed one month after the onset of symptoms revealed 90% stenosis of the middle portion of the left anterior descending coronary artery. Left ventriculography showed mild hypokinesis of the anterior wall. His left ventricular ejection fraction was 71%.

leads (fig 2). Time from the onset of myocardial infarction to R wave recovery in 10 patients of the GNT:R(+) group was 376 (300) h (range: 37–816). In all patients,

Figure 2 The number of precordial leads showing a QS pattern in the acute and chronic phase of myocardial infarction in group GNT (giant negative T wave).



appearance of the deep inverted T wave preceded R wave recovery. The remaining 21 patients showed no R wave recovery (GNT:R(-)). QS was observed in one to five leads (mean, 3.5) during the acute phase of myocardial infarction in these patients. The number of leads that showed QS in the acute stage was lower in GNT:R(+) than in GNT:R(-) (P < 0.01). There were no significant differences in age, sex, the percentage of patients who received coronary revascularisation treatment during the acute stage, the infarct related segment, or the severity of stenosis in the responsible lesion in the chronic stage between subgroups (table 3).

The maximum CK value and total CK were significantly lower in GNT:R(+) than in GNT:R(-). The left ventricular ejection fraction in the chronic stage was significantly higher in GNT:R(+) than in GNT:R(-) (table 3).

GNT INDICES IN SUBGROUPS WITH AND WITHOUT R WAVE RECOVERY

The time from the onset of infarction to the appearance of GNT was shorter in GNT:R(+) than in GNT:R(-), at 102.8 (158.2) v 303.0 (186.0) h (P < 0.01) (fig 3). The duration of GNT did not differ significantly between subgroups. The maximum potential of the GNT was higher in GNT:R(+) than in GNT:R(-), at 1.76 (0.41) v 1.30 (0.24) mV (P < 0.01) (fig 4).

Examination of the cumulative frequency distribution of the time from the onset of infarction to the appearance of GNT revealed 100 h as the cut off point that distinguished GNT patients with R wave recovery from GNT patients without R wave recovery. The appearance of GNT within 100 h of disease onset had a sensitivity of 80.0%, a specificity of 76.0%, a rate of diagnostic accuracy of 77.4%, a positive predictive value of 61.5% and a negative predictive value of 88.9% for identification of R wave recovery. Examination of the cumulative frequency distribution of the maximum GNT potential revealed 1.4 mV as the cut off point. GNT potential ≥ 1.4 mV had a sensitivity of 90.0%, a specificity of 71.4%, a rate of diagnostic accuracy of 77.4%, a positive predictive value of 60.0%, and a negative predictive value of 93.8% for identification of R wave recovery. The combination of the appearance of GNT within 100 h of onset and a potential of ≥ 1.4 mV had a diagnostic accuracy of 80%.

Discussion

Transient or persistent giant T wave inversion has been observed in a variety of conditions,^{9 14-16} including ischaemic heart disease, Stokes-Adams attacks associated with complete heart block, bradycardia, right ventricular hypertrophy and right bundle branch block, metabolic disturbances, apical hypertrophy, and cerebral disturbances. A previous study suggested that the development of a new T wave inversion predicted significant coronary artery stenosis in patients with unstable

Table 3 Characteristics of GNT patients with and without R wave recovery. Values are means (SD) or n (%)

	GNT:R(+) (n = 10)	GNT:R(-) (n = 21)
Males/females	8/2	20/2
Age (years)	61.1 (3.4)	58.2 (9.8)
Reperfusion treatment in the acute phase		
CT	5 (50%)	15 (71%)
PTCA	1 (10%)	2 (10%)
Total	6 (60%)	17 (81%)
Infarct related coronary artery		
LAD segment 6	6 (60%)	10 (48%)
segment 7	2 (20%)	11 (52%)
segment 8	1 (10%)	0
Unknown	1 (10%)	0
Stenosis of responsible lesion (%)	53.9 (31.1)	60.5 (25.6)
Maximum CK value (IU/l)	981 (797)	2610 (1108)†
Total CK (IU/ml)	562 (454)	1507 (662)†
LVEF (%)	65.5 (7.3)	52.2 (8.9)†

GNT:R(+), GNT patients with R wave recovery; GNT:R(-), GNT patients without R wave recovery; GNT, giant negative T wave; CT, coronary thrombolytic treatment; PTCA, percutaneous transluminal coronary angioplasty; LAD, left anterior descending artery; CK, creatine kinase; LVEF, left ventricular ejection fraction.

