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Localization of the culprit artery in inferior myocardial infarction: Influence of the point of measurement of ST segment

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A R T I C L E   I N F O

A B S T R A C T

Background: There are several approaches widely used in the localization of the responsible artery in inferior myocardial infarction. However, the existing papers show differences in the point where the ST segment is measured. The purpose of our investigation is to analyse the influence of the point at which elevation of the ST segment is measured on the results of these algorithms.
Methods: We analysed the 12 lead electrocardiograms of 90 consecutive patients with inferior myocardial infarction. The ST segment elevation or depression was measured at the J-point and at 80 ms, and three algorithms were applied to predict the culprit artery with both measurements. Sensitivity, specificity, the area under the curve, and the kappa index of agreement were analysed to compare each algorithm at the J-point and at 80 ms.
Results: The area under the curve was better at the J-point than at 80 ms in two algorithms (0.696 vs. 0.635, $p <$ 0.043, and 0.754 vs. 0.661, $p < 0.045$) and did not change in one. Agreement between the J-point and 80 ms was suboptimal in all three algorithms (0.71, 0.65, and 0.58).
Conclusions: The result of different algorithms to detect the culprit artery in inferior STEMI patients can change significantly depending on the point where ST elevation or depression is measured.

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Introduction

The initial diagnostic tool in the decision-tree of ST segment elevation myocardial infarction (STEMI) is the 12 lead electrocardiogram (ECG) [1]. Additionally, analysis of the ST segment is fairly useful as a prognostic marker and to identify the infarct-related artery (IRA) [2–6]. Although the recommendation from the current American and European guidelines is to measure ST segment elevation at the J-point, many of the published algorithms to determine the IRA in STEMI and to correlate ST segment elevation with necrosis size and prognosis take other reference points to measure the ST, ranging from 20 to 80 ms after the J-point [2,4–8].

The purpose of our investigation is to apply different algorithms to predict the left circumflex artery (Cx) or the right coronary artery (RC) as the IRA in patients with inferior STEMI and to analyse the influence on their accuracy of the point at which elevation of the ST segment is measured.

Material and methods

We analysed consecutive patients with inferior STEMI admitted to our coronary care unit from December 2015 to March 2017. Criteria of inclusion were (1) first ECG before 12 h of evolution of STEMI; (2) ST segment elevation ≥0.1 mV in at least two of the inferior leads; (3) coronary arteriography showing total occlusion or severe stenosis in either the Cx or the RC that could be considered as the IRA, with or without disease in other coronary arteries.

Analysis of the ST elevation or depression was made blinded to the coronary arteriography results. Electrocardiograms were scanned and magnified to facilitate a more precise measurement. The reference line was TP, and ST segment elevation (positive value) or depression (negative value) was measured at the J-point and at 80 ms. ST was expressed in mm (10 mm = 1 mV), with a precision of 0.1 mm. We applied three algorithms to both measurements and considered the result positive if it pointed to the Cx as the IRA. The algorithms are described in Fig. 1 based on previous publications [5,6].

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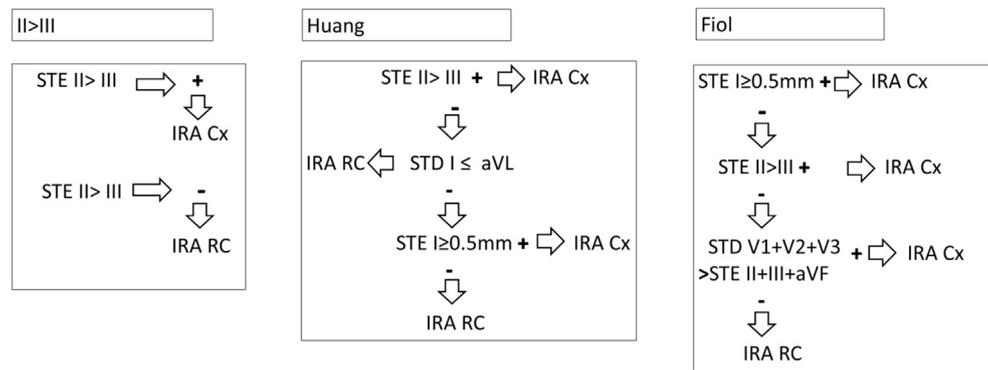
Fig. 1. The three algorithms to detect the culprit artery in inferior myocardial infarction. In the first, if ST elevation in lead II was greater than in III, the responsible artery was the left circumflex; otherwise, it was considered negative, and then the responsible artery was the right coronary. The methods from Huang [6] and from Fiol [5] are three-step algorithms, and both are described in the methods. STE: ST segment elevation; IRA: infarct-related artery; Cx: left circumflex coronary artery; RC: right coronary artery; STD: ST segment depression.

