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Predicting the Culprit Lesion in Acute Inferior ST-Elevation Myocardial Infarction Based on Wellens' Criteria and Tierala's Algorithm

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Background: Defining the infarct related artery in acute myocardial infarction helps in better and faster management of patients. Therapeutic choices may differ according to the culprit lesion.
Objectives: This study aimed to evaluate multiple electrocardiography (ECG) criteria and one algorithm in defining the culprit artery in single vessel inferior ST elevation myocardial infarction (I-STEMI). A new criterion based on posterior leads was also proposed.
Materials and Methods: In this retrospective study from June 2007 to July 2012, ECG and angiography films of patients with acute inferior STEMI were reviewed. From a total of 138 studied patients, 25 had 3-vessel disease and 37 had two occluded arteries. Remaining 76 patients were diagnosed with single vessel acute I-STEMI, 56 had right coronary artery (RCA) occlusion [22 (29.3%) proximal RCA, 24 (32%) middle RCA, and 10 (13.3%) distal occlusion of RCA], 19 had left circumflex artery (LCx) lesion and one had middle left anterior descending (LAD) artery occlusion.
Results: Prediction of the RCA as culprit lesion using Tierala's algorithm was 86% sensitive and 50% specific. Prediction of LCx occlusion based on ST-elevation $\geq$ 1 mm in V6 was 87% specific (P = 0.005). Sum of ST elevation in leads V5 and V6 more than 2.5 mm, was a good marker of LCx prediction (P = 0.044). ST-elevation in V4R was 48% sensitive and 89% specific for RCA prediction (P = 0.004). Wellens' criterion was 82% sensitive and 47% specific for proximal RCA prediction (P = 0.002). Our new criterion "Sum of ST elevation in posterior leads (V7 - V8 - V9) < 3 mm" was 82% sensitive and 50% specific for RCA prediction (P = 0.017). We also revised Tierala's algorithm by adding the presence of ST-elevation in V3 and V4 to the first step (when STe II $\geq$ III), which increased the specificity and PPV of LCx prediction (86% vs. 84% and 53% vs. 50%).
Conclusions: Although several criteria and algorithms were previously suggested, they could not reliably determine the site of occlusion. Right and posterior leads may be needed in order to increase the accuracy of prediction.

Keywords: Coronary Angiography; Electrocardiography; Myocardial Infarction

1. Background

Electrocardiography (ECG) as the first step in managing the patients with acute chest pain may help defining the culprit lesion before performing invasive steps. However, exact determination of ECG-culprit lesion relationship is confounded by multi-vessel involvement; thus, we only enrolled patients with single vessel inferior ST elevation myocardial infarction (I-STEMI). Stenosis of proximal right coronary artery (PRCA) may lead to devastating outcomes because of right ventricular (RV) failure, shock, and/or hypotension (1). Distal lesions of left circumflex (LCx) compared with proximal lesions of RCA or LCx is not associated with poor prognosis (2, 3). To differentiate between RCA and LCx, several algorithms and criteria were previously proposed, but their sensitivity and specificity were limited (4). In this study, the main issue was focused on the fact that whether 12-lead ECG and right precordial leads could identify the infarct related artery. Adding more leads, posterior leads may also help in emergent decision-making. The clinical point of view about categorizing high-risk patients with right ventricular involvement is of great value and importance. In 1984, right precordial lead V4R was proposed as another marker to predict the right ventricular involvement. As we routinely record right precordial leads in emergency wards in training hospitals, it was worthy to evaluate this criterion in our sample size. In the recent studies, in addition to several criteria, some algorithms were also proposed; for example, in 2004 and 2009 two interesting algorithms were designed and published by two different researchers.

Implication for health policy/practice/research/medical education:
Coronary artery disease is the leading cause of death in most countries. Taking accurate and fast therapeutic measures in emergency wards is the key point in managing the outcomes. ECG is the most feasible tool in this situation. Defining the site of occlusion based on this tool will help physicians to categorize patients in high and low risk groups and choose individualized treatments.

2. Objectives

In this study, we decided to evaluate the sensitivity and specificity of previously-suggested criteria and one algorithm. We hope in the future meta-analysis of past studies will reveal the most accurate and practical criteria and/or algorithm.

