



Electrocardiographic characteristics in angiographically documented occlusion of the dominant left circumflex artery with acute inferior myocardial infarction: limitations of ST elevation III/II ratio and ST deviation in lateral limb leads^{☆,☆☆}

Zhan Zhong-qun, MS,* Wang Wei, MS, Dang Shu-yi, MD, Wang Chong-quan, MD, Wang Jun-feng, MD, Cao Zheng, MD

Department of Cardiology, Shiyen TaiHe Hospital, Yunyang Medical College, Shiyen, Hubei Province, China

Received 17 December 2008

Abstract

Background: The prognosis of dominant left circumflex artery (LCx) occlusion-related inferior acute myocardial infarction (AMI) patients is poor, but the electrocardiographic (ECG) characteristics of this AMI entity have not been described.

Methods: One hundred thirty-five patients with first dominant right coronary artery (RCA) or dominant LCx-related inferior AMI were included. The characteristics of ECG obtained on admission for 55 patients with culprit lesions proximal to the first major right ventricular (RV) branch of dominant RCA (group proximal dominant RCA), 62 patients with culprit lesions distal to the first major RV branch of dominant RCA (group distal dominant RCA), and 18 patients with culprit lesions in dominant LCx (group dominant LCx) were compared.

Results: There were no significant differences among the 3 groups in the prevalence regarding an S/R ratio greater than 1:3 in aVL, ST elevation in aVR ($ST_{aVR}^{\uparrow}$), ST depression in aVR ($ST_{aVR}^{\downarrow}$) of 1 mm or more, and atrioventricular block. Greater ST elevation in lead III than in II and greater ST depression in aVL than I showed specificity of 17% and 44% to identify dominant RCA as culprit lesion, respectively. All 3 groups could be distinguished on the basis of $ST_{V4R}^{\uparrow}$, $ST_{V4R}^{\downarrow}$, $ST_{V3}^{\downarrow}/ST_{III}^{\uparrow}$ of 1.2 or less, and $ST_{V3}^{\downarrow}/ST_{III}^{\uparrow}$ of more than 1.2.

Conclusions: Greater ST elevation in lead III than in II, greater ST depression in aVL than I, and an S/R ratio of greater than 1:3 in aVL were not useful to discriminate between dominant RCA and dominant LCx occlusion-related inferior AMI. ST-segment deviation in lead V_{4R} and the ratio of $ST_{V3}^{\downarrow}/ST_{III}^{\uparrow}$ were useful in predicting the dominant artery occlusion-related inferior AMI.

© 2009 Elsevier Inc. All rights reserved.

Keywords:

Electrocardiography; Occlusion; Myocardial infarction

Introduction

Inferior acute myocardial infarction (AMI), which accounts for 40% to 50% of all AMIs, can be caused by the occlusion of either the right coronary artery (RCA) or the left circumflex coronary artery (LCx) (the infarct-related artery [IRA]).¹ Timely identification of IRA and even the

location of the culprit lesion within the IRA, using electrocardiography, is important because the electrocardiogram (ECG) from the acute phase could provide clinically important information to augment decision making, tailor reperfusion therapy, and early risk stratification. Previous studies^{2–11} have proposed ECG criteria in identifying the IRA after inferior AMI. Several criteria implicate the RCA as the IRA including (1) greater ST elevation in lead III than in II ($ST_{III}^{\uparrow} > ST_{II}^{\uparrow}$), (2) greater ST depression in aVL than I ($ST_{aVL}^{\downarrow} > ST_I^{\downarrow}$), (3) an S/R ratio of greater than 1:3 in aVL, and (4) $ST_{V4R}^{\uparrow}$. Criteria implicating the LCx as the IRA include (1) $ST_{III}^{\uparrow} < ST_{II}^{\uparrow}$, (2) no $ST_{aVL}^{\downarrow}$, (3) an S/R ratio of 1:3 or less in aVL, and (4) ratio of $ST_{V3}^{\downarrow}$ to $ST_{III}^{\uparrow}$ is greater

[☆] No conflicts of interests were found.

^{☆☆} This study was funded by Hubei Provincial Department of Education (No. B20082407), Wuhan, China.

* Corresponding author. Department of Cardiology, Shiyen TaiHe Hospital, Yunyang Medical College, Shiyen, Hubei Province, China.

E-mail address: zzqun21@yahoo.com.cn

than 1.2. These ECG criteria reflect that most patients are of dominant RCA. Dominant LCx-related AMI results in a high proportion of patients with cardiogenic shock, as well as a high mortality rate.^{12,13} Early recognition and faster primary percutaneous coronary intervention (PCI) may decrease the mortality rate. Because of absence of reports regarding the ECG characteristics of a dominant LCx occlusion-related inferior AMI, we analyzed the ECG characteristics of dominant LCx occlusion in patients with first inferior AMI who were referred for primary PCI.

Methods

Patients

From January 2004 to October 2008, 755 consecutive patients in total admitted to the coronary care unit of Shiyuan TaiHe hospital with ST elevation AMI, in which, 382 patients with the diagnosis of *inferior AMI*, which was defined as chest pain lasting more than 30 minutes accompanied by ST $\uparrow$ of 1.0 mm or more in 2 or more inferior leads (II, III, or aVF) and a transient increase in cardiac enzymes to more than 2-fold the normal laboratory value. One hundred thirty-five patients, including 84 men and 51 women, whose mean age was 60 ± 12 years, fulfilled the following inclusion criteria: (1) first myocardial infarction, (2) having the standard 12-lead and the right chest lead (V₃R, V₄R, or V₅R) and the posterior lead (V₇, V₈, or V₉)

Table 1
Clinical and angiographic characteristics based of study patients

	Group proximal dominant RCA (n = 55)	Group distal dominant RCA (n = 62)	Group dominant LCx (n = 18)
Sex (male-female)	35:20	38:24	11:7
Age (y)	59 ± 11	61 ± 12	60 ± 12
Time to ECG (h)	5.0 ± 3.5	5.1 ± 3.0	4.8 ± 2.8
Previous angina	30 (54.5%)	29 (46.8%)	9 (50.0%)
Nondominant LCx or RCA stenosis $\geq 50\%$	5 (9.1%)	5 (8.1%)	2 (11.1%)
LM stenosis $\geq 50\%$	3 (5.5%)	3 (4.8%)	1 (5.6%)
LAD stenosis $\geq 50\%$	11 (20.0%)	12 (19.4%)	4 (22.2%)
TIMI flow grade 0/1/2/3	49/3/3/0	53/5/3/1	15/1/1/1
Rentrop grade 0/1/2/3	33/20/2/0	36/24/2/0	10/7/1/0
Killip class I/II/III/IV	19/15/11/10	26/17/11/8	2/3/7/6*
In-hospital death	5 (9.1%)	4 (6.5%)	5 (27.7%)*
Intraaortic balloon pump	12 (21.8%)	11 (17.7%)	9 (50.0%)*,**
Procedural unsuccessful reperfusion	5 (9.1%)	6 (9.7%)	2 (11.1%)
Glycoprotein IIb/IIIa inhibitors	49 (89.1%)	52 (83.9%)	16 (88.9%)

