About Possibility of Remote Diagnostics of the Respiratory System by Auscultation

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Abstract

Development of technical base, software, accumulated information on the diagnosis of the respiratory system provided the prerequisites for creating remote diagnostics of the human respiratory system through auscultation. The known methods do not solve the problem of determining auscultation points at patent´s housing without a diagnostic specialist. The purpose of this study is to develop a method for remote diagnostics of the respiratory system which provides ability to determine the points of auscultation without presence of a diagnostic specialist.

The definition of auscultation points is provided using a computer program that allows to calculate the points´ coordinates based on the coordinates of points that determine the anatomical structure of the patient's torso. The patient or his assistant places the recording device at the auscultation points combining their images on the display with the image of the location of the recording device. The signal recorded at the auscultation point is remotely transmitted to a specialist for direct analysis and/or computer processing. The diagnostic module consists of two main units. The first unit contains a stethoscope, microphone, and amplifier connected to a mobile phone or other similar device containing an accelerometer. The patient or his assistant at the housing uses the unit. The second unit is a mobile phone with a mechanical marker or a computer with the ability to access the network in conjunction with the necessary software and is used remotely by a diagnostic specialist. The layout of the unit for recording and transmitting breath sounds was made. To avoid discrepancies in the diagnostic results the technical characteristics of the module elements must be normalized. Unified software is required for the module to function. The organizational tasks that need to be solved for the implementation of diagnostics are formulated.

Use of the method of remote diagnostics of the respiratory system, providing the ability to determine points of auscultation without the direct presence of a diagnostic specialist and the module will allow increasing efficiency of treatment of pulmonary diseases reduce infection risks and economic costs.

Keywords: remote medical diagnostics, human respiratory system, auscultation points, diagnostic module.

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О возможности дистанционной диагностики дыхательной системы человека методом аускультации

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Развитие технической базы, программного обеспечения, а также накопленная информация по диагностике дыхательной системы обеспечили предпосылки для создания дистанционной диагностики дыхательной системы человека посредством аускультации. В известных методиках не решена проблема определения точек аускультации в домашних условиях без присутствия специалиста по диагностике. Целью настоящего исследования является разработка методики дистанционной диагностики дыхательной системы, обеспечивающая возможность определения точек аускультации без присутствия специалиста по диагностике.

Для этого предусмотрено определение точек аускультации с использованием компьютерной программы, позволяющей вычислить их координаты на основе координат точек, определяющих анатомическое строение торса пациента. Пациент или его помощник устанавливают записывающее устройство в точки аускультации, совмещая на дисплее их изображения с изображением точки нахождения записывающего устройства. Записываемый в точке аускультации сигнал дистанционно передаётся специалисту для непосредственного анализа и/или компьютерной обработки. Диагностический модуль состоит из двух основных узлов. Первый содержит стетоскоп, микрофон и усилитель, соединённые с мобильным телефоном или другим аналогичным устройством, содержащим акселерометр. Узел используется пациентом или его помощником в домашних условиях. Второй узел представляет мобильный телефон с механическим маркером либо компьютер с возможностью выхода в сеть в совокупности с необходимым программным обеспечением и используется дистанционно специалистом по диагностике. Изготовлен макет узла записи и передачи звуков дыхания. Чтобы избежать расхождения результатов диагностики, технические характеристики элементов модуля необходимо нормировать. Для функционирования модуля требуется унифицированное программное обеспечение. Сформулированы организационные задачи, которые необходимо решить для внедрения диагностики.

Использование разработанной методики дистанционной диагностики дыхательной системы, обеспечивающей возможность определения точек аускультации без присутствия специалиста по диагностике и соответствующего модуля позволит увеличить эффективность лечения пульмонологических заболеваний, уменьшить риски инфицирования и экономические затраты.

Ключевые слова: дистанционная медицинская диагностика, дыхательная система человека, точки аускультации, диагностический модуль.

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Introduction

Traditional methods of medical diagnostics require direct contact of the patient with a specialist and, in most cases, a visit to a medical institution. In order to carry out primary diagnostics faster, an alternative strategy is the introduction of telemedicine and mobile medicine which has already been successfully used in a number of countries [1–6]. Remote diagnostics has a number of advantages over traditional methods. Firstly, increase the efficiency of the disease detection at early stage and also effective and timely treatment. There are no need to transport patients to a medical facility, contact between patients and medical personnel in a medical facility, and thus decreasing the risk of mutual infection and spread of infection with all consequences of these. In addition, there is an opportunity to save money, as the number of home visits to patients, the time of patient care, and the cost of servicing premises in medical institutions are reduced. Federal law No. 242 of July 29, 2017 "On amendments to certain legislative acts of the Russian Federation on the use of information technologies in the field of health protection" comes into force in the Russian Federation on January 1, 2018. It provides possibility of medical care using telemedicine technologies through consultations as well as remote medical monitoring of the patient's health [1].

