Electrocardiogram in patients with acute inferior myocardial infarction due to occlusion of circumflex artery

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Abstract
To investigate the diagnostic value of electrocardiographic (ECG) ST-segment in acute inferior myocardial infarction (AIMI) caused by the left circumflex branch (LCX).

A total of 240 clinical cases with AIMI in our hospital were retrospectively analyzed. All of them had received percutaneous coronary intervention (PCI) within 12 hours after symptom onset. The clinical features, ECG manifestations, and coronary artery lesion characteristics of the patients were collected.

The right coronary artery (RCA) was shown to be the infarct-related artery (IRA) in 177 patients, while LCX was responsible for AIMI in 63 cases. There was no significant difference in the risk factors of coronary heart disease (CHD) (P > .05 for all) between the 2 groups. ST-segment elevation in lead II, III, and AVF could be found in all patients. Moreover, ST-segment depression in lead I (STD I), ST-segment elevation in lead III (STE III), STE III-STE II, STE AVF, STD AVL, STD AVL-STD I and STE v6 lead ST-segment deviation exhibited significant difference in 2 groups (P < .05 for all). The changes of STD I, STE III < STE II, STD AVL < STD I could discriminate between LCX and RCA in AIMI patients with high sensitivity and specificity.

ECG may be an effective tool to predict the IRA in patient with AIMI.

Abbreviations: AIMI = acute inferior myocardial infarction, AMI = acute myocardial infarction, CAG = coronary angiography, CK-MB = MB iso-enzyme of creatine kinases, ECG = electrocardiographic, IRA = infarct-related artery, LCX = left circumflex branch, MI = myocardial infarction, NSTEMI = non-ST elevation MI, PCI = percutaneous coronary intervention, RCA = right coronary artery, STD = ST segment depression, STE = ST segment elevation, STEMI = ST elevation MI

Keywords: acute inferior myocardial infarction, electrocardiographic, infarct-related artery, left circumflex branch

1. Introduction
Acute myocardial infarction (AMI), commonly referred to as heart attack, is a type of coronary heart disease (CHD) that causes great mortality especially in industrialized countries.[1,2] Despite of the decreased mortality caused by AMI observed in high-income countries, the low- and middle-income countries still exhibit an increasing trend.[3,4] AMI is often caused by insufficient blood flow and oxygen supply to heart muscle owing to thrombosis, erosion, or rupture of the coronary atherosclerotic plaque.[5] Globally, there were a total of 8.6 million MI cases in the year of 2013.[6] MI can be divided into inferior, anterior, posterior, septal, and lateral. In addition, according to the ST elevation on the electrocardiogram (ECG), the myocardial infarctions (MIs) are commonly categorized into ST elevation MI (STEMI) and non-ST elevation MI (NSTEMI).[7] STEMI is characterized by poor oxygenation of the heart, ST segments elevation on ECG, and increased levels of proteins associated with heart muscle’s death in the blood, accounting for 25% to 40% of all cases.[8] Early diagnosis and timely treatments are pivotal for outcomes of patients suffering from STEMI. Therefore, initiating monitoring of ECG is necessary for patients with STEMI to improve the management of the disease.[9]

The occlusion of left circumflex branch (LCX) or right coronary artery (RCA) is the major reason for acute inferior myocardial infarction (AIMI). The infarct-related artery (IRA) of AIMI can significantly influence the disease progression of AIMI patients.[10] When RCA shown to be the IRA, the patients often undergo right ventricular infarction, intermittent cardiac pacing, as well as severe hemodynamic complications, leading to shock, arrhythmias, and even death.[10-12] However, the prognosis for those with LCX occlusion is much better.[10] Unfortunately, the RCA shown to be the culprit artery in AIMI is much more common than the LCX.[13] In order to prevent and improve the adverse complications of AIMI, early identification of the IRA is required. Currently, coronary angiography has emerged as a gold standard for recognition of IRA among patients with AIMI. However, the procedures of conventional coronary angiography are invasive; moreover, the method shows difficulty in the selection of ostium of anomalous vessel, due to the lack of 3D information and unclear association of coronary arteries with great vessels.[14] Identification of IRA represents a great challenge for patients with AIMI.[13] In the 1980s, the ECG was introduced to solve this problem.[16] In the case of AIMI, there are ST elevations in leads II, III, and AVF, but the elevation level of
inferior leads caused by RCA and LCX are different owing to the different vector direction of ST elevations. Several previous studies have demonstrated that the ST segment changes in ECG could be used to identify the IRA in AMI. For example, according to the retrospective analysis of Datz et al., when chest lead ST segment elevated and II, III, and AVF lead ST segment elevated, the left anterior descending (LAD) branch distal occlusion could occur, and the specificity was 100%. In the study of Hertz et al. when inferior II lead ST-segment > III lead ST-segment and I lead ST-segment > AVL lead ST-segment, the positive predictive value of LCX occlusion was 100%.