In the three-step method proposed by Fiol et al. [5], first, ST elevation in lead I suggests Cx, while ST depression >0.5 mm suggests RC; second, ST elevation in lead II > III suggests Cx; and third, the sum of ST depression in leads V1–V3 being greater than the sum of ST elevation in leads II, III, and aVF suggests Cx; otherwise, RC is suggested. Alternatively, in the method proposed by Huang et al. [6], first, ST elevation in III < II suggests Cx; second, ST depression in lead I ≤ aVL suggests RC; and third, ST elevation in lead I ≥ 0.5 mm suggests Cx; otherwise, RC is suggested.

The present investigation was approved by the ethics committee of University Hospital Virgen Macarena, Sevilla.

Statistical analysis

We defined two groups according to the IRA: RC if the IRA was the right coronary artery and Cx if the IRA was the Cx. Qualitative variables are expressed as absolute numbers and percentages, with 95% confidence interval (CI) if adequate, and were compared by chi-square test. Continuous variables were explored for normality by the Kolmogorov test and are expressed as means and 95% CIs if normal and as medians and interquartile ranges if not normal. We compared continuous variables with the Student t-test if the distribution was normal or the Wilcoxon signed rank test in the absence of normality. Receiver operating curves (ROCs) were obtained for each algorithm to detect Cx as the IRA, with the ST segment measured at the J-point and at 80 ms. Each pair of ROCs was compared with the algorithm created by DeLong et al. [9] Analyses were performed with the Stata 13.0 package (StataCorp LP).

Results

We included 90 patients, of whom 19 were Cx (21%), mean age was 61.5 years, and 22% were women. Revascularization was performed with primary angioplasty in 88% of patients, and 70% had single-vessel disease. Clinical characteristics and in-hospital evolution are shown in Table 1. We did not find clinical differences between RC and Cx patients.

Measurement of the ST segment showed significant differences between the J-point and 80 ms in all 12 leads. Comparing RC and Cx patients, ST was significantly different if measured at the J-point in I, III, aVL, V1, V3, V5, and V6. If the reference point for measuring the ST segment was 80 ms, there were differences in I, aVL, V1, V3, V5, and V6, but not in III (Table 2). In Cx patients, the ST segment was more elevated than among RC patients in leads I, V5, and V6; less elevated in III; less depressed in lead aVL; and more depressed in leads V1 and V3.

Sensitivity, specificity, AUC (area under the curve), global agreement, and kappa index for each of the three methods with measurement at the J-point and at 80 ms are shown in Table 3. AUC was improved significantly through applying II > III and Fiol's algorithm at the J-point, but there was no change in Huang's algorithm. The kappa

index was lower than 0.8 in all three algorithms. The ROC curves are compared in Figs. 2–4.

Discussion

We have found that measurements of the ST segment in inferior STEMI are significantly different at the J-point and at 80 ms and that such differences affect the results of different algorithms used to detect the responsible artery. The mechanism of ST segment elevation after occlusion of a coronary artery has been widely studied in the past and is related to regional loss of function of ion channels, generating electrical gradients and, as a consequence, regional elevation or depression of the

Table 1
Clinical characteristics and in-hospital evolution.

