RESEARCH ARTICLE / *Araştırma Makalesi*

ECG Criteria for the Prediction of Infarct-Related Artery and Impact of Coronary Dominance on ECG in Patients with Inferior ST-elevation Myocardial Infarction

İnferior ST-Segment Elevasyonlu Miyokard Enfarktüsü Hastalarında Infarkt ile Ilişkili Damarın Öngörülmesinde EKG Kriterleri ve Koroner Arter Baskınlığının EKG Üzerine Etkisi

Eser Durmaz, Bilgehan Karadag, Cansu Ebren, Deniz Mutlu, Orhan Furkan Karaca, Ali Ugur Soysal, Sinem Gürel, Hasan Tokdil, Zeki Ongen

Istanbul University-Cerrahpasa, Cerrahpasa School of Medicine, Istanbul/ Turkey

Yazışma Adresi / *Correspondence:*
Eser Durmaz

Kocamustafapasa Street, Cerrahpasa School of Medicine, Cardiology department Fatih/ Istanbul
T: **+90 533 773 71 21** E-mail **: durmazeser@hotmail.com**

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Orcid :

Eser Durmaz https://orcid.org/0000-0002-1468-0153
Bilgehan Karadag https://orcid.org/0000-0002-1361-5229
Cansu Ebren https://orcid.org/0000-0002-8689-5380
Deniz Mutlu https://orcid.org/0000-0003-4432-4595
Orhan Furkan Karaca https://orcid.org/0000-0001-8810-2420
Ali Uğur Soysal https://orcid.org/0000-0002-0834-1956
Sinem Gürel https://orcid.org/0000-0002-8426-6935
Hasan Tokdil https://orcid.org/0000-0003-3873-5101
Zeki Öngen https://orcid.org/0000-0003-1835-5929

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Abstract

Objective — Previous studies reported the distribution of ST elevation (STE) may predict the infarct related artery (IRA). However, the impact of coronary dominance on ECG is not clearly demonstrated. Our primary aim was to investigate the impact of coronary dominance on the distribution of STE.

Materials and Methods — We retrospectively included patients with inferior STEMI. Previously defined ECG predictors of IRA were tested; higher STE in DIII>DII or presence of ST depression in aVL and/or DI presumes right coronary artery (RCA); STE in DII>DIII presumes left circumflex artery (LCX).

Results — Our study encompasses 192 patients. The culprit artery was RCA in 151 patients and LCX in 41 patients. The sensitivity and specificity of STE DIII>DII for prediction of RCA were 84% and 35% respectively. In comparison, the sensitivity of STE DII>DIII for prediction of LCX was lower, whereas specificity was considerably higher (48% and 65%, respectively). However, the best sensitivity was observed with a STE DIII>DII,which strongly predicts the coronary dominance with a sensitivity of 97% and a specificity of 27 %. If the IRA is RCA the magnitude of STE was significantly higher when the reference point was QRS onset (p: 0.021) compared to the prior guideline recommendations. However, this significance was not observed in patients with LCX occlusion (p: 0.212).

Conclusion — In this study, we have demonstrated that ECG predictors of IRA are significantly related to coronary dominance. Moreover, new ECG criteria increased the diagnostic ability of ECG when RCA is the culprit artery but did not differ when the LCX is the IRA.

Keywords — inferior STEMI; ECG; coronary dominance

Öz

Amaç — *Daha önceki çalışmalarda ST-segment yüksekliğinin dağılımının enfarktan sorumlu damarı öngörebileceği gösterilmiştir. Ancak koroner arter baskınlığının EKG üzerine etkisi yeterince gösterilmemiştir. Bu çalışmada birincil amacımız koroner arter baskınlığının ST-segment yükselmesi dağılımı üzerine etkisini araştırmaktır.*

Gereç ve Yöntemler — *Retrospektif olarak primer perkütan girişim ile tedavi edilmiş inferior miyokard enfarktüsü hastaları çalışmaya dahil edildi. Daha önce tanımlanan şu EKG öngördürücüleri araştırıldı; DIII derivasyonundaki ST-segment elevasyon miktarı DII'den fazla ise infarktan sorumlu arter sağ koroner arterdir(RCA), aVL veya DI'de ST-segment depresyonu mevcut ise sorumlu arter yine RCA'dır ve DII ST-segment elevasyonu DIII'den fazla ise sorumlu arter Sirkumflex(LCX) arter sorumludur.*

