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Research Progress of Atrial Fibrillation Detection Technology

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Abstract

Atrial fibrillation (AF) is the most common chronic arrhythmia in clinical practice, which can cause high disability and mortality with the progress of the disease. Many studies at home and abroad have shown that the incidence of atrial fibrillation gradually increases with age. Clinically, the onset of most AF patients is insidious, which is difficult to capture by routine electrocardiogram, and there is some difficulty in the diagnosis. In order to make the early diagnosis of atrial fibrillation more efficient and accurate, this paper reviews the current status and research progress of detection technology for atrial fibrillation at home and abroad, in order to provide a scientific basis for the early diagnosis of atrial fibrillation.

Keywords

Atrial Fibrillation, ECG, Detection Technology

1. Introduction

Atrial fibrillation (AF) [1] is an arrhythmia caused by the loss of effective contraction of the atrium due to the imbalance of electrical activation of the heart, which affects the atrium to pump blood effectively. Atrial fibrillation (AF) is a common chronic arrhythmia in the community, which has a huge impact [2] [3] on the activities of daily living and physical and mental health of patients, and brings a huge physiological, psychological and economic burden [4] [5] to patients, doctors and medical systems around the world. Atrial fibrillation (AF) has a great impact on various systems. A number of studies have shown that AF is highly correlated with heart failure, myocardial infarction, dementia, ischemic stroke and cognitive impairment, resulting in increased disability and mortality. The vast majority of patients with AF are initially asymptomatic, but it is also accompanied by high risk. The symptoms of atrial fibrillation vary [6] greatly

among different individuals. Most patients have no conscious symptoms in the early stage, and the onset time and duration are uncertain, so it is difficult for routine electrocardiograms to capture relevant data. Therefore, there are a certain number of patients with paroxysmal atrial fibrillation in the community population who have not received early diagnosis and treatment. Therefore, early diagnosis of AF is particularly important for reducing disability and mortality and improving the long-term prognosis of patients with AF. This article reviews the research progress of atrial fibrillation detection technology, in order to provide scientific basis for the early diagnosis of atrial fibrillation.

2. Electrocardiogram

2.1. A Regular 12-Lead ECG

Conventional electrocardiogram (ECG) is a bioelectrical pattern that records cardiac activity at a specific site on the body surface due to potential changes. It is the gold standard for the diagnosis of atrial fibrillation and has high clinical accessibility. Persistent AF can be quickly identified by the ECG characteristics of sinus P wave replaced by f wave and absolute RR interval irregularities. In addition, the F-wave amplitude is related to the occurrence of thromboembolism in patients with AF. The reason is that the F-wave is an indicator of atrial vitality and contractility. When the F-wave amplitude is higher, the incidence of cerebral embolism in patients with AF is lower, and the F-wave amplitude in lead V1 is more clinically significant [7]. Conventional ECG has limitations in the diagnosis of paroxysmal AF with unstable duration and onset time. In addition to finding the specific cardiac events occurring at the onset and termination of paroxysmal AF attacks, it is also difficult to grasp the heart rate variability and circadian rhythm during AF attacks.

2.2. Holter Monitoring

Compared with conventional ECG, dynamic electrocardiogram (DCG) can completely and accurately record the long-term real cardiac electrical activity of patients, and will not affect the daily life of patients. The 24 h/48h DCG is widely used in clinical practice. Therefore, compared with conventional 12-lead ECG, DCG has advantages in the diagnosis of paroxysmal atrial fibrillation with fewer attacks and short duration, and can greatly improve the detection rate [8] of paroxysmal atrial fibrillation. Studies have shown that the accuracy of DCG in the detection of paroxysmal atrial fibrillation is 24% [9] higher than that of ECG, which ensures the accuracy of the diagnosis of paroxysmal atrial fibrillation and enables the early intervention of the disease. In addition, DCG can also effectively distinguish the type of AF and the specific ECG characteristics during the onset of AF, including cardiac rhythm, termination mode, circadian rhythm and accompanying ectopic beats [10]. Based on this, clinicians can implement more accurate diagnosis and treatment for patients to ensure the prognosis and safety of patients. However, the diagnosis of paroxysmal AF requires retrospective

analysis of 24 h original ECG, especially in the case of high frequency and short duration of AF, it needs to be artificially analyzed by segment, which consumes too much time and energy and limits efficiency.