Time to ECG indicates time from onset of chest pain to recording of the ECG; LM, left main coronary artery; TIMI, thrombolysis in myocardial infarction; Rentrop grade, Rentrop collateral flow grade.¹⁴ *Procedural unsuccessful reperfusion* is defined as TIMI flow of 2 or less. Data are expressed as mean $\pm$ SD for continuous variables and as n (%) or ratio for categorical variables.

* $P < .05$ vs group distal dominant RCA.

** $P < .05$ vs group proximal dominant RCA.

Table 2

Relationship between ECG changes and IRA

ST-segment finding and lead	IRA		
	Group proximal dominant RCA (n = 55)	Group distal dominant RCA (n = 62)	Group dominant LCx (n = 18)
ST $\uparrow$ _{III} > ST $\uparrow$ _{II}	54 (98.2%)	61 (98.4%)	15 (83.3%)*,†
ST $\uparrow$ _{III} = ST $\uparrow$ _{II}	1 (1.8%)	1 (1.6%)	3 (16.7%)*,†
ST $\downarrow$ _{aVL} > ST $\downarrow$ _I	49 (89.1%)	55 (88.7%)	10 (55.6%)*,††
ST $\downarrow$ _{aVL} = ST $\downarrow$ _I	1 (1.8%)	2 (3.2%)	0 (0%)
Isoelectric I	5 (9.1%)	5 (8.1%)	5 (27.8%)
combined with ST $\downarrow$ _{aVL}			
ST $\uparrow$ _I combined with ST $\downarrow$ _{aVL}	0 (0%)	0 (0%)	3 (16.7%)*,††
S/R-wave ratio > 1:3	54 (98.2%)	61 (98.4%)	16 (88.9%)
ST $\uparrow$ _{V7-V9} ≥ 0.5 mm	48 (87.3%)	55 (88.7%)	17 (94.4%)
ST $\uparrow$ _{V4R}	52 (94.5%)	25 (40.3%)*	0 (0%)*,††
ST $\downarrow$ _{V4R}	0 (0%)	20 (32.3%)*	16 (88.9%)*,††
ST $\uparrow$ _{aVR}	7 (12.7%)	9 (14.5%)	4 (22.2%)
ST $\downarrow$ _{aVR} ≥ 1 mm	32 (58.2%)	41 (66.1%)	12 (66.7%)
ST $\uparrow$ _{V6} ≥ 1 mm	16 (29.1%)	18 (29.0%)	6 (33.3%)
ST $\uparrow$ _{V1} > ST $\uparrow$ _{V2}	1 (1.8%)	0 (0%)	0 (0%)
No ST $\downarrow$ _{V1} combined with ST $\downarrow$ _{V2}	10 (18.2%)	0 (0%)*	0 (0%)*
ST $\downarrow$ _{V3} /ST $\uparrow$ _{III} ≤ 1.2	55 (100%)	51 (82.3%)*	1 (5.6%)*,††
ST $\downarrow$ _{V3} /ST $\uparrow$ _{III} > 1.2	0 (0%)	11 (17.7%)*	17 (94.4%)*,††
AVB	12 (21.2%)	13 (21.0%)	5 (27.8%)

ST $\uparrow$ _X indicates ST-segment elevation in lead X; ST $\downarrow$ _X, ST-segment depression in lead X; no ST $\downarrow$ _{V1}, ST $\uparrow$ _{V1} or isoelectric V₁; AVB, atrioventricular block.

* $P < .05$ vs group proximal dominant RCA.

† $P < .05$ vs group distal dominant RCA.

** $P < .01$ vs group proximal dominant RCA.

†† $P < .01$ vs group distal dominant RCA.

* $P < .01$ vs group proximal dominant RCA.

ECG before start of reperfusion therapy, (3) all patients underwent coronary angiography within 12 hours after the onset of symptoms for primary PCI, and (4) the IRA was dominant RCA or dominant LCx. Patients with complete left bundle branch block and ECG signs of an *old myocardial infarction* (defined as abnormal Q waves in standard 12-lead ECG or in V₇-V₉) were excluded. Each patient provided informed consent before study.

Electrocardiogram

In the acute phase, the standard 12-lead and the right chest leads (V₃R, V₄R, or V₅R) and the posterior lead (V₇, V $\uparrow$, or V₉) ECG recorded on admission of all patients, using a paper speed of 25 mm/s and a standardization of 1 mV/10 mm, was analyzed by 2 investigators who were blinded to coronary angiography findings. Electrocardiograms were recorded using Cardiofax ECG-9130K or ECG-9020P machine, Nihon Kohden Cooperation, Tokyo, Japan, which all meet the international standard. Any disagreement between the investigators was resolved by consensus. The TP segment was used as the isoelectric line; the PR segment was used when the P wave and the T wave merged; and the RR segment was used when the ECG represented with atrial fibrillation. The J point was determined for each lead independently. Both ST $\uparrow$ and ST $\downarrow$ were measured at the J point in all leads.

Table 3

Sensitivity, specificity, and accuracy of different ECG criteria for predicting the site of coronary artery occlusion

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
$ST_{III} > ST_{II}$ predicts dominant RCA occlusion	98	17	88	60
$ST_{aVL} > ST_{I}$ predicts dominant LCx occlusion	89	44	91	38
ST_{V4R} predicts dominant RCA occlusion proximal to the RV branch	95	69	68	95
ST_{V4R} predicts dominant LCx occlusion	89	83	44	98
$ST_{V3}/ST_{III} \leq 1.2$ predicts dominant RCA occlusion	91	94	99	61
$ST_{V3}/ST_{III} > 1.2$ predicts dominant LCx occlusion	94	91	61	99

PPV indicates positive predictive value; NPV, negative predictive value.