The profile of medical module for remote diagnostics is determined by the parameters of the body system to be monitored. For example, methods of remote monitoring of the cardiovascular system are already known and widely used since the procedure for measuring blood pressure (BP) is quite simple and can be performed independently at home [6]. Remote blood Pressure monitoring is based on a computer system that automatically sends patients requests for blood Pressure levels in the form of mobile phone text messages. Data on the blood Pressure level received from patients via text messages are saved in the system, automatically processed, and the physician makes the therapy correction if necessary based on the information received.

Remote diagnostics of the respiratory system is a more complex task. Traditional non-invasive method for diagnosing the respiratory system is auscultation which on the one hand is particularly effective in the early stages of the disease, on the other hand creates prerequisites for computer processing of diagnostic results [7]. The usual auscultation procedure requires highly qualified and experienced specialist [8]. Description of airway sounds, their classification and standardization [9, 10] created opportunities for moving to their computer analysis [11, 12]. There are technical devices that allow to directly convert the sounds of breathing into a digital signal, and it is possible to simultaneously record an acoustic signal at many points on the surface of the chest [12], and sequential recording [13]. From the above, it follows that based on the existing equipment and software it is possible to create a module for remote diagnostics of the human respiratory system. At the same time, analysis of these sources shows that the problem of determining auscultation points on the chest surface is not solved without the direct presence of a diagnostic specialist, that is, the patient or his assistant cannot find these points themselves.

The purpose of this study is to develop a method for remote diagnostics of the respiratory system, which provides the ability to determine the points of auscultation without the direct presence of a diagnostic specialist. Creating an appropriate module requires solving a number of problems. First, it is necessary to ensure that the patient or his assistant can independently determine the position of auscultation points at home. Secondly, it is necessary to ensure the availability of the appropriate technical base and software. Using the module will speed up the diagnosis process and, increase the effectiveness of treatment of pulmonological diseases due to their detection at earlier stages, prevent the risks of infection when patients contact each other and with medical staff, reduce the economic costs associated with the need to move patients and staff for their contact during the diagnosis process.

The structure of the diagnostic module and the algorithm of remote diagnostics

The developed method provides determining of the primary points of auscultation using a computer program that allows to calculate the coordinates of these points based on the coordinates of the points that determine the anatomical structure of the patient's torso (here in after – the base points). The patient or his assistant determines the coordinates of the base points by installing a coordinate detection device on them in accordance with the program instructions. Based on the processing of the coordinates of the base points images of auscultation points are generated on the display. The patient or his assistant places the recording device at the auscultation points

combining their images on the display with the image of the location of the recording device. The signal recorded at the auscultation point is remotely transmitted to a specialist for direct analysis and/or computer processing in order to establish a diagnosis. If it is necessary to clarify the diagnosis the patient or his assistant receives information from a remotely located specialist about the location of additional auscultation points, after which the recording and analysis procedure is repeated.

The method of remote diagnostics of the respiratory system without the direct presence of a diagnostic specialist for determining the points of auscultation can be implemented on the basis of the module the scheme of which is shown in Figure.

