Innovative Mobile Device for Human Health Monitoring

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Abstract. In this article the integrated set of measured values and computational informative parameters for the mobile diagnostic devices used for monitoring and diagnostics of cardiovascular system of the person is brought. Methods of definition of current values of controllable parameters are examined, their merits and demerits are revealed. For the most effective estimation of a condition of cardiovascular system of the person (definition of parameters of central and peripheral hemodynamics, control parameters of transport of oxygen) it is necessary to use the complex method including volumetric compression oscillometry, electrocardiography, the blood pressure measurement by pulse wave together with a method of an estimation of requirement of an organism of the patient in oxygen. This mobile device can be used for the early diagnosis of COVID-19. The functional scheme of mobile diagnostic device is presented. The scheme includes the set of blocks, which are optimal by price and quality. All modules have built-in batteries, equipped with non-contact charging system that supports wireless communication channel, and boxed in waterproof, ergonomic case. Results of testing of separate blocks of mobile diagnostic device are described in the article.

Keywords: Mobile diagnostic device · Hardware-software complex · Monitoring of health · Cardiovascular system · Hemodynamic parameters · Cardiac index · Oxygen delivery index · Early diagnosis of COVID-19

1 Introduction

Modern technologies allow remotely monitoring a set of core patient’s hemodynamic parameters. Data obtained from a patient who is at home, in familiar surroundings, with a minimum stress load are the most informative and allow adjusting the treatment more accurately. The article [1] discusses the prospects for development of systems for remote cardiac function monitoring, introduction of such systems in Russia and importance of this problem.

The article [2] presents a model of mobile diagnostic device (MDD) for continuous monitoring of patient’s cardiac activity with the use of Bluetooth-based sensor network.
However, this article does not indicate the set of measured and estimated hemodynamic parameters that allow detailed assessment of the state of human cardiovascular system (CVS).

Due to the fact that MDDs are intended for wide distribution to the population for home use, an important indicator of such devices is the ratio price/quality of assessment of human CVS. Justification of the choice of adequate and complete set of hemodynamic parameters to monitor CVS activity is an important task.

2 Set of Measured and Estimated MDD Parameters

The full picture of the state of patient’s circulatory system can be obtained by knowing not only peripheral but also central hemodynamic parameters. Cardiac index (CI) is the main parameter characterizing the state of central hemodynamics. Its real-time monitoring is a key task in the assessment of patient’s state. Currently CI measurement function is available only in specialized cardiac bedside monitors and is not available in MDDs.

In order to assess patient’s current status and timely detect early symptoms of hemodynamic and oxygen transportation disorders, it is advisable to monitor the oxygen delivery index.

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The following shows main parameters that allow assessing patient’s state in terms of peripheral and central hemodynamics and oxygen transport. All parameters are grouped by methods of their measuring or processing on the basis of measured parameters. Every parameter has its name and description.

2.1 Volumetric Compression Oscillometry (VCO) Method

1. **Diastolic Blood Pressure (DBP or BPD), [mmHg]** - minimum pressure in the arteries when the heart muscle is relaxed (diastole); **measurable parameter:** recorded at the start point when oscillometric curve goes down in the volume compression oscillogram (VCO method)

2. **End Systolic Pressure or Final Systolic Blood pressure (ESP or Bpyw), [mmHg]** - minimum pressure in the ventricle at a maximum emptying, which leads to the opening of the mitral valve; **measurable parameter:** corresponds to a point of expressed slowing down of the reduction of oscillation amplitude in the VCO method.

3. **Lateral arterial pressure (LAP or TSP), [mmHg]** - true systolic pressure on the internal surface of the artery vessel wall; **measurable parameter:** determined by the last maximum wave in the VCO method.
4. Pulse rate (PR), [1/min] - periodic fluctuations of vessel volume within one cardiac cycle; **measurable parameter.**

5. Mean arterial pressure (MAP or BPav), [mmHg] - integral value of all types of blood pressure that reflects their average level within full cardiac cycle; **measurable parameter** - determined by the first maximum wave that corresponds to the largest oscillations amplitude in the VCO method.