Coronary angiography

The *infarct-related artery* was defined as the most severe and/or that lesion with local dissection or thrombus. The infarct-related artery was considered dominant when both the posterior descending artery (PDA) and posterolateral artery (PLA) arose from the IRA, and the non-IRA (either RCA or LCx) was very small size and supplied neither PDA nor PLA. The films were interpreted by 2 experienced

angiographers without knowledge of the ECG findings. In case of a discrepancy, a third investigator reviewed the coronary angiography. Patients were classified into 3 groups according to the site of coronary artery occlusion documented by coronary angiography as follows: group proximal dominant RCA, a site proximal to the origin of the first major right ventricular (RV) branch of the RCA ($n = 55$); group distal dominant RCA, a site distal to the origin of the first major RV branch of the RCA ($n = 62$); and group dominant LCx ($n = 18$).

Statistics

All data were analyzed by SPSS 11.0 for Windows (SPSS Inc, Chicago, IL). Data were expressed as mean $\pm$ SD for continuous variables and as rates (%) for categorical variables. For comparison of continuous variables, the analysis of variance was used. For comparison of categorical variables, the χ^2 test or the Fisher exact test was used. A probability value of less than .05 was considered statistically significant.

Results

Demography and clinical data

The 3 groups were comparable with regard to baseline characteristics, with the exception of adverse hemodynamic presentations, which was a higher proportion Killip class III and IV in the dominant LCx group as follows: 13 (72%) of

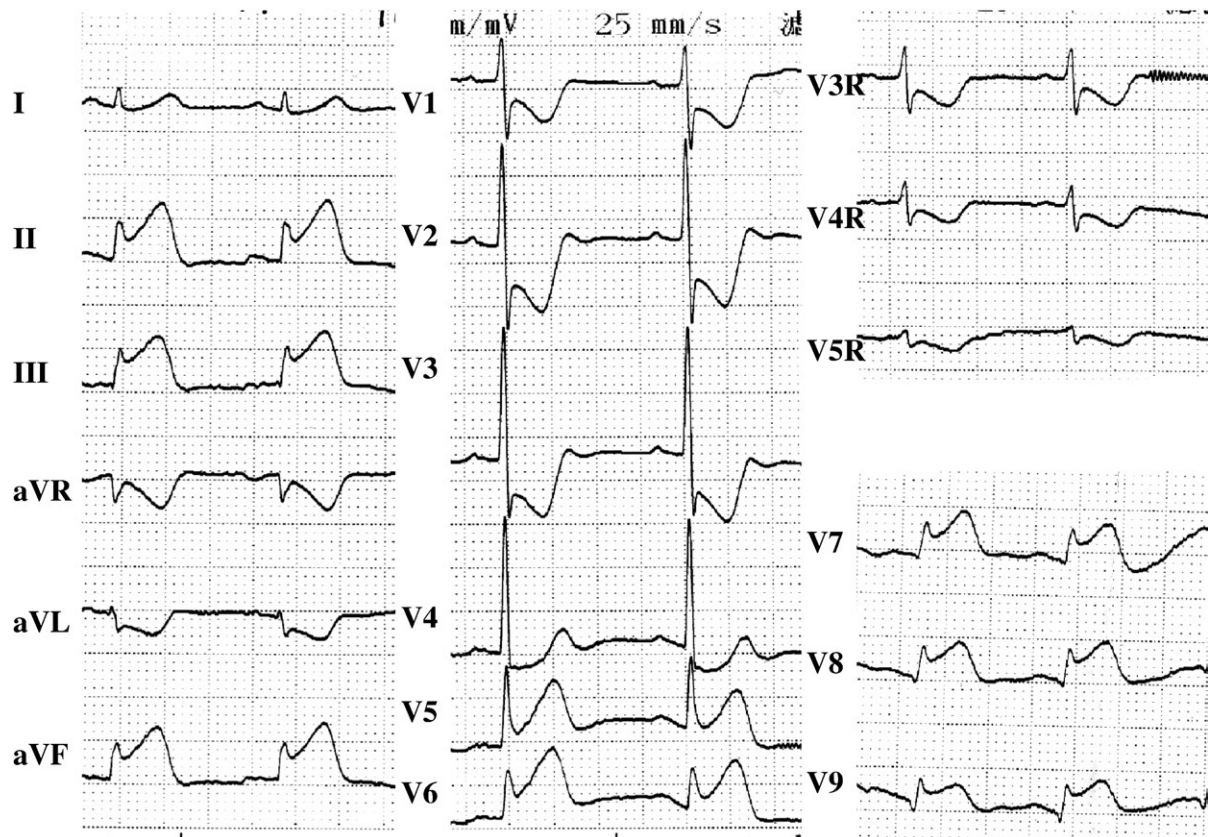


Fig. 1. Electrocardiogram of a patient with an inferior AMI as a consequence of dominant LCx occlusion, showing $ST_{III} > ST_{II}$, $ST_{aVL} > ST_{I}$, an S/R ratio of greater than 1:3 in aVL and $ST_{aVR} = 1$ mm. The degree of ST_{V3} is 4.0 mm. The degree of ST_{III} is 3.0 mm. The ST_{V3}/ST_{III} ratio is 1.3. Lead V_{4R} shows ST depression.

18 patients vs 21 (38%) of 55 patients in the proximal dominant RCA group ($P < .05$) and 21 (31%) of 62 patients in the distal dominant RCA group ($P < .01$). Angiographic and procedural characteristics were similar among the 3 groups, with the exception of need for insertion of intraaortic balloon pump, which was more frequently used in the dominant LCx group as follows: 9 (50%) of 18 patients vs 12 (22%) of 55 patients in the proximal dominant RCA group ($P < .05$) and 11 (18%) of 62 patients in the distal dominant RCA group ($P < .05$). There was a significantly higher mortality rate in the dominant LCx group than the distal dominant RCA group (28% vs 6.5%; $P < .05$) (Table 1).

Electrocardiographic findings

Of the 18 patients with dominant LCx occlusions related inferior AMI, there were 8 culprit lesions proximal to the first obtuse marginal branch (OM1) and 10 culprit lesions distal to OM1, but there were no significant ECG differences between the 2 subgroups. Therefore, we did not divide the group dominant LCx into 2 subgroups.

