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Features of Analysis and Daily Registration of ECG in Patients with Paroxysmal Atrial Fibrillation

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Abstract

Registration of atrial late potentials (ALP) on signal-averaged (SA) ECG recorded in the six leads is one of the methods for evaluation of the changes of atrial electrophysiological properties involved in the mechanisms of paroxysmal atrial fibrillation (AF). However, in most cases, the occurrence of paroxysms of AF is preceded by various diseases of the cardiovascular system, such as coronary heart disease (CHD), hypertension (GB), cardiac malformations (CHM) of the heart rheumatic etiology, and primary myocardial disease. This does not exclude the role of disturbances in autonomic regulation of cardiac activity, so in modern cardiology, interest in this field of study of the role of the autonomic nervous system (ANS) in the genesis of AF increased significantly. Thus, a comprehensive assessment of a causal relationship of the occurrence of paroxysms of AF in clinical cardiology is necessary to evaluate a whole range of factors. It is necessary to analyze not only clinically relevant diagnostic indicators, but also the characteristics of the digital filtering of ECG, spectral and temporal indices of ECG signal registered during the day to select the factors and parameters. This article provides an overview of the factors, values, and criteria that have to be processed in the analysis of ECG recorded during the day in patients with assumed diagnosed paroxysmal AF. The list of analyzed factors is the basis for personalized registration algorithms, filtering, and subsequent analysis of the ECG signal in six leads.

Keywords

Personalized medicine; Prediction of atrial fibrillation paroxysms; Correlation analysis; ECG multi-recorder; GPS in medicine; Atrial fibrillation; ECG signal receiver; Daily monitoring ECG; Analysis of medical signals; Mechanisms of atrial fibrillation

Introduction

Atrial fibrillation (AF) is caused by an irregular, chaotic electrical activity of the atria accompanied by the termination of effective heart pumping function. AF develops when the frequency of ectopic impulses is between 400 and 500 per minute. At this frequency of excitation, myocardial cells cannot respond by coordinated simultaneous reduction covering the entire myocardium. Separate fibers or microsites of the myocardium contract irregularly as they release from refractory period. AF is detected in 2% of the adult population, and 5.9% of people older than 65 years [1]. Within the last few years, there has been a decrease in the average age of the patients with AF. This is the most common cause of ischemic infarction [2]. In addition, the fast rhythm of the heart that results from AF leads to other negative consequences, including congestive heart failure and tachysystolic-mediated cardiomyopathy [3].

Methods

Paroxysmal AF is the term used when AF has a recurring pattern of at least two episodes where an AF episode terminates spontaneously within 7 days, and persistent AF is AF surpassing 7 days or requiring pharmacological or DC cardioversion for restoration of SR. In patients undergoing cardioversion within 48 h, AF is considered paroxysmal, whereas in patients undergoing cardioversion later than 48 h from AF start, AF is considered persistent [3]. Persistent AF sustained for over 1 year is termed longstanding AF, and when a decision has been taken to accept the AF and no further attempts are made to restore and maintain SR, the AF is considered as permanent. At the same time, ECG in paroxysmal AF registers RR intervals varying in length, so there is no correct ventricular rate, although the QRS complex is not changed. Also, RR intervals are the same, that is, rhythm of ventricular contractions is regular (due to ventricular automaticity on full blockade of AV conduction). Thus, the AF is clinically characterized by changes in the frequency and rate of peripheral pulse; therefore, necessary and sufficient condition for registration of paroxysms is electrocardiogram in six main leads.

Treatment of AF may be therapeutic, but drugs have limited efficacy for this purpose and can cause a number of serious side effects, including life-threatening pro-arrhythmogenic effect. It is proved that patients with paroxysmal AF may be treated by radiofrequency ablation (RFA) [4], which is a direct prerequisite for verification and diagnosis of AF at the early stages, that is, of a paroxysmal form.

A number of overseas studies, the results of which were summarized in the recommendations for the management of patients with AF [5], show that local triggers usually located in one of the pulmonary veins (PV) are the starting element in the patients with AF [6]. However, for persistent AF, a dominant theory explaining the mechanism of a persistent AF implies the presence of multiple excitation waves creating chaotic heart rhythm (Figure 1) [7,8].

In such circumstances, drug therapy is not an objectively effective treatment as in paroxysmal AF [9-11]. Thus, the need to identify and diagnose paroxysmal AF in order to maximize the effectiveness of both medical and surgical treatment is important. We should not forget that