6. Systolic blood pressure (SBP or BPs), [mmHg] - highest pressure generated in large vessels during contraction of the heart; **estimated parameter:**

\[ BPs = 2 \cdot BPav - BPd \]  

(1)

7. Arterial pulse pressure (APB or BPstr), [mmHg] - magnitude of hemodynamic impact that reflects the state of the vessel walls; **estimated parameter:**

\[ BPstr = BP_{yw} - LAP \]  

(2)

8. Pulse pressure (PP) [mmHg] - indirectly reflects the volume of blood flowing into the aorta; **estimated parameter:**

\[ PP = BPs - BPd \]  

(3)

9. Specific peripheral resistance (SPR) [conventional unit] - total precapillary resistance per unit of body surface area; **estimated parameter:**

\[ SPR = \frac{BPav}{CI} \]  

(4)

10. Peripheral resistance unit (PRU or TPR) [mmHg min/ml] - the total precapillary resistance depends on the vascular tone and blood viscosity; **estimated parameter:**

\[ TPR = \frac{BPav}{CO} \]  

(5)

11. Stroke volume (SV) [L] - volume of blood ejected by the heart into periphery per one systole; **estimated parameter:** it is calculated by the Starr-Akuel formula [3]

\[ SV = 100 + 0.5 \cdot BPs - 1, 1 \cdot BPd - 0.6 \cdot A + S \]  

(6)

where S - cross-sectional area of the aorta (can be found by N.N. Savitsky nomogram or calculating the diameter of the aorta D); A - age in years

12. Shock index (SI), [L/m2] - pulse volume per body surface area or the heart rate divided by the systolic blood pressure [4]; **estimated parameter:**

\[ SI = \frac{SV}{BSA} \quad \text{or} \quad SI = \frac{HR}{SBP} \]  

(7)

13. Aorta Diameter D (DA), [mm] - cross-sectional area of the aorta can be found by N.N. Savitsky nomogram **estimated parameter:**

\[ DA = \sqrt{\frac{2.81 \cdot SV}{PP}} \]  

(8)
2.2 Electrocardiography Method

14. Heart rate HR, [L/min] - number of heart beats per time unit; **measurable parameter** - interval between R-R waves on the ECG.

15. Respiratory rate (RR), [L/min] - number of inhalation-exhalation cycles per minute; **measurable parameter** - lung rheography (with the use of cardiac electrodes, measurements at frequency 10–30 kHz) is integrated into ADAS 1000 chip.

16. **Ejection fraction (EF) [%]** - shows the percentage of blood leaving the heart chamber (ventricle) during its contraction; **estimated parameter**:

\[
EF = \left(1 - \frac{t_{QRS}}{t_{ST-T} - 0.5t_{QR}}\right)
\]  

(9)

where: \(t_{QRS}\) - QRS time; \(t_{ST-T}\) - time from the end of the S wave to the end of the T wave, \(t_{QR}\) - time from the start of the Q wave to the top of the R wave.

Formula (1) is used in the absence of BP data (Calculation is only according to the ECG data.). In other cases it is possible to use the formula (10)

\[
EF = \frac{SV}{EDV} \times 100\%
\]  

(10)

17. **End-diastolic radius (EDR), [mm]** - maximum radius of the ventricle immediately before the opening of the aortic valve; **estimated parameter**:

\[
EDR = (44.5 - 100t_{RS})t_{QRS} - 11t_{RS}
\]  

(11)

where: \(t_{QR}\) - time from the beginning of the Q wave to the top of the R wave; \(t_{RS}\) - time from the top of the R wave to the end of the S wave.

18. **End-systolic radius or of course systolic radius (ESR), [mm]** - minimum radius of the ventricle immediately before the opening of the mitral valve; **estimated parameter**:

\[
ESR = (44.5 - 100t_{RS}) \times (t_{QR} + t_{RS}) \times \sqrt{\frac{1}{3t_{ST-T}}} - 11t_{RS} \times \sqrt{\frac{1}{3t_{QRS}}} \times \sqrt{3t_{ST-T}}
\]  

(12)

where: \(t_{QRS}\) - QRS time, sec; \(t_{ST-T}\) - time from the end of S wave to the end of the T wave.

