Right Precordial Leads V4R and V5R in ECG Detection of Acute ST Elevation MI Associated with Proximal Right Coronary Artery Occlusion

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Abstract

ST elevation myocardial infarction (STEMI) in the right ventricle (RV) associated with right coronary artery (RCA) occlusion is known to have high hospital mortality. The hypothesis tested in this study is: right precordial leads V4R and V5R help detect STEMI in the right ventricle. ECGs from 1,970 subjects were collected in Ruijin Hospital (n =1,342), Shanghai, China and Lund University Hospital, Lund (n = 565), Sweden. All ECGs were recorded with additional leads on the right precordial location in V4R and V5R. Our results show that the subjects with middle to upper RCA occlusion often show ST elevation in leads V4R and V5R and ST depression in lateral leads I, aVL, V5-V6, and are often undetected as STEMI or AMI in the standard 12-lead ECG. We conclude that adding V4R and V5R to standard ECG recording in assessing patients presenting with acute coronary syndrome is an easy and convenient way to increases the sensitivity of STEMI detection.

1. Introduction

Acute myocardial infarct (AMI) with right ventricular (RV) involvement leads to an increased risk of death for patients due to failure of sufficient preload from the paralyzed right to the left ventricle, and sabotage of regular heart rhythm which is often followed by cardiogenic shock, especially in the elderly [1-4]. A substantially different reperfusion therapy may be required if a patient is suspected of RV myocardial infarct (RVMI). The clinical concerns of the current study are to better detect high grade proximal right coronary artery (RCA) diseases as a high grade risk factor for coexisting inferior/inferoposterior MI or isolated RVMI. ST elevation MI in the anterior or inferior region of the left ventricle (LV) with extension to the RV are known to presents higher risk but is often undetected by commonly used standard 12-lead ECG and patients may not receive appropriate therapy until diagnosed by biochemical cardiac markers or angiogram. In the 1970's, Erhardt et al. first showed a right precordial lead V4R was of value in the diagnosis of right ventricular infarct [5]. Since the early 80's, a number of researchers published studies based on relatively small numbers of study subjects. However, the conclusion is that the right precordial leads are most useful in detection of RV ischemia or infarct only if an inferior/inferoposterior MI is present [6-13]. Consequently, AHA/ESC published an official recommendation to add lead V4R if IMI is present in the new practice guideline [14]. The hypothesis tested in the current study is to use the right precordial leads V4R, V5R in addition to the standard 12 leads to detect ST elevation associated with high grade proximal right coronary artery occlusion regardless the presence or absence of inferior/inferoposterior MI.

2. Study population

Consecutive patients (n=1,970) admitted for chest pain, chest discomfort or other acute coronary syndrome (ACS) over a period of 12 months were collected in Rui-Jin Hospital (n=1,342), Shanghai, China and Lund University Hospital, Lund (n=565), Sweden. Some of patients' chest pain was chronic. All ECGs were recorded with standard lead placement and additional leads on the right precordial location in V4R and V5R.

Among 1,342 subjects from Rui-Jin Hospital, 1,232 had coronary angiography and 110 subjects refused the angiography test. Angiogram reports showed that 758 subjects had some occlusion in one or more coronary arteries. A subgroup of 94 subjects who had 85% to 100% occlusion in the middle to upper portion of the right coronary artery (RCA) was selected as the study group. Of the 94 study subjects, 27 had 100% proximal RCA occlusion, and 67 had an occlusion of 85-99%. Excluding

paced rhythm, LBBB, RBBB, LVH with ST-T changes, only 60 subjects were included in the study group. A total of 474 subjects were found without occlusion. Excluding 65 ECGs with presence of ECG confounders, 409 subjects are included in the ACS-matched control group.

Validation test was performed using an independent test set collected from Cath lab and ICU of Lund University Hospital. Acute myocardial infarct in this set was defined as: one or more of cardiac enzymes (TnT, CK or CK-MB) is elevated at 200% of the normal limits. Of the 565 subjects, 247 subjects were diagnosed as acute myocardial infarction. Excluding 18 subjects with presence of ECG confounders, a total of 229 ECGs were included in the validation test set.

3. Data analysis

ECGs were analyzed by Philips ECG analysis program PH08 [15]. Measurements were extracted from electronic ECG files for statistical analysis using a commercial statistical analysis program S-plus [16]. Measurements studied focused on ST amplitude at j point (ST_j), ST amplitude at j point plus 80 ms (ST_{j+80}), and T amplitude. Q wave amplitude and duration from the study and control groups are also compared.