3. Materials and Methods

In this retrospective study, we enrolled patients admitted in the Emergency Department (ED) of Tehran Heart Center (THC) between 23 June 2007 and 2 July 2012 because of acute I-STEMI. They underwent percutaneous coronary intervention during their hospitalization. Basis of the diagnosis of I-STEMI was acute typical chest pain with increased cardiac markers and ST elevation of ≥ 0.5 mm in two of the three inferior leads. ST changes were measured at 80 ms from J points, and the TP segment was the isoelectric line of the ECG. ST deviations < 0.5 mm in frontal leads and < 1 mm in precordial leads were regarded as isoelectric. Significant stenosis was considered as > 70% luminal narrowing. The mean ST deviations of three consecutive beats were reported as the final ST deviations. In almost 10% of ECG reports there was > 0.5 mm difference, and they were re-evaluated in the presence of two cardiologists at the same time. There was no disagreement in angiographic reports. We excluded multi-vessel occlusion, left bundle branch block, left ventricular hypertrophy, prior history of coronary artery bypass graft, and prior myocardial infarction. Two cases of acute I-STEMI with “wrap-around” left anterior descending (LAD) occlusion at distal parts with concomitant RCA involvement were also excluded. There was one case of single vessel apical myocardial infarction (MI) due to mid portion occlusion of LAD which was included in the analysis. Posterior leads were recorded in the THC emergency ward; so we analyzed the association between ST deviations in these three leads with the site of occlusion. In our analysis 76 patients were included, 75 of which had significant narrowing limited to RCA or LCx and one had occlusion of the mid portion of LAD.

Patients’ on-admission-ECGs were interpreted by two skilled cardiologists. They were blinded to the angiographic reports. The same strategy was also performed for the angiographic data. ECGs were recorded within six hours of the symptoms onset. The maximum time between the symptoms onset and coronary angiography was less than 6 days during the hospitalization period. Tierala’s algorithm was analyzed in terms of its accuracy in defining the site of occlusion in acute I-STEMI. Patients with Wellens et al. (5) inclusion criteria were separately analyzed.

3.1. Statistical Analysis

We reported continuous variables in terms of means ± standard deviation and for discrete variables, frequencies and percentages. We compared means of continuous variables with independent samples T-test. Correlations of discrete variables were measured by chi-square test of independence. P value < 0.05 was considered statistically significant. Data analysis was performed using the SPSS version 13.0 statistical package (Chicago, Illinois). For all criteria, sensitivity, specificity, and predictive values were calculated.

4. Results

Demographic and clinical features of the patients are shown in Table 1. Culprit arteries based on angiographic repots are illustrated in Table 2. All 76 patients were analyzed according to the algorithms of Tierala et al. (6) and prespecified criteria (Tables 3 and 4).

Table 1. Baseline Features of the Patients (n = 76) [a, b]

Characteristics	Group 1 (RCA), n = 56	Group 2 (LCx), n = 19	Group 3 (LAD), n = 1
Age, y	56 ± 10	57 ± 12	55
Gender, female	9 (16)	6 (32)	0 (0)
Hypertension	11 (19.6)	6 (31.6)	0 (0)
Diabetes mellitus	12 (21.4)	5 (26.3)	1 (100)
Dyslipidemia	20 (35.7)	8 (42.1)	1 (100)
Smoking	30 (53.7)	10 (52.6)	1 (100)
< 10 pack/y	18 (32.1)	6 (31.5)	0 (0)
10 - 20 pack/y	8 (14.2)	3 (15.7)	0 (0)
> 20 pack/y	4 (7.14)	1 (5.2)	1 (100)
Left ventricular ejection fraction at the time of admission, %	49.5 ± 6	47 ± 6	44

[a] Abbreviations: LAD, left anterior descending artery; LCx, left circumflex artery; RCA, right coronary artery.
[b] Data in this table is presented as Mean ± SD or No. (%).

Table 2. Infarct-Related Artery Based on Angiography Reports in I-STEMI [a] (n = 76)

Culprit artery	Distribution, No. (%)
Right coronary artery	56 (74.7)
Proximal	22 (29.3)
Middle	24 (32)
Distal	10 (13.3)
Left circumflex artery	19 (25.3)
Proximal	7 (9.3)
Nonproximal	11 (14.6)
Obtuse marginal branch	1 (1.3)
Left anterior descending artery	1 (1.3)
Mid portion	1 (1.3)

[a] Abbreviation: I-STEMI, inferior ST-elevation myocardial infarction.

