Value of ST-Segment Depression in Lead V_{4R} in Predicting Proximal against Distal Left Circumflex Artery Occlusion in Acute Inferoposterior Myocardial Infarction

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Summary

Background: Lead V_{4R} faces the right ventricular free wall; it also reflects ischemia in the posterolateral wall lying opposite and manifests as ST-segment depression.

Hypothesis: The aim of this study was to evaluate the usefulness of V_{4R} ST-segment depression in distinguishing proximal from distal left circumflex artery occlusion in acute inferoposterior wall myocardial infarction.

Methods: We retrospectively analyzed 239 patients who had first acute inferoposterior myocardial infarction, were admitted within 6 h from onset of symptom, and had coronary angiography performed within 4 weeks. Patients who had bundle-branch block or concomitant significant stenoses in the proximal and distal segments of the same vessel or of both vessels were excluded. The electrocardiographic and angiographic findings were reviewed by two independent groups of investigators.

Results: V_{4R} ST-segment depression ≥ 1.0 mm was found in 8 of 46 patients (17.4%) with left circumflex artery occlusion but none (0%) with right coronary artery occlusion. Among the group with left circumflex artery occlusion, the mean magnitude of V_{4R} ST-segment depression was greater in proximal than distal occlusion

(0.82 ± 0.65 vs. 0.03 ± 0.12 mm, $p < 0.0001$). V_{4R} ST-segment depression ≥ 1.0 mm was found in 8 of 14 patients (57.1%) with proximal occlusion but none (0%) in 32 patients with distal occlusion. The sensitivity and specificity to predict proximal occlusion were 57.1 and 100%, respectively.

Conclusions: V_{4R} ST-segment depression ≥ 1.0 mm was not useful for differentiating left circumflex and right coronary artery occlusion because of its low sensitivity. It is a fairly sensitive and very specific sign of proximal left circumflex artery occlusion.

Key words: electrocardiography, acute inferoposterior myocardial infarction, infarct-related lesion

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Introduction

In acute inferoposterior myocardial infarction (MI), it is crucial to identify the culprit artery as well as the site of occlusion before initiating treatment since revascularization therapy is associated with substantial risk, especially in octogenarians.^{1,2} The risk and benefit of therapy should be carefully evaluated before selecting the most appropriate treatment strategy. Previous studies have described different electrocardiographic (ECG) criteria to differentiate between right coronary artery (RCA) and left circumflex artery (LCx) occlusion, and between proximal and distal RCA occlusion with good accuracy.^{3–10} An effort to distinguish between proximal and distal LCx occlusion is lacking. The aim of this study was to elucidate the usefulness of lead V_{4R} ST-segment depression (Fig. 1) in predicting proximal and distal LCx occlusion in acute inferoposterior MI.

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FIG. 1 Right precordial electrocardiogram showing ≥ 1.0 mm ST-segment depression in lead V_{4R} in a patient with acute inferior myocardial infarction.

Methods

Patients

From January 1997 to September 2005, 530 patients were admitted to our Coronary Care Unit with a diagnosis of acute inferoposterior MI, defined as typical chest pain of >30 min duration, ST-segment elevation of ≥ 1 mm in ≥ 2 inferior leads (II, III, aVF), and a more than two-fold increase in serum creatinine kinase levels. We only retrospectively analyzed those who met the following criteria: first episode of MI, <6 h from onset of chest pain, no left ventricular hypertrophy and bundle-branch block on ECG, and coronary angiography performed within 4 weeks of symptom onset.

Electrocardiographic Recordings

Standard 12-lead and right precordial lead ECGs were recorded at a speed of 25 mm/s and a voltage of 10 mm/mV at the time of admission. Electrocardiograms were magnified two-fold by photocopiers and reviewed by two independent investigators blinded to the patients' clinical and angiographic data. The ST-segment changes were measured at 40 ms from the J point using calipers. Measurements were made to the nearest 0.5 mm (0.05 mV). The preceding TP-segment was used as an isoelectric line. ST-segment depression <0.5 mm was considered isoelectric. In cases of discrepancy, the final decision was made by a third investigator.