2.3. Scatter Plot of ECG

The ECG scatter plot is to analyze the ECG information recorded by DCG to form the corresponding graph. [11] Different rhythms in the cardiac electrical activity will correspond to different scatter plots. Doctors can quickly grasp the overall cardiac electrical activity of patients according to different scatter plot characteristics, especially for abnormal ECG signals. [12] There are three kinds of ECG scatter plots: 1) Time RR interval scatter plot, which can simultaneously display the ventricular rate; 2) Lorenz-RR interval scatter plot, which mainly shows the interaction between two or two types of rhythm; 3) Scatter plot of RR interval difference, reflecting the variability of heart rate. [13] At present, the ECG scatter plot is widely used in the diagnosis of DCG. If the paroxysmal AF attacks are not fixed and the duration is not fixed, the diagnostic efficiency of 24-hour DCG alone is low. The ECG scatter plot can take advantage of the absolute irregularity of ventricular rate (*i.e.* When AF occurred, the RR interval scatter plot showed a wide band in the downward direction and the upward direction. The Lorenz-RR interval scatter plot was fan-shaped. According to the typical characteristics of the electrocardiogram scatter plot during the onset of AF, the diagnosis of AF can be more accurate by tracing and analyzing the specific electrocardiogram segment corresponding to the point. [14] In addition, according to the difference of ventricular rate regularity during AF attack, the corresponding changes of ECG scatter plot pattern can be displayed, and then the diagnosis of AFL, AF and AFL combined with AF can be made by macroscopic RR interval change rules. [15] In addition, for the diagnosis of AF with atrial flutter, electrocardiogram scatter plot is superior to 24-hour DCG. [16] The electrocardiogram scatter plot shows the rhythm and time information of the overall cardiac electrical activity for clinicians, which makes the diagnosis of AF more efficient.

2.4. Waterfall Plot of ECG

ECG waterfall diagram integrates and processes all ECG segments recorded by DCG, and centrally presents [17] ECG information in terms of morphology, time and rhythm. Compared with the electrocardiogram scatter plot, the electrocardiogram waterfall plot provides a new idea for the clinical diagnosis of various types of arrhythmia. During the onset of AF, for the ECG manifestation of "absolutely irregular RR interval", electrocardiogram scatter plot can quickly identify the occurrence of AF. In addition, based on the characteristics of AF electrocardiogram, the ECG waterfall diagram showed that the P peak band suddenly disappeared, and the R peak band appeared as a color band [17]. Compared with persistent AF, paroxysmal AF is not easy to be identified, but in

the diagnosis process of paroxysmal AF, according to the characteristic performance of ECG waterfall map, the junction point of AF onset and termination with normal sinus rhythm can be quickly identified, and then the original ECG can be backward reviewed to ensure the accuracy of diagnosis. Waterfall plot is another efficient diagnostic tool for rapid analysis of holter, and it provides a new way and idea for clinicians to diagnose early AF. At present, there are still few studies on ECG waterfall diagram for the diagnosis of AF. It is hoped that through in-depth research in the future, it can be better applied to clinical practice, and even become an important resource for deep learning of artificial intelligence diagnostic models in the future.

3. Mobile Medical Devices

3.1. Cardiac Electronic Implantable Devices

For the early diagnosis of AF, we need to extend the observation window to improve the detection rate of AF. DCG has some problems in this regard, such as time limitation and inconvenience of long-term carrying, and long-term ECG screening device solves this problem. cardiac electronic implantable devices (CIDs) are portable electrocardiographic monitoring devices, including implantable pacemaker, cardioverter defibrillator and insertable cardiac monitor (ICM). Varma [18] *et al.* retrospectively analyzed the archival data of 276 patients with an implanted cardiac electronic device, of whom 29 patients had paroxysmal atrial fibrillation episodes. In addition, ICM can detect the onset of arrhythmia in time, which greatly ensures the safety [19] of patients. Compared with 24 h DCG, ICM has a higher [20] recognition rate of atrial fibrillation. ICM [21] can be used to identify the rhythm of atrial fibrillation in patients with cryptogenic stroke and to control the rhythm of atrial fibrillation after treatment. However, the implantation of cardiac electronic devices involves invasive operation and high price, coupled with problems such as battery capacity limitation, so it is difficult to be widely used in clinical practice.

