

Clinical Features of Emergency Electrocardiography in Patients With Acute Myocardial Infarction Caused by Left Main Trunk Obstruction

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Background To diagnose left main trunk (LMT) infarction by 12-lead standard electrocardiogram (ECG) is an important emergency technique, but the features in LMT infarctions have not been clarified.

Methods and Results The study enrolled 140 subjects who were divided into 4 groups according to the location of the culprit artery: 35 with LMT, 35 with left anterior descending artery (LAD), 35 with right coronary artery and 35 with left circumflex artery. Various parameters obtained from the ECGs were analyzed. Average QTc interval (0.51 ± 0.06 s) in LMT group was markedly longer than that in the 3 other groups. Average QRS axis (-10 ± 77 degrees) in LMT infarction showed a remarkable left deviation. ST-segment elevation in lead aVR occurred in 28 patients (80.0%) in the LMT group. The ECG features of the LMT group could be classified into 2 main groups: right bundle branch block (RBBB) with a marked left axis deviation (RBBB + LADEV type) and ST-segment elevation in leads V₂₋₅, I and aVL without abnormal axis deviation (LAD type).

Conclusion Either ST-segment elevation in lead aVR and marked prolongation of both the QRS width and QTc interval with a prominent abnormal axis deviation or ST-segment elevation in the broad anterior precordial lead with a normal QRS axis strongly suggests LMT infarction. (Circ J 2006; 70: 525–529)

Key Words: Electrocardiography; Left main trunk; Myocardial infarction

Standard 12-lead electrocardiography (ECG) is the simplest examination for diagnosing acute myocardial infarctions (AMI) because generally the infarct area and the segments with ST elevation correspond well with each other; that is, for AMI of the left anterior descending artery (LAD), right coronary artery (RCA) and left circumflex artery (LCX), the specificity of ST segment elevation is more than 90%.¹⁻⁵

Recording the ECG in AMI is very useful for making a prompt and precise diagnosis of the culprit artery, but for left main trunk (LMT) infarction, it is sometimes difficult to obtain the characteristic ECG findings because lethal arrhythmias, such as ventricular fibrillation, or atrioventricular block with hemodynamic compromise often occurs. These unstable hemodynamics can lead to cardiac arrest before the patient arrives at the hospital and thus a poor prognosis. Consequently, it is important to diagnose LMT infarction from the ECG on admission and institute coro-

nary interventions, such as mechanical assistance by an intra-aortic balloon pump, or surgical treatment without any delay.

Some research has indicated that ST-segment elevation in lead aVR may indicate LMT infarction;⁵⁻⁷ but to the best of our knowledge, the ECG features in LMT infarction have not been fully described.

Methods

Study Population

The records of 2,190 patients admitted to Gifu University Hospital and its referral hospitals with AMI from 1988 to 2004 were retrospectively collected from the data bank and 140 were enrolled and divided into 4 equal groups according to the location of the culprit artery: LMT, LAD, RCA (#3 and #4 AV) and LCX (#13 and #14). All patients immediately underwent coronary angiography and the extent of stenosis was evaluated according to American Heart Association classification. Exclusion criteria were (1) prior Q-wave myocardial infarction (MI), (2) prior coronary artery bypass graft operation, and (3) inability to identify the culprit lesion as a result of severe stenosis in 2 or 3 vessels.^{2,3} A lesion was considered to be the culprit when it occluded or showed severe narrowing and ulceration with or without thrombus.

Standard 12-lead surface ECG (paper speed: 25 mm/s, calibration: 1 mV=10 mm) was recorded as soon as possible after admission and various parameters (heart rate (HR),

(Received November 8, 2005; revised manuscript received January 16, 2006; accepted February 8, 2006)

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Table 1 Patient Characteristics

	LMT	LAD	LCX	RCA
No. of patients	35	35	35	35
Age (years)	68±11	66±8	64±12	62±10
Gender (M/F)	23/12	23/12	9/26**	11/24**
Stenosis >90%	31/35	35/35	35/35	35/35
DM (%)	13/35	11/35	12/35	16/35
HT (%)	17/35	19/35	21/35	15/35
HL (%)	20/35	22/35	15/35	19/35
Smoking (%)	17/35	16/35	24/35	21/35
Forrester subset IV	29/35	12/35**	5/35**	3/35**
PCI (POBA/stent/others)	4/26/5	9/26/0	11/23/0	8/27/0

**Statistical significance ($p<0.05$) between LMT group and other groups. LMT, left main trunk; LAD, left anterior descending artery; LCX, left circumflex artery; RCA, right coronary artery; DM, diabetes mellitus; HT, hypertension; HL, hyperlipidemia; PCI, percutaneous coronary intervention; POBA, plain old balloon angioplasty.

