



Approach to Displaying Data to Users of Telemedicine Systems for Early Detection of Diseases by ECG

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Abstract. With the development of modern technologies in medical organizations, there is an opportunity to modernize existing methods of monitoring public health and detecting diseases. The use of telemedicine can reduce costs and increase the efficiency and accessibility of medical services including monitoring the state of health by remote (outside of medical and preventive institutions) registration and processing of ECG that helps to detect diseases in the initial stages. In this paper, we propose an approach to displaying data to users of telemedicine systems for independent (without medical staff) early detection of diseases by ECG. This approach can be used in the development of a graphical interface for telemedicine systems for the early detection of diseases by ECG.

Keywords: medical systems; user interface; remote screening

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Подход к отображению данных для пользователей телемедицинских систем раннего обнаружения заболеваний по ЭКГ

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Аннотация. С развитием современных технологий в медицинских организациях появилась возможность модернизировать существующие методы мониторинга здоровья населения и выявления заболеваний. Использование телемедицины позволит сократить расходы и повысить эффективность и доступность медицинских услуг, включая мониторинг состояния здоровья с помощью удаленной (за пределами медицинских и профилактических учреждений) регистрации и обработки ЭКГ, с помощью которой можно обнаружить заболевания на начальных этапах. В настоящей работе предлагается подход к отображению данных пользователям телемедицинских систем раннего обнаружения заболеваний с помощью ЭКГ без участия медицинского персонала. Данный подход может быть использован при разработке графического интерфейса телемедицинских систем раннего обнаружения заболеваний с помощью ЭКГ.

Ключевые слова: медицинские системы; пользовательский интерфейс; дистанционный скрининг

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1. Introduction

With the development of modern technologies, it became possible to modernize existing methods for early detection of diseases in the population, including people in remotely located places from medical institutions, using telemedicine. This opportunity allows increasing the coverage of the population with medical services without resorting to an increase in the staff of medical personnel, which makes it possible to reduce the costs of their provision and further treatment of the patient with timely detection of the disease at an early stage [1, 2].

The need for telemedicine technologies manifests itself during planning a mass clinical survey of the population with the aim of early detection of a specific disease - during planning a screening [3]. For example, the screening of the population for the presence of carbohydrate metabolism disorders on a national scale has not yet been carried out in Russia, although, in 2016, the prevalence of undiagnosed type 2 diabetes mellitus (T2DM) among the adult population was higher than the prevalence of diagnosed T2DM [4]. Without the implementation of telemedicine, screening tests recommended in the current standards (blood tests) [5] are too difficult and expensive to carry out, because a large number of medical personnel and laboratory equipment will be required in primary care.

Due to the increased availability of ECG recording devices [6] and the entry into force of the law on telemedicine, since 2018 in Russia [7], a new opportunity has been appeared for the early detection of diseases during the screening - with processing and analyzing ECG obtained from many remote electrocardiographs located outside medical facilities. The patient takes an ECG in a convenient place for himself where the electrocardiograph is located, then the ECG itself is transmitted via the Internet to a data center for processing. After that, the processing results are transmitted back to the

patient’s smartphone or e-mail, based on which the patient decides what to do next – to consult the doctor or not.

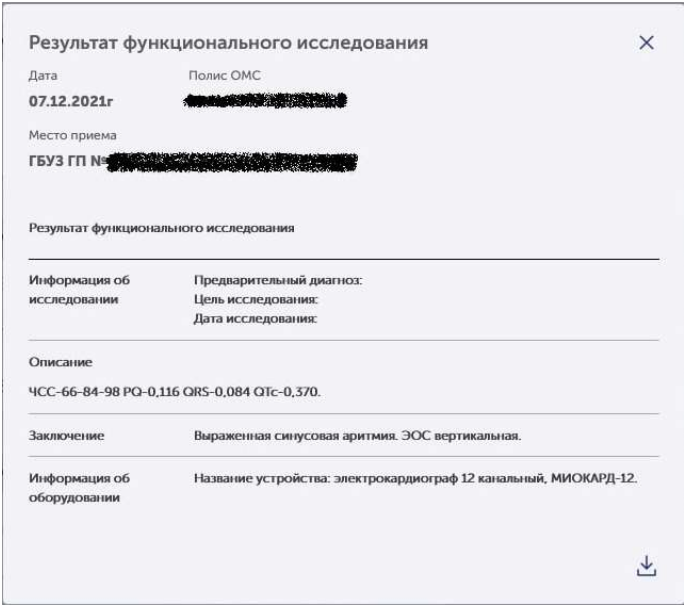


Fig. 1. An example of the results of an ECG study from an electronic medical record EMIAS (text in Russian)

When considering existing medical systems, it was found that they are not suitable for remote ECG screening studies. The main reason is that the systems do not consider the user’s qualifications. For this reason, the results of ECG analysis in such systems are provided to the user in terms that are understood by the medical specialist, but incomprehensible to the patient. As a result, the patient will have (if he wants) to find out on his own what to do next after the screening. An example of such results from the EMIAS electronic medical record is shown in Fig. 1.

