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Original article

Clinical significance of reversed R wave progression in right precordial leads

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Abstract

Objective: Poor R wave progression in right precordial leads is a relatively common electrocardiogram (ECG) finding that indicates possible prior anterior myocardial infarction (MI); however, it is observed frequently in apparently normal individuals. In contrast, reversed R wave progression (RRWP) may be more specific to cardiac disorders; however, the significance of RRWP in daily clinical practice is unknown. The purpose of this study was to clarify the significance of RRWP in clinical practice.

Materials and Methods: We analyzed consecutive ECGs obtained from 12,139 patients aged ≥20 years at Mito Kyodo General Hospital in Ibaraki between November 2009 and August 2012. Our setting is a secondary emergency hospital in the community, and the study participants were inpatients or patients who visited the general or emergency outpatient departments. RRWP was defined as RV2 < RV1, RV3 < RV2, or RV4 < RV3. Regarding ECGs considered to show RRWP, we confirmed the presence or absence of an abnormal Q wave and whether ultrasound cardiography, contrast-enhanced computed tomography, coronary angiography, and/or left ventriculography were performed to obtain detailed information.

Results: RRWP was identified in 34 patients (0.3%). Among these patients, 29 (85%) had undergone cardiac evaluation. The final diagnosis was previous anterior MI in 12 patients (41%) and ischemic heart disease (IHD) without MI in 5 patients (17%). All 17 patients with IHD had left anterior descending (LAD) artery stenosis. The other patients were diagnosed with dilated (two patients, 7%) and hypertrophic (one patient, 3%) cardiomyopathy, left ventricular hypertrophy (one patient, 3%), or pulmonary embolism (one patient, 3%). Only seven patients (24%) were normal.

Conclusions: RRWP is rare in daily clinical practice; however, it is a highly indicative marker for cardiac disease, particularly IHD with LAD artery stenosis.

Key words: poor R wave progression, myocardial infarction, ischemic heart disease, electrocardiogram

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Introduction

Poor R wave progression (PRWP) is a relatively common electrocardiogram (ECG) finding in adults, occurring in as many as 10% of all hospitalized patients[1]. PRWP indicates possible prior anterior myocardial infarction (MI); however, it is observed frequently in apparently normal individuals. In contrast, reversed R wave progression (RRWP), which occurs in as many as 2% of all hospitalized patients, may be more specific to cardiac disorders[2]. However, the clinical significance of RRWP in daily clinical practice is unknown. The purpose of this study was to clarify the significance of RRWP in clinical practice.

Materials and Methods

Patient selection

We analyzed consecutive ECGs obtained from 12,139 patients aged ≥20 years at Mito Kyodo General Hospital in Ibaraki between November 2009 and August 2012. The mean subject age was 62.5 ± 17.8 years, and men accounted

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for 51.5% of the participants. Our setting is a secondary emergency hospital in the community, and the study participants were inpatients or patients who visited the general or emergency outpatient departments. Among the 12,139 ECGs, some of them were performed for routine screening before admission or during perioperative screening in patients who had no symptoms or cardiovascular risk factors. Others included studies for scheduled regular cardiac evaluations or evaluations for various symptoms including chest symptoms or non-chest or generalized symptoms performed on outpatient or hospitalized basis. Although some patients underwent ECG examination more than once, each patient was counted only once, and only one ECG per patient was included in the analysis.

Informed consent to use the participants' medical record was obtained from all participants. This report was reviewed and approved by the research ethics committee of Mito Kyodo General Hospital.

RRWP criteria

We defined RRWP as RV2 < RV1, RV3 < RV2, or RV4 < RV3. We included patients in whom there was an accompanying abnormal Q wave (defined as the presence of a QS complex or Q wave ≥1 mm width in V2, V3, or V4) in one of the leads. Participants with RRWP associated with proportional decrease in S wave amplitude, left bundle branch block, or Wolff-Parkinson-White syndrome were excluded. We also reanalyzed data after excluding participants with Q wave.

ECG interpretation

We analyzed 12-lead ECGs recorded in recumbent position with standard lead placements. A physician, nurse, or clinical laboratory technologist placed the electrodes. ECGs were interpreted by one of the four cardiovascular specialists and double-checked by one advisory cardiologist. When RRWP occurred, ECGs were re-recorded several times, and it was confirmed that lead misplacement did not attribute to RRWP. We quantitatively analyzed the ECG using a scale. When there was discordance in ECG interpretations between the two cardiologists, the advisory cardiologist made the final decision. ECGs were interpreted without the knowledge of the results of ultrasound cardiography (UCG) or coronary angiography (CAG).