There were no significant differences among the 3 groups in the prevalence regarding to S/R ratio of greater than 1:3 in aVL, $ST\uparrow_{aVR}$, $ST\downarrow_{aVR}$ of 1 mm or more, $ST\uparrow_{V6}$ of 1 mm or more, $ST\uparrow_{V7-V9}$ of 0.5 mm or more, and atrioventricular block. Greater ST elevation in lead III than in II was slightly more prevalent in dominant RCA than in dominant LCx-associated inferior AMI ($P < .05$), but $ST\uparrow_{III} > ST\uparrow_{II}$ showed low specificity (17%) to identify dominant RCA as culprit lesion. Greater ST depression in aVL than I was more prevalent in dominant RCA than in dominant LCx-associated inferior AMI ($P < .01$), but $ST\downarrow_{aVL} > ST\downarrow_I$ showed low specificity (44%) to identify dominant RCA as culprit lesion. All 3 groups could be distinguished on the basis of $ST\uparrow_{V4R}$, $ST\downarrow_{V4R}$, $ST\downarrow_{V3}/ST\uparrow_{III}$ of 1.2 or less, and $ST\downarrow_{V3}/ST\uparrow_{III}$ of greater 1.2. ST elevation in I combined with $ST\downarrow_{aVL}$ was associated with dominant LCx involvement ($P < .01$). ST elevation in V_1 or isoelectric V_1 combined with $ST\downarrow_{V2}$ was associated with proximal dominant RCA involvement ($P < .01$); $ST\uparrow_{III} = ST\uparrow_{II}$ was associated with dominant LCx involvement ($P < .05$). ST elevation in V_4R identified proximal dominant RCA occlusion, $ST\downarrow_{V4R}$ identified dominant LCx occlusion, $ST\downarrow_{V3}/ST\uparrow_{III}$ of 1.2 or

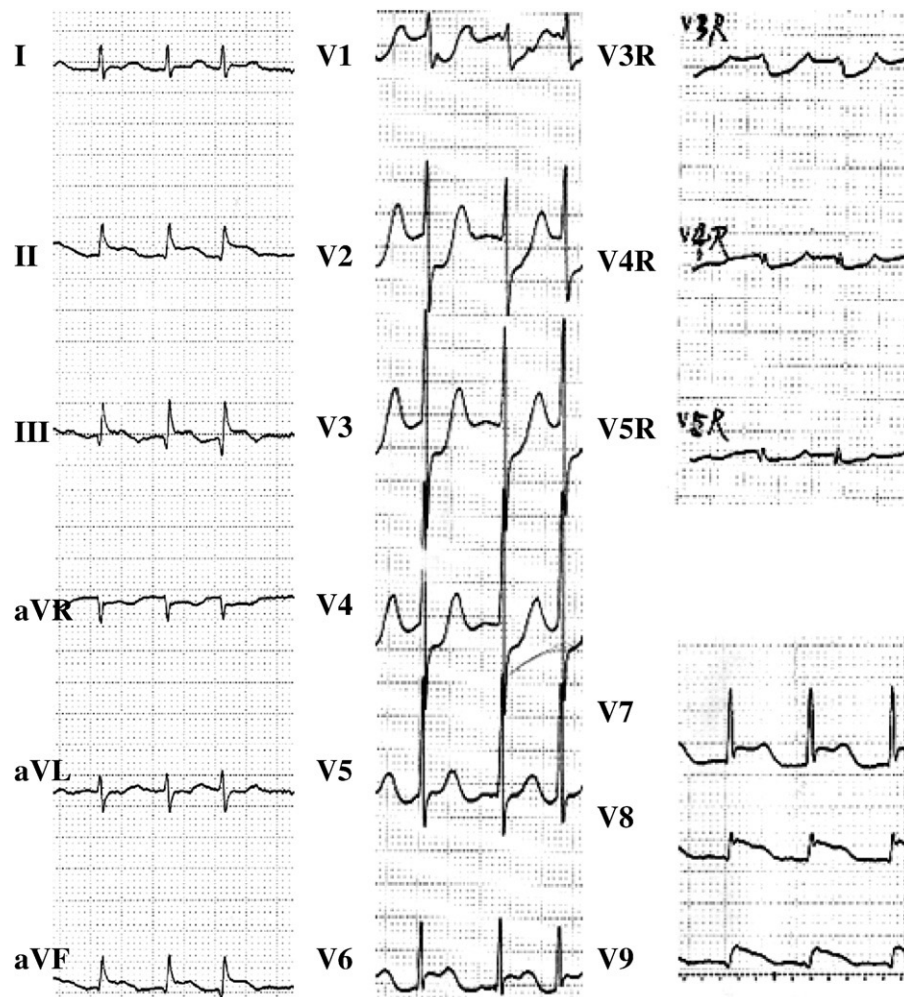


Fig. 2. Electrocardiogram of a patient with an inferior AMI as a consequence of dominant LCx occlusion, showing $ST\uparrow_{III} = ST\uparrow_{II}$, isoelectric I and $ST\downarrow_{aVL}$, an S/R ratio of greater than 1:3 in aVL and $ST\downarrow_{aVR} > 1$ mm. The degree of $ST\downarrow_{V3}$ is 5.0 mm. The degree of $ST\uparrow_{III}$ is 1.25mm. The $ST\downarrow_{V3}/ST\uparrow_{III}$ ratio is 4.0. Lead V_4R shows ST depression.

less identified dominant RCA occlusion, and $ST\downarrow_{V3}/ST\uparrow_{III}$ of greater than 1.2 identified dominant LCx occlusion with sensitivity of 95%, 89%, 91%, and 94%, respectively, and specificity of 69%, 83%, 94%, and 91%, respectively (Tables 2, 3, and Figs. 1–5).

Discussion

Poor outcome was observed in the dominant LCx-related inferior AMI patients despite a high rate of procedural success reperfusion and use of intraaortic balloon pump, which was in accordance with the previous studies.^{12,13}

Greater ST elevation in lead III than in II has been shown to indicate RCA-related inferior AMI.^{2,3} Additional limb leads criteria involve careful analysis of leads I and aVL. Patients with LCx-related inferior AMI less frequently show reciprocal ST depression in lead aVL and more often show an isoelectric or a raised ST segment in leads I and aVL compared to patients with RCA-related inferior AMI.^{4,5} Hasdai et al⁶ reported that absence of reciprocal ST depression in lead aVL indicates injury of the anterosuperior base of the heart typically caused by LCx occlusion proximal to the first obtuse marginal branch. Greater ST depression in

aVL than I suggests an RCA-related inferior AMI.⁵ Assali et al⁷ found that a decrease in R-wave amplitude and an increase in S-wave amplitude with an S/R ratio of greater than 1:3 in lead aVL predicted RCA occlusion, whereas an S/R ratio of 1:3 or less predicted LCx occlusion. In the initial stages, leads facing an infarcted wall with ST elevation tend to show QRS changes as well, including an increase in R-wave amplitude and a decrease in S-wave amplitude.^{15,16} Therefore, in inferior AMI, the opposite pattern (is, decrease in R wave and increase in S wave) would be expected in lead aVL, if there is no involvement of the high posterolateral region (RCA infarction). In contrast, if there is concomitant involvement of the high posterolateral segments (as expected in LCx infarction), these reciprocal changes in the QRS may not be apparent. But in this dominant IRA-related inferior AMI, the criteria mentioned above were not useful to discriminate dominant RCA from dominant LCx occlusion. Although $ST\uparrow_{III} > ST\uparrow_{II}$ was slightly more prevalent in dominant RCA than in dominant LCx-associated inferior AMI, group dominant LCx contained 83% patients representing $ST\uparrow_{III} > ST\uparrow_{II}$.