Coronary Angiography

Coronary angiography was performed within 4 weeks of MI. Angiographic findings were evaluated by two independent investigators blinded to clinical and ECG

data. In cases of discrepancy, the final decision was made by a third investigator. The infarct-related lesion was identified by (1) total occlusion or a significant stenosis ($\geq 70\%$ diameter narrowing) of the LCx or RCA or their major branches, or (2) angiographic evidence of an intraluminal thrombus. Patients who had concomitant significant stenoses in both vessels, or in proximal and distal segments of the same vessel, were excluded from analysis. Proximal and distal RCA were defined as the coronary segment that lay proximal or distal, respectively, to the first right ventricular branch. Proximal and distal LCx were defined as the corresponding coronary segment that lay proximal or distal with respect to the origin of the first obtuse marginal (OM) branch. The angiographic classification was based on revised American College of Cardiology/American Heart Association guidelines.¹¹

Statistical Analysis

Mean values $\pm$ standard deviation (SD) were calculated for continuous variables, and absolute and relative frequencies were measured for discrete variables. For continuous variables, the statistical significance of differences between groups was analyzed by unpaired Student's *t*-test. The Fisher's exact test was used to compare differences between discrete variables. A *p* value of <0.05 was considered statistically significant. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for various diagnostic criteria.

Results

After all the inclusion and exclusion steps were taken, a total number of 239 patients (194 men, 45 women)

were recruited. The mean age was 61.8 ± 12.1 years; the average time from onset of symptom to hospital was 2.3 ± 1.4 h. Of the 239 patients recruited, 163 (68.2%) were treated with thrombolytic therapy, 34 (14.2%) with primary angioplasty, 20 (8.4%) with early angioplasty at admission, and 22 (9.2%) with elective angioplasty.

Left Circumflex versus Right Coronary artery Occlusion (Table 1)

The ratio of ST-segment elevation in leads II/III ≥ 1 (84.8 vs. 1.6%, $p < 0.0001$) and isoelectric ST-segment or ST-segment elevation in lead I (82.6 vs. 3.1%, $p < 0.0001$) were observed significantly more often in LCx than in RCA occlusion. These ECG signs were highly accurate in identifying the infarct-related artery (Table 2).

Among 193 patients with RCA occlusion, only 2 had V_{4R} ST-segment depression ≥ 0.5 mm; all were distal RCA occlusions. On the other hand, 12 of 46 patients (26.1%) with LCx occlusion had V_{4R} ST-segment depression ≥ 0.5 mm. The sensitivity and specificity positive predictive value (PPV) and negative predictive value (NPV) to predict LCx occlusion were 26.1, 99.0, 85.7, and 84.9%, respectively. If a more stringent criterion of V_{4R} ST-segment depression ≥ 1.0 mm was used, no patient from the RCA group and only eight patients in the LCx group showed this ECG sign. (Table 2).

Proximal versus Distal Left Circumflex Artery Occlusion (Table 3)

Among 46 patients with LCx occlusion, the group with proximal LCx occlusion had significantly more ST-segment depression ≥ 1.0 mm in leads V1–4 and ST-segment elevation ≥ 1.0 mm in leads V6 and I than the group with distal LCx occlusion.

ST-segment depression in V_{3R} and V_{4R} of different degrees were all observed significantly more in proximal LCx occlusion ($V_{3R} \geq 0.5$ mm: 78.6 vs. 3.1%, $p < 0.0001$; $V_{3R} \geq 1.0$ mm: 71.4 vs. 3.1%, $p < 0.0001$; $V_{4R} \geq 0.5$ mm: 71.4 vs. 6.3%, $p < 0.0001$; $V_{4R} \geq 1.0$ mm: 57.1 vs. 0%, $p = 0.0003$). In addition, the individual and summation of magnitudes of ST-segment depression in leads V_{3R} and V_{4R} were significantly greater in proximal than in distal LCx occlusion (Table 3). The sensitivity, specificity, PPV, and NPV of V_{4R} ST-segment depression ≥ 1.0 mm to predict proximal LCx occlusion were therefore 57.1, 100, 100, and 84.2%, respectively. If a less stringent criterion of V_{4R} ST-segment depression ≥ 0.5 mm were used, the values would become 71.4, 93.8, 83.3, and 88.2%, respectively. The sensitivity and specificity would be improved further if the summation of ST-segment depression in V_{3R} and $V_{4R} \geq 1.0$ mm were used. The sensitivity, specificity, PPV, and NPV would become 78.6, 96.9, 91.7, and 91.2%, respectively (Table 4).