Data analysis

With regard to ECGs considered to show RRWP, we confirmed the presence or absence of an abnormal Q wave and whether UCG, contrast-enhanced computed tomography (CT), CAG, and/or left ventriculography (LVG) were performed to obtain detailed information. MI was defined as the presence of localized left ventricular wall motion reduction that corresponds to coronary artery perfusion area in UCG or LVG. Ischemic heart disease (IHD) without MI was defined as the presence of a coronary artery lesion without MI. Coronary artery lesion was defined as the presence of coronary stenosis of >75% that was analyzed using quantitative CAG. Dilated cardiomyopathy (DCM) was defined as the evidence of dilatation and impaired systolic function on one or both ventricles. Hypertrophic cardiomyopathy (HCM) was defined as hypertrophy of the myocardium of >1.5 cm. Left ventricular hypertrophy (LVH) was defined as a diffuse increase in wall thickness of the left ventricle of >1.2 cm and hypertension.

Results

RRWP was identified in 34 patients (0.3%). Of these patients, 29 patients underwent echocardiography and/or cardiac catheterization examination. The remaining five patients were excluded from the analysis.

We collected patient characteristics and the reasons for the performance of ECG when ECG showed RRWP (Tables 1, 2). The median age was 74 years (range, 61–85 years). Eleven patients were women. Twenty-two patients had hypertension, 11 had hyperlipidemia, 12 had diabetes, and 9 had a cigarette smoking habit. Three patients had dyspnea, and other symptoms included "syncope and dyspnea"; "disturbance of consciousness"; and "pale, cold sweat, and tachypnea". The reasons for the performance of ECG included "outpatient follow-up by cardiologist" for 13 patients, "routine admission ECG" for 10 patients, "initial work-up for the symptom" for 5 patients, and "intensive examination after checkup" for one patient.

Of these 29 patients, RRWP was present in V2 in 12 patients, V3 in 15 patients, and V4 in 6 patients (overlaps present). Examples of typical morphologies of RRWP are shown in Figure 1.

The causes of RRWP included IHD in 17 of 29 patients (59%), including 12 patients (41%) with previous anterior MI and 5 patients (17%) who had IHD without MI. All 17 patients with IHD had left anterior descending (LAD) artery stenosis. In addition, two patients had DCM, one had HCM, one had LVH, and one had pulmonary thromboembolism (PTE). Only seven patients (24%) were found to be free of cardiovascular disease (Table 3).

Of the 12 patients who presented with RRWP in V2, six (50%) had IHD; of the 15 patients who presented with RRWP in V3, nine (60%) had IHD; and of the 6 patients who presented with RRWP in V4, four (67%) had IHD. Moreover, RRWPs were found in four patients by multiple leads (V2 and V3 in 1 patient; V3 and V4 in 3 patients), of

Table 1 Clinical characteristics, reasons for performance of electrocardiogram, leads where RRWP were present

No.	Age	Sex	Past Medical History				Symptoms	Reasons for electrocardiogram
			HT	HL	DM	CS		
1	41	F	–	–	+	+	syncope and dyspnea	initial work up for the symptom
2	92	F	+	–	–	–	pale, cold sweat, tachypnea	initial work up for the symptom
3	58	M	+	–	+	+	hemiparalysis	routine admission electrocardiogram
4	55	M	+	+	–	–	none	outpatient follow-up by cardiologist
5	79	M	–	+	–	+	none	outpatient follow-up by cardiologist
6	74	M	+	+	+	–	none	outpatient follow-up by cardiologist
7	59	F	+	+	+	–	none	outpatient follow-up by cardiologist
8	63	F	+	+	–	–	none	outpatient follow-up by cardiologist
9	89	M	–	–	–	–	none	routine admission electrocardiogram
10	85	M	–	–	–	–	disturbance of consciousness	routine admission electrocardiogram
11	86	F	–	–	+	–	dyspnea	routine admission electrocardiogram
12	91	F	+	–	–	–	melena	routine admission electrocardiogram
13	79	F	+	–	+	–	disturbance of consciousness	routine admission electrocardiogram
14	52	M	+	+	+	–	none	outpatient follow-up by cardiologist
15	93	F	+	–	–	–	none	outpatient follow-up by cardiologist
16	63	F	–	–	–	–	none	intensive examination after checkup
17	73	F	+	+	+	–	none	routine admission electrocardiogram
18	61	M	+	+	+	+	none	routine admission electrocardiogram
19	64	M	+	–	+	–	none	outpatient follow-up by cardiologist
20	71	M	+	+	–	–	none	outpatient follow-up by cardiologist
21	88	M	+	–	–	–	none	outpatient follow-up by cardiologist
22	84	M	+	–	–	–	none	outpatient follow-up by cardiologist
23	76	M	+	–	+	–	none	outpatient follow-up by cardiologist
24	51	M	–	–	+	+	none	routine admission electrocardiogram
25	68	M	+	–	–	+	dyspnea	initial work up for the symptom
26	89	F	+	+	–	–	dyspnea	initial work up for the symptom
27	81	M	+	–	–	+	none	routine admission electrocardiogram
28	76	M	+	–	–	+	syncope and dyspnea	initial work up for the symptom
29	59	M	+	+	–	+	none	outpatient follow-up by cardiologist