19. **End-diastolic volume (EDV), [ml]** - maximum volume of the ventricle immediately before the opening of the aortic valve; **estimated parameter**:

\[
EDV = \frac{4}{3}\pi \times EDR^3
\]  

(13)

20. **End-systolic volume (ESV), [ml]** - minimum volume of the ventricle immediately before the opening of the mitral valve; **estimated parameter**:

\[
ESV = \frac{4}{3}\pi \times ESR^3
\]  

(14)

21. **Stroke volume (SV), [ml]** - volume of blood ejected by the heart into periphery per one systole; **estimated parameter**:

\[
SV = EDV \times EF \quad \text{or} \quad SV = EDV - ESV
\]  

(15)
2.3 Pulse Wave Analysis Method

22. Pulse wave velocity (PWV), [m/s] - characterizes viscoelastic properties and tone of the vascular wall (it is important for determination of the risk of CVD); estimated parameter:

\[ PWV = \frac{L}{PWPT} \]  

(16)

where L - distance between the cuff and pulse oximeter sensor; PWPT - pulse wave propagation time.

23. Pulse wave propagation time (Tv), [10-3 s] - time during which the pulse pressure wave passes a certain portion of the arterial system; measurable parameter: fix the time of registration of the pulse wave maximum amplitude using VSO (BPav point) and obtain time T1. Fix the pulse wave maximum amplitude using pulse oximetry sensor and obtain time T2. After that calculate PWPT = T2 − T1

2.4 Pulse Oximetry Method

24. Oxygen saturation SpO2, [%] - percentage of oxygen content in the blood; measurable parameter – pulse oximeter

2.5 Additional Methods of Measurement and Calculation

25. Temperature (T), [°C]; measurable parameter - with the help of thermometer.

26. Body surface area (BSA) [m²]; estimated parameter - DuBois formula

\[ BSA = 0.007184 \times Height^{0.725} \times Weight^{0.425} \]  

(17)

2.6 Complex Estimated Parameters

27. Cardiac output (CO), [L/min] - blood volume ejected by ventricle into the systemic circulation per one minute; estimated parameter:

\[ CO = SV \times HR \]  

(18)

Formula (18) is used if SV calculated by Starr-Akuel formula. (BP data obtained with the use of VSO method). You can use also Bremser-Ranke formula:

\[ CO = \frac{799, 8 \times S \times (LAP - BPdi) \times Ts \times Tp}{PWP \times Td} \]  

(19)

where: 799, 8 = 0, 6·1333 - product of the correction factor (the ratio of the arterial bed length to entire vascular bed) and the multiplier to convert pressure into Dina; S - cross-sectional area of the aorta calculated based on the aorta diameter or can be found by N.N. Savitsky nomogram; BPdi - actual diastolic blood pressure (invasive) can be replaced by BPd determined by VSO method; Ts - systolic period time; Tp - time of full involution of the heart; Td - diastolic period time;
28. **Cardiac index (CI), \( [L/min \cdot m^2] \)** - cardiac output per body surface area; **estimated parameter:**

\[
CI = \frac{CO}{BSA}
\]  

(20)

29. **Hemoglobin in the blood, (Hb), \([g/L]\)** - main function of hemoglobin is to carry oxygen to the tissues and to bind carbon dioxide (CO2) with its following release in the lungs; **estimated parameter:**

\[
Hb = \frac{MCH \times 200304}{\left( \Delta T \times 66.03 \times A^{-0.37} \times BP_s \times BP_d \times \frac{PWPT}{L} \right)^{-0.2}}
\]  

(21)

where: \(\Delta T\) - the duration of the trailing edge of the pulse wave, \(A\) - amplitude of the pulse wave; \(L\) - distance between the cuff and pulse oximeter sensor; \(PWPT\) - pulse wave propagation time; \(MCH\) - mean corpuscular hemoglobin in absolute units. (norm 27–31).

30. **Oxygen content in arterial blood (CaO2), \([ml/100 ml]\)** - volume of oxygen in every 100 ml of arterial blood; **estimated parameter:**

\[
CaO_2 = (1.39 \times Hb \times SaO_2) + (PaO_2 \times 0.0031),
\]  

(22)

where: 1.39 - Huefner index (number of milliliters of oxygen bound to 1 g of hemoglobin); \(Hb\) - content of hemoglobin in the blood; \(SaO_2\) - saturation of arterial blood; \(PaO_2\) - oxygen tension in arterial blood (quantitative parameter of oxygen pressure dissolved in the blood). Normal values are in the range: 80 ÷ 100 mmHg, 0.0031 - solubility coefficient of oxygen in the plasma;

31. **Oxygen delivery index (DO2I), \([ml/min/m^2]\)** - shows the quantity of oxygen delivered to organs and tissues per time unit; **estimated parameter:**

\[
DO_2I = CaO_2 \times CI
\]  

(23)

These parameters can be obtained using the following methods: volumetric compression oscillometry, pulse wave analysis, electrocardiographic (ECG) analysis. Additional pulse oximetry data can be used to assess oxygen transport. As a result we can get enough data for a comprehensive assessment of the state of patient’s CVS.