For the dominant RCA occlusion-related inferior AMI, both PDA and PLA arose from the RCA, resulting in (1)

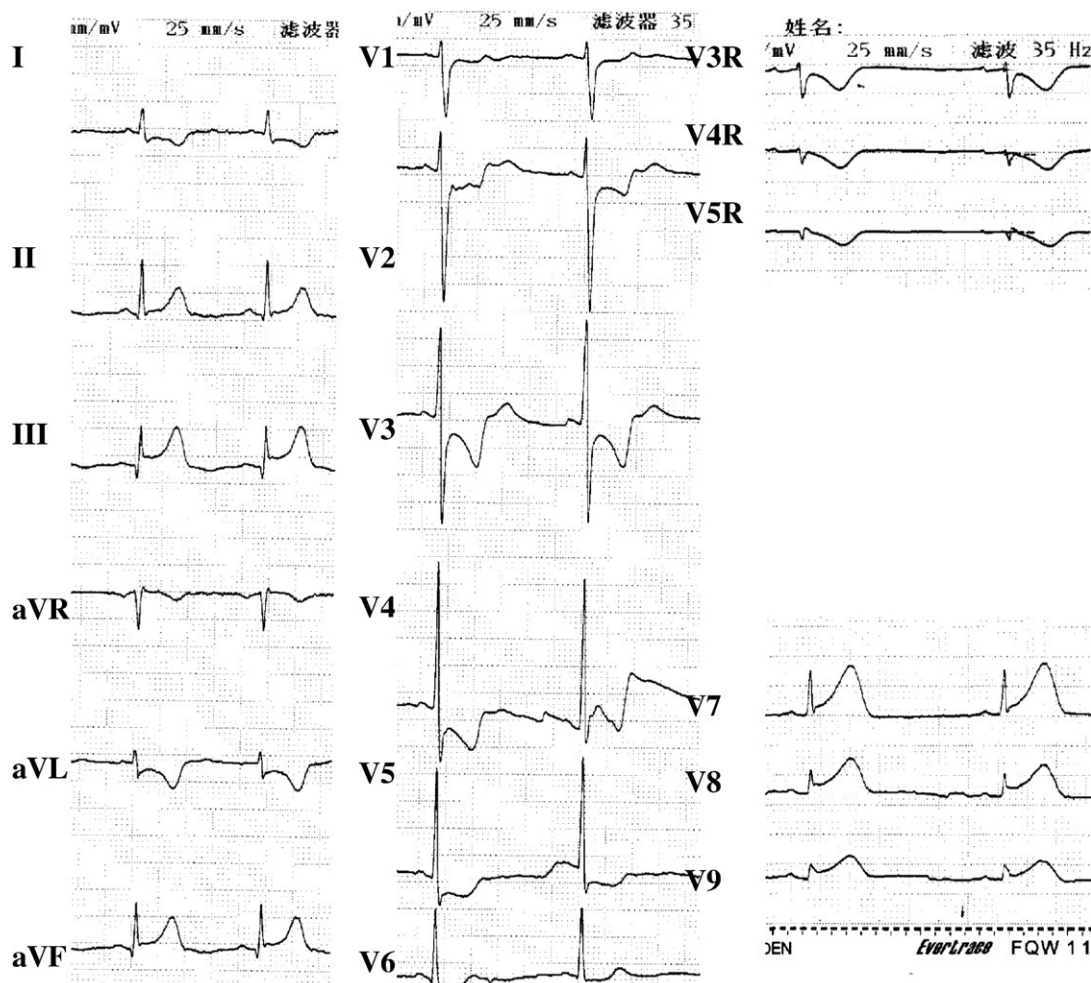


Fig. 3. Electrocardiogram of a patient with an inferior AMI as a consequence of dominant LCx occlusion and with stenosis of 80% at the LAD proximal to first septal perforator, showing $ST\uparrow_{III} > ST\uparrow_{II}$, $ST\downarrow_{aVL} > ST\downarrow_I$, an S/R ratio of greater than 1:3 in aVL, and $ST\uparrow_{aVR}$. The degree of $ST\downarrow_{V3}$ is 3.0 mm. The degree of $ST\uparrow_{III}$ is 1.5 mm. The $ST\downarrow_{V3}/ST\uparrow_{III}$ ratio is 2.0. Lead V_{4R} shows ST depression.