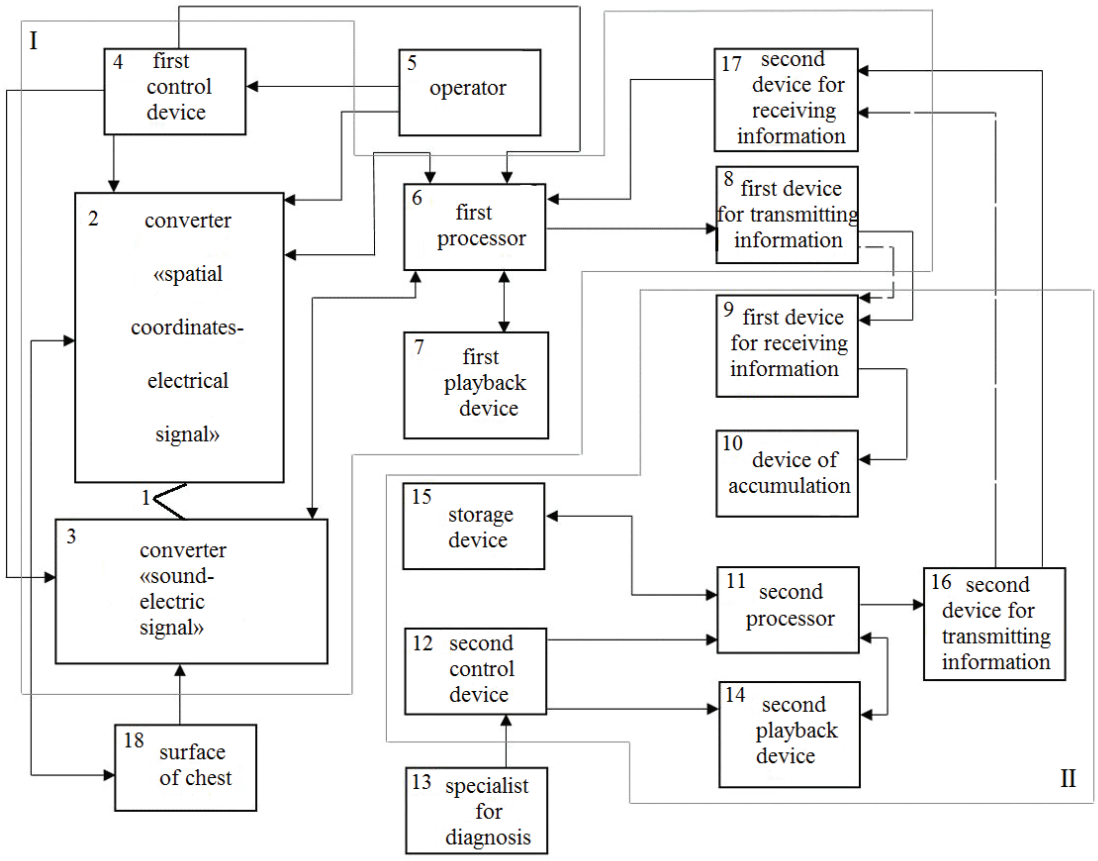

Figure – Scheme of the module for remote diagnostics of the respiratory system by auscultation method

The module contains a unit 1 consisting of two connected elements: the converter 2 "spatial coordinates of the object – an electric signal", and the converter 3 "sound – an electric signal". The first converter uses the accelerometer of a mobile phone or other device in combination with the appropriate software and the second one uses a stethoscope, microphone, and amplifier. Connection of the converters should provide an unconditional dependence between the spatial coordinates of the stethoscope and the mobile device with the accelerometer.

The presence of an accelerometer in unit 1 allows to perform the first, most problematic stage of diagnosis – to set the position of the auscultation points on the surface of the chest in absence of a diagnostic specialist. To do this through the first control device 4 on the mobile phone, the operator 5 (the patient or his assistant) must initiate the corresponding program in the first processor 6 plased in the mobile device and determine the coordinates of the base points for a specific patient. When the program is initiated the first playback device 7 (phone display) displays an image of a person's torso with marked base points. At the same time the image of the point that determines the position of the stethoscope (hereinafter referred to as the stethoscope point) is displayed there.

When the operator 5 moves unit 1 along the torso surface the coordinates of the stethoscope point are determined based on the twice-integrated accelerometer signal and the image of the stethoscope point is moved on the display in accordance with these coordinates. Operator 5 moves the block 1 along the torso surface until the display combines the images of the stethoscope point with the image of one of the base points. This means that the coordinates of the base point on the torso coincide with the coordinates of the stethoscope point after which the coordinates of the current base point are fixed. After combining all the base points with the stethoscope point the first processor 6 calculates the coordinates of the auscultation points (points on the surface of the chest where it is necessary to record breath sounds) based on information about the coordinates of the base points of the torso that determine its geometric parameters.

The second stage of diagnostics is the primary recording of breath sounds at auscultation points by the operator 5 and their remote transmission through the first information transmission device 8 for analysis and listening. As part of this step the first processor 6 creates images of auscultation points on the phone's display, whose spatial coordinates have been calculated for a specific patient. At the same time the image of the stethoscope point is displayed on this display. The operator must move the stethoscope along the chest surface until the images on the display match the stethoscope point and one of the auscultation points. After that it initiates the recording of breath sounds at this auscultation point in different breathing modes through the first control device 4 and transmits the recorded signal for listening and analysis. The specified operation is repeated for each auscultation point.

All the elements necessary for performing the above operations can be structurally combined into one common unit I based on a stethoscope and a mobile phone. To implement the method a layout of the node for recording and transmitting breath sounds was created. The "sound – electric signal" converter used a combination of a phonendoscope with a microphone which was connected via an amplifier to a mobile phone that had a built-in accelerometer.