Thus, when planning remote screening by ECG using telemedicine technologies, it is necessary to consider the qualifications of the system user that will be involved in the screening process.

2. Aims and objectives

The aim of the study is to develop an approach to inform the user about the results of a remote ECG analysis, which the patient will understand on his own, without the assistance of medical personnel. This approach is proposed to be implemented by creating a personal patient’s account of the telemedicine system for the early detection of diseases by ECG (hereinafter referred to as the System), in which the data will be displayed in accordance with the qualifications of the patient. The way medical data is presented should be flexible enough to meet the needs of users with different qualifications and experience. Most of the existing medical systems are designed for the fact that the user will not independently decipher the results of your examination, or it will be a patient with experience in the field of medicine. Our approach to displaying data will help to design the user interaction with the System so that the user with limited medical knowledge understands what to do next when passing the remote screening.

In particular, the developed approach helps to design the patient’s interaction with the System during remote screening without the participation of a doctor.

To achieve this aim, it is necessary to solve the following tasks:

- Analysis of the patient’s role model of the System;
- Determining the requirements for the personal patient’s account of the System;
- Developing an example of the personal patient’s account of the System.

As an example, it is planned to develop an automated system for carbohydrate metabolism disorders (CMD) screening by ECG together with a personal patient’s account.

It is supposed to evaluate the developed personal patient’s account by checking for compliance with the stated requirements (verification) and the declared CMD screening process (validation).

3. Overview

When designing a personal patient’s account of the System, it is necessary to determine the requirements. To determine the requirements, it is necessary to analyze the role model of the users of the System. The role models of telemedicine systems users affect what information should be displayed at all and in what form. Depending on the functions and purpose of the System, the model may include several roles: Patient, Medical Worker, etc. In the System with a mobile device for recording an ECG and displaying ECG analysis results, the role model includes only the Patient.

The characteristics of the Patient are:

- The Patient does not know medical terminology;
- The Patient may mishandle the electrocardiograph. Although portable electrocardiographs usually have clear and simple instructions, due to various factors (power line interference, unnecessary patient movements that degrade the quality of the ECG, etc.), the resulting ECG may not be suitable for further analysis;
- The Patient does not necessarily record an ECG in a medical facility, so there may not be a qualified medical worker nearby who will check whether the patient is recording the ECG correctly and tell what to do next.

Taking into account the process automated by the system, it is necessary to classify what the Patient needs to know first of all, and what does not need to know at all. Such a description of the user’s role model will allow you to answer questions such as:

- What information should be displayed on the main page of the personal account?
- What information may be put on additional pages or displayed when clicking on the button?
- What should not be displayed at all, even at the Patient’s request?

For example, during the process of remote ECG screening:

- First of all, it is necessary for the Patient to know the results of the screening and further steps. It is necessary to display information that answers the following questions:
 - "Is he/she all right?" - it should be said whether the Patient has signs of the presence of the studied disease;
 - "Does he/she need to see a doctor?" - a recommendation should be submitted to go to a doctor of a certain specialization when identifying signs of the presence of the disease under study;
 - "Did he/she take an ECG properly?" - if the ECG turned out to be of insufficient quality for further analysis, a recommendation to take the ECG again should be submitted.
- Secondly, if the Patient is interested, it is necessary to let them know additional information. For example, how the result was obtained, other details (the ECG tape or ECG analysis dynamics);
- Finally, the patient must be denied access to data other than the Patient’s. For example, the negotiations of doctors at the consultation and data about other patients.

The Patient’s needs during remote screening determine the structure of the personal account:

- Priority things need to be displayed on the main page;
- Additional information can be displayed on a separate request to the patient. For example, by clicking a certain button on the main page or expanding a certain list.

Information should be provided in a simplified form for the Patient, such as infographics.

However, prior to displaying data, the Patient must be authorized and authenticated so he wouldn't have access to data not related to the Patient.

4. Implementation

Based on the requirements laid down above, a personal patient's account of an automated system for CMD screening has been developed.

The screening process, based on which the system was developed, is presented in the following algorithm [8]:

- 1) Stage one:
 - a) Registration of the patient during screening;
 - b) ECG recording using a recording device involved in the screening process;
 - c) Checking the quality of the taken ECG. If there are critical interferences on the recorded ECG, the patient will go through steps (b) and (c) again;
 - d) Repeat steps (b) and (c) until enough ECGs are obtained without critical interference;
 - e) Upon successful completion of the ECG quality check, the patient receives a message on the smartphone/e-mail about the presence/absence of CMD signs on the ECG;
 - 2) In the second stage, the patient is re-examined for signs of CMD based on national recommendations, with which an appropriate diagnosis is made.
- As part of the work, the automation of the first stage is carried out, since the second stage must be performed manually by an endocrinologist in accordance with national recommendations.

