New Criteria Based on ST Changes in 12-Lead Surface ECG to Detect Proximal versus Distal Right Coronary Artery Occlusion in a Case of Acute Inferoposterior Myocardial Infarction

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Background: The outcome of patients with inferoposterior myocardial infarction (MI) due to occlusion of right coronary artery (RCA) depends mainly on the location of occlusion (distal vs. proximal). The aim of this study was to evaluate the value of new ECG criteria: the sum of ST depression in I and VL leads and ST changes in V1 lead to predict the location of RCA occlusion in the case of an inferoposterior MI.

Methods: The ECG and angiographical findings of 50 patients with acute inferoposterior MI due to RCA occlusion were analyzed. The value of new criteria was studied alone and in combination to predict proximal versus distal RCA occlusion and compared with previously described criterion based only on ST changes in VL.

Results: Isoelectric or elevated ST in V1 allowed predicting proximal RCA occlusion with 70% sensitivity and 87% specificity with high positive and negative predictive value (87% and 71%, respectively). The new criterion of the sum of ST depression in I and VL $\geq$ 5.5 mm compared to the criterion based only on ST depression in VL was also more specific (91% vs. 72%) for proximal RCA occlusion with better positive and negative predictive values.

Conclusions: The new criterion based on the ST changes in V1 lead is highly accurate in detecting the location of occlusion in the RCA compared to the criteria based only on ST changes in lateral leads. The use of this criterion might increase the accuracy of ECG-based identification of myocardial involvement in acute inferoposterior MI. **A.N.E. 2004;9(4):383–388**

ECG criteria; ST changes; inferior myocardial infarction; RCA occlusion

ST elevation in inferior leads indicates an evolving myocardial infarction (MI) of the inferoposterior wall. This infarction in nearly 80% of cases is due to right coronary artery (RCA) occlusion and the rest by the occlusion of left circumflex artery (LCx).[1] The outcome of patients with RCA as a culprit artery is determined mainly by the location of occlusion. Proximal RCA occlusion usually leads to right ventricle (RV) involvement and this determines worse prognosis and higher mortality.[2,3] Additionally, it is more often accompanied by conduction AV disturbances.[4] Therefore, it is extremely important from the clinical point of view to recognize where the location of occlusion to determine the optimal treatment and management of evaluated patient is.

ECG criteria based on 12-lead ECG have been studied to determine the location of RCA occlusion.[5] The aim of this study was to assess the value of ECG criteria based on ST changes in lateral leads (I and VL leads) as well as ST changes in V1 to predict the location of RCA occlusion in case of

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Table 1. Clinical Characteristics of Studied Patients

	All patients (N = 50)	RCA Proximal Occlusion (N = 27)	RCA Distal Occlusion (N = 23)
Age (years)	59 ± 11	63 ± 12*	56 ± 19*
Men/women	41/9	21/6	20/3
Time from onset of symptoms to first ECG trace (minutes)	130 ± 69	125 ± 69	180 ± 70
Antecedents			
Active smoker	39 (78%)	19 (70%)	20 (87%)
Diabetic	6 (12%)	3 (11%)	3 (13%)
Arterial hypertension	18 (36%)	12 (44%)	6 (26%)
Dyslipemia	16 (32%)	11 (41%)	5 (22%)
Previous angina	5 (10%)	4 (15%)	1 (4%)
Familiar ischemic cardiomyopathy	9 (18%)	2 (8%)	7 (30%)
Cocaine	1 (2%)	1 (4%)	0 (0%)
Stroke	3 (6%)	2 (8%)	1 (4%)
LVEF at the time of admission (%)	59 ± 12	55 ± 10	60 ± 13
Enzymes peaks			
CPK (IU/L)	2386 ± 1722	1515 ± 1867	2793 ± 1517
CK-MB (IU/L)	299 ± 229	243 ± 262	315 ± 158
Primary angioplasty	25 (50%)	15 (55%)	10 (43%)
Rescue angioplasty	24 (48%)	12 (44%)	12 (52%)
Facilitated angioplasty	1 (2%)	1 (4%)	0 (0%)
RVI with cardiogenic shock	2 (4%)	2 (8%)	0 (0%)
Death in the acute phase	1 (2%)	1 (4%)	0 (0%)
AV block	7 (14%)	7 (26%)*	0 (0%)*
Dominant RCA	40 (80%)	21 (78%)	19 (83%)