### 3 Techniques for Estimation of Peripheral and Central Hemodynamics Parameters

After reviewing promising non-invasive methods that allow the calculation of the parameters of peripheral and central hemodynamics, we selected four methods for use in MDUs: electrocardiographic, volume compression oscillometry, pulse oximetry and pulse wave analysis. These methods still more recently were considered difficult to realize because of the need for of significant computational capacity. Therefore, they were accessible only in expensive stationary equipment. The emergence of cheap 32-bit
microcontrollers, combining low cost, high performance, with minimal power consumption allowed to implement complex algorithms for computing, working in real time and implemented in the developed MDU.

Electrocardiographic method allows defining main functional characteristics of the left ventricle cardiac hemodynamics by modeling electrocardiosignal (ECS) parameters. There are a large number of publications showing close conjugation of electrical and mechanical parameters of the heart [3]. Experimental studies of ECS spreading from the perspective of antenna-wave theory have shown the dependence of its time parameters and mechanical activity of the heart, and the possibility to assess the functional volumes of the left ventricle with the use of ECG.

Volumetric compression oscillometry (VCO) method is indirect, non-invasive method for determination of blood pressure (BP) levels in humans by registering arterial volume oscillogrames. VCO consists of separate pulse waves (PW) of the major artery registered during the increase of pressure in the cuff with a linear amplitude characteristic throughout the path of transformation and amplification. We can measure diastolic, mean, lateral systolic and end systolic pressure in the main blood vessel by analyzing PW. Based on obtained data we can calculate a number of hemodynamic parameters, including cardiac index (CI) [4]. To measure BP by oscillometric method [10] there is no need to pressurize the cuff up to systolic pressure, it is enough to raise the cuff pressure up to average arterial pressure and then calculate systolic pressure [5–7]. The disadvantage of this method is sensitivity to vibrations due to patient’s motions. In order to ensure functional (BP + ECG) monitoring (BP monitoring under conditions of expected physical load) the authors [8] used auscultatory method to measure BP (use of microphone instead of phonendoscope). This method is sensitive to external noise. We believe that the use of accelerometer in VCO is the most effective way to measure BP when a person is at rest.

Pulse wave (PW) method. Among other methods that allow assessing BP without the use of compression cuffs, the BP measurement by pulse wave (PW) propagation time should be noted. When using this method there is no need to create any mechanical effects [9]. The PW propagation velocity can be determined from the difference between the moments of occurrence of characteristic peaks of cardiosignal and photo sensor signal. The photo sensor is mounted on patient’s finger, wrist or ear lobe together with the illuminator. Peripheral pulse signal, in particular the radial artery, contains information about many physiological processes in the body, and especially about the CVS. The PW propagation velocity is an index of arterial stiffness of the vessel wall. The higher the velocity, the higher the stiffness and lower the possibility of extensibility of the vessel wall [10]. There are a number of publications by authors [11–13] who show the relationship between the frequency of occurrence of cardiovascular diseases and PW velocity.

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The fourth method uses a pulse oximeter. The principle of operation of the pulse oximeter is well known. It is based on measuring the absorption of red and infrared light that passes through a patient’s finger or earlobe. Hemoglobin, which carries oxygen (oxy-hemoglobin), absorbs infrared wavelengths (940 nm), hemoglobin, which does not carry oxygen (deoxy-hamoglobin), absorbs the visible red spectrum wavelength (660 nm) LEDs are used as light source and in series alternately switch at a frequency of 25 Hz [16].

This method can be used for the early diagnosis of COVID-19. It is known that the oxygen content in the blood of a healthy person is 96–100%. A rapid decrease in this indicator (SpO2) indicates the development of pulmonary or cardiovascular diseases. A decrease in the value by 3–4% from the usual level for a person may indicate the presence of a viral disease.

All MDD parameters listed in Sect. 1 can be measured or calculated based on these four methods. The above mentioned methods were recently considered too difficult for implementation because of the need for significant processing power and were available only as a part of expensive hospital equipment. The advent of cheap 32-bit microcontrollers combining low cost and superior performance at minimum power consumption allowed to implement sophisticated algorithms for computing, operating in real time.

