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Research and development of the device for diagnostics of arrhythmia

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Abstract. The article describes the results of the research for sensors optimal arrangement during one limb ECG detection. The found placement provides the registration of the enough quality signal sufficient for the diagnosis of arrhythmia, the QRS complex is clearly recognized. Authors also show the test results of the device developed for the diagnosis of arrhythmia and sudden cardiac death.

1. Introduction

In recent years the demand for the telemedicine market on cardiovascular diseases diagnostics has grown strongly and continues to grow [1]. One of the reasons is the fact that cardiovascular diseases are leading in the structure of mortality in the world and in response to this danger a large number of devices for heart condition check have been created.

Cardiovascular diseases can be asymptomatic, a person can be at risk and not even suspect of violations. A typical example is sudden cardiac death [2], one of the most insidious manifestations of cardiovascular diseases.

Often the primary sign of the disease are different types of arrhythmia. And since the manifestations of arrhythmia are episodic, it is preferable to use permanently worn devices for its diagnosis. Arrhythmia, which has chaotic nature, can manifest itself at different times and in different time intervals, from which it is difficult to identify at the early stages of the disease.

ECG allows revealing objective signs of arrhythmia, to establish the cause of the disturbed conductivity as well as the type of arrhythmia. Usually doctors prescribe a daily Holter monitoring [2, 3], but not always the arrhythmia can appear during the day.

Therefore, portable cardiographs have long been popular abroad. A person can carry this small device with him at all times and in case he feels the symptoms, he can immediately measure the ECG and send to the doctor.

Most cardiographs are designed in such a way that monitoring can't be carried out constantly, only once, when a person himself wants. But arrhythmia can arise in such a way that a person does not even feel it. Healthy people do not feel how the heart works and can't immediately feel a violation.

There are various fitness trackers and pulse monitors, but they do not allow to shoot an electrocardiogram, as a result of which it is impossible to determine the nature of the arrhythmia [4]. Most heart rate monitors do not work well under non-stationary conditions. The vast majority of such devices are not intended for medicine, but for entertainment and sports. Therefore it's actual to develop a device adapted for medicine.

An efficiency of identifying arrhythmia and sudden cardiac death means the use of permanent wear devices that record ECG and automatically determine pathological episodes and life-threatening syndromes. Other main factors in successful implementation are the ease of use and affordability.

In Tomsk Polytechnic University the group of researches is developing a wristband monitor for permanent wearing that will detect episodes of arrhythmia, carry out ECG recording and sudden cardiac death.

2. Materials and methods

The created device is aimed for daily use and appears as a cuff.

Experiments were conducted to find out which leads can be used to sense an electrocardiogram of the required quality. ECG leads are the difference of two potentials on the surface of a person's skin [5]. And based on this potentials difference the diagnosis is occurring.

The main goal of current design is to provide the maximum usability and comfort for a user. So the experiment was conducted to find out whether it's possible to obtain a clear ECG from a single arm lead or not.

To verify and compare the data measured from the arm the ECG was simultaneously registered the breast surface. And thus we found those time intervals in which the heart contraction occurs. The ideal solution would be to record the ECG from the wrist of one arm, but, unfortunately, the potential difference at this point is very small and the received signal was lost in interference (Figure 1).

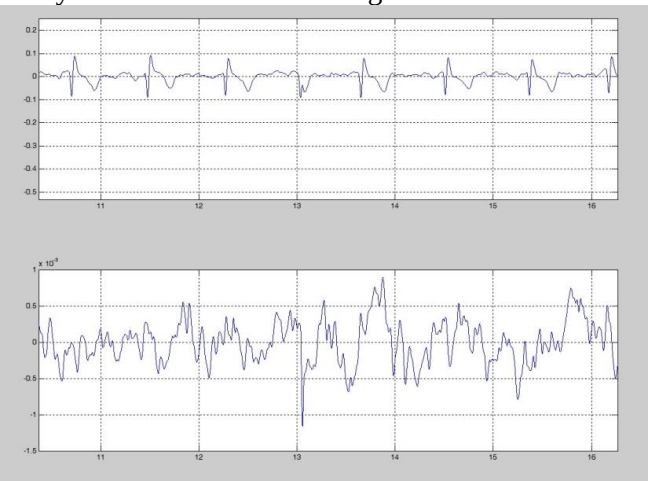

Figure 1. The ECG obtained from the chest (from above) and the wrist (from below).

Another solution was to use two bracelets and synchronize them wirelessly (Figure 2). If we compare it with the ECG obtained from the thoracic lead, it can be seen that the R-teeth and the QRS complex coincide, and so we can talk about the reliability of this experiment. Simply said it is just usual lead I from the standard 12-lead ECG but measured wirelessly. Despite of this fact the given method could be potentially used as it provides high reliability and the comfort for the user.