*$P < 0.05$.

evolving inferoposterior MI and to determine whether they are better than the previously described criterion based only on ST changes in VL.[5]

MATERIAL AND METHODS

Studied Population

We retrospectively analyzed ECG and angiographical findings of 50 consecutive patients admitted to the Emergency Unit with an evolving acute inferoposterior myocardial infarction with ST elevation in inferior leads (II, III, VF) due to RCA occlusion. Patients were recruited between January 1999 and June 2003. The study population consisted of patients who met the following inclusion criteria: no prior history of a myocardial infarction, less than 6 hours from the onset of symptoms, sinus rhythm in ECG, ST elevation of over 1 mm in at least 2 of 3 leads (II, III, VF), no left or right bundle branch block, coronary angiography performed during first 12 hours from the beginning of symptoms onset, and critical (>70%) stenosis in only one vessel (RCA). Diagnosis of myocardial infarction was based on clinical symptoms (anginal pain lasting over 20 minutes), ECG findings, and enzymatic changes. In all the patients, data on demographics (age, sex), clinical characteristics, and the post-MI outcome were collected (Table 1).

ECG Recordings

Standard 12-lead ECGs were recorded at a paper speed of 25 mm/s and a voltage of 10 mm/mV at the time of admission. The ECG tracings were reviewed by two independent investigators blinded to clinical and angiographical data of studied patients. In case of discrepancy the final decision was taken by the third investigator. ST changes were measured at 20, 40, 60, and 80 ms from point J in all the leads. Measurements were made to the nearest 0.5 mm (0.05 mV); amplifier glass was used. The TP segment in the ECG was used as an isoelectric line, and ST elevation or depression of ≥0.5 mm were considered abnormal. Therefore, ST segment between <0.5 mm depression or >0.5 mm elevation was considered as isoelectric.We have studied the value of ST changes in conventional 12-lead ECG

to predict the location of occlusion in RCA. The following ECG criteria were assessed: (1) ST changes in VL lead (dichotomized at 1 mm); (2) the sum of ST changes in I and VL lead (dichotomized at the value of 5.5 mm); (3) ST changes in V1 lead. All the criteria mentioned above were selected before ECG recordings were evaluated. The specificity, sensitivity, positive and negative predictive values of these ECG criteria were evaluated to determine their association with the location of occlusion in RCA.

Coronary Angiography

All the studied patients underwent coronary angiography within the first 12 hours from the beginning of symptoms. Angiographical findings were evaluated by two independent investigators blinded to clinical and ECG data of patients. In any case of discrepancy regarding the results the final decision was taken by the third investigator. Only patients with total occlusion or clear critical stenosis in one vessel (RCA) were recruited. Critical stenosis was defined as over 70% narrowing of coronary artery lumen diameter determined by visual inspection. Patients were divided into two groups according to the location of occlusion: proximal (before right ventricle artery) and distal (after acute marginal artery). None of the subjects had occlusion between these two branches.

Statistical Analysis

Groups were compared using the chi-square test with Fisher's correction when appropriate. P value <0.05 was considered as statistically significant. Sensitivity (SE), specificity (SP), positive and negative predictive values (PPV and NPV) were assessed for all criteria.

RESULTS

Fifty patients, 41 men and 9 women, mean age 58 ± 11 years met the inclusion criteria. Table 1 shows the details of the clinical characteristics of the studied group. There was one death during the acute phase of MI in a group of proximal RCA.