Bulgular — *Çalışmamızda 192 hasta dahil edildi. 151 hastada sorumlu arter RCA, 41 hastada LCX idi.DIII ST-segment elevasyonunun DII'den fazla olmasının RCA oklüzyonunu göstermede duyarlılığı %84 özgüllüğü %35 olarak saptandı. DII ST-segment elevasyonunun DIII'den fazla olmasının LCX oklüzyonunu göstermede duyarlılığı %48 ve özgüllüğü %65 olarak saptandı. Duyarlılık ve özgüllük açısından en yüksek oran koroner arter baskınlığını öngörmede izlendi; DIII ST-segment elevasyonunun DII'den fazla olmasının koroner arter baskınlığını göstermede duyarlılığı %97 ve özgüllüğü ise %27 olarak saptandı. ST-segment elevasyon miktarının ölçümü için güncel kılavuz önerisi olarak J noktası yerine QRS başlangıcı olarak seçilmesi RCA oklüzyonu olan hastalarda anlamlı değişikliğe neden olmuştur(p: 0.021) ancak LCX oklüzyonu olan hastalarda bu anlamlı değişim izlenmemiştir (p: 0.212).*

Sonuç — *Bu çalışmamızda infarktan sorumlu arteri öngörmek için kullanılan EKG kriterlerinin koroner arter baskınlığına güçlü bir şekilde ilişkili olduğunu gösterdik. Ayrıca yeni EKG kriterleri, RCA oklüzyonu olan hastalarda EKG'nin tanısal doğruluğunu artırdığını ancak LCX oklüzyonu olan hastalarda anlamlı değişiklik yapmadığını gösterdik.*

Anahtar Kelimeler — *inferior STEMI; EKG; koroner arter baskınlığı*

INTRODUCTION

The default reperfusion strategy in patients with ST-elevation myocardial infarction (STEMI) is recanalization of infarct-related artery (IRA) via primary percutaneous coronary intervention (pPCI).[1]

Prediction of IRA is of clinical importance for several reasons particularly in patients presenting with inferior STEMI; first, operators may choose "culprit artery first" strategy to avoid reperfusion delay; second, patients' clinical situations such as shock, hypotension, incessant ventricular tachycardia or bradycardia may require immediate recanalization of IRA; third, chronic total occlusion (CTO) or severe stenosis in both left circumflex artery (LCX) and right coronary artery (RCA) may cause confusion in identification of IRA and finally presence of significant left main and left anterior descending disease may demand simple balloon recanalization of IRA and avoidance of stent implantation when an urgent surgical revascularization is likely. Contemporarily, great efforts are made for shortening of the ischemic period, starting from the pre-hospital diagnosis and initiation of antithrombotic therapy to catheterization laboratory preparation, however, there are no well-defined recommendations aiming minimization of recanalization time of IRA with respect to pPCI strategies.[2] Chiang et al. have reported that 58% of interventional cardiologists prefer imaging of the presumed non-IRA with diagnostic catheters and then directly pick a guiding catheter for the IRA. However, 19% of the operators prefer guiding catheter for the IRA and perform diagnostic angiography for the non-IRA following pPCI of IRA.[3] Hence, the prediction of the IRA has utmost importance particularly in patients presenting with inferior MI in which both RCA and LCX could be infarct related arteries. In patients with severe disease in both LCX and RCA, ECG has even an extra value for identification of the IRA. The reports in the literature on ECG predictors of IRA in patients with STEMI are based on the ECG diagnostic criteria of 3rd Universal Definition of myocardial infarction guidelines, which suggests the J point elevation as the reference for ST-segment elevation calculation.[4] On the other hand, the recent 4th universal definition of myocardial infarction guidelines recommends the calculation from the onset of QRS segment rather than the J point.[5] To the best of our knowledge, our study is the first analysis of ECG criteria for prediction of the infarct related artery according to the new definition in patients presenting with inferior MI. Regarding the coronary dominance, the dominant artery is defined as the artery which has the origin of the posterior descending artery (PDA).[6] PDA supplies the inferior part of the interventricular septum and when occluded substantial amount of myocardium becomes ischemic. Therefore, occlusion of PDA might have a considerable impact on ECG. In this regard, coronary dominance may alter the ECG predictors of IRA.

In this study, our primary aim was to investigate the impact of coronary dominance on surface ECG findings in patients presenting with inferior ST segment elevation myocardial infarction undergoing pPCI. Our secondary aim was to investigate the ECG predictors of infarct related artery according to the 4th universal definition of myocardial infarction in comparison to previous criteria in the same patient population.