†P < 0.01 v GNT:R(+).

angina, and that patients with a new T wave inversion who were treated medically were at high risk of subsequent myocardial infarction and cardiac death.⁷ However, Matetzky *et al* recently reported that early inversion of T waves (<24 hours) in patients with acute myocardial infarction who were treated with thrombolytic drugs was associated with a better perfusion grade of the infarct related artery, a better left ventricular function, and a more benign hospital course.⁸

In the present study, the early appearance of GNT (within 100 hours of the onset of symptoms) and a GNT with a large potential (≥ 1.4 mV) predicted R wave recovery in the chronic stage and were associated with better preservation of the left ventricular ejection fraction. Q wave regression in acute myocar-

Figure 3 Time from the onset of myocardial infarction to the appearance of giant negative T wave (GNT) in GNT:R(+) and GNT:R(-). Means with SD are shown. GNT:R(+), GNT patients with R wave recovery; GNT:R(-), GNT patients without R wave recovery; MI, myocardial infarction.

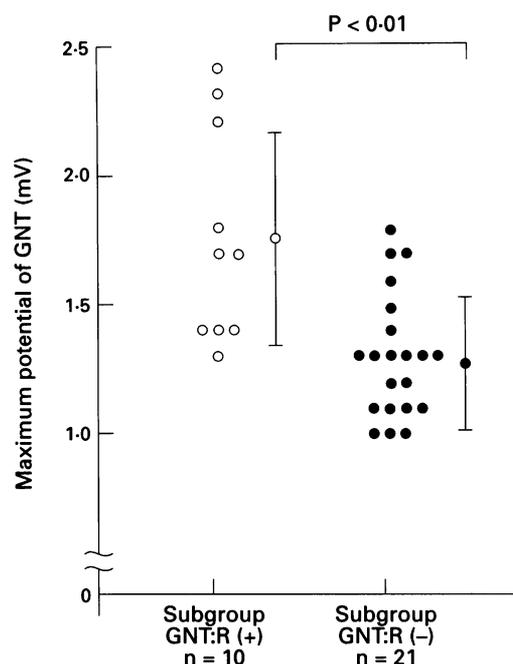
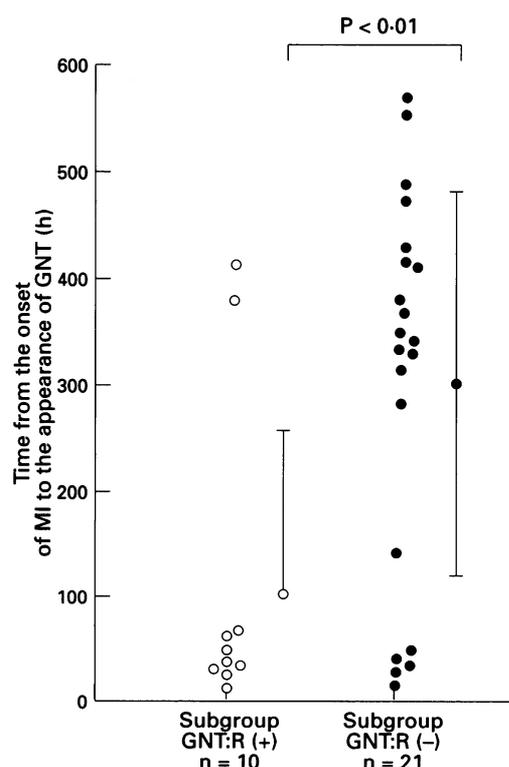


Figure 4 Maximum potential of giant negative T wave (GNT) in GNT:R(+) and GNT:R(-). Means with SD are shown. GNT:R(+), GNT patients with R wave recovery; GNT:R(-), GNT patients without R wave recovery.

dial infarction is believed to indicate the potential of myocardial salvage.¹⁷ Thus the early appearance of GNT followed by regression of the Q wave may have indicated myocardial salvage in the present study.