PQ interval, QRS width, QRS axis, QT and QTc interval, ST-T change, abnormal Q) obtained from those that were recorded within 12h of the onset of the heart attack were analyzed. QTc interval was measured according to Bazett's equation ($QTc=QT$ divided by RR root), and ST-segment elevation or depression at the most prominent point was measured 0.06s after the J point and a significant ST-segment change was defined as more than 0.05mV deviation from the baseline.

Statistical Analysis

All values are expressed as mean±standard deviation. Differences among the qualitative data were analyzed by Student's t-test and chi-square test. The results are reported as relative risks with 95% confidence intervals. Differences with a value of $p<0.05$ were considered significant.

Results

Patients Characteristics (Table 1)

The selected 140 patients comprised 96 men and 44 women: 23 men and 12 women in the LMT group, 23 men and 12 women in LAD, 26 men and 9 women in LCX and 11 men and 24 women in RCA. The average age in the 4 groups was 67.7 ± 11.0 , 65.8 ± 8.2 , 63.9 ± 11.9 and 61.9 ± 10.0

years, respectively. There was not a statistically significant difference in ages among 4 groups but there was a significant difference in the sexes between LMT group and the LCX and RCA groups.

The ratio of underlying disease and risk factors, such as diabetes mellitus, hypertension, hyperlipidemia and smoking, was not significant by different among the groups, but the ratio of Forrester subset IV was significantly higher in the LMT group than that in the other 3 groups.

The immediate coronary interventions that were performed were: plain old balloon angioplasty (32 cases), directional coronary atherectomy (4 cases), stent (103 cases) and transluminal extraction catheter (1 case). Effective reperfusion greater than thrombolysis in myocardial infarction grade 3 was achieved in all cases except the 2 patients who died during the intervention.

ECG Parameters (Table 2)

There was a significant difference between the LMT and RCA groups in average HR, but none between the LMT and the other 2 groups. The average PQ interval was not significantly different among the 4 groups. Compared with the LAD, LCX and RCA groups, the average QRS width and QTc interval in the LMT group were significantly longer and the average QRS axis showed a significant left axis deviation. Abnormal Q wave was seen in 40%, 17.1%, 14.3%, and 11.4% of the LMT, LAD, LCX and RCA groups, respectively.

Intraventricular conduction delay occurred in 40% of the LMT group, which included 17 cases (37.1%) of complete right bundle branch block (CRBBB) and only 1 case of complete left bundle branch block. CRBBB also occurred in 14.3%, 8.6% and 11.4% of the LAD, LCX and RCA groups, respectively.

ST-segment elevation in lead aVR occurred in 80.0% of the LMT group, compared with 22.9% of the LAD group, 3% of the LCX group and 5.7% of the RCA group. The sensitivity and specificity of ST-segment elevation in lead aVR in the LMT group were 80.0% and 92.3%, respectively. ST-segment depression in lead aVR occurred in 5.7%, 14.2%, 14.2% and 11.4% of the 4 respective groups.

Types of ECG Features in LMT Infarction

According to our analysis, the ECG features of LMT

Table 2 ECG Parameters

	LMT	LAD	LCX	RCA
No. of patients	35	35	35	35
HR (beats/min)	88±19	89±15	78±18	72±15**
PQ interval (s)	0.18±0.03	0.17±0.03	0.16±0.03	0.17±0.03
QRS width (s)	0.13±0.03	0.10±0.01**	0.10±0.02**	0.10±0.02**
QRS axis (degree)	-10±77	46±39**	42±50**	32±33**
QTc interval (s)	0.51±0.06	0.45±0.03**	0.44±0.05**	0.42±0.06**
Frequency of ST elevation in lead aVR (%)	28/35 (80%)	8/35** (23%)	1/35** (3%)	2/35** (6%)
Frequency of ST depression in lead aVR (%)	2/35 (6%)	5/35** (14%)	5/35** (14%)	4/35** (11%)
Frequency of abnormal Q wave (%)	16/35 (46%)	6/35** (17%)	5/35** (14%)	4/35** (11%)
Frequency of inverted T wave (%)	11/35 (31%)	16/35 (37%)	15/35 (43%)	14/35 (40%)
Frequency of CRBBB type (%)	13/35 (37%)	5/35** (14%)	3/35** (9%)	4/35** (11%)

**Statistical significance ($p<0.05$) between LMT group and other group.

ECG, electrocardiography; HR, heart rate; CRBBB, complete right bundle branch block. Other abbreviations see in Table 1.