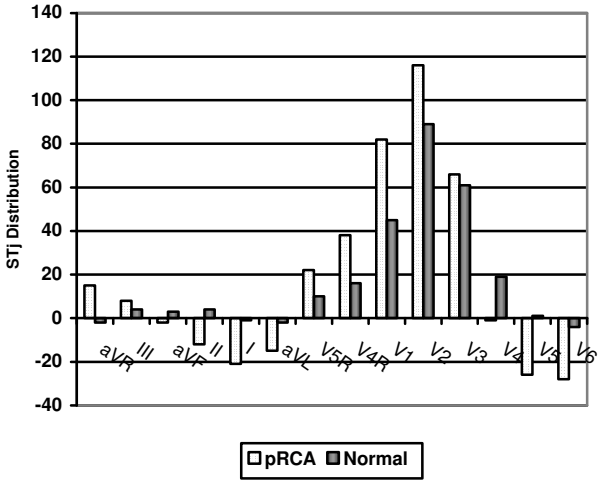

Figure 1: Mean STj distribution in standard 12 leads plus V4R and V5R in subjects with RCA occlusion (n=60) and subjects without occlusion (n=409).

Distributions and comparisons of ST_j, ST_{j+80} and T wave amplitudes are presented in Figures 1-3 respectively. ST_j is significantly higher in subjects with RCA occlusion than the ACS-matched control group in right side leads aVR, V4R, V5R, V1, V2 and significantly lower in the frontal and left side leads II, aVF, III, V5 and V6, and the differences are not statistically different in leads V2, V3, and aVL. The distribution of ST_{j+80} shows slight different pattern than ST_j amplitude due to the difference in ST segment slope. The difference of ST_{j+80} between the study group and the control group are significant in most leads except leads III, V2 and V3. Amplitudes of ST_j and ST_{j+80} in V4R are greater than V5R in subjects with high grade RCA occlusion.

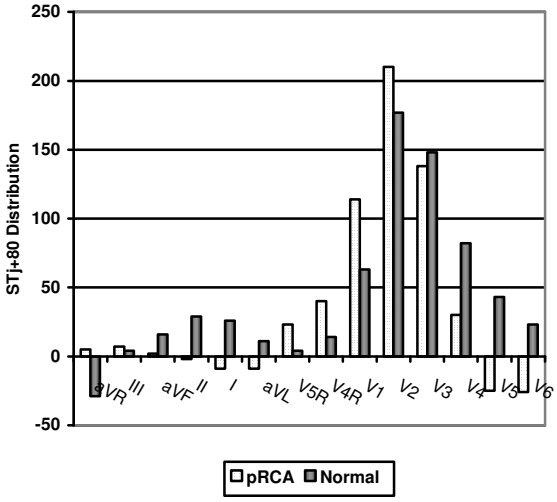

Figure 2: Mean STj+80ms distribution in standard 12 leads plus V4R and V5R in subjects with RCA occlusion (n=60) and subjects without occlusion (n=409).

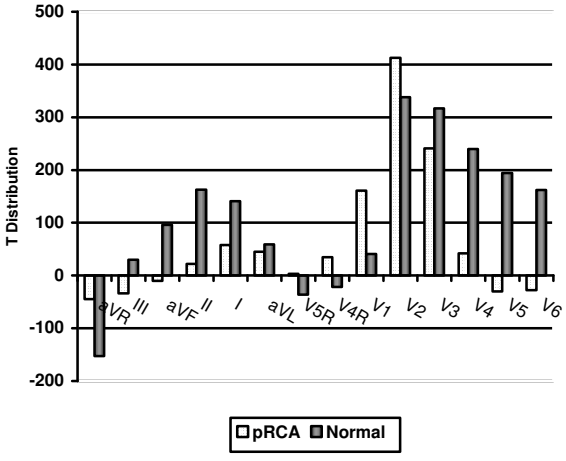

Figure 3: Mean T wave amplitude distribution in standard 12 leads plus V4R and V5R in subjects with RCA occlusion (n=60) and subjects without occlusion (n=409).

As shown in Figure 3, though the distribution of T wave amplitudes is heavily overlapped between the study

and control groups, the statistical comparison still shows significant difference in most leads except in left side leads in both frontal and horizontal planes aVL, V5 and V6. Note that the normal subjects have inverted T wave amplitude while study subjects with RCA occlusion tend to have upward T wave amplitudes in lead V4R, and less inverted T waves in leads aVR and V5R. This unique behavior is different from T wave distribution in anterior or lateral infarct and is in agreement with previously published data [17].

Q wave amplitude in right precordial leads is compared between study and control groups. Large Q waves in the right precordial leads are seen more often in the study group than in the control group. Statistical comparisons of Q amplitude in V4R and V5R have shown highly significant differences ($p<0.0001$) between the study group and the control group. Q duration of V4R and V5R is also significantly different ($p<0.01$). But, adding Q wave as a variable does not add to detecting high grade RCA disease as a risk factors for RVI.

