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Article

Correlation between Electrocardiogram Changes and Right Ventricular Systolic Function in Patients with Chronic Atrial Fibrillation

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Abstract

Background: Chronic atrial fibrillation (CAF) induces various electric disturbances, and a single mutation can cause multifarious phenotypes or combinations. Identifying the correlation of electrocardiogram changes corresponding to the disorders of electrical activity with right ventricular systolic function (RVSF) is important for the treatment and prognosis of CAF. Therefore, this study explored the correlation of electrocardiogram changes and RVSF in patients with CAF. **Methods**: From March 2022, to March 2023, 97 patients with CAF admitted to the Department of Cardiology of our hospital (study group) and 100 normal people who received health examination (control group) were subjected to echocardiogram and electrocardiogram to record relevant parameters for correlation analysis. **Results**: Significant differences were found in the electrocardiogram indices and right heart function parameters between the two groups. The study group had significantly higher heart rate, QTc interval, QT interval and T wave time than the control group ($p < 0.05$). The study group showed significantly higher right ventricular end-diastolic volume (RVEDV) and right ventricular end-systolic volume (RVESV), and lower right ventricular stroke volume (RVSV) and right ventricular ejection fraction (RVEF) than the control group ($p < 0.05$). Pearson correlation analysis showed that QTc interval, QT interval, and T wave time were positively correlated with RVESV ($p < 0.05$); QTc interval, QT interval, and T wave time were negatively correlated with RVSV ($p < 0.05$); and QTc interval was negatively correlated with RVEF ($p < 0.05$). **Conclusion**: A correlation exists between electrocardiogram changes and RVSF in patients with CAF.

Keywords

chronic atrial fibrillation; right ventricular contraction; electrocardiogram; ultrasonic diagnosis

Introduction

Clinically, atrial fibrillation (AF) is the most frequent arrhythmia, whose prevalence increases with age [1]. The atrium cannot fill the ventricle because of ineffective contraction during AF. Due to the lack of atrial contraction, blood accumulates in the right atrium, thus increasing the risk of stroke, heart failure, and all-cause mortality [2]. Nowadays, studying the clinical morbidity of AF is of considerable importance on account of ambiguous pathological and physiological pathogenesis of chronic atrial fibrillation (CAF), the uncertainty of drug therapy and frequent recurrence of AF after catheter ablation [3].

AF refers to the generation of 350–600 irregular impulses per minute in the atrium, and the uncoordinated fibrillation of muscle fibers in each part of the atrium. This high-frequency activation eliminates the synchronized work of the atria and ventricles, lessening myocardial performance [4]. A previous study displayed a distinct decrease in strain and function of left atria among patients with AF [5]. Inflammation and structural remodeling of left atrium are involved in the pathogenesis of AF [6]. However, the further study on AF in recent years has confirmed that right atrial parameters have a high association with paroxysmal AF [7], and an increased dispersion in atrial repolarization is one of the electrophysiological properties of AF. Hence, the exploration of electrocardiogram markers of ventricular repolarization and depolarization is likely to predict AF in advance. The dynamic electrocardiogram monitoring, a long-term 12-lead electrocardiogram, is a key tool for the diagnosis of AF [8] and the gold standard for dynamic monitoring of AF [9]. Characterized by simple operations, reproducibility, and low cost, this method is commonly used for the early detection of cardiac function. Currently, there are relatively few studies on electrocardiogram changes and right ventricular systolic function in patients with AF. If the correlation between electrocardiogram changes and abnormalities in right ventricular contraction is confirmed among patients with CAF, early diagnosis can provide a reference for evaluating right ventricular function in such patients and help formulate reasonable treatment plans in clinic. In this study, the correlation between electrocardiogram changes and right ventricular systolic function (RVSF) was investigated to provide a clinical reference for patients with CAF.

Table 1. Comparison of general information.