The mean time from the beginning of symptoms to recording of ECG was 130 ± 69 minutes. Considering the location of occlusion in RCA the following findings were found during the coronary angiography performed during first 12 hours: the occlusion was proximal to right ventricle artery in 27 patients and distal in 23 patients. The first group had a higher incidence of complications (see Table 1). The higher level of necrotic enzymes observed in patients with distal RCA occlusion, although statistically not significant, coincided with the higher percentage of patients with dominant RCA artery.

ECG Criteria in Prediction of the Location of Occlusion in RCA

The examples of ECG changes in the case of acute inferoposterior MI are shown in Figure 1. ST changes were measured at 20, 40, 60, and 80 ms after point J. As the difference in values of the SE, SP, and PVs between these and the measurement was not statistically significant, we decided to present only the measurement at 60 ms. Table 2 displays the values of ST changes in V1, I, and VL. The criterion of the sum of ST depression in I and VL leads ≥ 5.5 mm was found in 30% of patients with proximal RCA occlusion and in 9% of patients with distal RCA occlusion (P values not significant). The criterion of ST isoelectric or elevated in V1 was observed in 70% of patients with proximal RCA occlusion and only in 13% of cases with distal occlusion ($P < 0.001$). Figure 2 displays the sensitivity, specificity, and predictive values of ECG criteria assessed as ST changes at the 60 ms after point J for proximal and distal RCA occlusion.

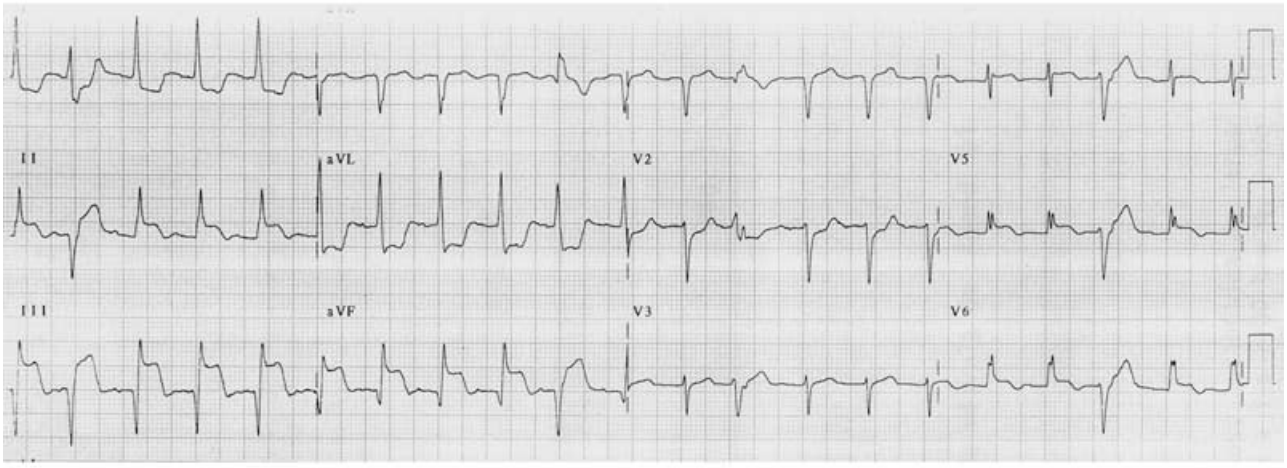
DISCUSSION

In the case of inferoposterior MI due to occlusion of RCA, ST changes in inferior leads (ST elevation in II, III, and VF) are the key to recognizing the injured area because the injury vector of the affected area is directed predominantly downward. However, as the injury vector is also directed slightly to the right it provokes ST depression in I and VL lead. In the case of RV involvement the injury

Table 2. ST Changes in Different Leads in Patients with Proximal versus Distal RCA Occlusion

	Proximal RCA Occlusion Med ± SD (mm)	Distal RCA Occlusion Med ± SD (mm)	P value
ST in I lead	-1 ± 0.95	-1 ± 0.48	ns
ST in VL lead	-2 ± 1.46	-3 ± 1.09	ns
ST in V1 lead	0 ± 1.21	-1.5 ± 1.3	<0.001

a)



b)