New materials, efficient sources of power supply, miniature sensors and new ways of mounting them on patient’s body stimulate a decrease in the size of MDDs and expansion of their functions.

If the hemodynamic and oxygen transport data are insufficient for the diagnosis, then biochemical analysis data is required. These data can be obtained by using biosensors. The article [17] describes the principle of designing biosensors with specified performance characteristics.

4 Mobile Diagnostic Device for Human Health Monitoring (MDD)

The authors developed the MDD in accordance with the following functional diagram (Fig. 1). The MDD is a hardware-software complex consisting of three blocks, interchangeable sensors, a cuff and electrodes.

Block 1 (Fig. 1) consists of four modules: a module for blood pressure measurement (6), a module for measuring cardio parameters and ECG recording (7), a module for pulse oximetry (8), a module for a biochemical blood and urine analysis (9). To get started, any of the above modules must be installed in the MDD (10) frame and the corresponding sensor must be connected to it. The following modules are installed in the MDD: altimeter, accelerometer, GPS module, Bluetooth module, wireless charging module, rechargeable battery, data processing and storage module. The memory capacity is sufficient for storing the recorded trends of the daily Holter ECG monitoring and blood
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The battery charge is sufficient for the operation of any module during the day.

The module for measuring cardio parameters is built according to the classical principle with three leads, and three additional electrodes V1, V2, V3. The module solves the following tasks: obtaining HR, RR, ST, QT trends, recognition of QRST complexes on ECG, detection of rhythm disturbances, its HRV triangular index, marking of anomalies and artefacts. Distinctive features of the cardio module design are the ability to work in conjunction with the cardio microphone and EPIC PS25255 cardio electrodes (Electric Potential Integrated Circuit) from Plessey Semiconductors. These electrodes are designed for “dry” (without the use of conductive gels) contact with the patient’s body and can be installed in a cardio belt developed by authors and designed for quick installation and removal of the MDD along with cardio electrodes. To highlight periodic changes in heart activity, the techniques described in detail [8, 10, 18] are used. If a patient has a pacemaker, an assessment of its functionality could be made, including statistical data on unresponsive stimulation. The problem of selecting the optimal stimulation parameters and the choice of methods for calculating them is extremely relevant, since statistics show that up to 30% of pacemakers due to improper settings or for other technical reasons not only do not improve the condition of patients but even lead to deterioration, such as ventricular fibrillation of the heart.

An analysis of various types of contact and contactless electrodes is given in [5]. Electrodes are embedded in a special belt or vest that fits over the patient’s body. A cardio microphone (2) can be attached to this garment for listening to the noise of the heart and lungs. Typically, during the Holter monitoring, the patient is asked to keep a diary, where he should record the current activity, indicate the time of night and daytime sleep, exercise stress, record the time of food and drugs intake, the appearance of pain, dizziness and other signs of illness. Therefore, a capacitance sensor is built in, which activates audio recording when the patient’s hand is close to it. The resulting record has a timeline and allows the patient to simplify keeping a diary. However, as follows from the medical practice, patients often forget to make marks and the pathologies discovered by the doctor remain unclarified. To solve this problem, the MDD uses an altimeter, an accelerometer and a GPS module. According to the altimeter, we can judge the patient’s ascent or descent, the movement on the stairs can be determined with an accuracy of one step. The three-axis accelerometer allows you to find out if the patient is in motion or at rest. Using this data, we will correct the time when the blood pressure measurement started. GPS data is used to calculate the distance travelled and determine the location of the patient.

On the expiry of 24 h, the cardio module will beep to signal the end of monitoring. Much less often, doctors use seven-day Holter ECG monitoring, which provides comprehensive information about the electrical activity of the heart. If it is required to continue monitoring on the next day, it is necessary to replace the removable battery.

The important feature of the pressure measurement module (6) is the use of an oscillometric method. This method allows inflating the cuff to the mean arterial pressure, not to the systolic pressure, which is calculated. This allows you to improve the comfort of measurement, reduce the relaxation time of blood vessels, as well as provide greater
measurement accuracy and the ability to calculate the whole spectrum of hemodynamic parameters.

To determine the pulse wave velocity, oxygen saturation, hemoglobin level, and pulse filling, the pulse oximetry module is used (8).