Table 3. Correlations of ST-segment Deviation and the Culprit Artery in I-STEMI, in Prespecified Criteria [a]

Criteria	LCx as a Culprit Artery, n = 19, No. (%)	RCA as a Culprit Artery, n = 56, No. (%)	Sensitivity	Specificity	PPV	NPV	P Value
STe in III ≥ II	8 (42%)	54 (96%)	96% for RCA	45% for RCA	83% for RCA	82% for RCA	0.000
STd in I ≥ 0.5 mm	7 (36%)	38 (67%)	68% for RCA	65% for RCA	84% for RCA	42% for RCA	0.017
STe V6 ≥ 1	8 (42%)	7 (12.5%)	42% for LCx	87% for LCx	53% for LCx	82% for LCx	0.005
STe in V4R ≥ 1 mm	2 (10%)	27 (48%)	48% for RCA	89% for RCA	93% for RCA	40% for RCA	0.004

[a] Abbreviations: e, elevation; d, depression; NPV, negative predictive value; LCx, left circumflex artery; PPV, positive predictive value; RCA, right coronary artery.

Table 4. Sensitivity, Specificity and Predictive Values of Each Step of Algorithms [a] (n = 76)

Tierala's Algorithm Steps	Culprit Artery	Sensitivity, %	Specificity, %	PPV, %	NPV, %
Step 1: ST elevation II ≥ III	LCx	42	91	62	83
Step 2: part A and part B	RCA	48	36	78	13
Step 3: ST depression aVR ≥ aVL	LCx	25	85	20	88

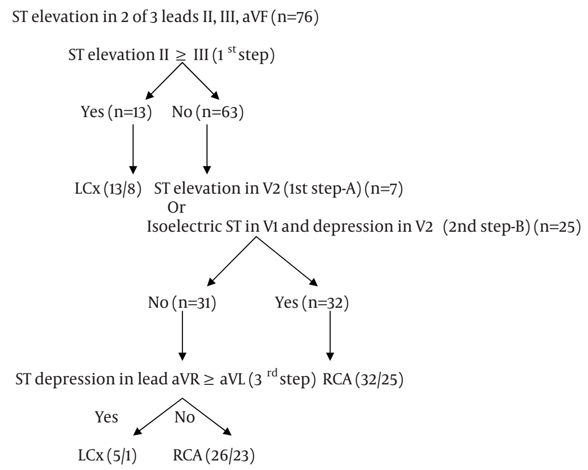
[a] Abbreviations: LCx, left circumflex artery; NPV, negative predictive value; PPV, positive predictive value; RCA, right coronary artery.

4.1. Tierala's Algorithm Analysis

Tierala's Algorithm is presented in Figure 1 and Table 4.

In our study, 13 patients had STeII ≥ III and according to the first step of this algorithm, eight of them were truly defined as LCx. Sixty-three patients had ST elevation III > II, analyzed in the second step. We categorized the second step in two parts: A and B. In part A and B of the second step, Tierala algorithm defined seven and 25 patients as RCA occlusion, respectively, 25 of which had been primarily predicted as RCA. We still need an additional step to define all of the culprit arteries. The last step compared ST depression in aVR and aVL. This step could truly define one LCx and 23 RCAs. Based on the Tieral's algorithm, our patient with LAD lesion and resulting apical MI had been predicted to have LCx occlusion. Values of three steps together are shown in Table 5. Reported sensitivity and specificity for RCA as the occluded vessel in Tierala et al. (6) algorithm were 96% and 56%, respectively. Positive predictive value (PPV) was 92% and negative predictive value (NPV) was 75% in their study.

Figure 1. Thierala's Algorithm



ST elevation in two of three leads II, III, aVF (n = 76)

Table 5. Sensitivity, Specificity and Predictive Values for Tierala's Algorithms a (n = 76)

ECG algorithm	Sensitivity, %	Specificity, %	PPV, %	NPV, %
Tierala				
RCA	86	50	83	56
LCx	47	84	50	83

[a] Abbreviations: ECG, electrocardiogram; LCx, left circumflex artery; NPV, negative predictive value; PPV, positive predictive value.

Our case with apical MI and LAD lesion had ST elevation in leads II and III (STe II > III) and V3 to V6. Right precordial leads were not deviated in this case. It was predicted as LCx in Tierala's algorithms. We added the presence of ST-elevation in V3 and V4 to the first step (when STe II ≥ III), which increased the specificity and PPV of LCx prediction compared to Tierala's main algorithm (86% vs. 84% and 53% vs. 50%).