	Total N = 90	RC N = 71	Cx N = 19	
Age[a]	61.9 (59.4, 64.4)	62.5 (59.7, 65.3)	59.6 (53.6, 65.)	0.345
Female	22.2%	23.9%	15.8%	0.448
Diabetes	27.8%	31.0%	15.8%	0.189
Smoking	53.3%	53.5%	52.6%	0.945
Hypercholesteremia	43.3%	39.4%	57.9%	0.149
Hypertension	46.7%	50.7%	31.6%	0.138
Previous infarction	11.1%	9.9%	15.8%	0.465
Revascularization				0.390
Primary angioplasty	88.9%	90.1%	84.2%	
Thrombolysis	8.9%	7.0%	15.8%	
None	2.2%	2.8%	0%	
Coronary disease				0.312
1 vessel	70.0%	66.2%	84.2%	
2 vessels	21.1%	23.9%	10.5%	
3 vessels	8.9%	9.9%	5.3%	
Killip at admission				0.132
1	88.4%	83.1%	89.5%	
2	7.8%	8.5%	5.3%	
3	1.1%	0.0%	5.3%	
4	6.7%	8.5%	0.0%	
Killip, maximum				0.233
1	73.2%	68.8%	88.9%	
2	12.2%	14.1%	5.6%	
3	0	0	0	
4	14.6%	17.2%	5.6%	
CK, peak[b]	1473 (921, 2831)	1612 (950, 2718)	1183 (773, 3781)	0.616
LVEF[b]	50 (45, 55)	50 (45, 55)	50 (45, 55)	0.624
In hospital mortality	5.7%	5.9%	5.3%	0.907

CK: creatine kinase; LVEF: left ventricular ejection fraction; Cx: left circumflex coronary artery; RC: right coronary artery.
[a] Variable with normal distribution; values are mean and 95% confidence interval (in brackets).
[b] Variables without normal distribution; values are median and interquartile range (in brackets).

Table 2
Measurement of ST at 80 ms and at the J-point.

	Total N = 90		RC N = 71	Cx N = 19	
I	−0.7 (−1.5, 0.0)	0.032	−1.0 (−1.8, −0.3)	0.0 (−0.3, 0.2)	<0.001
Ij	−0.6 (−1.2, 0.0)		−1.0 (−1.5, −0.3)	0.0 (−0.3, 0.2)	<0.001
II	1.8 (1.2, 3.7)	<0.001	1.8 (1.2, 3.9)	2.2 (1.3, 3.1)	0.835
IIj	1.3 (1.0, 2.4)		1.3 (0.8, 2.5)	1.2 (1.0, 2.3)	0.766
III	2.5 (1.7, 4.9)	<0.001	3.0 (1.8, 5.0)	2.2 (1.5, 2.8)	0.079
IIIj	2.0 (1.2, 3.6)		2.2 (1.3, 3.8)	1.5 (1.0, 3.0)	0.048
aVR	−0.6 (−1.3, −0.2)	<0.001	−0.6 (−1.1, −0.0)	−0.8 (−1.8, −0.5)	0.115
aVRj	−0.3 (−1.0, 0.0)		−0.2 (−0.8, 0.0)	−0.6 (−1.2, −0.2)	0.076
aVL	−1.9 (−3.0, −0.8)	<0.001	−2.1 (−3.2, −1.0)	−1.0 (−1.1, −0.5)	0.001
aVLj	−1.3 (−2.2, −0.6)		−1.4 (−2.5, −1.0)	−0.6 (−1.0, −0.2)	0.002
aVF	2.3 (1.3, 4.0)	<0.001	2.4 (1.3, 4.2)	2.0 (1.3, 2.0)	0.381
aVFj	1.8 (1.0, 3.0)		2.0 (1.0, 3.2)	1.2 (1.0, 2.3)	0.218
V1	−0.5 (−1.3, 0.0)	<0.001	−0.5 (−1.2, 0.1)	−1.1 (−2.6,-0.2)	0.015
V1j	−0.3 (−1.1, 0.0)		−0.3 (−1.0, 0.1)	−0.6 (−2.0, −0.5)	0.007
V2	−1.5 (−2.8, −0.5)	0.003	−1.4 (−2.8, −0.5)	−1.5 (−2.6, −0.5)	0.681
V2j	−1.3 (−2.5, −0.5)		−1.3 (−2.5, −0.5)	−1.3 (−2.4, −0.4)	0.972
V3	−0.2 (−1.8, 0.6)	0.044	0.0 (−1.5, 0.5)	−1.6 (−3.2, −0.2)	0.005
V3j	−0.5 (−1.5, 0.2)		−0.4 (−1.1, 0.4)	−1.5 (−2.3, −0.2)	0.016
V4	0.4 (−0.6, 1.4)	<0.001	0.5 (−0.6, 1.4)	0.3 (−0.5, 1.3)	0.798
V4j	0.0 (−0.9, 1.0)		0.0 (−0.9, 1.0)	0.0 (−0.6, 1.1)	0.916
V5	0.8 (−0.1, 1.8)	<0.001	0.7 (−0.3, 1.3)	1.5 (0.3, 2.5)	0.032
V5j	0.3 (−0.5, 1.1)		0.2 (−0.5, 1.0)	1.2 (0.0, 2.2)	0.010
V6	0.6 (0.0, 1.5)	<0.001	0.5 (−0.2, 1.2)	1.6 (0.6, 2.5)	0.002
V6j	0.5 (0.0, 1.0)		0.2 (−0.2, 1.0)	1.0 (0.5, 1.9)	0.002