M: male; F: female; HT: hypertension; HL: hyperlipidemia; DM: diabetes; CS: cigarette smoking.

whom two (50%) had IHD (Table 1).

Some previous studies on PRWP excluded patients with abnormal Q waves. Here, abnormal Q waves were observed in one or more leads in 14 of 29 patients with RRWP. Of these 14 patients, nine patients (64%) had IHD, and one patient had LVH, whereas four patients were normal. Of the remaining 15 patients without Q waves, eight patients (53%) had IHD (four patients with MI and four patients without MI), two patients had DCM, one patient had HCM, and one patient had pulmonary embolism, whereas three patients had no abnormalities.

Discussion

Etiology of PRWP and RRWP

A number of conditions result in a relative decrease in the amplitude of anteriorly directed cardiac electrical forces. Some conditions, such as left bundle branch block, Q wave anterior MI, Wolff–Parkinson–White syndrome, and right and left ventricular hypertrophy, are easily recognized. Lead misplacement in the cranial direction may also produce a PRWP pattern. Using a similar mechanism, emphysema may also produce a PRWP pattern by displacing the heart downward. In addition, PRWP may represent a normal variant. There are few reports describing the causes of RRWP alone. Zema *et al*.[3] stated that RRWP caused by MI has been found only in patients with circumferential nontransmural MI, suggesting more extensive myocardial necrosis in patients with RRWP than in those with PRWP.

Comparison with other studies

Yamauchi *et al*.[4] stated that PRWP is defined as an abnormal failure to increase the relative amplitude of the R wave without its disappearance as the chest electrode is moved to the left of V1 and used the term RRWP synonymously, as observed in other reports in the literature. Zema

Table 2 Diagnosis of 29 patients with RRWP

No.	Reversed R wave progression			Diagnosis
	RV2 < RV1	RV3 < RV2	RV4 < RV3	
1	+	–	–	DCM
2	+	–	–	PTE
3	+	–	–	IHD without MI
4	+	–	–	IHD without MI
5	+	–	–	IHD with MI
6	+	–	–	IHD with MI
7	+	–	–	IHD with MI
8	+	–	–	IHD with MI
9	+	–	–	Normal
10	+	–	–	Normal
11	+	–	–	Normal
12	+	+	–	Normal
13	–	+	+	DCM
14	–	+	+	IHD without MI
15	–	+	+	IHD with MI
16	–	+	–	HCM
17	–	+	–	IHD without MI
18	–	+	–	IHD without MI
19	–	+	–	IHD with MI
20	–	+	–	IHD with MI
21	–	+	–	IHD with MI
22	–	+	–	IHD with MI
23	–	+	–	IHD with MI
24	–	+	–	Normal
25	–	+	–	Normal
26	–	+	–	Normal
27	–	–	+	LVH
28	–	–	+	IHD with MI
29	–	–	+	IHD with MI

DCM: dilated cardiomyopathy; PTE: pulmonary thromboembolism; IHD: ischemic heart disease; MI: myocardial infarction; HCM: hypertrophic cardiomyopathy; LVH: left ventricular hypertrophy.