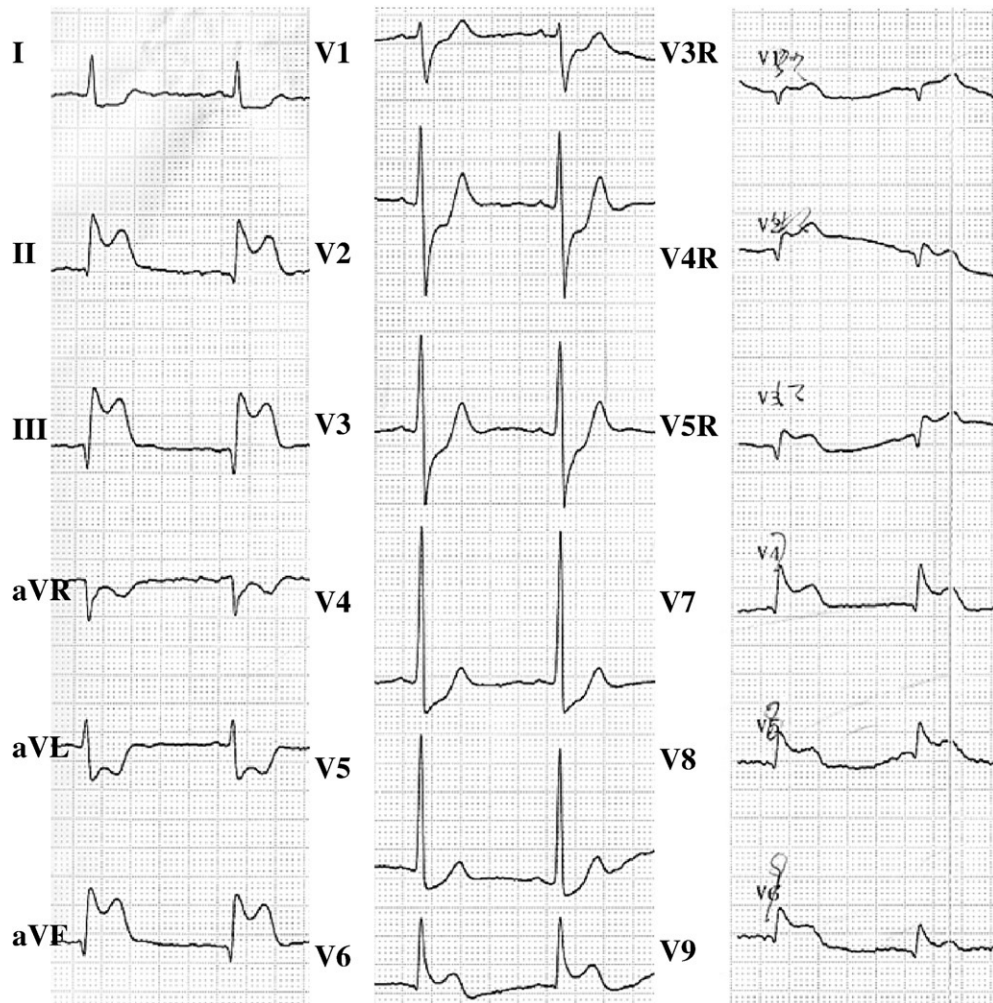


Fig. 4. Electrocardiogram of a patient with an inferior AMI as a consequence of dominant proximal RCA occlusion, showing $ST\uparrow_{III} > ST\uparrow_{II}$, $ST\downarrow_{aVL} > ST\downarrow_I$, an S/R ratio of greater than 1:3 in aVL and $ST\downarrow_{aVR} > 1$ mm. The degree of $ST\downarrow_{V3}$ is 4.0 mm. The degree of $ST\uparrow_{III}$ is 5.0 mm. The $ST\downarrow_{V3}/ST\uparrow_{III}$ ratio is 0.8. Lead V4R shows ST elevation.

$ST\uparrow_{III} > ST\uparrow_{II}$, (2) $ST\downarrow_{aVL} > ST\downarrow_I$, and (3) an S/R ratio of greater 1:3 in aVL. But for the dominant LCx occlusion-related inferior AMI, both the PDA and PLA also arose from the LCx, which could result in $ST\uparrow_{III} > ST\uparrow_{II}$. Lead aVL faces the superior or high lateral wall of the left ventricle that is not influenced by extension of the infarct to the posterior, apical or right ventricular regions, and lead aVL is the lead truly reciprocal to the inferior wall.^{6,17} However, concomitant high lateral ischemia due to involvement of a high marginal branch (proximal LCx obstruction) may induce $ST\uparrow$ in lateral limb leads. We can assume that lateral limb leads ST deviation in dominant LCx-related inferior AMI is caused by summing of $ST\downarrow$ due to reciprocal changes in inferior $ST\uparrow$ (especially $ST\uparrow_{III}$) and $ST\uparrow$ due to involvement of a high marginal branch. In this study, of the 18 patients with dominant LCx-related inferior AMI, 10 patients presented with $ST\downarrow_{aVL} > ST\downarrow_I$, and only 3 patients presented with $ST\uparrow_I$ and $ST\downarrow_{aVL}$. A likely explanation for this phenomenon was that $ST\downarrow_{aVL}$ due to reciprocal changes in inferior $ST\uparrow$ (especially $ST\uparrow_{III}$) was the dominating factor and $ST\uparrow_{aVL}$ due to involvement of a high marginal branch was the secondary factor because the lateral zone of the left

ventricular was supplied by the marginal branches from the proximal LCx and the diagonal branches from the left anterior descending coronary artery (LAD). Furthermore, distal occlusion of dominant LCx did not involve the lateral zone of the left ventricular wall. Probably, for these reasons, 89% of patients with dominant LCx occlusions presented with an S/R ratio of greater than 1:3 in aVL. Although $ST\downarrow_{aVL} > ST\downarrow_I$ was more prevalent in dominant RCA than in dominant LCx-associated inferior AMI, the group with dominant LCx contained 56% patients representing $ST\downarrow_{aVL} > ST\downarrow_I$.

There were no significant differences among the 3 groups in the prevalence regarding to $ST\uparrow_{aVR}$ and $ST\downarrow_{aVR}$ of 1 mm or more. About 60% patients in 3 groups presented with $ST\downarrow_{aVR}$ of 1 mm or more. Menown and Adgey¹⁸ reported that the display of lead aVR (-150°) in inverted format as lead $-aVR$ (-30°) bridges the gap between lead I (0°) and lead II (60°). ST depression in aVR might be a reciprocal change resulting from $ST\uparrow$ in the apical and posterior walls, which none of the standard 12 leads directly faces. For dominant RCA or dominant LCx-related inferior AMI, such regions of the left ventricle are