SIGNIFICANCE OF EARLY APPEARANCE OF GIANT NEGATIVE T WAVES

Honma previously reported that 109 patients with anterior myocardial infarction showed biphasic fluctuations in electrocardiographic changes,¹⁸ with deep negative T waves and QT prolongation (lead V₃) occurring at 48 hours and again at three weeks after the onset of symptoms. The negative T wave showed an early peak in these 109 patients, who had small infarctions and achieved early reperfusion. The time from the onset of disease to the appearance of the first phase of the negative T wave was closely related to reperfusion. We considered the appearance of a GNT within 100 hours or a GNT with a potential ≥ 1.4 mV to be indications of a particularly deep negative change in the T wave, suggesting the possibility of early reperfusion. Our results are consistent with the findings of Matetzky *et al*.⁸ Early appearance of a deeper negative T wave, or GNT, appeared to be a favourable sign of improved electrocardiographic findings, myocardial viability, and better left ventricular function in the chronic stage, even when a QS pattern was present in the acute phase.

MECHANISMS OF GIANT NEGATIVE T WAVE

Negative T waves appear when the duration of the excitation of the area of the myocardium just below the electrode exceeds that in the surrounding area.^{16,19,20} Den *et al* recorded electrocardiograms from the left ventricular

surface during graded constriction of the major coronary arteries or their branches in anaesthetised dogs.²¹ They reported that prolonged persistent constriction of the coronary artery produced shortening of repolarisation, whereas reperfusion after the release of a five minute coronary constriction produced marked prolongation of repolarisation. Thus they concluded that the duration of excitation is prolonged in a mildly ischaemic area, whereas the duration of excitation is shortened in severe ischaemia. They suggested that the negativity of the T wave becomes prominent when a profound ischaemic area is located next to a mildly ischaemic area. Based on these studies and the present findings, we speculate that if there is complete transmural necrosis in the central area of infarction, there will be no GNT because there is no excitation of the myocardium. The presence of a severely ischaemic, but viable, endocardial myocardium near the central area of infarction will shorten the duration of excitation. Recent experimental studies of transmural myocardial infarction in the dog²²⁻²⁵ have revealed that in the salvaged myocardium distal to the area of necrosis sympathetic denervation occurs and delays repolarisation. Another possible mechanism of GNT may be the presence of a denervated, but viable, myocardium with delayed repolarisation over the severely ischaemic endocardial myocardium with shortened repolarisation. The marked difference in repolarisation properties between the severely ischaemic area with a shortened action potential duration and the adjacent mildly ischaemic area with a prolonged duration of excitation may result in GNT. Thus the appearance of GNT may indicate the presence of severely ischaemic but viable myocardial tissue, which is potentially recoverable in the chronic stage, located next to mildly ischaemic myocardial tissue.

STUDY LIMITATIONS

Further studies involving a greater number of patients with and without thrombolytic treatment are needed. We hypothesised that early inversion of T waves was an indication of salvaged but sympathetically denervated myocardium distal to an area of myocardial necrosis, but we did not clarify the mechanism of GNT. Further studies using measurements of monophasic action potentials and MIBG (¹²³I-metaiodobenzylguanidine) scintigraphy are needed to investigate the role of repolarisation properties and myocardial denervation in GNT.²⁶

CLINICAL IMPLICATIONS

A recent study has suggested that early inversion of T waves in patients with acute myocardial infarction who receive thrombolytic treatment is an indication of the presence of a patent infarct related artery, a higher perfusion grade, and better left ventricular function.⁸ In the present study, there were no significant differences in the rate of patency of the infarct related artery, the percent stenosis of the culprit lesion, or the number of patients receiving

thrombolytic agents or balloon coronary angioplasty between groups GNT and N. Electrocardiographic findings and left ventricular function were improved in group GNT compared with group N. Of the 23 GNT patients who underwent emergent coronary angiography, seven (including three with spontaneous recanalisations) achieved recanalisation associated with a TIMI 2 or 3 perfusion grade²⁷ within two hours of the onset of symptoms. No spontaneous recanalisation occurred in group N. These findings suggest that the presence of a salvaged myocardium resulting from early recanalisation, including spontaneous recanalisation, may induce an early and deep T wave inversion, resulting in better left ventricular function in the chronic stage.

CONCLUSIONS

Our results indicate that a transient giant negative T wave during the acute phase of myocardial infarction suggests the presence of viable myocardium. The appearance of a GNT within 100 hours of the onset of symptoms or a GNT with a potential of ≥ 1.4 mV, or both, was associated with an increased frequency of R wave recovery and a preservation of the left ventricular ejection fraction in the chronic stage. Thus a giant negative T wave appears to be a useful predictor of a viable myocardium resulting from early revascularisation in patients with acute anterior Q wave myocardial infarction.

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