Table 3 Causes of reversed R wave progression

Cause	n=29	(%)
Ischemic heart disease	17	59
With myocardial infarction	12	
Without myocardial infarction	5	
Dilated cardiomyopathy	2	7
Hypertrophic cardiomyopathy	1	3
Left ventricular hypertrophy	1	3
Pulmonary thromboembolism	1	3
Normal	7	24

et al.[5] and Suzuki *et al.*[6] defined RRWP as the presence of decreasing R waves such that RV2 < RV1, RV3 < RV2, and/or RV4 < RV3 and RV3 ≤3.0 mm, excluding blockage in the left lead. According to this definition, Depace *et al.*[7] excluded wide QRS complexes, Wolff–Parkinson–White syndrome, LVH, QS pattern, and low QRS voltage. In these studies, both PPWP and RRWP are referred to as PRWP. With regard to RRWP, there are differences in the exclusion criteria and inclusion or exclusion of the voltage of RV3 in the definition, although previous studies are essentially consistent in applying the RV2 < RV1, RV3 < RV2, or RV4 < RV3 definition. Definitions of PRWP have varied greatly among studies. PRWP is a common ECG abnormality, accounting for approximately 10% of all cases. Because anterior MI is suggested at times, with Depace *et al.*[7] showing that 20% of patients with PRWP had anterior MI, the report of Zema *et al.*[3] comparing PRWP with histopathological findings revealed that 13 of 33 patients (39%) had anterior MI. However, underlying diseases showing PRWP include LVH, chronic obstructive pulmonary disease, and cardiomyopathy. Furthermore, many normal individuals also show PRWP. Thus, the presence of PRWP alone only has a limited contribution to the diagnosis of MI. Therefore, with regard to PRWP, Zema *et al.*[2] and Depace *et al.*[7] reported that the addition of a unique algorithm increased the diagnostic capability. Gami *et al.*[8] compared PRWP with loaded (Single photon emission computed tomography) SPECT and found its algorithms to be minimally useful in the diagnosis of anterior MI. There are limited reports discussing RRWP along with PRWP. Yamauchi *et al.*[4] compared ECG and vectorcardiographic (VCG) findings to show that RRWP suggests anterior MI. In PRWP versus RRWP comparison using VCG findings, Zema *et al.*[5] pointed out that RRWP was more specific for acute MI than simple PRWP. Depace *et al.*[7] performed Tl-201 myocardial scintigraphy in 102 patients and found nine patients with RRWP, among whom four patients (44%) had anterior MI. Suzuki *et al.*[6] autopsied 692 patients and found 24 patients with RRWP, among whom 16 patients (66%) showed evidence of anterior MI.

We also investigated each lead with which RRWP was found. In addition, patients with RRWPs using multiple leads at multiple sites were also analyzed. There were no clear correlations between these differences and the results.

We also reanalyzed RRWP separately with or without Q wave. The presence of pathological Q waves on ECG signifies a prior transmural MI[9]. However, the overall sensitivity of Q wave for prior MI is limited[10] because there are normal variants. Sixty-four percent of patients with RRWP with Q wave had IHD. The combination of Q wave and RRWP may have higher diagnostic accuracy than Q wave only. RRWP without Q wave also indicates IHD with a high probability of 53%.

Although many studies have shown RRWP to be useful in the diagnosis of anterior MI, to the best of our knowledge, this is the first study using consecutive ECGs and CAG to

RRWP was observed in V2 and V3.
LAD and LCX artery stenosis was detected.

RRWP was observed in V2.
LAD artery stenosis was detected.