3.2. Portable Wearable ECG Monitoring Devices

In order to pursue convenience, portable wearable ECG monitoring devices have gradually entered the population. The more commonly used portable wearable ECG monitoring devices to detect atrial fibrillation include photoplethysmography, single lead and multi-lead ECG monitoring technology. Photoplethysmography [22] is an optical measurement method that identifies atrial fibrillation by the change of RR interval according to the change of peripheral pulse and the change of light reflected by human tissue, which is synchronized with the R wave in the electrocardiogram. However, this monitoring method is easy to be disturbed by the external environment, so the accuracy needs to be investigated. Many devices are based on photoplethysmography combined with single-lead electrocardiogram technology to improve the accuracy of detection. Single-lead ECG is closer to lead II ECG with the help of contact, patch, wear

and other methods. At present, Kardia Band, Kardia Mobile, Heart Scan and Apple Watch are widely used. Studies have found that single-lead electrocardiogram technology has unique advantages [23] [24] [25] in the detection and identification of atrial fibrillation. The multi-lead electrocardiogram technology is similar to the conventional medical electrocardiogram, which can record the electrocardiogram information of multiple leads, so the authenticity is high. Kristensen [26] *et al.* found that the sensitivity and specificity of the three-lead portable ECG monitoring device in identifying atrial fibrillation rhythm were high. Therefore, portable ECG monitoring devices are feasible for AF screening. On this basis, some scholars have proposed the concepts of AHRE and SCAF, which are of great significance for the management of AF. At the same time, the ECG information collected by portable wearable devices still needs to be improved and developed, such as whether it conforms to the standards and data storage.

4. Artificial Intelligence Diagnosis Model

In order to improve the efficiency of diagnosis, more and more research is directed to artificial intelligence (AI) diagnostic models. Artificial intelligence diagnostic models rely on deep learning of machine learning, artificial neural network and convolutional neural network, which can identify the occurrence of arrhythmia. In the diagnosis of AF, artificial intelligence diagnostic models can identify and predict AF based on the P-wave shape of ECG, RR interval variation characteristics, the combination of P-wave shape and RR interval characteristics, nonlinear ECG characteristics, and two-dimensional Lorenz plot output. Cai [27] *et al.* used a one-dimensional deep densely connected neural network to analyze AF in 12-lead ECG, and its accuracy, sensitivity and specificity are high. Although a number of studies have shown that artificial intelligence diagnostic models have unique advantages for the diagnosis of AF, their clinical generalization and accuracy evaluation need to be further improved. In addition, the electrocardiogram information collected based on mobile medical devices needs to be effectively combined with artificial intelligence diagnostic models, and related technologies and usage methods should be improved to ensure the efficiency and accuracy of AF diagnosis.

5. Summary

In conclusion, the population structure of China is aging, and there are many potential AF patients. Based on various complications of AF, early diagnosis of AF is particularly important. Conventional 12-lead ECG can be used for persistent AF. For paroxysmal atrial fibrillation, holter monitoring can be selected, and electrocardiogram scatter plot and electrocardiogram waterfall plot can be used to assist the interpretation. For symptomatic high-risk patients, cardiac electronic implants can be installed to help complete diagnosis and risk assessment. For people with high cardiovascular risk factors, portable wearable ECG

monitoring devices should be used to record cardiac electrical activity, combined with artificial intelligence diagnostic models and other comprehensive detection and analysis technologies for early diagnosis of AF. With the rapid development of science and technology, the progress of society, as well as the continuous update and improvement of auxiliary detection technologies and methods, there will be more sensitive and specific detection technologies in the future, which will provide important basis and guidance for the early diagnosis and treatment of atrial fibrillation, make the diagnosis and treatment of atrial fibrillation more accurate and timely, so that patients can benefit to the greatest extent.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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