MATERIALS and METHODS

Patient selection

This study was designed as a cross-sectional descriptive and methodologic study. We retrospectively investigated the patients' files and angiography records who have a clear diagnosis of inferior STEMI. Permission of the local ethics committee of our institution was obtained (25.01.2019/14898). The study was conducted in Cerrahpasa School of Medicine between the years 2018-2020. ECG records and angiography images were assessed in accordance with the declarations of Helsinki. The inclusion criteria were as follows; i) definite diagnosis of IRA after the diagnostic angiography, ii) interpretable pre-intervention 12-lead electrocardiography which demonstrates inferior ST-segment elevation (STE), iii) patients presenting within 6 hours fol-

lowing symptom onset, iv) patients over 18 years old. Patients excluded from the study if; i) if left anterior descending is the culprit artery, ii) patients with other than type 1 myocardial infarction, iii) significant stenosis in both RCA and LCX and identification of IRA could not be made, iv) any CTO in the non-infarct related artery. Patients' baseline characteristics and comorbidities were recorded.

ECG criteria

The initial diagnostic ECG of patients were used to measure the amount of ST-segment elevation. Previously defined ECG predictors of IRA in inferior STEMI setting were tested in our study cohort; if ST-segment elevation in DIII derivation is higher than DII (DIII> DII) the culprit artery is more likely to be RCA and if ST-segment elevation in DII derivation is higher than DIII (DII> DIII) the culprit artery is more likely to be LCX. Likewise, when ST depression (STD) in aVL derivation is higher than DI derivation (aVL> DI) culprit artery is more likely to be RCA.[7-10] Diagnosis of inferior STEMI was made in patients with ST-segment elevation of more than 1 mm in at least two of DII, DIII or aVF derivations.[5] In patients with ST-segment depression in V1 and V2, posterior leads were placed and V7-9 obtained in order to diagnose concomitant posterior STEMI. The magnitude of ST-segment elevation was calculated as follows; the magnitude of elevation from the onset of QRS segment as recommended in 4th universal definition of myocardial infarction and magnitude of elevation from the J point elevation as stated in previous definition.[4,5]

Invasive procedure

Coronary angiography was performed using the Philips Allura Exper (Philips, Amsterdam, and The Netherlands) angiography system. Each patient underwent full diagnostic angiography prior to pPCI. The vast majority of procedures were performed via femoral access using the modified Seldinger method. At least two projections (right anterior oblique, cranial and caudal angulation) for left coronary system and left anterior oblique for RCA. Culprit artery was defined as total or subtotal occlusion of the epicardial coronary artery. Lesions with a contrast staining, luminal filling defects suggesting intracoronary thrombus or haziness signifying complicated atherosclerotic plaque considered infarct-related lesion. Presences of collateral blood supply via an epicardial collateral connection or bridging collateral were used to define chronic total occlusion. Coronary dominance was decided according to the origin of PDA. PDA was defined as the vessel, which supplies inferior aspects of interventricular septum via septal arteries. In the case of co-dominance, the right coronary system was deemed dominant as suggested by SYNTAX algorithm.

Statistical analyses

SPSS version 20.0 software was used for all statistical analyses. Normally distributed variables were expressed as mean ± standard deviation (SD). The frequencies of nominal variables were compared using Fisher's exact test and chi-square test. The categorical variables are presented as percentages. The Kolmogorov-Smirnov test was used to assess the normality of the data distribution.

Standard methods were used to calculate sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV); 95% confidence intervals were calculated. The discriminative power of each ECG criterion was assessed by the mean of the area under the receiver operating characteristic curve (c-statistic). P value < 0.05 in the two-tailed tests was considered significant.

RESULTS

Clinical properties of the study population

We retrospectively included 192 patients with a definite diagnosis of inferior STEMI who were treated with pPCI. Patients were assigned into two groups; group 1 included patients with an IRA of RCA and group 2 included patients with an IRA of LCX. Table 1 demonstrates the clinical variables of patients. There was male dominance in both groups with no significant gender differences be-

