

The experience of using the personal electrocardiograph "ECG-Express"

I A Lezhnina¹, K V Overchuk², A A Uvarov³, V A Perchatkin⁴ and A B Lvova⁵

¹ Assistant Professor, Institute of Non-Destructive Testing, Tomsk Polytechnic University, Tomsk, Russia

² Postgraduate Student, Institute of Non-Destructive Testing, Tomsk Polytechnic University, Tomsk, Russia

³ Professor, Institute of Non-Destructive Testing, Tomsk Polytechnic University, Tomsk, Russia

⁴ Head of the Department of Rehabilitation of Patients with Cardiovascular Diseases, Cardiology Research Institute, Tomsk, Russia

⁵ Postgraduate Student, Cardiology Research Institute, Tomsk, Russia

E-mail: innalezhnina@inbox.ru

Abstract. The article describes the results of testing ECG-Express devices, previously developed at the Tomsk Polytechnic University. The testing was carried out on the basis of Tomsk Scientific Research Institute of Cardiology. Here we show the argumentation for application of such a devices in medical practice as well as number of cases of successful use.

1. Introduction

The history of electrocardiography (ECG) as a sub-section of electrophysiology begins with the famous experiment of Galvani who discovered the presence of electrical phenomena in the animal's body in 1786 and published a treatise on electrical forces arising in the course of muscle movement in 1791. In 1843 Matteucci also found the electrical phenomena in an isolated heart. And since that there was a need for an instrument capable to record the electromotive force in the live heart. The prototype of such a device was designed by Waller in 1887. In 1903 Eithoven introduced ECG into clinical practice using the Adler string galvanometer (Adler, 1897). In Russia the method of ECG diagnostics was introduced by S. Steriopullo and V. Zelenin in 1911. Under the care of Professor A. Samoilov the first ECG rooms were organized in the country in 1926. ECG telemetry was first used in 1935 by transmitting data over a phone wires [1]. During the following years the method was improved and developed. Until now no doubts ECG is affordable and simple diagnostic tool.

Nowadays the ECG makes it possible to diagnose and control many conditions, e.g. coronary heart disease [2], various rhythm and conductivity disorders, control of therapy with certain medications [3].

2. Calculated part

Doesn't matter how convenient and informative this diagnostic method was, it still remains accessible to people only with a special medical education. Currently in the range of medical products there is a wide variety of different devices for monitoring certain indicators that a patient can buy and use



independently [4]. These devices are widely distributed and are in the public domain. This is first of all sphygmomanometers, devices for non-invasive measurement of blood pressure which are successfully used by patients at home. It is extremely important for patients with diabetes mellitus to monitor blood glucose level, so devices for self-use by patients which are glucometers have also been developed. Of course it is worth mentioning probably the most common device that everyone has in their home, a thermometer is a device for measuring body temperature. But that's not the case for electrocardiogram equipment. Electrocardiographs as a rule are much more complicated (electrodes are tricky to apply, interface isn't intuitive) and require the presence of at least one other person who has special skills and is able to correctly register the ECG which absolutely excludes the possibility of using this equipment outside the doctor's office. But thanks to the scientists of Tomsk Polytechnic University the first batch of personal electrocardiographs was released for preclinical trials [5, 6]. At this stage the devices are tested in the Scientific Research Institute of Cardiology in Tomsk.

There are always a number of tasks that need to be determined at the initial stages of any new device testing:

1. Identification of the use of the product,
2. Ease of use for patients.

3. Materials and methods

For ECG registration we used a personal electrocardiograph "ECG-Express" developed in Tomsk Polytechnic University (Figure 1).

The device is based on capacitive ECG sensors. The capacitive sensor in contrast to standard metal electrodes employs the conductivity of a flat capacitor formed on one side by the metal surface of the sensor and on other side by the surface of the human skin. Between these two layers of conductors a dielectric layer with a high dielectric constant applied to the sensor surface. The bioelectric potential thus obtained is then fed to an analog matching circuit mounted on the upper surface of the sensor. The circuit is built with high-impedance amplifiers allowing to correctly condition the biopotential sensed by the electrode and also to amplify the power and then transfer it further to the circuit.

The key advantage of capacitive sensors is their ability to get the signal without preliminary preparation of the skin which ensures the convenience of application on the principle of "apply and measure". At the same time the signal quality is maintained at a high level which makes it possible to perform medical diagnostics. The disadvantage of the sensor is its high sensitivity to mechanical movements of the sensor. In this case the parameters of the flat capacitor formed by the skin-electrode contact change and the signal distortions appear. This defect is compensated in ECG-Express by a specially developed mechanical damping system [5,6]. The device also meets the following requirements:

1. It is personal and mobile so that the patient can use it in any life situation.
2. Measurement is made from the surface of the chest providing the essential information for an ischemic diseases diagnostics.
3. All the necessary tools are already built in the device. There is no need to carry about the imposition of electrodes and other operations. So this ease of use helps people with a different levels of technical skills. ECG-Express operates by the principle of one button, "just push and forget it".
4. Measurement is equally qualitative and stable for people with a different individual characteristics: chest anatomy, hair density, skin contamination and condition.



Figure 1. View of "ECG-Express".

The device has an anatomical shape (it is convenient to hold in the hand), the electrodes are located on special cushioning legs, which are elastically deformed, taking the shape of the chest, which allows the sensor to be fixed in a flat arrangement. The shock-absorbing feet are terminated by silicone straps with the help of which the device is reliably fixed during the registration process. Such an approach excludes all additional operations like skin cleaning and shaving, application of electrically conductive gels, fastening of electrodes. The main technical characteristics of the device are given in Table 1.