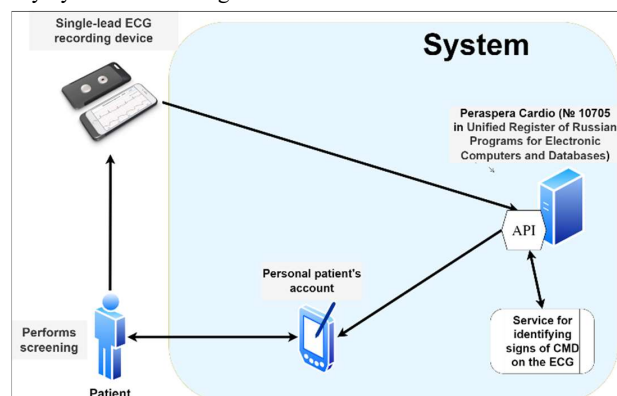


Fig. 2. The overall scheme of the automated system for CMD screening

The developed System consists of the following subsystems/services (Fig. 2):

- Peraspera Cardio software platform [9] is designed to assess the state of the human cardiovascular system based on ECG processing. This platform was chosen as the basis of the System as it accelerates its development since the platform already has the necessary functionality: collection, storage, pre-processing of ECG, performing basic calculations, and providing calculation results via API to related systems;
- Service for identifying signs of CMD on the ECG. The ECG data stored in Peraspera Cardio is

transmitted to the API service to perform calculations to detect signs of CMD based on ECG analysis. ECG analysis is carried out according to the mathematical methods described in [8,10]. Calculation results are sent back to Peraspera Cardio;

- Personal patient's account. The main purpose of the personal patient's account is to provide the patient with the opportunity to get acquainted with the results of the ECG analysis and view further recommendations during and after the screening.

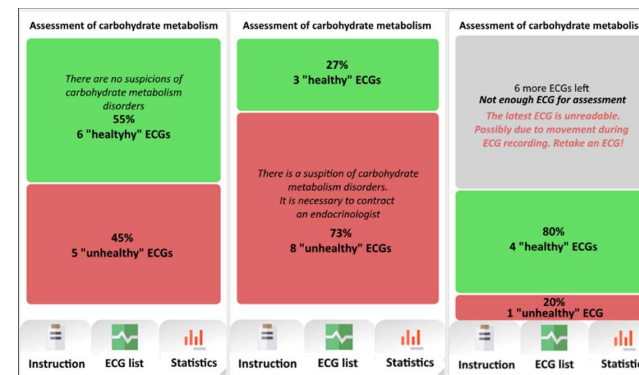


Fig. 3. Examples of displaying the results of ECG analysis on a smartphone in a web application

Access to the personal patient's account is implemented through a web application adapted for smartphones. Fig. 3 shows examples of displaying data for a patient by results or during screening from left to right:

- “The patient has no suspicions of carbohydrate metabolism disorders”;
- “The patient has a suspicion of carbohydrate metabolism disorders, it is necessary to contact an endocrinologist”;
- “The patient needs to retake the ECG due to poor quality. A possible reason is a movement during ECG recording.”

The developed system is compatible with all current operating systems and browsers with JavaScript support. The server part runs under Windows OS or Linux. The server part of the application is implemented using the JavaScript language, PostgreSQL is used as the DBMS.

5. Evaluation

At the moment, all the requirements for displaying data for the patient in the corresponding personal patient's account of the automated screening system for carbohydrate metabolism disorders have been met:

- after each ECG recording, updated values of health indicators are displayed in the personal patient's account, namely, indicators for assessing the state of carbohydrate metabolism (the proportion of ECG with identified signs of CMD);
- the patient is informed in his personal patient's account when it is recommended to take a new ECG to get an accurate answer, whether he needs to consult an endocrinologist;
- if there are enough ECGs for analysis, the patient is informed whether he has a suspicion of CMD and whether he needs to consult an endocrinologist;
- if the current ECG was taken with insufficient quality, the Patient is informed about the need to take the ECG again.

- prior to displaying data, the Patient must log in to his personal account by login and password sent to his smartphone after registration during screening and first ECG recording.

According to the implemented functions, we can say that the patient's personal account corresponds to the declared screening process for CMD.

To evaluate the work of the developed system with the patient's personal account, it is necessary to test the system in practice during the study. The system has not yet been tested, it is required to check in the form of trial operation during the screening study.

6. Conclusion

An approach has been developed to inform the user about the results of a remote examination in telemedicine systems for the early detection of diseases by ECG (Systems), which will be understandable to the patient without the help of medical professionals. The approach is implemented through the development of a user's personal account.

The role model of the patient as the central user of the System has been analyzed. Based on the role model of the patient, the requirements for displaying data in the personal account have been developed - based on the results of processing each ECG, the following information should be provided in the first place:

- whether he has signs of a specific disease;
- if so, which specialty doctor he should go to;
- a recommendation to take the ECG again if the previously obtained ECG has insufficient quality.

An example of a patient's personal account within the System, an automated system for screening for carbohydrate metabolism disorders (CMD) has been developed. The patient's personal account complies with the stated requirements and the CMD screening process. A trial operation of the system is planned for its approbation.

The obtained approach to inform the user about the results of a remote ECG recording can be used later for developing requirements for the graphical interface of the personal user's account for the above-mentioned Systems.

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