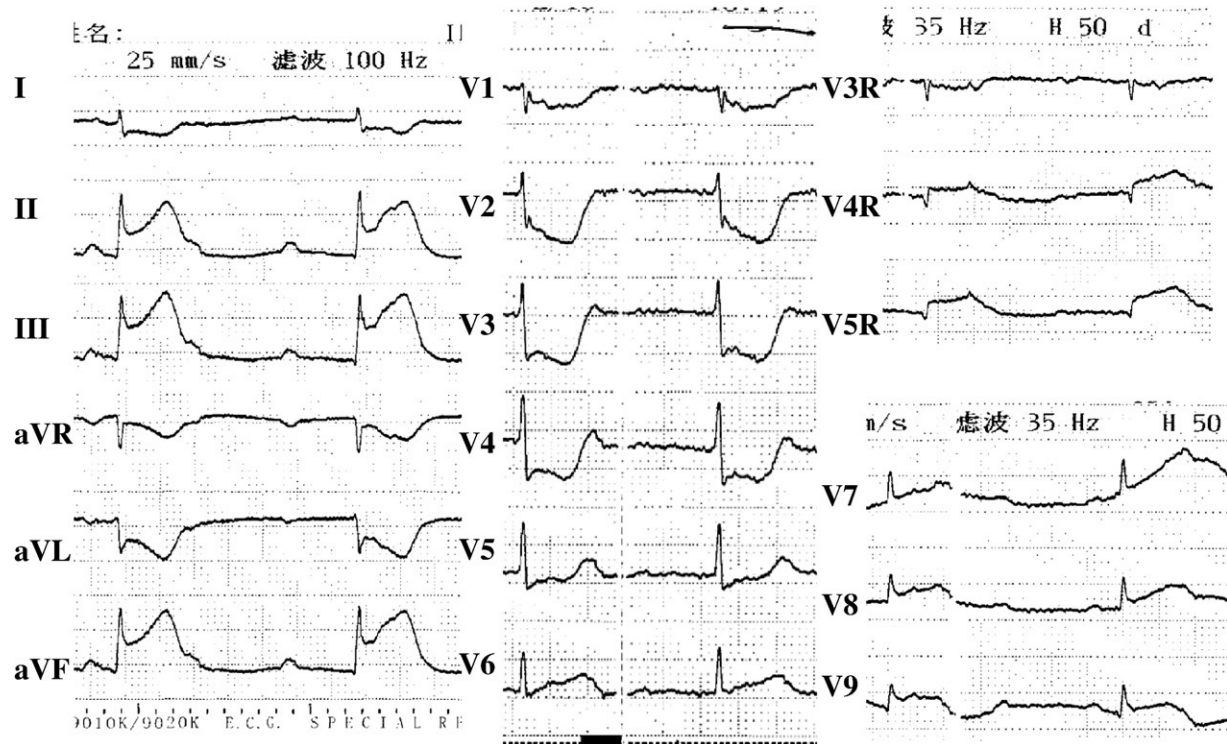


Fig. 5. Electrocardiogram of a patient with an inferior AMI as a consequence of dominant distal RCA occlusion, showing $ST\uparrow_{III} > ST\uparrow_{II}$, $ST\downarrow_{aVL} > ST\downarrow_I$, an S/R ratio of greater than 1:3 in aVL and $ST\downarrow_{aVR} > 1$ mm. The degree of $ST\downarrow_{V3}$ is 5.0 mm. The degree of $ST\uparrow_{III}$ is 5.0 mm. The $ST\downarrow_{V3}/ST\uparrow_{III}$ ratio is 1.0. Lead V4R shows ST elevation.

supplied by the large PLA. Therefore, concurrent $ST\downarrow_{aVR}$ during inferior AMI might reflect transmural ischemia extending to the apical and posterior wall in addition to the inferior wall, which could account for most study population representing with $ST\downarrow_{aVR}$ of 1 mm or more. Kosuge and his colleague¹⁹ conclude that the degree of ST-segment depression in lead aVR is a useful predictor of impaired myocardial reperfusion in patients who have experienced inferior AMI. Our angiographic observations demonstrated that most (95%) of these patients with dominant RCA or dominant LCx occlusion-related $ST\downarrow_{aVR}$ of 1 mm or more presented with reference lumen diameter of the IRA of 3.5 mm or more and usually contained high-burden thrombus formation, which usually represented impaired myocardial reperfusion.¹³ The number of $ST\uparrow_{aVR}$ in the 3 groups was 7 (12.7%) in group dominant proximal RCA, 9 (14.5%) in group dominant distal RCA, and 4 (22.2%) in group dominant LCx, respectively. Interestingly, 16 (80%) patients presented with $ST\uparrow_{aVR}$ had concomitant left main trunk stenosis more than 50% or LAD stenosis proximal to first septal perforator more than 75%, which was possibly the main reason why these patients presented with $ST\uparrow_{aVR}$ (see Fig. 3).²⁰

Because the major first RV branch originates from the proximal RCA, criteria for RV infarction, especially $ST\uparrow_{V3R}$ and $ST\uparrow_{V4R}$, provide compelling evidence that the IRA in inferior AMI was the RCA. ST elevation in V4R identified proximal dominant RCA occlusion with sensitivity of 95% and specificity of 69%. In contrast, dominant LCx-related inferior AMI was suggested by observing

reciprocal $ST\downarrow_{V4R}$. ST depression in V4R identified dominant LCx occlusion with sensitivity of 89% and specificity of 83%. In distal RCA-related inferior AMI, the ST deviation in V4R lead is affected by summing of $ST\downarrow$ due to reciprocal changes $ST\uparrow$ in leads of II, III, aVF, V7 to V9, and $ST\uparrow$ due to involvement of RV branches other than the first RV branch. Therefore, there were 20 (32.3%) patients in distal dominant RCA-related inferior AMI presented with $ST\downarrow_{V4R}$.

Kosuge et al.⁸ reported that the magnitude of $ST\downarrow_{V3}$ relative to the $ST\uparrow_{III}$ ($ST\downarrow_{V3}/ST\uparrow_{III}$) was useful in distinguishing the culprit artery in inferior AMI. These investigators found that $ST\downarrow_{V3}/ST\uparrow_{III}$ of less than 0.5 indicated a proximal RCA occlusion; an $ST\downarrow_{V3}/ST\uparrow_{III}$ of 0.5 to 1.2 indicated a distal RCA occlusion; and a $ST\downarrow_{V3}/ST\uparrow_{III}$ of more than 1.2 indicated an LCx occlusion.⁸ The cutoff value of 1.2 can be chosen to discriminate between RCA and LCx occlusion in patients with inferior AMI. In this study, $ST\downarrow_{V3}/ST\uparrow_{III}$ of 1.2 or less identified dominant RCA occlusion, and $ST\downarrow_{V3}/ST\uparrow_{III}$ of more than 1.2 identified dominant LCx occlusion with the sensitivity of 91% and 94%, respectively, and the specificity of 94% and 91%, respectively.

ST segment in lead V1 may be elevated or isoelectric when proximal dominant RCA is occluded because it is influenced by the current of injury from RV infarction and the reciprocal changes in posterior leads and inferior leads. Therefore, $ST\uparrow_{V1}$ or isoelectric V1 combined with $ST\downarrow_{V2}$ was a feature when proximal dominant RCA occlusion is involved ($P < .01$).