Table 1. Patients' demographics and clinical characteristics				
	All patients	**Group 1**	**Group 2**	**p-value**
Gender (male)	192 (79%)	138 (78.2%)	54 (81.9%)	0.621
Age (years)	58.3±10.7	59.7±11.2	54.9±10.3	0.007*
HT	131 (68.2%)	89 (64.4%)	42 (77.7%)	0.073
DM	57 (29.7%)	49 (35.6%)	8 (14.9%)	0.005*
CVA	8 (4.1%)	6 (4.3%)	2(3.7%)	0.841
HPL	13.0%	19 (13.7%)	6 (11.1%)	0.623
Laboratory values				
Hgb (gr/dl)		13.0±1.86	13.4±1.61	0.239
Wbc (1000/dl)		11.9±3	11.4±4.1	0.472
Plt (1000/dl)		245±73	249±74	0.718
Creatinin (mg/dl)		0.908±0.2	0.880±0.21	0.189
Peak Hs-TnT (ng/dl)		2.46(1.26- 4.62)	2.46(1.12-4.03)	0.865
Pro-BNP (pg/dl)		281(69-677)	286(120-828)	0.280
LVEF (%)		47.8±7.2	48.7±6.1	0.431

HT: hypertension; DM: diabetes mellitus; CVA: Cerebrovascular accident; HPL: hyperlipidemia; Hgb: haemoglobin; Wbc: White blood cell; Plt: platelet; Hs-TnT: high sensitive troponin T; LVEF: left ventricular ejection fraction
* Statistically significant

tween groups (108 (78.2%) vs 44 (81.9%), p: 0.621). Patients in group 1 were significantly older than patients in group 2 (59.7±11.2 vs 54.9±10.3, p: 0.007). There was no significant difference between groups in terms of hypertension (89 (64.4%) vs 42 (77.7%) p: 0.073), previous ischemic cerebrovascular accident (6 (4.3%) vs 2(3.7%), p: 0.841) and hyperlipidaemia (19 (13.7%) vs 6 (11.1%), p: 0.623). Diabetes was more prevalent in group 1 patients (49 (35.6%) vs 8 (14.9%), p:0.005). Left ventricular ejection fraction was similar between groups (47.8±7.2% vs 47.8±7.2%, p:0.431) and concordant with the LVEF, pro-BNP levels were also similar between groups (281(69-677) ng/dl vs 286(120-828)ng/dl, p: 0.280).The haemoglobin levels, leukocyte and platelet counts were similar.

Angiographic properties

Each patient underwent successful reperfusion of the IRA. Right coronary was the dominant artery in 173 patients. The infarct related artery was RCA in 138 patients (group 1) and LCX in 54 patients (group 2). Left coronary dominance was observed in 4 patients in group 1 and 15 patients in group 2.

Electrocardiographic parameters

In the overall study population, the magnitude of ST-segment elevation was more prevalent in DIII compared to DII. There were 26 patients with ST depression in V1-3 suggesting posterior involvement. ST depression more than 0.5 mV in DI and aVL was detected in 80 patients. Considering the overall study population, the mean number of leads in which ST-elevation observed were 3.57±1.27 when QRS onset was used as a reference point and 3.6±1.34 when J point was used as a reference point and there was no significant difference (p:0.874) (table 2). Analysis of the patients with RCA occlusion revealed that the magnitude of ST-elevation was significantly higher when the accepted reference point was QRS onset (2.62±0.89 vs 2.27±0.90, p: 0.021) based on the suggestion of the 4th universal definition of myocardial infarction.

Table 2. Comparison of ST-segment elevation according to previous and current guidelines			
	Reference point		p-value
	QRS onset*	J point**	
Extension of ST elevation	3.57±1.27	3.6±1.34	0.874
Magnitude of ST-segment elevation			
RCA occlusion	2.62±0.89	2.27±0.90	0.021^
LCX occlusion	2.025±0.9	1.85±0.74	0.212
RCA: right coronary artery, LCX: left circumflex artery * Forth universal definition of myocardial infarction ** Third universal definition of myocardial infarction ^ Statistically significant			

However, this significance was not observed in patients with LCX occlusion (2.02±0.90 vs 1.85±0.74, p: 0.212) (table 3). In the group of patients with IRA of RCA, the magnitude of ST elevation according to QRS onset was significantly higher in DIII compared to DII [116(76.2%) vs 35 (23.2%), p<0.001]. However, this significant difference was not observed in patients with IRA of LCX [22 (53.6%) vs 19 (46.3), p: 0.368] (table 3).