Listening to and analyzing recorded breath sounds are performed remotely by a specialist. Depending on the method of organization of diagnostics this function can be performed in a public or private medical institution and if possible, it is advisable to provide for the possibility of rapid communication between the patient and the specialist. For technical support of the subsequent stages of diagnostics a mobile phone with a mechanical marker or a computer with the ability to access the network in conjunction with the necessary software can be used (unit II in Figure).

During the third stage of diagnostics parameters of the recorded signal are compared with the normal values and a decision is made about further operations. The signal is sent to the first information receiving device 9 (see Figure) contained in the phone or computer then it is directed to the accumulation device 10, from there – to the second processor 11. Through the second control device 12 the diagnostics specialist 13 initiates the broadcast of the recorded breath sounds through the second playback device 14 and listens to them. Simultaneously in the processor 11 using the appropriate software the parameters of the audio signals are calculated and compared with normal values received from the storage device 15. After analyzing the audio information and the results of computer comparison of parameters with the norm the specialist can make three possible decisions:

– If the specialist makes a decision about the compliance of the breathing sounds with the norm, then through the second control device 12 he proceeds to the fourth stage of diagnostics. He remotely sends the results of listening, comparing parameters, recommendations for further actions and, if necessary, additional information via the second device 16 for transmitting information, via the second device 17 for receiving information to the operator on the first processor 6. The processor generates information on the first playback device 7 (phone display).

– In case of deviation of breath sounds from the norm based on the results of listening by a specialist and/or deviation of their parameters from the norm during computer comparison, two options for further actions are possible. If the specialist desides to formulate a decision on further necessary actions based on the information already received then the fourth stage is repeated. If the specialist needs additional information, i.e. analysis of breath sounds in additional auscultation points that have not yet been analyzed, then he initiates the fifth stage of diagnostics through the second control device 12. In this case, the second playback device 14 generates images of additional points to be analyzed selected depending on the specific nature of deviations from the norm. The position of these points can be determined by the appropriate software, if necessary, the specialist changes the position of these points on the second playback device 14 (its

display) through a device 12 for controlling of a mechanical or electronic marker. Then, through the second processor 11, the transmission device 16 and the second reception device 17, the first processor 6, the information is sent to the first playback device 7 (phone display). The operator repeats the second stage of diagnostics for the additional points indicated on the display after which the third and fourth stages are repeated for these points.

The diagnostic results at the final stage should be entered both in the patient's electronic chart and in the General statistical database.

To implement the remote diagnostics module for the human respiratory system it is necessary to solve a number of technical and organizational problems. First, experimental testing of the method is necessary for which the specialist must simultaneously perform auscultation using traditional and remote methods. Based on the expert's opinion a decision is made on the prospects and/or need to improve the method.

Since the parameters of breath sounds are determined by the technical characteristics of the nodes used they must be normalized within the framework of this technique to avoid discrepancies in the results. The same applies to software. A review of the sources showed that a large amount of information on classification, standardization and computer analysis of breath sounds has been accumulated from which it is necessary to reasonably select or additionally create a unified software for the module. Specifically, the necessary programs include: a program for determining the coordinates of base points, a program for determining the coordinates of auscultation points by base points, a program for calculating and comparing the parameters of the breath sound with normal values, a program for selecting the coordinates of additional auscultation points depending on the specific nature of deviations of breath sounds from the norm, and auxiliary programs for moving to the next stages of diagnostics. In addition, it is necessary to ensure the possibility of transmitting the received data to the patient card and statistical database.

To solve these problems a number of organizational measures are necessary. First, the use of remote diagnostics must have a legal basis. Secondly, the interaction of physicians, engineers, and programmers to create a remote diagnostics module for the respiratory system should be carried out within the framework of organized groups that have legal and material support. The effectiveness of the introduction of remote diagnostics provides for the organization of training to work with this technique both on the part of specialists and on the part of patients and their relatives. In addition for preventive purposes, regular repetition of the diagnostic procedure is required which also requires certain organizational measures on a legal basis.

Conclusion

A method has been developed for remote diagnostics of the respiratory system, providing the ability to determine auscultation points without the presence of a diagnostic specialist. Using this technique will increase the effectiveness of treatment of pulmonological diseases; reduce the risks of infection and economic costs. The structure of the corresponding module is proposed. A part of the module was made in the form of a unit for recording and transmitting breath sounds. The technical and organizational tasks that need to be solved for the implementation of the proposed diagnostics of the respiratory system are formulated.

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