Discussion

In electrocardiography, lead V_{4R} looks directly at the right ventricular free wall. ST-segment elevation in this

TABLE 1 Relation of various electrocardiographic signs to infarct-related artery

	RCA (n = 193)	LCx (n = 46)	p Value
Ratio of ST elevation in II/III ≥ 1 (%)	3 (1.6)	39 (84.8)	<0.0001
Isoelectric or ST elevation in I (%)	6 (3.1)	38 (82.6)	<0.0001
V_{4R} ST depression ≥ 0.5 mm (%)	2 (1.0)	12 (26.1)	<0.0001
V_{4R} ST depression ≥ 1.0 mm (%)	0 (0)	8 (17.4)	<0.0001

Abbreviations: RCA = right coronary artery occlusion, LCx = left circumflex artery occlusion.

TABLE 2 Sensitivity, specificity, positive and negative predictive value of different electrocardiographic signs in predicting left circumflex artery occlusion as the infarct-related artery

	Sensitivity	Specificity	PPV	NPV
Ratio of ST elevation in II/III ≥ 1 (%)	84.8	98.4	92.9	96.4
Isoelectric or ST elevation in I (%)	82.6	96.9	86.3	95.9
V_{4R} ST depression ≥ 0.5 mm (%)	26.1	99.0	85.7	94.9
V_{4R} ST depression ≥ 1.0 mm (%)	17.4	100	100	83.5

Abbreviations: PPV = positive predictive value, NPV = negative predictive value.

TABLE 3 Correlation between ST-segment deviation and site of left circumflex artery (LCx) occlusion

	Proximal LCX (n = 14)	Distal LCX (n = 32)	p Value
ST depression $\geq$ 1.0 mm			
V1 (%)	13 (92.9)	11 (34.4)	0.0002
V2 (%)	13 (92.9)	15 (46.9)	0.003
V3 (%)	13 (92.9)	16 (50)	0.005
V4 (%)	8 (57.1)	7 (21.9)	0.02
ST elevation $\geq$ 1.0 mm			
V5	4 (28.6)	9 (28.1)	0.6
V6	11 (78.6)	15 (46.9)	0.04
I	3 (21.4)	0 (0)	0.02
ST depression $\geq$ 0.5 mm			
V3R	11 (78.6)	1 (3.1)	<0.0001
V _{4R}	10 (71.4)	2 (6.3)	<0.0001
ST depression $\geq$ 1.0 mm			
V3R	10 (71.4)	1 (3.1)	<0.0001
V _{4R}	8 (57.1)	0 (0)	0.0003
V3R ST depression (mm)	1.25 $\pm$ 0.94	0.05 $\pm$ 0.21	<0.0001
V _{4R} ST depression (mm)	0.82 $\pm$ 0.65	0.03 $\pm$ 0.12	<0.0001
V3R + V _{4R} ST depression (mm)	2.08 $\pm$ 1.54	0.05 $\pm$ 0.23	<0.0001

TABLE 4 Sensitivity, specificity, positive and negative predictive value of different electrocardiographic criteria in predicting proximal left circumflex artery occlusion

ST-segment depression	Sensitivity	Specificity	PPV	NPV
V3R $\geq$ 0.5 mm (%)	78.6	93.8	84.6	90.9
V3R $\geq$ 1.0 mm (%)	71.4	96.9	90.9	88.6
V _{4R} $\geq$ 0.5 mm (%)	71.4	93.8	83.3	88.2
V _{4R} $\geq$ 1.0 mm (%)	57.1	100	100	84.2
V3R + V _{4R} $\geq$ 1.0 mm (%)	78.6	96.9	91.7	91.2

Abbreviations as in Table 2.

lead is the hallmark of right ventricular infarction, which indicates proximal RCA occlusion and carries a poor prognosis.^{12,13} By the same token, an extensive infarct involving the posterolateral wall, which lies directly opposite, may produce reciprocal ST-segment changes in V_{4R}. The LCx gives off OM branches and the terminal posterobasal branch to supply blood to the posterior parts of the lateral wall and the posteroinferior wall, respectively. Proximal LCx occlusion causes extensive injury to the entire posterior wall, whereas distal LCx occlusion only produces ischemia limited to the posterior part of the posteroinferior wall. With respect to the right precordial leads, the vector of injury is more opposed in the posterolateral rather than posteroinferior wall. Both the extent of ischemia and direction of vector of injury current support the hypothesis that proximal LCx occlusion causes more pronounced reciprocal ST-segment depression in V_{4R}, which can serve to distinguish it from distal LCx occlusion.

