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Electrical activity with ECG analysis for Body Surface Potential Mapping

Abstract*. The article presents tests of electrical activity with ECG analysis for mapping body surface potential. Diagnostic tests involve placing available standard electrodes on the patient's body over specific anatomical skin areas. The main idea of the solution is to combine body surface potential mapping with electric impedance tomography imaging. This solution can provide a greater amount of medical data for analysis, whereby a larger number of cardiopulmonary disorders can be detected using specialized algorithms.*

Streszczenie. *Artykuł przedstawia badaia aktywności elektrycznej z analizą EKG do mapowania potencjału powierzchni ciała. Testy diagnostyczne polegają one na umieszczeniu dostępnych standardowych elektrod na ciele pacjenta na ściśle określonych anatomicznych obszarach skóry. Główną ideą rozwiązania jest połączenie mapowania potencjału powierzchni ciała z elektrycznym obrazowaniem tomografii impedancyjnej. Takie rozwiązanie może dostarczyć większą ilość danych medycznych do analizym gdzieza pomocą specjalistycznych algorytmów można będzie wykrywać większą ilość zaburzeń sercowo-płucnych.. (**Aktywność elektryczna z analizą EKG do mapowania potencjału powierzchni ciała**).*

Keywords: ECG, surface potential mapping, BSPM.
Słowa kluczowe: EKG, mapowanie potencjału powierzchniowego, BSPM.

Introduction

Methods of imaging human health based on measuring the electrical activity of the body surface have a long history. Their established position in the medical diagnostics industry is based on solid scientific foundations, as well as on easy implementation and a number of devices available on the market. The main areas monitored in this way are the heart, muscles and the brain. Specific standards for performing individual tests and analyzes are also developed. This enables easy exchange of test results and simplifies consultation and description.

In our solution, we focus on testing the electrical activity of the heart. This value is relatively easily measurable, because the potentials produced by the cardiac stimulating system are quite strong. However, their proper acquisition from the body surface requires specific rules. Certain standards have arisen regarding the placement of the electrodes as well as the electrical issues of measuring. This procedure is dictated by the location and parameters of internal organs such as the heart. Compliance with these procedures is also important for the exchange of diagnostic information and the training of medical personnel.

For heart tests, the rules determining the exact location of the electrodes on the patient's body are very important. This allows data standardization, and thus the development of a standard presenting observations, typical results. With such standards developed, you can look for anomalies and associate them with specific clinical cases. The location of the electrodes is mainly associated with the topography of the human body, and reflects the location of the monitored internal organs. However, it should be remembered that individual patients may differ slightly in this respect, the differences also result from many sexes and body parameters (height, weight).

Already in the 1980s, many researchers sought to better understand the electrical behavior of the heart, dramatically increasing the number of electrodes, which resulted in body surface potential (BSPM) research. By placing numerous electrodes on the surface of the body near the heart, it obtains voltage synchronized with the heartbeat on each electrode. This is due to the propagation of electrical excitation in the tissues. Collecting data in more places and in a larger area and not limiting the measurement results to one time-changing potential for each of the 12 leads (as in the standard 12-lead ECG). Providing many new readings of heart activity allows its more accurate analysis and description of many phenomena [1].

Combining information obtained from reading the electrical potential from the patient's body and implantable devices is a trend in electrocardiology. Important potential applications are detection and localization of ischemia, continuous monitoring of cardiac cycle parameters and telemedicine. These technologies are widely used to detect ischemia and improve the accuracy of localization of ischemia and other arrhythmias. However, they are associated with costly and often dangerous procedures for the patient's health. They also cannot be routinely conducted for people, e.g. practicing sports. The classic 12-lead ECG is not very sensitive to detecting changes in the electrical activity of the heart, and some heart attacks may be missed. Lack of patient identification in the early stages of acute myocardial infarction - AMI may result in failure to provide beneficial therapies. New technology using body surface mapping to provide a more complete picture of the electrical activity of the heart. Body surface mapping is more sensitive in detecting AMI in the lower left ventricle and right ventricle [2-5].

Electrical tomography has undergone 30 years of development [6-24]. There are many numerical methods to solve the forward and inverse problems [25-34].