Groups	Study group (n = 97)	Control group (n = 100)	z/t/χ^2	*p*
Gender			0.007	0.932
Male	52 (53.61)	53 (53.00)		
Female	45 (46.39)	47 (47.00)		
Age [years, M (P_{25}, P_{75})]	61.00 (55.00, 64.00)	58.50 (54.00, 64.50)	−0.711	0.477
Height [m, M (P_{25}, P_{75})]	1.69 (1.58, 1.79)	1.68 (1.60, 1.77)	−0.368	0.713
Body weight [kg, M (P_{25}, P_{75})]	65.00 (57.00, 71.00)	66.00 (59.00, 71.00)	−1.153	0.249
Body mass index [kg/m^2, ($\bar{x} \pm s$)]	22.90 ± 4.09	23.57 ± 4.18	−1.128	0.261
Systolic pressure [mmHg, M (P_{25}, P_{75})]	127.00 (124.00, 130.00)	126.00 (123.00, 129.00)	−1.624	0.104
Diastolic pressure [mmHg, M (P_{25}, P_{75})]	75.00 (72.00, 78.00)	76.00 (72.00, 79.00)	−1.333	0.183
Etiology				
Hypertension	39 (40.21)	–	–	–
Coronary artery disease	41 (42.26)	–	–	–
Cardiomyopathy	17 (17.53)	–	–	–
Course of atrial fibrillation [years, ($\bar{x} \pm s$)]	3.50 ± 0.91	–	–	–

Materials and Methods

General Data

The clinical data of 100 patients with CAF admitted to the Department of Cardiology of our hospital from March 2022, to March 2023, were selected in this study (all cases were patients with persistent AF). After one case with missing clinical data and two cases with other organ failure were excluded, a total of 97 patients were finally included in the study group. In addition, 100 normal people who underwent health examination in our hospital during the same period were included in the control group for retrospective analysis.

This study conforming to declaration of Helsinki [10] has been approved by the Clinical Trial Ethics Committee of Yantaishan Hospital (approval no. 2024013). As a retrospective analysis, informed consent was waived from the patients.

Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (1) patients conforming to Guideline for the Diagnosis and Management of Atrial Fibrillation: A report of the American Heart Association/American College of Cardiology Joint Committee on Clinical Practice Guidelines [11], and patients with most common symptoms of AF, such as palpitations, decreased activity endurance, and chest discomfort and dizziness, anxiety, and increased urine volume; (2) 12-lead electrocardiogram (≥10 s) showing the disappearance of P wave and the appearance of fibrillation waves (F wave) with irregular size, shape, and time limit and an absolutely irregular RR interval [12]; (3) no other organic heart disease and history of cardiac surgery.

The exclusion criteria were as follows: incomplete clinical data, malignant tumors, and severe injuries and failure in other organs.

Methods

Electrocardiogram

Both groups received electrocardiogram examination. When subjects took the sitting position, the position of electrode slices were determined, and the skins were disinfected with 75% ethyl alcohol. Subsequently, the limb-lead electrodes and pressurized limb-lead electrodes were pasted on the chest, upper limbs, lower limbs, infraclavicular fossa, and midline of the clavicle at 1 cm below bilateral costal margins. Then, the examination recorder was worn, with detection period from 9 AM to 9 AM the following day. The patients were informed of the precautions during wearing. After 24 h, the recorder was removed to collect electrocardiogram data, including QTc interval, QT interval and T wave time, to ensure that the time obtained effective electrocardiogram data was ≥23 h. These data were analyzed by a dynamic electrocardiogram analysis software.

The equipment used included a 24 h dynamic electrocardiogram recorder (Shenzhen Biomedical Instruments Co., Ltd.; model: BI6612; Guangdong Medical Products Administration Certified No.: 20012210376, Shenzhen, China) and a dynamic electrocardiogram analysis software (Shenzhen Biomedical Instruments Co., Ltd.; Guangdong Medical Products Administration Certified No.: 20172071766; model: EcgLab, Shenzhen, China).

Echocardiogram

Both groups received echocardiogram examination. The subjects were maintained in left lateral position and under calm respiration. The transthoracic echocardiogram was collected through a probe, and three-dimensional volume analysis of left and right hearts was taken. The right heart function parameters, including right ventricular end-systolic volume (RVESV), right ventricular end-diastolic volume (RVEDV), right ventricular stroke

Table 2. Comparison of electrocardiogram indicators [M (P_{25}, P_{75})].