Although changes of body surface 12-lead ECG play an important role in the diagnosis of MI and identification of IRA, it is difficult to diagnose AMI that is caused by left circumflex branch occlusion according to 12-lead ECG. This study, supported by coronary angiography, has confirmed the clinical features and ECG changes of AMI caused by different IRA, and aims to find out the ECG manifestations of patients whose IRA is the left circumflex branch.

2. Material and methods

2.1. Study subjects

This study was approved by the Ethics Committee of Beijing Tiantan Hospital. All the patients signed the informed consents. A retrospective clinical analysis was performed for 240 AMI patients admitted to the Department of Cardiology in Beijing Tiantan Hospital from Jan 1, 2004 to Dec 31, 2004. The study subjects included 84 men and 156 women, with the average age of 60.6±11.2 years. The electrocardiographic data of the patients were available. They were divided into 2 groups (RCA group and LCX group) according to IRA. The patients collected in the current study should meet the following inclusion criteria: diagnostic criteria of ST-segment elevation myocardial infarction (STEMI): myocardial ischemic symptoms ≥20 minutes; ECG changes: new onset of 2 or 3 inferior leads including II, III, AVF; ST-segment elevation: ≥0.01 mV; cardiac markers increased over 99% of the normal value. Time from the onset of myocardial ischemia symptom to the ECG examination: ≤12 hours. The gold standard for diagnosis of IRA responsible for coronary artery diseases depended on the coronary angiogram within 12hours. First time attack STEMI. Coronary angiogram revealed that LCX or RCA was the only coronary artery lesion and IRA. Exclusion criteria: double or multivessel diseases; old myocardial infarction; left ventricular hypertrophy; complete left bundle branch block (LBBB) or complete right bundle branch block (RBBB); diseases that affected ST-segment deviation, such as pacing rhythm, pericarditis, early repolarization syndrome (ERS), AMI, variant angina, and hyperkalemia; data of ECG, clinic or cardioangiography were not complete; AMI caused by coronary flow interruption due to invasive diagnosis and treatment, or other diseases instead of atherosclerosis.

2.2. Information collection

The following information was collected from the clinical records of the patients: baseline data of the cases: sex, age, disease history (diabetes, high blood pressure, high cholesterol), smoking; laboratory tests: taking venous blood within 24 hours of admission to detect the peak of cardiac muscle creatine kinase isozyme (MB iso-enzyme of creatine kinases, CK-MB), coronary angiography (CAG), IRA judgment, and percutaneous coronary intervention (PCI).

2.3. Coronary angiography and intervention treatment

All patients were taken to diagnostic emergency CAG via a standard right femoral artery path (Judkins technique) or right radial artery path. Two experienced cardiologists were independently responsible for the interpretation of IRA. The coronary angiography was done according to the previous descriptions. In brief, only the patients with one occluded coronary artery were recruited. When the coronary artery recanalizes, the narrowest one is selected according to coronary angiography. We also had to see if there was filling defect or contrast agents retention in the narrow part. Standard techniques were used for PCI. All patients before intervention therapy were required chewing 300 mg aspirin and 300 mg clopidogrel. Intervention strategies, stents technology, selection of stents, and the use of hydrochloric were determined by the operator. Intervention treatment success: residual stenosis after stent implantation was less than 25% and forward flow was TIMI 3. After operation, all patients should take 100 mg of aspirin and 75 mg of clopidogrel one time a day for at least 12 months. All patients’ stents were drug-coated stents (DES).

2.4. Electrocardiogram (ECG)

Patients received electrocardiogram inspection immediately after admission or in the emergency room, with the paper speed being 25 mm/s and the standard voltage being 1 mm = 0.1 mV. The T-P was chosen as an equipotential lines. ST segment elevation: J point represented the ST segment, 80 ms after the J point was the measurement point of ST segment depression, ST segment depression ≥0.05 mV in a horizontal or oblique way was considered significant. Two cardiology attending physicians who were blind to the coronary angiography results separately analyzed the electrocardiographic tracings. If the results were inconsistent, the superior doctors were responsible for unifying the results.

2.5. Statistical analysis

The continuous variables were shown in x±s, and analyzed using student t test. χ2 or Fisher exact test were used for the analysis of the classified variables which were expressed as percentages. Predictive value of related lead electrocardiogram (ECG) on the LCX occlusion was analyzed according to the receiver-operating characteristic curve (ROC). All statistical analyses were performed using SPSS13.0 software (SPSS Inc., Chicago, IL). P values less than .05 were considered statistically significant.