The preparation time for the measurement is about 10 seconds. The ECG is recorded for 50 seconds with 3 chest leads. Due to GSM connectivity module on the board the record is sent to the FTP server where the doctor grabs and analyses it in the specialized PC application and if necessary provides recommendations to the patient in accessible ways. All records are stored on the server and computer of the doctor in chronological order which makes it possible to return to them and analyze them anew. This device was offered to patients who were discharged from the hospital and continued treatment on an outpatient basis. Patients independently used ECG-Express at home.

Table 1.

Parameter	Value
Size / weight	200mm * 150mm * 65mm /150 gram
Power / Charging	LiPol battery / standard microUSB 5
Battery life	30 days in standby mode or 100 measuring and sending cycles
Type of connection	GSM/GPRS
Number of leads	3 Neb chest leads
Registration time	50 seconds
Memory	Queue for sending up to 10 entries
Software functions	Checking the quality of the signal, calculating the heart rate, storing the reference ECG in memory (for this user), comparing the shape of the ECG with the standard

4. Results

During the testing of the device we observed the following cases.

Patient T., 42 years old. Hospitalized in the Research Institute of Cardiology for examination and treatment with a diagnosis: IHD. CH. FKI. Percutaneous balloon angioplasty with stenting of the LCA trunk. At the outpatient stage I complained of pain in the chest pressing. Independently used a personal electrocardiograph, due to which it was possible to register changes in the T wave [8]. Hospitalized, examined, revealed postmyocarditis cardiosclerosis.

Patient U., 56 years old. Was in the Research Institute of Cardiology on examination and treatment with a diagnosis: IHD. PEAKS. Percutaneous balloon angioplasty with stenting PKA, ZMZHA, PNA. Ventricular extrasystole (Lown IVa). This patient underwent 24-hour ECG monitoring, according to which 3249 VES were registered, which is (3.7%) of the total QRS. The majority are monotopic paired. It was decided to initiate cordarone therapy [3]. Against the background of cordarone therapy, the number of VES decreased to 0.9% of the total number of QRS complexes. The patient is discharged with improvement. For the control of cordarone therapy at the outpatient stage the patient independently used a personal electrocardiograph. When analyzing the ECG the doctor noted the prolongation of the QT interval [5]. The dosage of Cordarone was reduced.

Patient K., 78 years old with a diagnosis: ischemic heart disease. PEAKS. Paroxysmal ventricular tachycardia. Persistent form of AF, tachysystole. This patient is stably heavy, as it has a spinal injury and, therefore, is constantly at home. The possibility to visit outpatient clinics and to be constantly monitored by a doctor is not available. Suddenly, this patient deteriorated. The use of a personal electrocardiograph made it possible to diagnose the onset of paroxysm of atrial fibrillation [8] and to call for emergency medical care, without waiting for the further development of negative symptoms.

Patient M. was observed outpatient with the therapist at the place of residence. Was advised by one of the staff of the Institute of Cardiology. He complained of attacks of irregularities in the heart, accompanied by mild dyspnoea, weakness, suddenly started, lasted 3-5 minutes and self-stopped. These episodes arose several times a month. Conducting daily monitoring of the ECG in this case was not informative [7, 9]. The patient used a personal electrocardiograph while in another city. It was possible to establish the probable cause of the described seizures and to register a rhythm disturbance - episodes of frequent ventricular extrasystole (Lown II) [8].

5. Summary

We analyzed the cases above and on this very early trials stage concluded that the personal electrocardiograph "ECG-Express" probably can be used for:

1. Detection of irregular heart rhythm disturbances, which can not always be detected with the help of daily ECG monitoring;
2. Receiving valuable information for diagnosis (ECG recording during an attack);
3. To establish possible episodes of myocardial ischemia;
4. To control the therapy with QT prolonging drugs.

When registering the ECG, patients did not notice any difficulties in using the device. The ability to transfer a record immediately to the doctor's workplace allows you to react immediately and take appropriate measures, while the patient can be thousands of miles away from his office. The development of telemedicine is one of the priority areas in medical technology.

References

- [1] Fogelson L 1957 *Clinical electrocardiography* (Moscow, State Publishing House of Medical Literature)
- [2] Montalescot G, Sechtem U, Achenbach S, Andreotti F et al. 2013 ESC guidelines on the management of stable coronary artery disease *European Heart Journal* **34** 2949–3003
- [3] 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)

- [4] Natalinova N, Avdeeva D, Kazakov V, Baranov V, Galtseva O and Ivashkov D 2016 *MATEC Web of Conf.* **79** 01005 DOI: 10.1051/mateconf/20167901005
- [5] Uvarov A, Lezhnina I, Overchuk K, Starchak A, Akhmedov S and Larioshina I 2016 *IOP Conf. Ser.* **671** 012032 DOI: 10.1088/1742-6596/671/1/012032
- [6] Overchuk K, Uvarov A and Lezhnina I 2016 *MATEC Web of Conf.* **79** 01029 DOI: 10.1051/mateconf/20167901029
- [7] Komolyatova V, Kupriyanov O, Pervova E and Ryabykina G 2014 National Russian recommendations on the use of Holter monitoring in clinical practice *Russian Cardiology Journal* **2** 6-71
- [8] Yartsev S 2014 *Electrocardiography: a practical guide-guide for doctors* (Moscow, RUDN)
- [9] Axelrod A, Chomakhidze P and Syrkin A 2007 *Holter monitoring of ECG: possibilities, difficulties, errors* (Moscow, Medical Information Agency LLC)