Groups	Study group (n = 97)	Control group (n = 100)	z	*p*
QTc interval (ms)	432.00 (401.00, 456.00)	411.00 (389.00, 433.00)	−4.147	<0.001
QT interval (ms)	408.00 (382.00, 435.00)	372.00 (350.00, 397.00)	−6.494	<0.001
T wave time (ms)	200.00 (171.00, 229.00)	165.00 (142.00, 183.00)	−6.648	<0.001
Heart rate (times)	142.00 (123.00, 157.00)	85.00 (76.00, 95.00)	−12.125	<0.001

Table 3. Comparison of right heart function parameters [M (P_{25}, P_{75})].

Groups	Study group (n = 97)	Control group (n = 100)	z	*p*
RVEDV (mL)	118.90 (106.60, 130.00)	110.85 (100.75, 122.95)	−3.794	<0.001
RVESV (mL)	71.80 (67.10, 78.70)	58.50 (50.00, 65.30)	−9.727	<0.001
RVSV (mL)	52.90 (44.40, 61.70)	66.50 (59.20, 74.60)	−8.245	<0.001
RVEF (%)	51.10 (45.90, 57.50)	55.35 (46.25, 63.40)	−2.958	0.003

RVEDV, right ventricular end-diastolic volume; RVESV, right ventricular end-systolic volume; RVSV, right ventricular stroke volume; RVEF, right ventricular ejection fraction.

volume (RVSV), and right ventricular ejection fraction (RVEF), were measured using single-beat real-time three-dimensional echocardiography.

The equipment used included a color Doppler ultrasound instrument (Philips; NMPA [I] no.: 20193061919; model: Philips epic7C; batch no.: Q7-190809, Shanghai, China) with a frequency of 1.0–5.0 MHz and a system built-in Qlab 10.8 3DQAdvanc analysis software.

Observation Indices

(1) The general information in both groups were compared, including gender, height, body weight, body mass index (BMI), systolic pressure, and diastolic pressure.

(2) The heart rate, QTc interval, QT interval and T wave time were compared between the two groups (QT interval was corrected according to Hodges formula, i.e., QTc = QT + 1.75 × (Heart Rate – 60)).

(3) RVEDV, RVESV, RVSV, and RVEF were measured in both groups for comparative analysis.

(4) Pearson correlation analysis was used to analyze the correlation of QTc interval, QT interval, and T wave time with RVEDV, RVESV, RVSV, and RVEF.

Statistical Methods

Data were analyzed by IBM SPSS (version 26.0, Armonk, NY, USA). Variance analysis was conducted on continuous variables meeting normal distribution, and the Mann–Whitney U test was used to analyze data meeting skewed distribution. Measurement data were analyzed by Pearson's chi-square test or Fisher's exact test. Pearson's test was used for correlation analysis. $p < 0.05$ was considered statistically significant.

Results

General Information

Table 1 shows no statistic difference in the general information between the two groups ($p > 0.05$).

Comparison of Electrocardiogram Indicators

Significant differences were found in electrocardiogram indicators between the two groups, and the study group had significantly higher heart rate, QTc interval, QT interval and T wave time than the control group ($p < 0.05$), as shown in Table 2.

Comparison of Right Heart Function Parameters

Significant differences were found in right heart function parameters between the two groups. The RVEDV and RVESV of the study group were significantly higher than those of the control group, whereas the RVSV and RVEF were significantly lower ($p < 0.05$), as shown in Table 3.

Correlation of Electrocardiogram Indicators and Right Heart Function Parameters

The results of Pearson correlation analysis showed that QTc interval, QT interval and T wave time were positively correlated with RVESV ($p < 0.05$); QTc interval, QT interval and T wave time were negatively correlated with RVSV ($p < 0.05$); and QTc interval was negatively correlated with RVEF ($p < 0.05$), as shown in Table 4.

Discussion

In this study, the current important knowledge in clinic was summarized, and some electrocardiogram parameters were explored. The results displayed significant differences

Table 4. Pearson correlation analysis.