CRBBB+LADEV type in LMT infarction

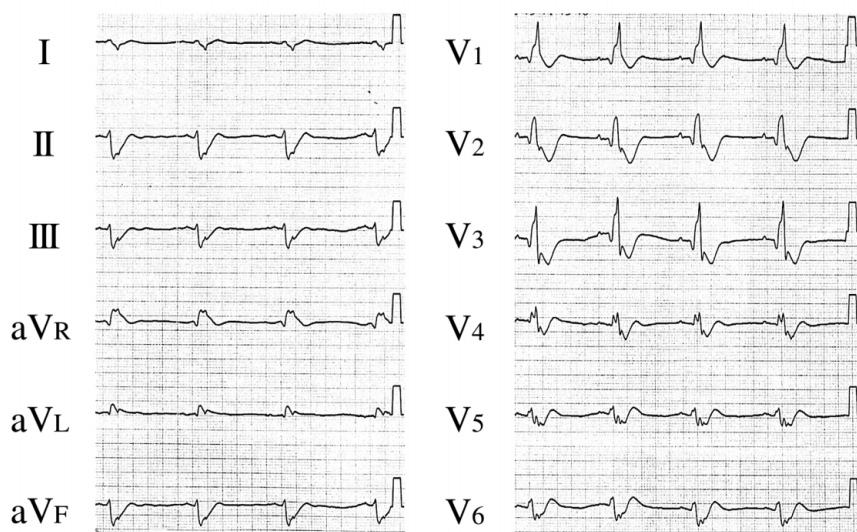


Fig 1. Right bundle branch block (RBBB)+ left axis deviation (LADEV) type. Heart rate=51/min, PQ=0.18, QRS=0.16, QRS axis=-135 degrees, QT=0.52, QTc=0.56, complete RBBB (CRBBB)+left anterior descending artery (LAD), ST depression in leads V2-6, II, III, aVF, ST elevation in lead aVR. LMT, left main trunk.

LAD type in LMT infarction

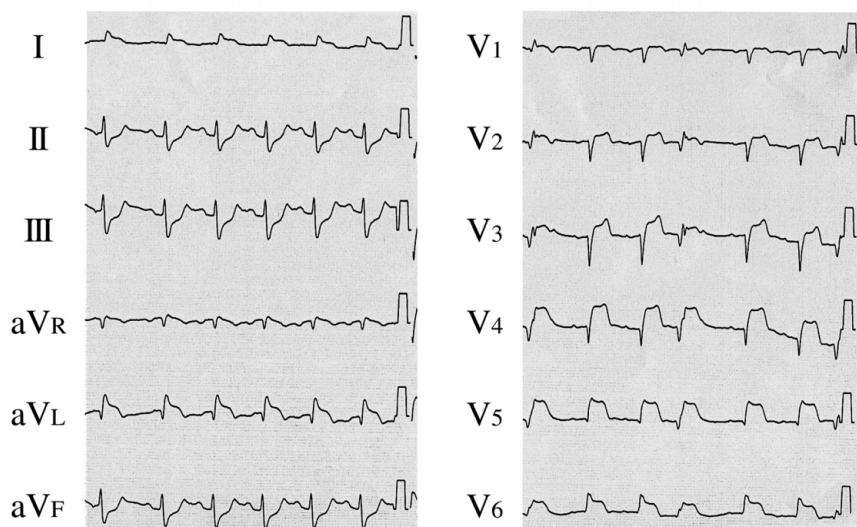


Fig 2. Left anterior descending artery (LAD) type. Heart rate=90/min, PQ=0.20, QRS=0.11, QRS axis=-10 degrees, QT=0.32, QTc=0.40, ST depression in leads II, III, aVF, ST elevation in leads aVR, I, aVL, V2-6. LMT, left main trunk.

infarctions can be classified into 2 main groups: one with right bundle branch block (RBBB) with marked left axis deviation (RBBB+LADEV type) or northwest axis, and the other with an anteroapical and lateral infarction appearance with ST-segment elevation in leads V2-5 (V6) and in leads I and aVL (LAD type). The RBBB+LADEV types and the LAD types occurred in 37.1% and 51.4%, respectively, of the LMT group and the remaining 11.5% could not be classified into either group.