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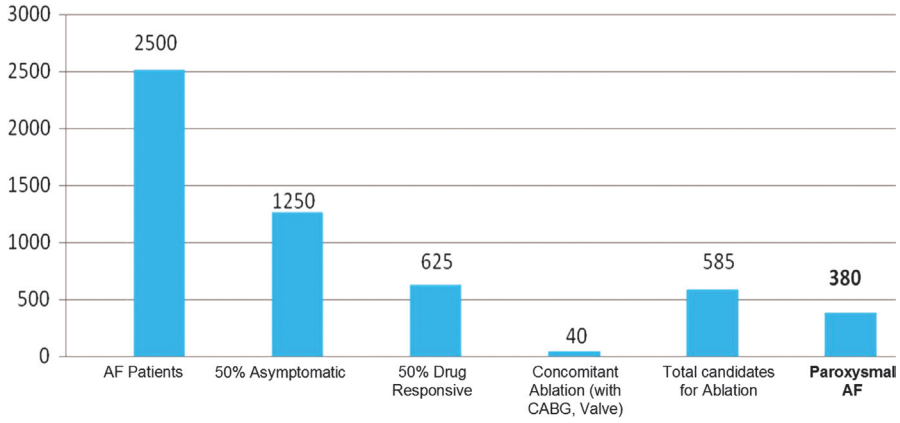

Figure 1: Statistical data of the multi-site study comprising 3,000 patients with a primary diagnosis of "atrial fibrillation" [9]

early diagnosis of paroxysmal AF requires the use of a compact ECG registrar for daily monitoring of cardiac activity, which would have high ergonomic parameters minimizing patient discomfort inherent for standard Holter monitors.

Another important feature of such devices should be using relevant software that would allow verifying and diagnosing AF paroxysms, their duration and combination of factors contributing to tachycardia startup. One of the key points that require in-depth analysis is a correlation relationship of motor components, hemodynamic component changing due to increased load on the body as a whole, and the manifestations of nervous activity caused by the activity of sympathetic and parasympathetic divisions. It is important to note the significant role of sympathetic and parasympathetic influences providing a high level of adaptation of a cardiac rhythm on its regulation [12-14].

Results and Discussion

When registering and further analyzing a daily monitoring ECG in patients with paroxysmal AF, comorbidities of a subject should be evaluated. It is important to note that patients with AF are often diagnosed with hypertension, and we should remember that these subjects have a predominance of sympathetic component over a parasympathetic one [15]. A changed balance of sympathetic and parasympathetic influences can lead to disorders of heart rate variability [16]; the effect of their relation changes should also be considered in the analysis of ECG and predictions of critical states of a subject. Thus, for a comprehensive analysis of the state of the body for verification of paroxysmal AF, it is necessary to evaluate such factors as: locomotor activity (to evaluate physical activity), change in body position in six degrees of freedom (for verification of presyncope and a number of other critical states), skin moisture and body temperature (for the assessment of vegetative-vascular system and the indirect estimation of sympathetic and parasympathetic components ratio), and, of course, ECG. Even when using (handheld or standard external loop) event recorders, episodes of an arrhythmia may be missed as the correlation between symptoms and relevant arrhythmias is often not very strong. In AF, for example, it is known that only 1 in 10 paroxysms is symptomatic. The European Heart Rhythm Association stated in a 2011 position paper on palpitations that it is especially important to exclude AF as the underlying cause of symptoms in patients with palpitations of unknown origin, as AF is associated with an increased risk of thrombo-embolism. Recent studies show that intermittent ECG recording with both regular and symptomatic registrations detects more episodes of silent AF in patients with known paroxysmal AF compared with 24-h Holter ECG and improves the detection of previously unknown asymptomatic paroxysmal AF in post-stroke patients.

The most commonly used method of extended ECG recording is a Holter monitor, which uses a conventional tape recorder or solid-state storage system for acquiring ECG information that can then be reviewed. There are two commonly used types of AECG recorders:

Continuous recorders:

- These recorders are typically used for 24 or 48 h to record events which might reasonably be expected to occur within that timeframe. The patient keeps a diary of symptoms and records the time on the Holter clock when the symptoms occur, for later correlation with ECG abnormalities.
- The ECG recording is in digital format, which allows for accurate and speedy interpretation of the recording, with some recorders even providing for "online" analysis as required. Their use is limited by cost and reliance on computer software to analyze the results accurately (former limited storage capacity of digital data is rapidly being overcome).

Intermittent recorders:

- These are generally for recording infrequent symptoms, and are one of the following two types.
- Event recorders (store only a brief recording of ECG activity when activated by the patient in response to symptoms) and loop recorders, which record the ECG in a continuous fashion, but store only a brief record when activated by the patient.
- Newer loop recorders continuously record and erase so that data gathered from 1 to 4 min before and then 30 to 60 s after the device was activated can be retained.
- Recordings may often be transmitted via Internet to a central point of analysis.

To solve the above medical and technical problems, multifunctional registrar should have the following elements that are part of the overall system: ECG recorder, GPS-module, accelerometer, gyroscope, barometer, galvanic skin response sensor, body temperature sensor (Figure 2).