3. Results

3.1. Baseline characteristics of the study population

According to coronary angiography, RCA was responsible for AMI in 177 patients, while LCX was shown to be the IRA in 63 patients. The detailed information of the 2 groups was listed in Table 1. The demographic characteristics such as age and sex were similar between the 2 groups (P > .05 for both). The risk factors for CHD, such as hypertension, diabetes, dyslipidemia, smoke, and CK-MB, were compared between RCA and LCX groups. The results suggested that the occurrence of the related risk factors did not show significant difference between the 2 study groups (P > .05 for all).
In addition, we also compared the electrocardiographic tracings between the 2 study groups. Analysis results demonstrated that ST-segment deviation, I, III–II, III, AVL, AVF, AVL-I, V1, V6 exhibited obvious difference between the 2 groups (all P < .05). However, ECG ST deviation, II, AVR, V2, V3, V4, and V5 showed similar between the 2 groups (all P > .05) (Table 1).

### 3.2. The predictive value of electrocardiogram on LCX occlusion

In the current study, ROC analysis was performed to evaluate the diagnostic value of ECG in AIMI caused by LCX. The ROC curves were plotted based on the data of ST segment in patients in LCX and RCA groups. Among the study population, the diagnostic sensitivity and specificity of I lead ST segment depression (STD) on LCX occlusion were 96.8% and 72.9%, respectively, with the area under the ROC curve (AUC) of 0.793 (95% CI = 0.735–0.851) (Fig. 1). As showed in the Fig. 2, ST segment elevation (STE) lead III < lead II might be used as a diagnostic indicator for LCX occlusion, with the AUC value of 0.799 (95% CI = 0.741–0.857), combing with the sensitivity and specificity of 93.7% and 66.1%, respectively. We also investigated the diagnostic value of STD in AVL < I. ROC curve demonstrated that the AUC value was 0.913 (95% CI = 0.864–0.963), suggesting its capacity to act as a diagnostic biomarker for LCX occlusion. The diagnostic sensitivity was 88.9%, and the specificity was 93.8% (Fig. 3).

### 4. Discussion

Previous researches had showed that in acute inferior wall myocardial infarction, the proportion of RCA and LCX was roughly between 2.2:1 and 7.0:1, with an average of 3.9:1.[25] This research showed that the proportion of RCA and LCX was 2.8:1, which was valuable for the diagnosis of STEMI caused by LCX occlusion combined multiple lead of ST segment deviation through the standard 12-lead electrocardiogram.

Chia et al.[26] study shows that ST segment elevation lead II > lead III or lead I ST segment having no depression is the diagnostic criteria of LCX occlusion. Chao et al.[27] study shows that when ST segment elevation (STE) lead III < lead II, lead AVL.
branch occluded, ST vector to the left side with an angle with lead AVL. As a result, ranges of ST segment change were smaller than the right coronary occlusion, and occlusion of the left circumflex branch can cause sidewall ischemic damage at the same time and side wall lead ST segment elevation. These two changes offset each other, and ECG showed that the range of STD AVL was lower than that of I lead, even elevated. The changes of ST segment of lead AVR had no statistical significance in 2 groups, which was not consistent with the results of Kanei et al.[25] study, which suggested STD AVR had some predictive value for LCX occlusion.

4.1. Study limitations

Although we proved the diagnostic value of ECG in IRA identification, there were still several limitations in the current study. First, as a single-center retrospective study, all selected cases were patients with acute inferior wall myocardial infarction admitted to our hospital, the selection bias might influence the final results. Furthermore, emergency death and patients who refused to accept the treatment were not included that might also increase the bias in the current study. Second, the analysis results might be limited by the relatively small sample size in the present research, and further investigations with larger sample size were required to identify the clinical significance of ECG in determination of IRA for AIMI patients.

5. Conclusion

I lead ST segment depression, II lead ST segment elevation > III lead, AVL lead ST segment depression < I lead exhibit predictive value for the occlusion of cyclotron branches, which can be used for identification IRA in patients with AIMI. This new method is simple, practical, and noninvasive, especially important for medical institutions that cannot carry out the coronary artery imaging technology and patients who are unwilling to undergo coronary angiography examination.