In the first three columns, ST segment measurements at 80 ms and at the J-point are compared. In the last three columns, ST segment is compared between RC and Cx patients. Cx: left circumflex coronary artery; RC: right coronary artery; I, II, III, aVR, aVL, aVF, V1, V2, V3, V4, V5, V6: ST segment measured at 80 ms; Ij, IIj, IIIj, aVRj, aVLj, aVFj, V1j, V2j, V3j, V4j, V5j, V6j: ST segment measured at the J-point. Values are median and interquartile range (in brackets).

ST segment [10,11]. The characteristic changes of the ST segment during ischemia have made the analysis of ST an indispensable tool, not only to diagnose STEMI but also to localize the occluded coronary artery [3]. However, ST segment elevation, the identity sign of STEMI, must be differentiated from other non-ischemic conditions that can simulate it and must be precisely measured following the recommendations from cardiology societies [12,13]. One of the key points of the standard method is where the ST segment should be measured, the J-point being the current recommendation [1,13], whereas other references have been applied not only in disease but also in population studies [2,4–8,12]. Our findings prove that changing the reference point to measure the ST segment has consequences for the results of some algorithms based on this analysis aimed at identifying the coronary occluded in inferior STEMI. Whether this finding can extend to other algorithms or diagnostic criteria should be investigated further.

In our series, one-fifth of patients with inferior STEMI had the left circumflex artery as the IRA, in agreement with previous publications [3–6,14]. Kim analysed 2281 patients from the Korea Acute Myocardial Infarction Registry (KAMIR) with single-vessel disease and total occlusion of the IRA. Cx was less frequent than RC (14% vs 35%), and only

27% of Cx patients presented with ST elevation in inferior leads [15]. Conversely, among patients with myocardial infarction presenting without ST segment elevation and occlusion of the IRA, Cx was more commonly responsible [16,17]. These findings might be explained at least in part by the localization of the myocardial area supplied by the Cx, with less expression in the 12 lead electrocardiogram than the inferior and anterior walls. But it has also been suggested that Cx is less prone to suffering total occlusion than the RC because it is subject to less strain, leading to a lower frequency of Cx occlusions [18].