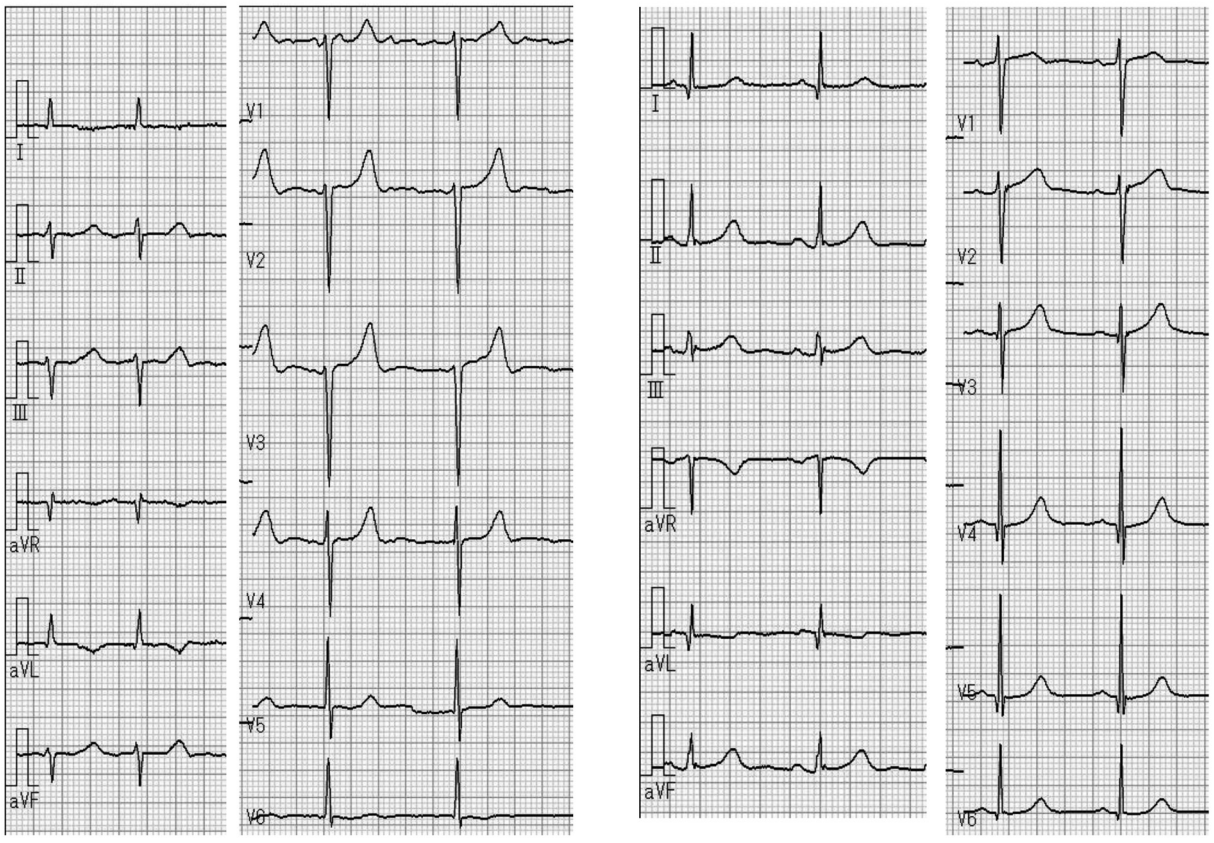

Figure 1 Examples of reversed R wave progression (RRWP). (a) ECG from a 62-year-old man showing RRWP in V1–V2 and V2–V3. Previous coronary angiography (CAG) showed stenosis in the left anterior descending (LAD) and left circumflex (LCX) coronary arteries. Percutaneous coronary intervention (PCI) was performed. (b) ECG from a 55-year-old man showing RRWP in V1–V2. Previous CAG showed stenosis in LAD artery, and PCI was performed. Neither patient had an abnormal Q wave.

assess the value of RRWP.

Study limitations

We analyzed ECGs of all patients who were examined at our hospital, not only those examined in the cardiovascular department. Thus, more ECG examinations were included than those in previous studies on PRWP. RRWP was observed in only 34 patients (0.3%). Of these patients, five patients did not undergo detailed cardiac examinations other than ECG, and therefore, the causes of their RRWP remain unknown. If none of these five patients had IHD, the rate of IHD might be no more than 50% (17/34). We used echocardiography and CAG as the reference standards for determining the presence or absence of anterior MI or IHD. Although these modalities are inferior to autopsy in terms of the information obtained, they are superior to previous standard methods, such as VCG, which could misdiagnose emphysema as anterior MI, or resting planar scintigraphy, which missed as much as 20% of cases of MI[7].

We did not collect data regarding the reasons why ECGs were performed in all 12,139 patients. We only collected the reasons for ECG performance in 29 patients, which showed RRWP. Some ECGs were performed for routine screening of patients who had no symptoms or cardiovascular risk factors before admission or during perioperative screening. If we focused on the ECGs that were performed due to cardiac symptoms, prevalence of RRWP may have more significance.

Further study is required to calculate the sensitivity and specificity of RRWP in the diagnosis of IHD.

Conclusion

RRWP is rare in daily clinical practice; however, it is

a highly indicative marker for cardiac disease, particularly IHD with LAD artery stenosis.

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