Evaluation of right precordial leads based on Wellens criteria: ST elevation ≥ 1 mm in V4R or isoelectric V4R combined with positive T wave was considered as RCA occlusion. In addition, ST depression ≥ 1 mm with a negative T-wave was LCx based on Wellens criteria. Therefore, 52 patients were analyzed based on Wellens' criteria. Occluded artery in these patients was RCA or LCx. Wellens criteria were 97% sensitive and 36% specific for RCA prediction. Positive and negative predictive values were 85% and 80%, respectively. Wellens' criteria significantly predicted the PRCA as the culprit lesion (P = 0.002). In this case, sensitivity and specificity were 82% and 47% respectively for PRCA prediction.

Our new criterion "Sum of ST elevation in posterior leads (V7-V8-V9) < 3 mm" was 82% sensitive and 50% specific for RCA prediction (P = 0.017). In our database, posterior leads were recorded in 68 patients. Sum of ST elevation < 3 mm was also significantly related to the site of occlusion within the vessels (P = 0.0016). We categorized RCA involvement in three (proximal, middle, and distal) and LCx occlusion in two groups (proximal and non-proximal). ST elevation < 3 mm was seen in 85% (17/20) of proximal, 88% (21/24) of middle, and 100% (8/8) of distal RCAs.

5. Discussion

RCA supplies blood for RV and some parts of the left ventricle. In most of the people, RCA also gives off the posterior descending artery (PDA) (7). RCA supplies blood for the inferior wall and posterior parts of the septum. LCx supplies the postero-lateral wall and posterior part of the inferoposterior septum. In 13.3% of the population, LCx gives rise to PDA (7).

The proposed criteria are based on vectors of injury, as in the case of RCA, results in infarction of more inferior parts of the heart, compared with posterolateral parts. The vector of injury towards lead III causes more ST elevation in lead III compared with lead II (8). The same insight is applied to LCx occlusion. Based on the literature review, in acute I-STEMI we can categorize all proposed criteria in four subdivisions: ST elevation in inferior leads; ST deviations in other leads based on the injury vector (5); reciprocal changes in I, aVL, V1 to V3 (9); and finally right precordial leads (5).

Recording right precordial leads are not routine in ED as the first on-admission ECG, so the reported sensitivity and specificity of those criteria based on them is limited. ST elevation in V4R is a reliable marker in cases of right ventricle (RV) involvement and proximal RCA occlusion (5, 7-10). Besides the presence of the elevation, the magnitude of deviation in the right precordial leads is an important determinant of prediction (5). ST-deviation in aVR is also considered as another marker for culprit artery prediction. According to this vector theory, other leads may also come to work to predict the site of occlusion. As an instance, one study from Iran in 2012 in Yazd Medical University, analyzed ST elevation in aVR as an indicator for left main artery obstruction which had sensitivity and specificity of 62.7% and 73.6%, respectively (11).

In some cases of middle or distal occlusion of LAD and apical MI, the ECG pattern may be similar to occlusion of RCA or LCx. In these cases, we may have I-STEMI and concomitant ST elevation in anterolateral leads. To deal with this issue, we revised Tierala's algorithm by adding a new step as ST elevation in V3 and V4.

We can't compare Wellens' criteria with Tierala's, because of unequal sample sizes. However, with high-probability assessing and reporting right precordial leads are associated with good sensitivity in right ventricular involvement. Right precordial leads changes may disappear in early stages of STEMI (8). Therefore, we should seriously consider the time lapse between the onset of symptoms and ECG recording.

5.1. Study limitations

Obviously, inferior STEMI is not always limited to just one vessel occlusion and in one site; thus, this study is less helpful to determine the exact value of the examined criteria in patients with multi-vessel involvement. Small number of patients, especially patients with LCx occlusion is another limitation of these kinds of studies.

To deal with the beat to beat variability of ST segment deviation, we calculated the mean of three consecutive beats as the final ST deviation reports.

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Authors' Contribution

First idea: Dr. karbalayi. Data gathering, statistical analysis, and paper writing: Kaveh Hosseini. Academic guidance: Dr. Bozorgi and Dr. Karbalayi. Angiography and ECG reporting: Dr. bozorgi and Dr. Karbalayi.

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