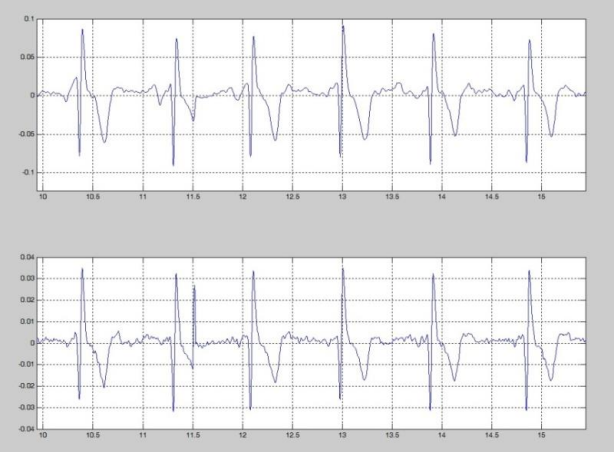

Figure 2. The ECG obtained from the chest (from above) and from the wrist of the right and left hands (from below).

The received signal is a quite stable, but we decided to check if the ECG can be obtained from one hand.

A number of measurement points were identified. They are depicted in Figure 3. The red dots are the points at which the signal was not observed and green are those where it was done. That is above the level of the elbow joint. The standard AgCl electrodes were attached to the shoulder and starting from this position the ECG was recorded. Then the electrodes were moved just below and the ECG was recorded again and so on down to the wrist.

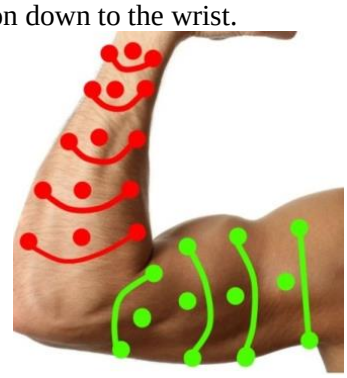

Figure 3. The scheme of the experiment.

Simultaneously the ECG was recorded from the chest. In previous experiments it was proved that the signal received from the chest is the strongest, therefore an ECG taken off the breast can be used as a reference for comparison with other records. Figure 4 shows an electrocardiogram from the thoracic lead as well as from the left arm bicep. The ECGs obtained from the biceps are inverted in relation to the ECG from the chest, but the R-teeth coincide and the myographic interference is very weak, which makes it possible to see a rather strong signal.

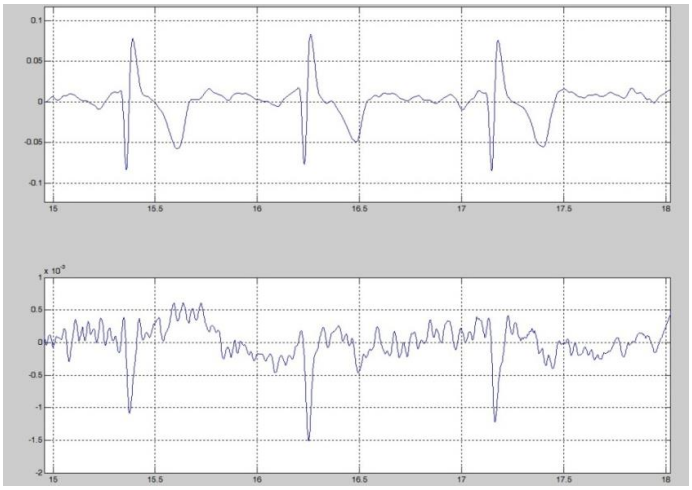

Figure 4. The ECG obtained from chest (from above) and from arm (from below).

In the following graph (Figure 5), the ECG was measured from the wrist and chest. Signal from the wrist is very weak; behind myographic interference it is completely unobservable.

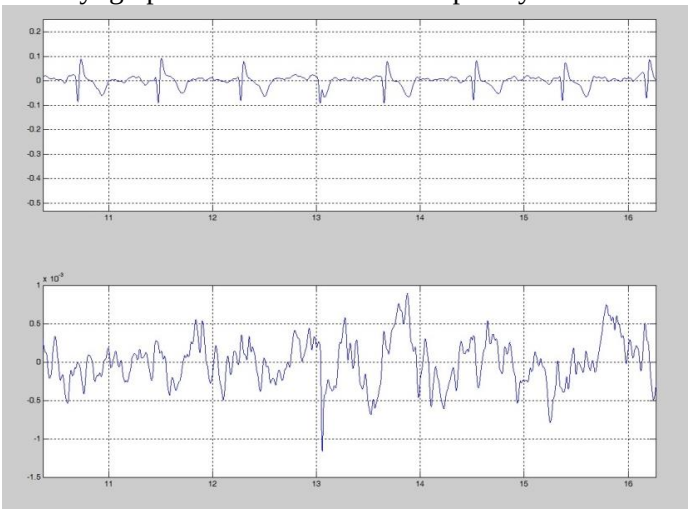

Figure 5. The ECG obtained from chest (from above) and from wrist (from below).

In case of recording ECG from the two points located at the wrist level which are very close to each other then the signal becomes indistinguishable at the level of various artifacts and disturbances.