For simplicity, we have presented sensitivity, specificity, and AUC data for each algorithm to detect Cx as the IRA. Some previous studies have found higher AUC than what we are showing here, but studies involving large numbers of patients and a recent meta-analysis do not confirm the promising findings of previously published algorithms [14,19]. The meta-analysis from Liang et al. included 24 studies, with 4431 cases in total, and analysed sources of heterogeneity in such methodological aspects as possible selection bias, differences in anatomical data, year of publication, and sample size. They limited their analysis to the predictive value of limb leads [19]. However, there was wide disparity in the method of measuring ST segment elevation among studies,

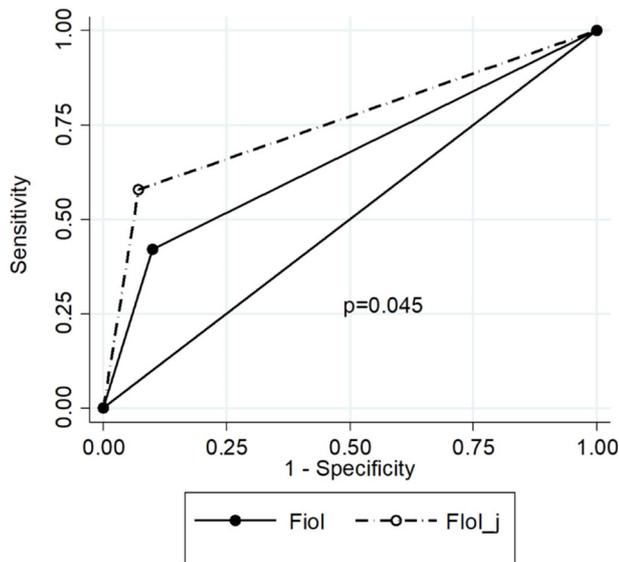**Table 3**
Predictive value of the different methods [4–6].

	ST at 80 ms	(95% CI)	ST at J-point	(95% CI)	p	Agreement (95% CI)	Kappa (95% CI)
II > III						93.3%	0.71
Sensitivity	36.8	16.3, 61.6	42.1	20.3, 66.5	0.740	(86.2, 96,9)	(0.50, 0.93)
Specificity	90.1	80.7, 95.9	97.2	90.2, 99.7	0.085		
AUC	0.635	0.518, 0.752	0.696	0.581, 0.812	0.043		
Fiol						89.9%	0.65
Sensitivity	42.1	20.3, 66.5	57.9	33.5, 79.7	0.330	(81.9, 94.6)	0.44, 0.86)
Specificity	90.0	80.5, 95.9	92.9	84.1, 97.6	0.546		
AUC	0.661	0.541, 0.780	0.754	0.636, 0.872	0.045		
Huang						83.3%	0.58
Sensitivity	42.1	20.3, 66.5	47.4	24.4, 71.1	0.744	(74.3, 89.6)	(0.39, 0.77)
Specificity	80.3	69.1, 88.8	74.6	62.9, 84.2	0.422		
AUC	0.612	0.489, 0.735	0.610	0.484, 0.736	0.960		