With a daily ECG recording and verification of clinically significant cardiac arrhythmias in subjects with fixed AF paroxysm, attention

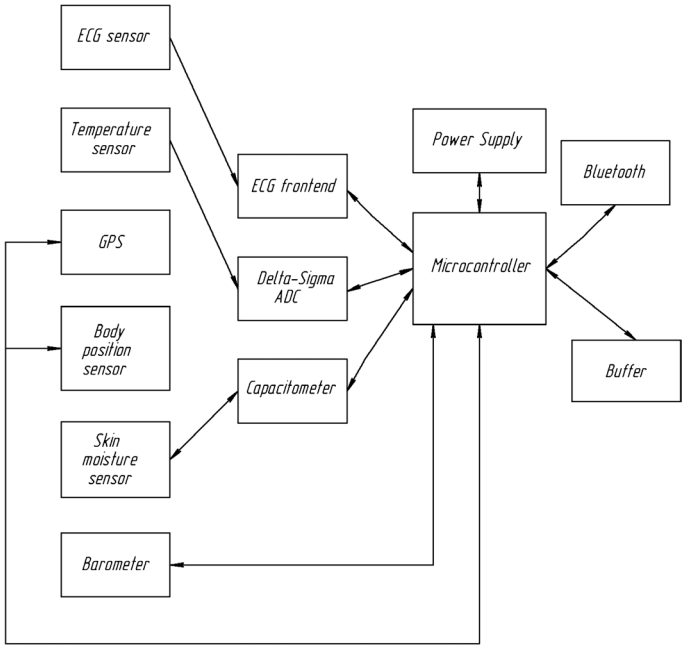

Figure 2: Schematic diagram of the multi-registrar

should be paid to the following significant clinical and diagnostic signs (both assessed by ECG and requiring further examination):

– presence of preliminary p-wave fixed with small changes of coordinate values

– lack of extrasystoles and complexes with noisy interference

– duration of low amplitude p-wave

– presence of fibrillation wave

– correlation of AF paroxysm and motor activity

– correlation of AF paroxysm and changes in galvanic skin response

– correlation of AF paroxysm and temperature changes

– presence of shortened atrial refractory period

– reducing the rate of intraatrial conduction

– trigger activity or automaticity of atrial cardiomyocytes

– presence of infectious and inflammatory changes

– presence of hyperlipidemia

– importance of international normalized ratio (INR)

– values of TIMI scale

– values of NYHA scale

It is important to take into account a number of requirements in addition to the characteristics of the ECG signal receiver during the ECG analysis in patients with paroxysmal AF:

– presence of a band-pass filter (BPF)

– BPF order, not below 4th

– bandwidth, at least 30-300 Hz

– noise level in all six leads, not more than 0.7 μV

In addition, the analysis of electrocardiogram registered during the day in patients with suspected diagnosis of AF paroxysms should be subjected to mathematical treatment using the following temporary indicators:

1. average duration of RR intervals during the period chosen for analysis – RR (ms)
2. standard deviation from the mean values of RR interval of the recording period selected for analysis – SDNN (ms)
3. standard deviation of the mean values of RR – intervals calculated by a 5-min recording period at intervals selected for analysis – SDANN (ms)
4. mean standard deviations of RR – intervals calculated by 5-min intervals for the recording period selected for analysis – SDNNi (ms)
5. number of pairs of neighboring RR – intervals differing more than by 50 ms for the entire period of record – NN50;

and spectral indicators:

1. total power of heart rate fluctuations (ms^2) – Total Power – fluctuations of heart rate in the range of 0.005-0.8 Hz
2. power of heart rate fluctuations in the ultralow-frequency range (ms^2) – Ultra Low Frequency – fluctuations of heart rate with a value ≤0.003 Hz
3. power of heart rate fluctuations in the very low frequency range (ms^2) – Very Low Frequency – fluctuations of heart rate in the range of 0.003-0.04 Hz
4. power of heart rate fluctuations in the low frequency range (ms^2) – Low Frequency – fluctuations of heart rate in the range of 0.05-0.15 Hz
5. power of heart rate fluctuations in the high frequency range (ms^2) – High Frequency – fluctuations of heart rate in the range of 0.15-0.4 Hz
6. LF to HF ratio (ms^2) – indicator of the dynamic balance between the sympathetic and parasympathetic divisions of the HNS – L/H.

Analyzing the spectral and temporal heart rate variability parameters (Figure 3) in the context of changes in electrophysiological parameters together with external factors of increasing load makes it possible to assess the adequacy of rate changes upon the body loads. Assessment of hemodynamic and electrophysiological response to stress conformity can help to achieve qualitative prediction of AF paroxysm [17].

Conclusion

Thus, with integrated indicators of the functional state of the human body, registered by a device during daily monitoring, it is

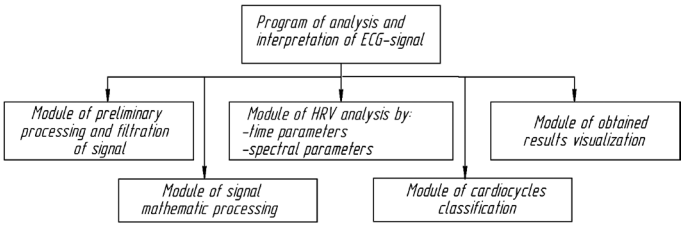

Figure 3: Diagram of ECG signal processing in patients with paroxysmal atrial fibrillation.

possible to determine the etiology of AF in a particular subject and predict significant hemodynamic and electrophysiological violations of the functional state of the body.

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