Methods and models

The solution proposed by our team will be based on placing over 100 electrodes on the patient's chest surface. This will provide a large amount of diagnostically useful data. The initial analysis is based on the acquisition of signals from body areas reflecting lead points for a standard 3-channel ECG and for more accurate cardiac diagnostics from areas corresponding to peri-cardiac leads (12-lead ECG). These data are used for ongoing cardiac activity and for serious deviations in organ function.

Recording large amounts of data regarding the skin surface potential will, however, enable a much more accurate understanding of electrical processes. Both what we accept as physiological states and those associated with certain heart diseases. Emerging data redundancy can be overlooked for healthy patients, but gives new diagnostic options beyond the standard 12-channel ECG. This is possible by placing the electrodes in non-standard places, which allows, for example, the collection of accurate data on the posterior wall of the heart. The solution we propose allows to infer about the heart surface potentials based on the recorded body surface potentials. Properly developed algorithms allow creating, in real time and retrospectively, based on the collected data, a three-dimensional map of changes in the electric potential of the body surface and the heart surface.

An additional advantage of our solution is total portability and integration of the measuring device in clothing (vest). Data from the electrodes will only be pre-processed in the device's systems and ultimately sent via a wireless network and the Internet to dedicated servers. Thanks to this solution, the device is autonomous, and at the same time has a low demand for electricity. Portable equipment and user-friendly software in combination with an easily applied vest on the torso containing electrodes allows the recording of the BSPM signal by identifying heart activity, but also EIT signals.

Remote data collection and analysis will enable optimal use. The use of computers with much more computing power will allow the doctor to access medical data quickly and conveniently.

The classic ECG records the revulsion of electric heartbeats collected in the body surface in a limited number of places, it lacks sensitivity and specificity, and its spatial resolution is very low. Many arrhythmias require simultaneous mapping of the atria or ventricles with high spatial resolution and for a sufficiently long period of time. An invasive mapping technique is a solution - with the help of probes with electrodes inserted into the body, in the immediate vicinity of the heart. This gives high resolution data, but the electrode location must be carefully selected for each patient. The risk, complexity and cost of invasive mapping limit its use. As you can see, a method of non-invasive mapping of the electrical activity of the heart is very desirable; would serve cardiac electrophysiology (EP) in a role similar to established non-invasive imaging methods (CT, MRI and USG), which are widely used in the practice of modern medicine. The solution we propose meets such conditions.

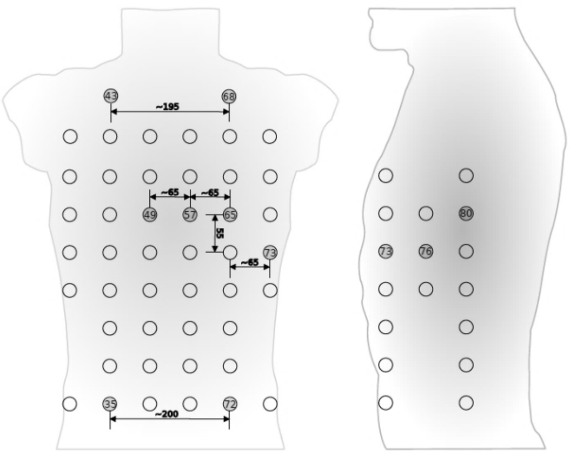

Fig. 1. Arrangement of electrodes on the vest.

The measuring apparatus used by our team in the form of many electrodes integrated with the vest has a number of advantages. The material from which it is used is ensured tight adhesion to the body surface, and then does not restrict movement. Due to the elimination of the analytical algorithms used, the electrodes are arranged in the form of a grid and the dimensions expect 6,5 to 5 cm. In traditional ECG, the location of the electrodes is connected to the connectors, Connect as their markings and lead colors. ECG, with two of them being the ‘Angle of Louis’ Method and the ‘Clavicular’ Method. When a measuring device was used - the vest, the arrangement of the electrodes for ECG measurements is as in Fig. 1.