Variables		RVEDV	RVESV	RVSV	RVEF
QTc interval	r	0.107	0.192	−0.229	−0.149
	p	0.134	0.007	0.001	0.036
QT interval	r	0.125	0.328	−0.229	−0.051
	p	0.080	0.000	0.001	0.476
T wave time	r	0.099	0.389	−0.316	−0.128
	p	0.166	0.000	0.000	0.074

in electrocardiogram indices in both groups, and heart rate, QTc interval, QT interval and T wave time of the study group were significantly higher than those of the control group. The QT interval reflects the time required for ventricular repolarization. The QTc interval, QT interval, and T wave time were significantly prolonged, which may be caused by Na^+ influx in patients with CAF. Abnormal P-wave morphology has been associated with a history of AF in earlier studies [13]. AF caused by electrophysiological abnormalities and alteration of atrial tissues leads to the generation of abnormal electrical impulses [14]. The substantial anisotropy of each part of the atrial muscle evokes the increase of dispersion in refractory periods.

This study showed overt differences in the right ventricular function parameters between the two groups. The study group showed significantly higher RVEDV and RVESV and lower RVSV and RVEF than the control group, indicating that the right ventricle has a certain compensatory function, possibly because it is composed of inflow tract, apex, and outflow tract, and its function depends on muscle fiber structure. The pathophysiology of AF consists in the activation of profibrotic signals and abnormal calcium handling at the atrial level [15]. The abnormal distribution of fibrotic tissue, electrical coupling, paracrine interactions, and biomechanical-electrical interactions are considered to be the causes of fibrosis-related arrhythmogenesis [16]. The pressure on the right side of the heart is significantly reduced because of thinness and poor elasticity in the right ventricular myocardium and low resistance in pulmonary arteries with high expansion [17]. Therefore, the right ventricle is more dependent on afterload than the left ventricle. Patients with CAF are prone to right coronary artery spasm, and decreased myocardial function in the blood supply area of right coronary artery could lead to reduced strain in the posterior wall, inferior wall, and interventricular septum below the papillary muscles of the left ventricle, thus affecting the RVSF.

The variations in the structure and function of atrioventricular cavity in patients with AF induce corresponding hemodynamic changes, which, in turn, cause structural and functional changes in the atrioventricular cavity, showing a strong correlation among cardiac structure, cardiac function, and hemodynamic changes. This study explored the correlation between electrocardiogram indexes and right ventricular function parameters through Pearson correlation analysis, showing that QTc interval, QT interval and T wave time were positively correlated with RVESV; QTc interval, QT interval and T wave time were negatively correlated with RVSV; and QTc interval was negatively correlated with RVEF. These findings suggest that electrocardiogram reflects the RVSF in patients with CAF, and it can be used for early diagnosis of CAF to guide the development of reasonable treatment plans. The reason is that AF may be related to ventricular pressure overload [18]. When AF occurs, the patient's right ventricle might change earlier. Irregular and rapid contractions of the atria lead to ineffective blood pumping [19]. The weakened blood pump function of the atrium and the enhanced atrial volume and reserve function result in increased atrial filling pressure and decreased ventricular compliance. As a consequence, decreased ventricular diastolic function becomes the first functional change. The enlargement of the right atrium related to AF-induced electrical remodeling and fibrosis of atrial muscle promotes an increase in the dispersion of atrial repolarization, resulting in abnormal electrocardiogram parameters. The data of this study confirmed a significant correlation between electrocardiogram indicators and right heart function parameters in patients with CAF, and the combination of the two is expected to achieve increased clinical value in the diagnosis and prognosis evaluation of CAF.

Limited by small sample size and the nature of retrospective study, the results of this study may have a certain deviation influenced by uncertain factors of previous data. Therefore, subsequent studies need to expand the sample size, and a prospective study must be conducted to obtain better clinical guidance.

Conclusion

The correlation between electrocardiogram changes and RVSF in patients with CAF provides a reference for evaluating right ventricular function in such patients through early diagnosis and helping to develop reasonable clinical treatment plans.

Availability of Data and Materials

Data to support the findings of this study are available on reasonable request from the corresponding author.

Author Contributions

LY and RY designed the research study. RY performed the research. LY analyzed the data. Both authors contributed to editorial changes in the manuscript. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study has been approved by the clinical trail ethics committee of Yantaishan Hospital (approval no.: 2024013). As a retrospective analysis, the patient's informed consent was waived.

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Conflict of Interest

The authors declare no conflict of interest.

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