Table 3. Infarct related artery according to comparative distribution of ST segment elevations in DII and DIII			
	STE DIII>DII (%)	**STE DII>DIII (%)**	**p-value**
IRA of RCA	76.18	23.17	p<0.001
IRA of LCX	53.6	46.3	p: 0.368
STE: ST-segment elevation, IRA: Infarct related artery, RCA: Right coronary artery, LCX: Left coronary artery			

Predictive value of ST-segment elevation in DIII and DII

In the study population, ST-segment elevation of DIII>DII was documented in 151 patients and ST-segment elevation of DII>DIII was documented in 41 patients. Among the patients with ST-segment elevation DIII>DII, the culprit artery was RCA in 116 patients and 35 in LCX, whereas among the patients with ST-segment elevation DII>DIII, the culprit artery was RCA in 22 patients and LCX in 19 patients. The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of ST-segment elevation in leads DIII and DII were as follows (table 4)

ST-segment elevation in DIII>DII predicts RCA as IRA; sensitivity: 84% specificity: 35% PPV: 76% NPV: 46%)
ST-segment elevation in DII>DIII predicts LCX as IRA; sensitivity: 48% specificity: 65% PPV: 56% NPV: 66%

ST-segment elevation in DIII>DII predicts coronary dominance for IRA; sensitivity: 97% specificity: 27% PPV: 77% NPV: 78%

Predictive value of ST-segment depression

In the study population, ST depression in aVL and DI was detected in 76 (50.3%) patients among group of patients with IRA of RCA and 10 (20.1%) patients among group of patients with IRA of LCX and there was statistically significant difference between these groups (p: 0.016). ST depression in V1-3 was detected in 26 patients (12.3% vs 16.6%, p: 0.892 respectively for groups of patients with IRA of RCA vs with IRA of LCX).

DISCUSSION

The principal findings of our study are i) ECG prediction of IRA in patients with inferior STEMI is reliable particularly when the right coronary artery is dominant, ii) the prediction models using the ST depression in various

Table 4. Sensitivity and specificity analysis of ECG predictors						
Predictor	**Presumed IRA**	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**C-statistics**
STE DIII>DII	RCA	84%	35%	76%	46%	0.59 (0.50-0.69)
STE DII>DIII	Cx	48%	64%	56%	66%	0.48 (0.39-0.58)
STE DIII>DII	RCA Coronary dominance	97%	27%	77%	78%	0.62(0.52-0.71)
IRA: infarct related artery, PPV: positive predictive value, NPV: negative predictive value, STE: ST segment elevation, RCA: right coronary artery, Cx: circumflex artery						

leads requires further validation iii) coronary dominance has considerable impact on the value of ECG predictors, iv) the use of new ECG criteria did not improve the diagnostic accuracy of ECG in STEMI related to LCX inferior occlusion. In patients with RCA as the culprit artery the magnitude of ST-elevation was significantly higher when reference point was accepted as QRS onset (p: 0.021) based on the suggestion of the 4th universal definition of myocardial infarction compared to prior criteria. However, this significance was not observed in patients with LCX occlusion (p: 0.212).

Accurate prediction of IRA in patients with inferior STEMI has clinical significance for decision making of the primary PCI operator. Operators may choose "culprit artery first" strategy to avoid reperfusion delay. In patients with electrical or hemodynamic instability urgent recanalization of IRA may be required. In such circumstances, the operators usually pick a guiding catheter with an intention to recanalize the presumed culprit artery. Furthermore, presence of chronic total occlusions or severe stenosis in both left circumflex artery (LCX) and right coronary artery (RCA) may cause confusion in identification of IRA. Finally, presence of significant left main and left anterior descending disease may demand balloon recanalization of IRA and avoidance of stent implantation when an urgent surgical revascularization is likely.

Therefore, prediction of IRA using ECG has many potential benefits. Previous studies focused on several ECG predictors of IRA and the most commonly investigated parameters were ST elevation in lead DIII and DII and ST depression in leads aVL, DI, V1-3. In our study, we have demonstrated that STE in DIII>DII has a high sensitivity for the prediction of RCA as the infarct-related artery which is concordant with the previous reports. The sensitivity of ST-segment elevation of DIII>DII in the previous reports were ranged 73% to 88% varying on the basis of used definition (inferior STEMI, inferolateral STEMI etc.). On the other hand, STE in DII>DIII has lower sensitivity but relatively higher specificity for the prediction of LCX as the IRA. In our study population the predictive value of ST-segment elevation DII>DIII was as follows; 48% sensitivity and 65% specificity, which is also concordant with previous reports. The possible explanation of this discrepancy between IRA as RCA and LCX might be the unpredictable variations of the LCX branching. RCA has a predictable course and branching pattern; conus artery at the proximal segment, right ventricular artery at the middle segment and posterolateral and posterior descending artery after the crux. On the other hand, LCX may have one or more marginal arteries, which are quite variable between patients. Therefore, in case of LCX occlusion variable ischemia vectors may be observed and impact of this diversity leads substantial difference of surface ECG between patients.