Results

As part of the work on the detection of bends in electrocardiographic examination, an algorithm was used based on the solution proposed in [1]. The research used a database with ECG tests located on the Physionet website. In the initial phase of work, the algorithm was designed to detect QRS complexes in the electrocardiographic signal. Specifies the place in the digital signal where the heart contractions are located. In the method used, the R waves are determined and based on them, by searching the local minima on the left and right, the Q and S waves are determined. The algorithm meets the following two conditions:

• detection of only QRS complexes
• each team is appointed exactly once.

As part of the research, an algorithm based on the Pan-Tompkins algorithm was used, i.e. signal transformations in the time domain. This assumes that an analysis of the curve slope, amplitude and length of the QRS complex is performed. The basic version of the algorithm consists of five steps:

1) Band-pass filtration, which aims to eliminate interference that results from:
   • Muscle tremors that generate 35 Hz noise.
   • Interference from the network at 50-60 Hz.
   • Impact of T wave.
   • A problem with the so-called "floating" electrical isoline.
2) Signal differentiation allows attenuation of low-frequency signal elements - such as T-waves and P-waves. At the same time, high-frequency signal elements, including the QRS complex, are amplified.
3) Signal intensification allows further filtering of the signal due to leveling of P and T waves, as well as amplification of the signal representing the QRS complex.
4) Signal integration is responsible for obtaining a single "wave" of the QRS complex in a given unit of time.
5) R-thresholding and determination of R-waves is the last stage at which adaptive signal thresholding and determination of subsequent R-waves take place.

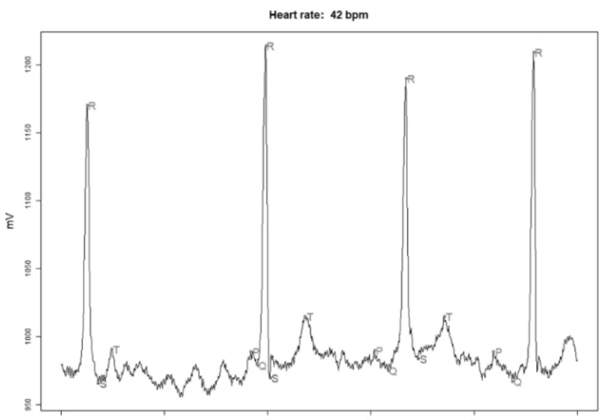

Fig. 2. An example of detecting a wave when atrial fibrillation occurs.

In the next iteration, an algorithm was also used to detect P and T waves. In addition, decision trees were used. The teaching set included 59 ECG readings for healthy people (23 readings) and sick people (46 readings) with cardiac arrhythmias. As part of the study, bends were detected for diseases such as atrial fibrillation, atrial flutter, ventricular rhythm problems, and fusion beats. Wolff, Parkinson and White were also interested.

Atrial fibrillation is the most common supraventricular tachyarrhythmia, characterized by rapid uncoordinated activation of atria from 350 to 700 per minute. Its detection is based on the differentiation of supraventricular tachycardia based on the relationship between P waves and QRS syndromes (Fig. 2).

A similar detection method will be used for atrial flutter. The disease is characterized by palpitations, shortness of breath, general weakness and chest pain in some patients. In addition, there is a steady rapid heart rate - about 150 per minute. The diagnosis of ECG bends is shown in Fig. 3.

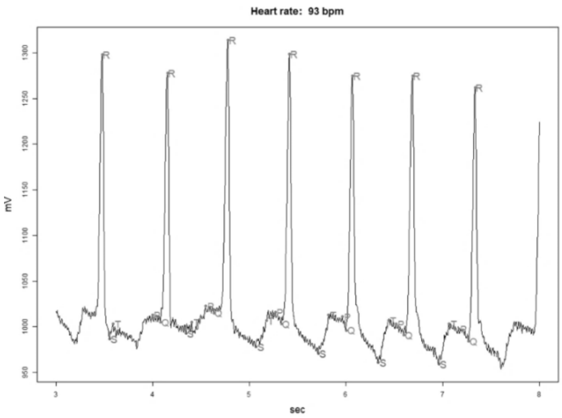

Fig. 3. An example of the detection of bends in the case of atrial flutter.