One of the most popular uses of MDD is monitoring the condition of elderly people. Taking into account the characteristics of this category, Block 2 was developed (Fig. 1). The main task to be solved is the assessment of physical activity during the day, the control of breathing and pulse in a non-contact way. The development is based on the method described in [19, 20].

For implementation, the USRP module (12) is used (universal programmable transceiver operating in the UWB range), antenna module (11) consisting of 16 antennas
installed in one package and switched at 100 Hz with a directional pattern close to circular. Antennas emit a signal varying from 7,000 to 7,500 MHz every two milliseconds. The signal emitted by the antennas is shifted in phase so that it can be differentiated. The device receives reflections of these signals from various objects. The arising phase beats upon reflection from a moving object are used to calculate the distance to the object. The accuracy grade of this method allows you to control changes in the position of the patient’s chest that occur as a result of breathing and heart work while the patient’s motionlessness.

As a module for collecting and processing information, Block 3 (tablet or smartphone) is used (Fig. 1). Peripheral devices (modules 16, 17, 20, 21, 22) are used to communicate with the patient’s doctor or family as well as to organize data processing using cloud services. It is enough for the patient to be in the Block 3 Bluetooth coverage area to automatically upload data from the MDD to the tablet or to the cloud. If there is no Internet connection, data downloaded from the MDD will be stored in the built-in memory card (21).

5 The Results of Laboratory Tests MDD

For testing MDD, a patient signal generator RIGEL UNI-SIM [21] was used. It is a handheld and battery-operated vital signs simulator which designed to generate and reproduce electrical signals of a special form when conducting checks and calibrations of functional diagnostics devices, patient monitors. This enables medical device engineers to quickly, easily and accurately perform NiBP, SpO2, ECG, temperature, IBP and respiration functionality tests simultaneously, using a single portable instrument.

The outcomes of tests of MDD had been the following.

- The parameters of ECG signal recording are determined by the characteristics of the used EPICPS25255 sensors. The input impedance of the ECG channel is at least 20 GΩ; input capacitance 15 pF; ECG bandwidth at minus 3 dB (0.05–80) Hz. The time constant of ECG channels is not less than 3.2 s; nonlinearity of the amplitude response of the ECG channel no more than 2%; measurement of heart rate in the range from 20 to 250 beats/min; HR measurement error was ±2 beats/min.
- The relative error in measuring blood pressure at rest is ±4%.
- The relative error of oxygen saturation measurement (SpO2) in the range of 80–99% - not more than ±2%; in the range of 50–79% - not more than ±4%; in the range of 0–49% is not standardized.
- The pulse rate measurement range is 20–250 beats/min.
- The range of determination of the perfusion index is 0.05–10%. It should be noted that after a person stays in the cold, the perfusion decreases significantly.
- Limits of an absolute error of measurement of pulse rate: in the range of 20–99 beats/min. ±2 beats/min; in the range of 100–250 beats/min. ±3 beats/min.

6 Conclusions

The systematic analysis of the parameters characterizing a person’s cardiovascular system (CVS) was carried out, the necessary set of measured parameters and the informative set of various calculated parameters based on the measured ones were identified.
It was shown that for the most effective assessment of the patient’s CVS status (i.e. determining parameters of central and peripheral hemodynamics, monitoring oxygen transport parameters), a comprehensive method should be used, including volumetric compression oscillometry, electrocardiography, pulse wave analysis together with a method for assessing the patient’s body oxygen needs.

It was concluded that the best choice is the modular design of the device. An MDD can consist of four modules: a pressure measurement module, a cardiological parameter measurement module, a pulse oximetry module, a contactless charging module with a case for storing modules. Oxygen saturation monitoring with this mobile device will diagnose COVID-19 in the early stages of the disease.

All modules used in MDD must have a waterproof ergonomic case. To monitor the condition of the elderly people, it is advisable to use contactless methods for determining their physical activity, respiratory rate and heart rate. Additionally, modern biochemical sensors could be used to monitor the parameters of capillary blood and urine. Laboratory tests of individual modules of the MDD showed that the measurement error does not exceed 3–4%.

One of the further directions of research of the authors of this article is the use of this mobile device for the early diagnosis of new viral infections, both on the basis of constant monitoring of many measured and calculated parameters characterizing the human condition, and by connecting the latest test systems (biosensors) to determine the presence of RNA virus.

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