References

[1] White HD, Chew DP. Acute myocardial infarction. Lancet 2008;372: 570–84.
[2] Go AS, Mozaffarian D, Roger VL, et al. Executive summary: heart disease and stroke statistics—2014 update: a report from the American Heart Association. Circulation 2014;129:399–410.
[3] Roger VL, Go AS, Lloyd-Jones DM, et al. Executive summary: heart disease and stroke statistics—2012 update: a report from the American Heart Association. Circulation 2012;125:188–97.
[4] Mozaffarian D, Benjamin EJ, Go AS, et al. Heart disease and stroke statistics—2013 update: a report from the American Heart Association. Circulation 2013;127:e29–322.
[5] Libby P. Current concepts of the pathogenesis of the acute coronary syndromes. Circulation 2001;104:365–72.
[6] Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 2015;386:743–800.
[7] Moe KT, Wong P. Current trends in diagnostic biomarkers of acute coronary syndrome. Ann Acad Med Singapore 2010;39:210–5.
[8] O’Gara PT, Kushner FG, Ascheim DD, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation 2013;127: e362–423.
[9] Sog PJ, James SK, Atat D, et al. ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. Eur Heart J 2012;33:2569–419.
[10] Wen CY, Guo JC, Gao GW, et al. Significance of ST—segment elevation or depression in inferior wall acute myocardial infarction to predict the culprit artery. Pract J Card Cereb Pneumal Vasc Dis 2010;18:699–701.
Braat SH, de Zwaan C, Brugada P, et al. Right ventricular involvement with acute inferior wall myocardial infarction identifies high risk of developing atrioventricular nodal conduction disturbances. Am Heart J 1984;107:1183–7.

Zehender M, Kasper W, Kauder E, et al. Right ventricular infarction as an independent predictor of prognosis after acute inferior myocardial infarction. N Engl J Med 1993;328:981–3.

Bayram E, Atalay C. Identification of the culprit artery involved in inferior wall acute myocardial infarction using electrocardiographic criteria. J Int Med Res 2004;32:39–44.

Marchesini J, Campo G, Righi R, et al. Coronary artery anomalies presenting with ST-segment elevation myocardial infarction. Clin Pract 2011;1:107.

Assali AR, Herz I, Vaturi M, et al. Electrocardiographic criteria for predicting the culprit artery in inferior wall acute myocardial infarction. Am J Cardiol 1999;84:87–9. A88.

Andersen HR, Nielsen D, Falk E. Right ventricular infarction: diagnostic value of ST elevation in lead III exceeding that of lead II during inferior/posterior infarction and comparison with right-chest leads V3R to V7R. Am Heart J 1989;117:82–6.

Zimetbaum PJ, Krishnan S, Gold A, et al. 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 1999;81:918–9.

Misumi I, Shono H, Nakao K, et al. [Electrocardiographic discrimination of infarct-related artery between left circumflex and right coronary artery: comparison of ST elevation between leads II and III]. J Cardiol 2003;41:271–6.

Almansori M, Armstrong F, Fu Y, et al. Electrocardiographic identification of the culprit coronary artery in inferior wall ST elevation myocardial infarction. Can J Cardiol 2010;26:293–6.

Kosuge M, Kimura K, Ishikawa T, et al. New electrocardiographic criteria for predicting the site of coronary artery occlusion in inferior wall acute myocardial infarction. Am J Cardiol 1998;82:1138–22.

Fiol M, Cygankiewicz I, Carrillo A, et al. Value of electrocardiographic algorithm based on “ups and downs” of ST in assessment of a culprit artery in evolving inferior wall acute myocardial infarction. Am J Cardiol 2004;94:709–14.

Herz I, Assali AR, Adler Y, et al. 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;80:1343–5.

Martine-Dotz L, Armou MA, Almenar L, et al. Usefulness of the electrocardiogram in predicting the occlusion site in acute anterior myocardial infarction with isolated disease of the anterior descending coronary artery [J]. Rev Esp Cardiol 2002;55:1036–41.

Hertz I, Assali AR, Adler Y, et al. New electrocardiographic criteria for predicting either the right or left circumflex artery as the culprit coronary artery in inferior wall acute myocardial infarction [J]. Am J Cardiol 1997;80:1343–5.

Li Q, Cheng KA, Sun LX, et al. [Deviation of ST-segment and detection of infarction related artery in patients with acute inferior wall infarction]. Zhonghua yi xue za zhi 2011;91:1546–9.

Chao BL, Yip JW, Tan HC, et al. Usefulness of ST elevation II/III ratio and ST deviation in lead I for identifying the culprit artery in inferior wall acute myocardial infarction. Am J Cardiol 2000;86:341–3.

Chao WN, Sun JH, Liu YP. Relationship between electrocardiogram and infarct related artery in patients with acute inferior myocardial infarction. Chinese J Hemorheol 2010;20:226–7.

Noriega FJ, Vives-Borras M, Sole-Gonzalez E, et al. Influence of the extent of coronary atherosclerotic disease on ST-segment changes induced by ST elevation myocardial infarction. Am J Cardiol 2014;113:757–64.

Kanei Y, Sharma J, Diwan R, et al. ST-segment depression in aVR as a predictor of culprit artery and infarct size in acute inferior wall ST-segment elevation myocardial infarction. J Electrocardiol 2010;43:132–5.