RBBB+LADEV Type Fig 1 is a representative ECG recording of the RBBB+LADEV type in LMT infarction. All cases of this type had ST elevation in lead aVR. Seven cases (53.8%) had a prominent left axis deviation with an average QRS axis (-108.1 ± 11.8 degree) ranging from -63 to -135 degrees. Moreover, ST-segment elevation in leads I, aVR and V2-5 with ST-segment depression in leads II, III and aVF were observed in 71.4% of this type. The remaining 46.2% with a QRS axis more than -63 degrees showed ST-segment depression only in leads V2-4. Abnormal Q

waves were seen in 2 cases: 1 in leads V1-3 and the other in leads V4-6. Inverted T wave was observed in leads V1-3 in only 1 case.

LAD Type Fig 2 is a typical ECG recording of the LAD type in LMT infarction. All 18 cases had marked ST elevation in leads V2-5, and furthermore, 15 (83.3%) had marked ST-segment elevation in leads V2-6 and 12 (66.7%) showed ST elevation in lead aVR and/or I and aVL. Moreover, ST depression in leads II, III and aVF via a reciprocal change was observed in 14 cases (77.8%). Abnormal Q wave was seen in 12 cases (66.7%) and inverted T wave was observed in 10 cases (55.6%). ST-segment elevation in lead aVR was also observed in the remaining 11.5% of unclassified LMT infarctions.

Discussion

Until recently, the ECG features in LMT infarction were commonly reported and known as ST-segment elevation in

leads V₁ and aV_R and ST-segment change in various leads. Thus, almost reports of LMT infarction have focused on ST-segment change and other ECG parameters have not been fully described.

In this report the study population of LMT infarction (35 cases) was larger than in previous reports and new findings of an earlier appearance of abnormal Q wave, marked prolongation of the QTc interval and QRS width with abnormal QRS axis deviation, and a high frequency of RBBB were obtained. The difference in the results of our study and those from previous studies may be related to the size of the study population.

The special ECG features of LMT infarction are summarized as follows: (1) relative left axis deviation, (2) prolongation of QTc interval, (3) prolongation of QRS interval, (4) ST-segment elevation in aV_R, (5) ST-segment elevation in extensive precordial lead and (6) newly emerged abnormal Q wave.

Relative Left Axis Deviation

The average QRS axis in the present LMT group showed a statistically significant left axis deviation (superior axis or northwest axis) compared with 3 other groups and indicated an injury current toward the right shoulder induced by severe anterior and posterolateral ischemia.

Prolongation of the QTc Interval

The average QTc interval in the LMT group was significantly longer than that in the 3 other groups and might be interpreted as follows. LMT infarction may initially induce severe ischemia in the anterosseptal and posterolateral sites of the heart, which would lead to decreased cardiac output and relative ischemia in the RCA area. As a result, LMT infarction evokes severe myocardial acidosis and ischemia in the entire heart, which delays the depolarization and repolarization process that is mainly regulated by cardiac ionic currents. As for QTc prolongation during acute ischemia, Chauhan and Tang¹¹ and Rukshin et al¹² reported that QTc prolongation was induced by M cell uncoupling and exposure, which depends on the extent of transmural ischemia and necrosis in LMT infarction.

Prolongation of the QRS Interval

The average QRS interval in the LMT group was significantly longer than that in the 3 other groups and reflects intraventricular conduction delay and disturbed depolarization process caused by the severe global ischemia and acidosis of the heart.

ST Elevation in aV_R

Until recently, the significance of lead aV_R in LMT infarction has been underestimated in the ECG diagnosis of AMI⁷ because ST-segment change in that lead was believed to only give information that duplicated data obtained from the left lateral side (ie, leads I, aV_L, V₅ and V₆).⁵ However, Anderson et al have reported that reciprocal change in lead aV_R is valuable in the diagnosis of AMI¹³ and Menown and Adgey have also documented that ST-segment elevation in lead aV_R predicts higher creatine kinase levels in patients with both inferior and lateral AMI.¹⁴ Moreover, Gaitonde and Viik have found that ST-segment elevation in lead aV_R with ST-segment depression in other leads indicates more severe subendocardial ischemia,^{5,16} and Engelen et al pointed out that ST-segment elevation in lead aV_R in LAD infarction indicates that the

culprit lesion of the AMI is located proximal to the first major septal branch with transmural ischemia in the basal part of the septum, which leads the injured electric current toward the right shoulder.⁷

All those studies suggest that more frequent ST-segment elevation in lead aV_R in LMT obstruction can be explained by severe ischemia in the basal part of the septum and in the lateral part of the heart, which interferes with the blood flow in the LAD and LCX and produces another injury-induced electric current toward the right upper part of the heart.