4. Results

ST elevation in right side leads aVR, V4R and V5R, ST depression in left side leads I, aVL, V5 and V6, upward or flat T amplitude in lead V4R and V5R, plus inverted or flat T amplitude in V5 and V6 were found as the best variables for high grade RCA disease detection.

Results from classification tests in the study group (n=60) and ACS-matched control group (n=409) with and without right precordial leads V4R and V5R are compared. Without right precordial leads V4R and V5R, a sensitivity of 46.7% with a specificity of 58.3% is obtained. With addition of V4R and V5R, the sensitivity is increased by 11.6% to 58.3% with a minor reduction in specificity from 96% to 93% (Table 1).

An independent AMI data set (n=229) collected from Lund University Hospital was used for a validation test. Cardiac enzyme at 200% of the normal limit is considered as acute MI. We obtained a comparable increase of 10.1% in sensitivity from 46.7% to 56.8% in acute MI detection by adding precordial leads V4R and V5R.

Table 1: Sensitivity and Specificity in STEMI detection in study group (n=60) and match control group (n=409) with and without precordial leads V4R V5R.

	Without V4R, V5R	With V4R, V5R	Δ
Sensitivity	46.7 %	58.3 %	11.6 %
Specificity	96.0 %	93.0 %	-3.0 %

5. Discussion and conclusions

It is unexpected that the subjects with high grade RCA disease have a lower mean ST amplitude in the inferior lead group (II, III and aVF). This means not all subjects with high grade RCA disease would have an IMI. This observation is inconsistent with much of previously published data. One explanation is that high grade proximal RCA disease usually coexists with IMI in patients who have right-dominant coronary circulation. This occurs in approximately 70% of the population. The RCA supplies blood not only to the right ventricle but also to 25-30% of the left ventricle via the posterior descending artery. Approximately 10-15% of patients with inferior infarct have left-dominant coronary circulation where the posterior descending artery branches off the left circumflex [19]. It is likely that our study group contains mostly subjects with right-dominate coronary circulation.

Our observations in the study group with high grade RCA occlusion and the ACS-matched control group with no occlusion give a better understanding of the ST and T amplitude distribution, especially in leads aVR, V4R and V5R which are not commonly used. The predominant inverted T amplitude pattern in V4R and V5R in subjects without occlusion is a very helpful clue in high grade RCA disease detection. Upward or flat T in V4R and V5R is a characteristic signature of ECGs with high grade RCA disease. In the study group with high grade RCA disease, we also find that ST elevation in right precordial leads V4R and V5R is lower than the recommended threshold value of 100 μV. Generalization of ECG criteria resulting from one or two dozens of subjects without a matched control group in the published studies may not be appropriate for computer analysis algorithm use. It seems ST elevation of 50 μV in the right precordial leads is more appropriate. In summary, ST elevation and upward T in V4R, V5R, V1 and aVR and ST depression and inverted T as reciprocal changes in leads I, aVL, V5 and V6 are the most useful ECG criteria.

Without V4R V5R, some ECGs from subjects with high grade RCA disease are detected as “ischemia” due to ST depression and inverted T in the left side leads (I, aVL, V5 & V6). Some ECGs show ST elevation in V1 and V2 but do not meet the traditional ECG criteria of 200 μV for septal infarct and may often be overlooked. Our study confirms Saetre and Startt/Selvester’s observation that ST elevation in right precordial leads is associated with high grade proximal RCA disease. It is most striking when the occlusion is proximal to the acute marginal branch supplying the right ventricle. An explanation for the relatively low sensitivity in our results is that the time from acute coronary symptom to ECG in the Shanghai Rui-Jin Hospital patient population is longer than the average symptom onset time to ECG in US hospitals. In addition, the ECGs from Lund University Hospital were taken several hours after perfusion therapy. Another explanation is that we exclude

right bundle branch block (RBBB) which is one of the most frequent conduction abnormalities associated with high grade proximal RCA disease, and may have significantly reduced the sensitivity in ECG detection. Left precordial leads have proximity to the left ventricle while right precordial leads have proximity to the right ventricle. Addition of right precordial leads broadens the window to include the right ventricle in ECG reading.

Studies from the emergency medicine community have shown increased AMI sensitivity from the addition of right precordial leads without significant reduction in specificity [21]. However, Brady et al. concluded the uselessness of right precordial leads from a three-month duration might be due to the limitation of the data [22].

Our results show that subjects with high grade proximal RCA disease often exhibit ST depression in lateral leads I, aVL, V5-V6, and are often undetected in standard 12-lead ECG except those coexisted with IMI. Adding V4R and V5R to standard ECG in assessing patients presenting with acute coronary syndrome is a simple and convenient way to detect subject with high grade proximal RCA disease as a risk factor for RVI.

Further studies are needed to validate the preliminary ECG criteria generated from this study and to establish common standards for computer interpretation and manual ECG reading of high grade proximal RCA disease.

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