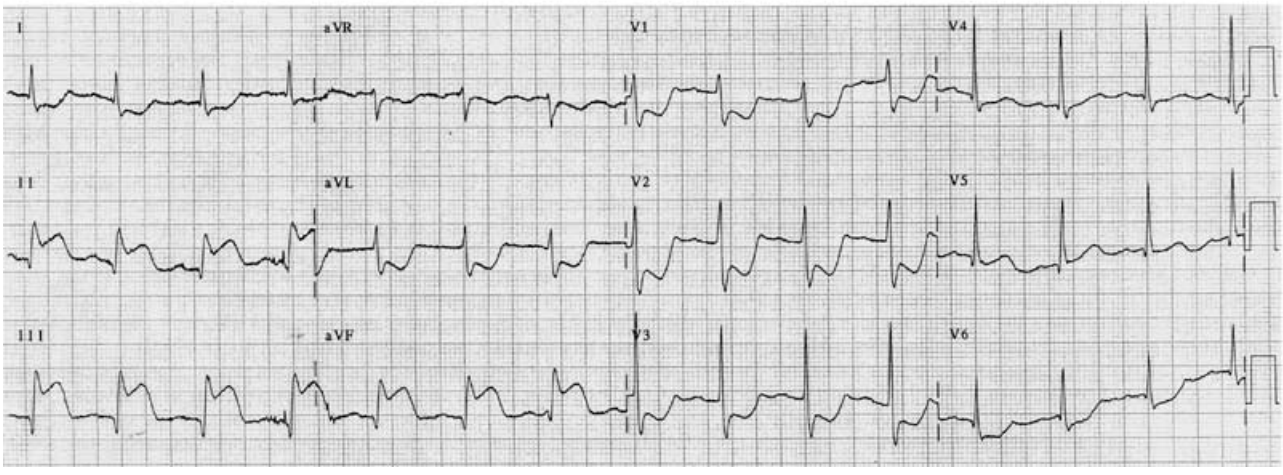


Figure 1. Examples of ECG tracings in patients with an acute inferoposterior myocardial infarction due to (A) proximal or (B) distal RCA occlusion. Note the differences of ST segment in V1 lead with similar behavior of ST segment in I and VL leads.

vector points more to the right and more anteriorly[6] (Fig. 3). Many authors have observed the importance of ST depression in lateral leads in the case of MI of inferoposterior zone to identify the culprit artery.[7–12] In our sequential algorithm based on ST changes in 12-lead ECG we were able to recognize RCA versus LCx occlusion with 95% accuracy.[13] However, the presumptive diagnosis of a culprit artery gives us only partial information required to predict the need of urgent revascularization procedures. From the clinical point of view the location of RCA occlusion is the next most important information in the case of the inferior MI due to occlusion of this artery. Therefore, once we have determined by ECG with high probability that RCA is the culprit artery we may use other ECG criteria to predict proximal versus. distal occlusion. The right ventricle involvement that usually accompanies the proximal RCA occlusion may be determined on the basis of ST changes in right precordial leads.[14] The changes in these leads are very specific but they disappear in the early stage of the evolution of MI. Furthermore, in some cases there are no changes in right precordial leads due