Conclusions and clinical significance

In patients with dominant RCA or dominant LCx occlusion-related inferior AMI, $ST\uparrow_{III} > ST\uparrow_{II}$, $ST\downarrow_{aVL} > ST\downarrow_{I}$, and an S/R ratio of greater than 1:3 in aVL were not useful to discriminate between RCA and LCx occlusion. ST-segment deviation in lead V₄R and the ratio of $ST\downarrow_{V3}$ to $ST\uparrow_{III}$ were useful in predicting the dominant culprit artery in inferior AMI. We consider our findings useful to discriminate between dominant RCA and dominant LCx occlusion in patients with inferior AMI who need a more aggressive approach to shorten door-to-reperfusion time and improve patient outcomes. As was disclosed in this study, ST-segment deviation in lead V₄R is useful in predicting the site of dominant artery occlusion-related inferior AMI. Hence, if conditions permitting a 12-lead ECG with right chest leads should be a routine part of the evaluation of inferior AMI to determine the site of dominant artery occlusion-related inferior AMI. When $ST\uparrow_{III} > ST\uparrow_{II}$, dominant LCx could be considered as the IRA if the ratio of $ST\downarrow_{V3}$ to $ST\uparrow_{III}$ is greater than 1.2, or lead V₄R shows ST depression.

Study limitations

In this study, 382 consecutive patients with inferior AMI admitted to the coronary care unit during the study period. Coronary angiography was performed on 216 patients in acute phase and 135 patients fulfilled the inclusion criteria. Fifty-two patients were excluded due to nondominant coronary artery-related inferior AMI, and 29 patients were excluded due to missing additional leads (9 patients) or other exclusion criteria (20 patients). There were some patients with inferior AMI, who died in the emergency department, and these are not included in the population of 382 patients. Possibly, there are patients with acute LCx occlusion, who present with other ECG manifestations than inferior AMI.²¹ Therefore, the patients studied represent a selected population. We could not conclude that dominant LCx occlusion-related AMI all represent inferior AMI. The incidence of LCx-related AMI is lower than either RCA or LAD infarct-related AMI, especially for dominant LCx-related inferior AMI. The number of the dominant LCx-related inferior AMI patients studied was limited, which was possibly the reason why no significant ECG differences between 8 patients with the occlusion proximal to OM1 and 10 patients distal of OM1-related inferior AMI. It could be worthwhile in future studies to observe the ECG differences between the 2 subgroups.

References

- Bairey CN, Shah PK, Lew AS, Hulse S. 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.
- Zimetbaum PJ, Krishnan S, Gold A, Carrozza II JP, Josephson ME. Usefulness of ST-segment elevation in lead III exceeding that of lead II for identifying the location of the totally occluded coronary artery in inferior wall myocardial infarction. *Am J Cardiol* 1998;81:918.
- Chia BL, Yip JW, Tan HC, Lim YT. 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.
- Kontos MC, Desai PV, Jesse RL, Ornato JP. Usefulness of the admission electrocardiogram for identifying the infarct-related artery in inferior wall acute myocardial infarction. *Am J Cardiol* 1997;79:182.
- Herz I, Assali AR, Adler Y, Solodky A, Sclarovsky S. New electrocardiographic criteria for predicting either the right or left circumflex artery as the culprit coronary artery in inferior wall acute myocardial infarction. *Am J Cardiol* 1997;80:1343.
- Hasdai D, Birnbaum Y, Herz I, Sclarovsky S, Mazur A, Solodky A. ST segment depression in lateral limb leads in inferior wall acute myocardial infarction. Implications regarding the culprit artery and the site of obstruction. *Eur Heart J* 1995;16:1549.
- Assali AR, Herz I, Vaturi M, Adler Y, Solodky A, Birnbaum Y, et al. Electrocardiographic criteria for predicting the culprit artery in inferior wall acute myocardial infarction. *Am J Cardiol* 1999;84:87.
- Kosuge M, Kimura K, Ishikawa T, Hongo Y, Mochida Y, Sugiyama M, et al. New electrocardiographic criteria for predicting the site of coronary artery occlusion in inferior wall acute myocardial infarction. *Am J Cardiol* 1998;82:1318.
- Braat SH, Brugada P, den Dulk K, van Ommen V, Wellens HJ. Value of lead V4R for recognition of the infarct coronary artery in acute inferior myocardial infarction. *Am J Cardiol* 1984;53:1538.
- Bayram E, Atalay C. Identification of the culprit artery involved in inferior wall acute myocardial infarction using electrocardiographic criteria. *J Int Med Res* 2004;32:39.
- Braat SH, Gorgels AP, Bar FW, Wellens HJ. Value of the ST-T segment in lead V4R in inferior wall acute myocardial infarction to predict the site of coronary arterial occlusion. *Am J Cardiol* 1988;62:140.
- Ilia R, Cafri C, Weinstein JM, Gueron M. Acute myocardial infarction due to occlusion of the dominant left circumflex artery proximally. *Am J Cardiol* 2003;92:54.
- Yip HK, Wu CJ, Fu M, Yeh KH, Yu TH, Hung WC, et al. Clinical features and outcome of patients with direct percutaneous coronary intervention for acute myocardial infarction resulting from left circumflex artery occlusion. *Chest* 2002;122:2068.
- Rentrop KP, Cohen M, Blanke H, Phillips RA. Changes in collateral channel filling immediately after controlled coronary artery occlusion by an angioplasty balloon in human subjects. *J Am Coll Cardiol* 1985;5:587.
- Birnbaum Y, Hale SL, Kloner RA. Changes in R wave amplitude: ECG differentiation between episodes of reocclusion and reperfusion associated with ST-segment elevation. *J Electrocardiol* 1997;30:211.
- Zhong-qun Z, Shu-yi D, Chong-quan W. Use of intramyocardial conduction delay during early transmural ischemia to interpret electrocardiograms. *J Electrocardiol* 2008;41:434.
- Birnbaum Y, Sclarovsky S, Mager A, Strasberg B, Rechavia E. ST segment depression in aVL: a sensitive marker for acute inferior myocardial infarction. *Eur Heart J* 1993;14:4.
- Menown IB, Adgey AA. Improving the ECG classification of inferior and lateral myocardial infarction by inversion of lead aVR. *Heart* 2000;83:657.
- Kosuge M, Kimura K, Ishikawa T, Ebina T, Hibi K, Toda N, et al. ST-segment depression in lead aVR: A useful predictor of impaired myocardial reperfusion in patients with inferior acute myocardial infarction. *Chest* 2005;128:780.
- Zhong-qun Z, Wei W, Chong-quan W, Shu-yi D, Chao-rong H, Jun-feng W. Acute anterior wall myocardial infarction entailing ST-segment elevation in lead V3R, V1 or aVR: electrocardiographic and angiographic correlations. *J Electrocardiol* 2008;41:329.
- Dunn RF, Newman HN, Bernstein L, Harris PJ, Roubin GS, Morris J, et al. The clinical features of isolated left circumflex coronary artery disease. *Circulation* 1984;69:477.