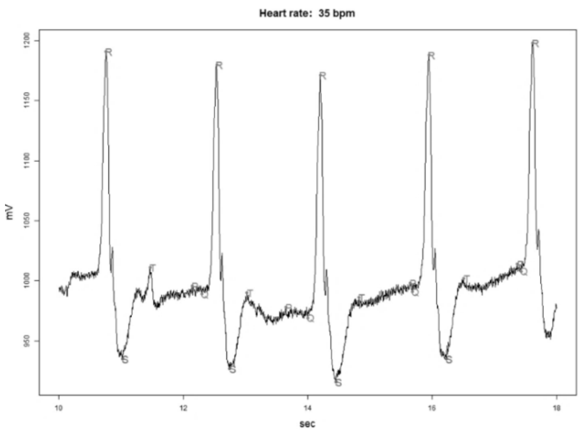

Fig. 4. An example of vibration detection for a ventricular rhythm.

The sinoatrial node is the stimulator responsible for triggering each heart beat (ventricular contraction). However, if the ventricle does not receive triggers fast enough either from the sinoatrial node or from the atrioventricular node, the heart itself becomes a pacemaker, it is called "escape rhythm" - ventricular rhythm. Ventricular signals are transmitted between cells and cardiomyocytes. So they are not transmitted through the conduction system. It causes extensive QRS complexes> 0.12 s. In this case, the speed remains between 20 and 40 beats per minute. If the frequency is greater than 40 beats per minute, then there is an accelerated rhythm. The factor causing the number of beats from 20 to 40 is the "internal automatism" of the ventricular myocardium. This can be considered as the physiological redundancy of the cardiac electrical system. An example of determining the folds in Fig. 4. Fusion heartbeats occur when electrical impulses from different sources act simultaneously on the same area of the heart. If it affects the ventricle, it is called the ventricular synthesis rhythm, while the collision currents in the atrial chambers produce atrial fusion connections. Ventricular beats can occur when the natural pulse and pacemaker pulse converge to activate the same part of the ventricle at the same time, causing visible differences in the configuration and height of the QRS complex of the electrocardiogram reading. heart. This contrasts with pseudofusion, in which the pacemaker's pulse does not affect the natural heart rhythm complex. The occurrence of pseudofusion is considered normal. Rare or isolated fusion beats caused by a pacemaker are also normal. However, if they occur too often, they can reduce cardiac output and therefore require adjustment of the pacemaker. In the ECG image, melting impacts generally have a higher amplitude R (Fig. 5).

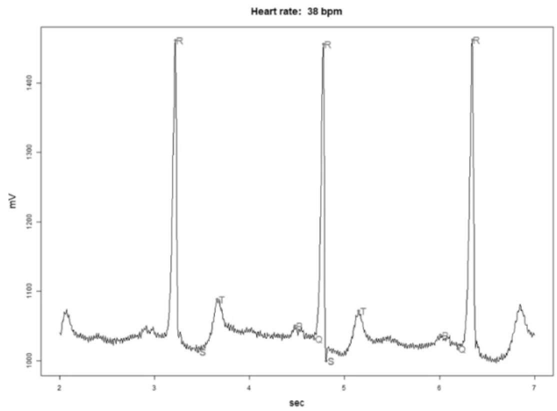

Fig. 5. Detection of waves when fusion heartbeats occur.

For each of the ECG readings P, Q, R, S, T waves and times between RR, PP, PR, RT, TP, QS and QT waves were determined. For each ECG reading, the mean times between the above waves were determined and a training set was constructed, where the categorizing variable determines the patient's condition (healthy, sick), while the quantitative variables represent the mean times between RR, PP, PR, RT, TP, QS, QT waves .

Conclusion

The article presents tests of electrical activity with ECG analysis for mapping body surface potential by providing more medical data for analyzes, where specialized algorithms can detect a specific amount of cardiopulmonary disorders. In the application, we focus on testing the electrical activity of the heart. This value can be measured because the potentials generated by the cardiac stimulating system are quite strong. Their proper acquisition from the body surface requires specific rules. To compare the results of tests carried out using our measuring device with tests using a standard ECG, appropriate conversion factors are used. The use of BSPM in combination with the impedance tomography technique gives better diagnostic results than using these medical techniques separately. This is due to the fact that we have 128 electrodes that give more data for further analysis. Our work will involve assigning disease units to measurement data and implementing appropriate machine learning algorithms for automatic diagnosis.

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