AUC: area under the curve; CI: 95% confidence interval. Sensitivity and specificity are calculated for detection of the left circumflex artery as responsible. AUC, agreement, and Kappa are for both arteries.
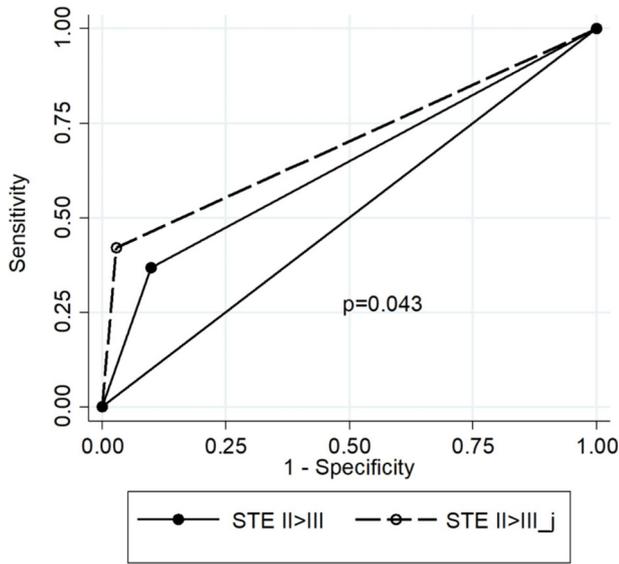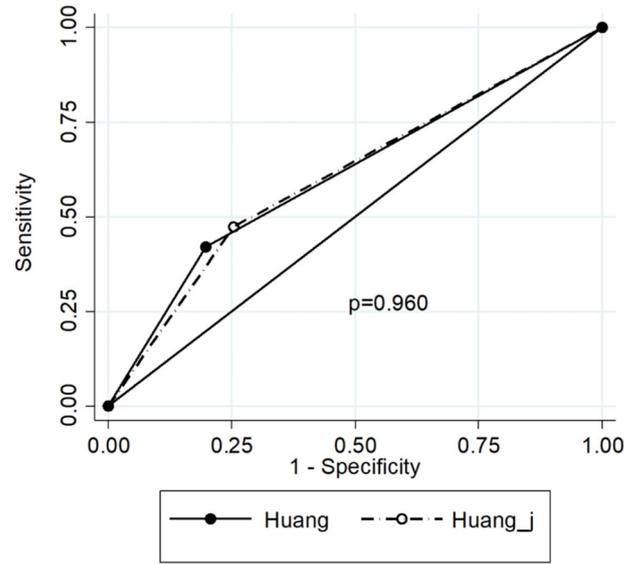
Fig. 2. Comparison of receiver-operating curves of ST segment elevation in II > III at 80 ms or at the J-point and the Cx as IRA. STE: ST segment elevation; II > III: measurement at 80 ms; II > III_j: measurement at the J-point; IRA: infarct-related artery; Cx: left circumflex coronary artery.

Fig. 3. Comparison of receiver-operating curves of the algorithm described by Fiol et al. [5] and the Cx as IRA. Fiol: measurement at 80 ms; Fiol_j: measurement at the J-point; IRA: infarct-related artery; Cx: left circumflex coronary artery.

Fig. 4. Comparison of receiver-operating curves of the algorithm described by Huang et al. [6] and the Cx as IRA. Huang: measurement at 80 ms; Huang_j: measurement at the J-point; IRA: infarct-related artery; Cx: left circumflex coronary artery.

as they took different points of reference from the J-point to 80 ms after the J-point [4,5,15,20]. That contrasts with the current recommendation from the European and American societies to measure ST segment elevation or depression at the J-point [1,13,21]. The physiopathology of the ST segment is complex, showing alterations in the presence of ischemia or channelopathies, or other pathologies or even racial differences, and these changes involve several ion channels that act sequentially across the action potential of the myocardial cells [10,17,22]. This can translate to some extent to a different significance of the ST measured at different reference points. We have found that changing the point of measurement from the J-point to 80 ms produces significant changes in the results of well-known and widely used algorithms for detecting the culprit artery in inferior STEMI. Our work is limited to inferior STEMI, but the question is open, and every algorithm aimed at detecting the

IRA in STEMI patients should be validated with the current standard method of measuring ST segment elevation or depression.

Clinical implications

Our data suggest that the usefulness of different algorithms for identifying the responsible artery in inferior STEMI, although of limited value, could be modestly improved by measuring the ST segment at the J-point.

Study limitations

Although we have proved the influence of the point of measurement of the ST segment on the magnitude of ST shift and the results of different algorithms to detect the IRA, our study has some limitations. First, although it is prospective, there is always some bias, as only patients reaching our coronary unit were included. Second, this is a single-centre study, and electrocardiographic patterns can have some differences in other geographical areas. And third, although the results are significant, the sample size was relatively small; with a larger sample, more differences could have been detected.

Conclusions

Among patients with ACS, measurements of ST segment elevation or depression are significantly different at the J-point and at 80 ms. The AUC of different algorithms for detecting the culprit artery in inferior STEMI patients can change significantly depending on the point where ST elevation or depression is measured.

Declaration of interests

None.

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