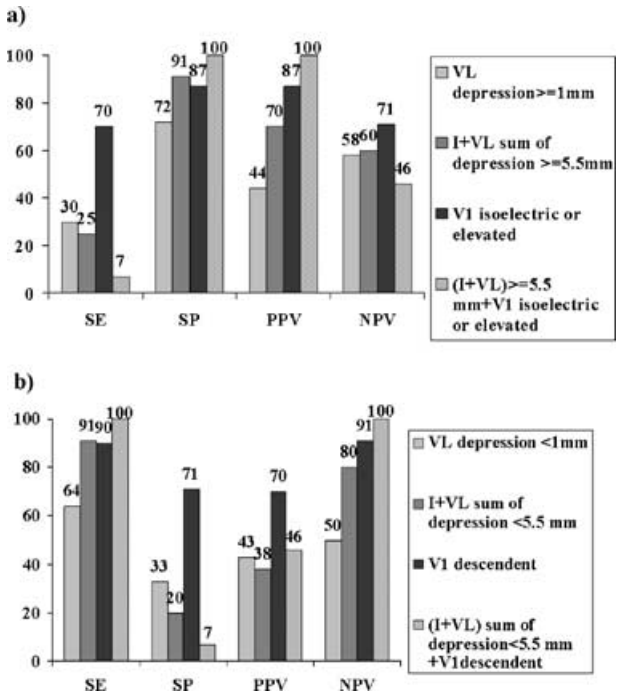


Figure 2. The values of sensitivity (SE), specificity (SP), negative (NPV), and positive predictive values (PPV) for different ECG criteria to predict (A) proximal and (B) distal RCA occlusion.

to the presence of concomitant lateral or posterior involvement.[15] Another important disadvantage of the diagnosis based on right precordial leads is that these leads are often not recorded in the majority of Emergency Rooms. Thus the predictive accuracy of these changes is of limited value.

In a recent published study Turhan et al.[5] evaluated the value of VL lead in the diagnosis of RV involvement in patients with acute MI. They found that ST depression of over 1 mm in VL was very sensitive and specific for RV involvement in patients with acute MI (compared to the diagnosis of RVI based on changes in right precordial leads ST elevation >1 mm in V4R). In our study we compared this criterion to our new criterion assessing simultaneously changes both in I and VL leads (ST depression in I and VL more or less than 5.5 mm) (Fig. 2). This new criterion allowed us to increase the specificity and positive predictive value to predict the proximal RCA occlusion from 72% to 91% and 44% to 70%, respectively, with comparable sensitivity and NPV. This criterion was more sensitive (91% vs. 64%; with comparable specificity) and has a high NPV (80% vs. 50%) with comparable PPV to predict distal RCA occlusion. Nevertheless, this criterion was found only in 30% of patients with proximal versus 9% of patients with distal RCA occlusion. This was not statistically significant. Therefore, we assume that this criterion does not allow us to predict the location of occlusion in a clinical practice.

The criterion of ST changes in V1 (ST elevation, depression, or ST isoelectric) had the highest accuracy for distinguishing proximal versus distal RCA occlusion. Isoelectric or elevated ST segment in V1 was observed in 70% of patients with proximal RCA occlusion and only in 13% of cases with distal occlusion and this criterion presented 70% SE, 87% specificity, 87% PPV, and 71% NPV for the detection of proximal RCA occlusion. Finally, the ST

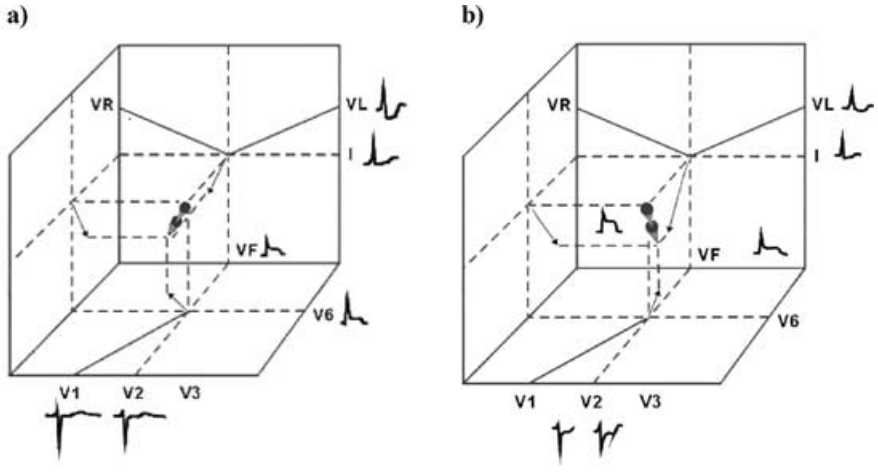


Figure 3. Injury vectors in case of an evolving inferior myocardial infarction (A) with or (B) without right ventricle involvement .

depression in V1 had 90% SE, 71% SP, 70% PPV, and 91% NPV for the detection of distal RCA occlusion. The combination of two new criteria analyzed together (the sum of ST changes in I and VL $\geq$ 5.5 mm and ST isoelectric or elevated in V1) has increased the specificity and PPV to 100% to detect proximal RCA occlusion but, on the other hand, the sensitivity decreased to 7%, which significantly decreased the utility of this combination in clinical practice. The same happens for the detection of distal RCA occlusion.