In addition, Yamaji and Hori found ST-segment elevation is more frequently observed in lead aV_R than in any other lead in patients with LMT infarction and they showed how to distinguish LMT occlusion from proximal LAD obstruction by using the ratio of ST-segment elevation in leads aV_R and V₁.^{18,19} Inoue et al did not report ST-segment change in lead aV_R in patients with takotsubo cardiomyopathy, which usually causes severe left ventricular (LV) dysfunction and mimics wide anterior MI, despite marked ST-segment elevation or abnormal Q wave in extensive precordial lead.²⁰

In our ECG analysis, ST-segment elevation in lead aV_R in LMT group was significantly higher than in the other 3 groups. Additionally, ST segment elevation in lead V₁ was only seen in 2 cases in LMT group, but ST-segment elevation in lead aV_R occurred in 28 cases. These results indicate that severe cardiac ischemia, such as LMT infarction and extended anterior infarction in LAD occlusion, can elevate the ST-segment in lead aV_R but not lead V₁. Based on the finding that ST-segment elevation was hardly seen in the LCX and RCA groups, ST-segment elevation in lead aV_R suggests a strongly directional vector toward the right shoulder generated from extensive ischemia.

Kosuge et al demonstrated that ST-segment depression in lead aV_R might be a useful predictor of patient prognosis and chronic LV dysfunction in LMT and LAD infarction.^{21,22} In our study, ST-segment depression in lead aV_R was less frequent in the LMT group than in the other 3 groups probably because it was offset by the ST-segment elevation.

ST Elevation in Extensive Precordial Lead

ST-segment elevation in the precordial leads is frequently observed in LMT and LAD infarctions. ST-segment elevation in broad anterior precordial leads (V₂₋₆) occurred more frequently in the LMT group (42.8%) than in the LAD group (14.3%), which indicates that LMT infarction evokes the most severe cardiac ischemia. In this regard, Kurisu et al reported that more than 10mm Σ ST elevation and severely reduced LV ejection fraction were frequently observed in wide anterior MI with less collateral branches.²³

Newly Emerged Abnormal Q Wave

The abnormal Q wave in LMT group was significantly higher than in the 3 other groups, which indicates that LMT infarction is likely to become a transmural ischemia.

ECG features of the Types of LMT Infarction

RBBB + LADEV Type All cases of the RBBB + LADEV type had ST-segment elevation in lead aV_R and prominent left axis deviation. Interestingly, 3 of the remaining 4 cases with ST-segment elevation in lead aV_R with RBBB showed right axis deviation of more than 120 degrees, but did not show ST-segment elevation in the precordial leads. A

summary of the ECG features of the RBBB+LADEV type is: marked QTc and QRS prolongation with an abnormal axis deviation (left axis deviation or a northwest axis) and ST-segment elevation in lead aVR and/or I and aVL, but inverted T and abnormal Q wave are uncommon. This RBBB and abnormal axis deviation also reflect severe ischemia of the LV and interventricular conduction abnormalities. The reason why abnormal Q wave are uncommon in this group may be explained by a degree of myocardial ischemia which depends on the collateral flow from RCA to left coronary artery (LCA).

LAD Type Most cases of the LAD type showed marked QTc prolongation and marked ST elevation in leads V2–6, aVR and/or I and aVL, with a higher incidence of inverted T and abnormal Q waves compared with the RBBB+LADEV type. The reason why the abnormal Q wave and inverted T wave are more frequent in the LAD type is the undeveloped collateral flow from the RCA to LCA.

Study Limitation

All analyses were only made from ECG recorded at admission, and none from ECG recorded after treatment. In addition, the number of patients in the LMT group was not large. To verify the accuracy of our results, more retrospective and prospective studies are required.

Conclusion

The present study clarified the ECG characteristics of LMT infarction. ST-segment elevation in lead aVR and marked prolongation of both QRS width and QTc interval with prominent abnormal axis deviation or ST-segment elevation in the broad anterior precordial leads with normal QRS axis strongly suggest LMT infarction.

If ST-segment elevation in lead aVR is not documented but there is remarkable prolongation of both QRS width and QTc intervals with a higher incidence of abnormal Q wave, these findings also indicate the urgent need for an invasive treatment strategy such as the coronary intervention or surgical treatment.

Acknowledgment

We thank all the referral hospitals for collecting and analyzing the ECG data from emergency admissions of acute myocardial infarction.

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