Right Coronary versus Left Circumflex Artery Occlusion

The ratio of ST-segment elevation in II/III $\geq$ 1 and isoelectric ST-segment or ST-segment elevation in lead I are reliable and accurate ECG criteria for identifying the infarct-related artery. These results are consistent with prior studies.³ The consistency may serve to prove the comparability of our patient cohort with other studies. V_{4R} ST-segment depression was virtually absent in the proximal RCA occlusion cohort; this result was compatible with the theory that the anterior vector of injury current caused by right ventricular infarct was cancelled out by the posterior vector caused by concurrent posterior infarction.¹⁴ This theory gained further support from the two patients with the ECG sign in the distal RCA occlusion group. They both had a very dominant RCA, which supplied big posterolateral branches, obstruction of which caused unopposed posterior infarction. V_{4R} ST-segment depression, no matter

whether ≥ 0.5 mm or ≥ 1.0 mm, was a very specific ECG sign of LCx occlusion (99 and 100%, respectively); it could not be used to distinguish LCx from RCA occlusion because of the low sensitivity. Previous studies have already described various ECG signs to identify the infarct-related artery. For instance, (1) ST-segment depression in lead I ≥ 0.5 mm;³ (2) ratio of ST-segment elevation in II/III < 1 ;⁴ (3) ratio of ST-segment depression in V3/ST-segment elevation in III < 0.5 ;⁵ (4) ST-segment elevation in V_{4R};⁶ (5) ST-segment depression in aVL $> I$;⁴ (6) T-wave magnitude in III $> II$ ⁷ predict RCA occlusion. By contrast, (1) ST-segment isoelectric or elevation in lead I;³ (2) ratio of ST-segment elevation in II/III > 1 ;⁴ (3) ratio of ST-segment depression in V3/ST-segment elevation in III > 1.2 ⁵ predict LCx occlusion. Fiol *et al.* developed an algorithm, which was able to predict proximal RCA and distal RCA and LCx occlusion with high accuracy.⁶ Once LCx occlusion is suspected, we can use V_{4R} ST-segment depression to predict the exact site of occlusion.

Proximal versus Distal Left Circumflex Artery Occlusion

The precordial leads V1–3 detect ischemia involving the anterior wall; posterior wall ischemia will cause reciprocal ST-segment depression.^{15,16} In proximal LCx occlusion, significantly more patients had an ST-segment depression of ≥ 1.0 mm in V1–4, probably because of more jeopardized posterior myocardium. However, these ECG signs are of no discriminatory value since they were present in 20–50% of the distal LCx occlusion cohort.

The mean magnitude of V_{4R} ST-segment depression was significantly greater in proximal than distal LCx occlusion (0.82 ± 0.65 vs. 0.03 ± 0.12 mm, $p < 0.0001$). Both criteria of V_{4R} ST-segment depression ≥ 0.5 and ≥ 1.0 mm were found more frequently in proximal than distal occlusion (see Table 3); thus, V_{4R} ST-segment depression is a very specific but only a fairly sensitive sign for proximal LCx occlusion. We can increase sensitivity without compromising much of specificity by adding the magnitude of V_{3R} to V_{4R}. Hence, if V_{4R} ST-segment depression ≥ 1.0 mm is found, proximal LCx occlusion is ascertained. If V_{4R} ST-segment depression is between 0.5 and 1.0 mm, the summation of V_{3R} and V_{4R} ST-segment depression ≥ 1.0 mm will pick up more proximal LCx occlusion with 78.6% sensitivity and 96.9% specificity.

Limitations

The timing of angiography was the major drawback of this study since only 14% of the cohort had primary angioplasty. The site of thrombotic occlusion revealed in elective angiography may not be exactly equal to that of the acute event. The exclusion of those with concomitant lesions in the proximal and distal segments of the

same vessel and of both vessels (LCx and RCA) has reasonably minimized the error. The anatomical variation of the coronary arterial system is another source of error. For instance, a ramus intermedius branch functions as a big OM branch; occlusion of proximal LCx will give rise to a false negative result. The functional importance of OM branches depends on their size; the first OM branch may not necessarily be the largest one. As a consequence, occlusion of distal LCx may still give rise to significant V_{4R} ST-segment depression, thus creating a false positive result. Finally, the ECG prediction was based on single-vessel involvement in either LCx or RCA territory; in real-world circumstances, the presence of multivessel disease is likely to affect ECG manifestation.

Conclusion

V_{4R} ST-segment depression is a very specific sign of LCx occlusion in acute inferior MI; however, it cannot be used to differentiate LCx from RCA occlusion due to low sensitivity. Once LCx occlusion is identified by other ECG signs, V_{4R} ST-segment depression is a very specific but fairly sensitive sign for proximal LCx occlusion.

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