CONCLUSIONS

The criterion of ST isoelectric or elevated in V1 allows prediction of the location of occlusion in RCA artery with the highest accuracy (proximal vs. distal). Therefore, this criterion may be recommended to be applied in the Emergency Room as it may help to make a decision regarding the need of urgent revascularization. The criterion based on the sum of ST depression in I and VL leads $\geq$5.5 mm, although more specific for proximal RCA occlusion compared to the criterion based only on ST depression in VL $>$ 1 mm, does not seem to be of clinical value due to its low sensitivity.

REFERENCES

1. Sclarowsky S. Electrocardiography of Acute Myocardial Ischaemia. London: Martin Dunitz, 1999.
2. Berger PB, Ryan TJ. Inferior myocardial infarction: high risk subgroups. Circulation 1990;81:401–411.
3. Zehender M, Kasper W, Kauder E, et al. Right ventricular infarction as an independent predictor of prognosis after acute inferior infarction. N Engl J Med 1993;328:981–988.
4. Braat SH, de Zwaan C, Brugada P, et al. Right ventricular involvement with acute inferior wall myocardial infarction identifies high risk of developing atrioventricular nodal conduction disturbances. Am Heart J 1984;107:1183–1187.
5. Turhan H, Yilmaz MB, Yetkin E, et al. Diagnostic value of aVL derivation for right ventricular involvement in patients with acute myocardial infarction. Ann Noninvasiv Electrocardiol 2003;8:185–189.
6. Bayes de Luna A. Clinical Electrocardiography: A Textbook, 2nd updated edition. Armonk, NY: Futura Publ., 1998.
7. Chia BL, Yip JW, Tan HC, et al. Usefulness of ST elevation II/III ratio and ST deviation in lead I for identifying the culprit artery in inferior wall acute myocardial infarction. Am J Cardiol 2000;86:341–343.
8. Bairey CN, Shah PK, Lew AS, et al. Electrocardiographic differentiation of occlusion of the left circumflex versus the right coronary artery as a cause of inferior acute myocardial infarction. Am J Cardiol 1987;60:456–459.
9. Berry C, Zalewsky A, Kovach R, et al. Surface electrocardiogram ischaemia during coronary artery occlusion. Am J Cardiol 1989;63:21–26.
10. Huey BL, Beller GA, Kaiser DL, et al. A comprehensive analysis of myocardial infarction due to left circumflex artery occlusion: comparison with infarction due to right coronary artery and left descending artery occlusion. J Am Coll Cardiol 1988;12:1156–1166.
11. Hasdai D, Birnbaum Y, Herz I, et al. ST segment depression in lateral limb leads in inferior wall acute myocardial infarction. Eur Heart J 1995;16:1549–1555.
12. Herz I, Assali A, Adler Y, et al. New electrocardiographic criteria for predicting either the right or left circumflex artery as a culprit coronary artery in inferior wall acute myocardial infarction. Am J Cardiol 1997;80:1343–1345.
13. Fiol M, Cygankiewicz I, Guindo J, et al. Evolving myocardial infarction with ST elevation: ups and downs of ST in different leads identifies the culprit artery and location of the occlusion. Ann Noninvas Electrocardiol 2004;9:180–186.
14. Wellens HJJ. The value of the right precordial leads of the electrocardiogram. N Engl J Med 1999;340:381–383.
15. Kosuge M, Kimura K, Ishikawa T, et al. Implications of the absence of ST segment elevation in lead V4R in patients who have inferior wall acute myocardial infarction with right ventricular involvement. Clin Cardiol 2001;24:225–230.