Previous studies reported various conclusions regarding the predictive value of ST depression in several leads, however, our study failed to demonstrate such a relationship. Posterior descending artery supplies the inferior 1/3 aspects of interventricular septum and loss of PDA supply has a substantial impact on the ischemic area, hence ischemia vector. Result of PDA occlusion, ischemia vector directed towards more inferior and backward compared to patients without PDA occlusion. Therefore, the expected findings on surface ECG are ST-segment elevations of DIII > DII and, ST depression in aVL and DI. There are very few data in the literature, which evaluated the impact of coronary dominance on surface ECG. Our findings have implied that ST-segment elevation of DIII> DII is related to an occluded PDA rather than involvement of the entire RCA. Zhan et al. investigated the value of DIII/DII ratio for prediction of the IRA and concluded that in patients with left dominance, DIII/DII ratio is not useful for IRA prediction.11 Previous studies have demonstrated the sensitivity of ST-segment elevation of DIII>DII in a range 82% to 89%. Considering the coronary dominance ratios; 80% RCA, 10-15% LCX and %5-10 co-dominance, the sensitivity of previous reports might be related to coronary

dominance. Moreover, in this study we have demonstrated that prediction models using ECG are quite feasible in patients with dominant RCA, however, when LCX is dominant, ECG models have moderate power for prediction of IRA which is in line with the findings of Zhan et al. Historically, ST-segment elevation of DII > DIII is related to the LCX as IRA, however our study and several other studies demonstrated that this prediction model has a poor sensitivity (ranging from 50 to 70 %), although with an acceptable specificity (66-85 %).[8,10,12]

The new definition of myocardial infarction modified the reference point when assessing the ST elevation. While the J point was suggested by the previous criteria, the new definition recommends the onset of the QRS segment for calculation of ST elevation as the new reference. We evaluated the diagnostic performance of new recommendations based on the magnitude of ST-elevation from QRS onset and J point. With the use of the new definition, the magnitude of ST-elevation was detected significantly higher when RCA is the culprit artery. However, when LCX was the culprit artery there was no significant difference in terms of the magnitude of ST-elevation between new and previous criteria. A possible explanation of this discrepancy might be the variable impact of LCX occlusion on the ECG.[13,14] Previous studies have demonstrated ECG findings of LCX occlusion have a broad spectrum ranging from subtle changes in ST-segment to marked ST elevation. Therefore, further studies with larger patient populations are required in order to assess the discriminatory impact of new criteria.

The clinical extrapolation of our findings indicate that invasive cardiologist should bear in mind that magnitude of STE in inferior leads are related to coronary dominance rather than right or left sided culprit coronary arteries. Couture at all, demonstrated that full diagnostic angiography and subsequent primary PCI results in 4-6 minutes delay compared to non-IRA diagnostic angiography and following IRA PCI strategy, however the clinical significance of 4 minutes is unknown.[15] Still, in the aforementioned clinical circumstances, 4-6 minutes might be life-saving and hence prediction of IRA is of clinical importance. On the other hand, in patients with stable clinical situation, it might be reasonable to select one of three strategies. Since the clinical significance of 4-6 minutes is unknown, ''full diagnostic angiography first" strategy might be reasonable considering that it allows proper choice of PCI equipment. Although the clinical significance of time delay in this situation is controversial, considering the difference in cost of guiding catheter vs diagnostic catheter, full diagnostic angiography first strategy still has its merits. Moreover, in patients with an IRA of LCX, larger size guiding catheters or catheters with extra back-up or different configurations may be required. In the light of these considerations, despite ECG predictors of IRA presumes the IRA, ''full diagnostic angiography first" strategy seems reasonable in patients with stable clinical situations.

In conclusion, our study demonstrated that the distribution of ST-segment elevation in inferior leads predicts infarct related artery and independently associated with coronary dominance. The sensitivity of ECG predictors of infarct related artery is feasible especially for RCA but not for LCX which is probably due to higher frequency of the right coronary system.

The use of new ECG criteria of 4th Universal Definition of Myocardial Infarction improves the diagnostic ability of ECG for the diagnosis of infarct related artery when RCA is the culprit artery but not when LCX is the culprit artery.

Etik kurul onayı

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