When measuring the ECG from the chest (Figure 6) and the shoulder, it was possible to obtain a signal of high quality without interference.

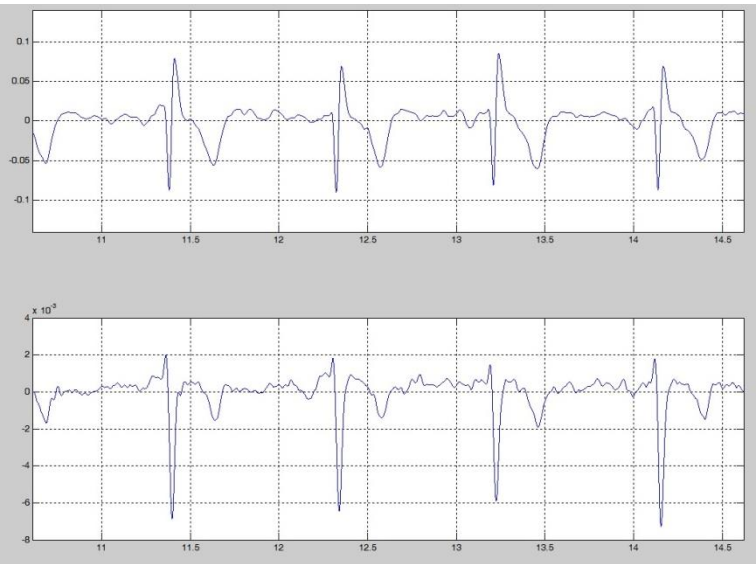

Figure 6. The ECG obtained from chest (from above) and from shoulder (from below).

According to the results of the experiments we were identified two possible electrode placement schemes: two bracelets on the wrists or one band on the shoulder.

The level of the ECG signal received from the shoulder is significantly lower than from standard leads, especially from the chest. Such types of diseases as ischemia can't be determined with such a small signal level, since the ischemia detection usually is made with a 0.1mV signal change on the standard ECG. But the QRS-complex is clearly visible from the shoulder, and due to this, it is possible to judge the periodicity of the signal, the sequence of teeth and the duration of the intervals making the arrhythmia detection possible this way. Based on the experiments we developed the simplest moqup for the test device (Figure 7).

Figure 7. The device prototype.

For the experiments we've chosen two types of electrodes:

1. Metal plates,
2. The standard adhesive type electrodes with silver chloride coating and conductive gel.

Figure 8 shows the device in action. Electrocardiogram from the shoulder was obtained with the metal plates electrodes.

Figure 9 shows the ECG measurement with adhesive medical electrodes.

Figure 8. The ECG measurement process from the shoulder (using metal plate electrodes).

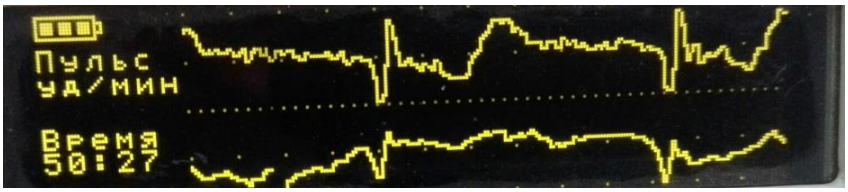

Figure 9. The ECG from shoulder (using medical electrodes).

3. Results

The quality of the ECG signal clearly depends on the tight contact of the electrode and skin. Comparing the ECG from conventional metal plates and ECG from medical electrodes it's clearly observed that with the second type of electrodes he ECG is more precise. It's all about the conductive gel. But since sticky medical electrodes are not convenient in daily use, the problem can be solved in the following ways:

1. Treat the skin every time before putting on the device with a special conductive solution,
2. Look for different types of electrodes that are less susceptible to external factors (for example, conductive rubber or capacitive sensors).

The use of high-quality electrodes will help to solve not only the problem of obtaining a clear signal in the static position, but also receiving a signal in the action.

1. This device works only in static mode. When body moves the device the interference affects the signal quality (the myographic artifacts from muscles). To solve this problem it is necessary to rigidly, but at the same time is comfortable, fix the device on the shoulder, and also to select a suitable electrodes.

References

[1] Mehra R *Global public health problem of sudden cardiac death* (Medtronic, Inc, Minneapolis, MN, USA, Journal of Electrocardiography)
[2] Estes N A *3rd, Predicting and preventing sudden cardiac death* (Department of Medicine, USA)
[3] Komolyatova V, Kupriyanov O, Pervova E and Ryabykina G National 2014 Russian recommendations on the use of Holter monitoring in clinical practice *Russian Cardiology Journal* **2** 6-71
[4] Dolgih A, Martemyanov V and Borikov V 2017 MATEC Web of Conf. **113** 01013
[5] Golitsyn S, Kropacheva E and Maikov E et al 2013 *Federal clinical guidelines for the diagnosis and treatment of cardiac arrhythmias and conduction: wedge Recommendations* (Moscow)
[6] Yartsev S 2014 *Electrocardiography: a practical guide-guide for doctors* (Moscow, RUDN)