Development of methods for results reliability raise during the diagnosis of a person's condition by pulse oximeter

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Abstract. A paper presents the problem of results reliability increasing a during person's condition diagnosing by pulse oximeter is considered. A new method for reliability evaluation of the measurement results of the pulse wave parameters and a technique for tuning of optical part of the pulse oximeter are developed. Developed by us the method and the technique allow to make the insignificant of number errors influence on the measurement results. The data on the experimental research of various people condition are presented.

1. Introduction

At present time the non-contact methods for research of human condition are find grand use in clinical medicine and in other spheres of human activities. The investigations with the non-contact methods, where blood uses as a source of information about the human health condition are represented the especial interest. Various investigations showed that blood contains a huge information amount. The decipherment of this information amount opens way to knowledge about the condition of almost all human organs. Nowadays researchers trying to solve this problem analyzing of blood streams in veins and vessels by magnetic resonance tommographs [1, 2]. The development of the MR tomograph, which should be compact and available to many people, at present time is unviable. The access to MR tomographs, which standing in laboratories and medical centers, is limited. Another method of research the flowing blood stream is the nuclear magnetic relaxometry [3]. The nuclear magnetic relaxometers are difficult in operation and have a large weight and dimensions [4-6]. Besides that information about the measured values of relaxation constants T₁ and T₂ allows only to declare the blood state (standard or not). People have various features of the body structure etc. Therefore, in most cases on the values T₁ and T₂ of people blood are significantly different with each other [7-8]. This leads to additional uncertainty in the diagnostics.

The modern pulse oximetry is the most preferred method for human condition monitoring as compared to the earlier considered methods [8-13]. The simplicity and painlessness of the procedure for measuring heart rate, saturation of arterial blood with oxygen proved the validity of using a pulse oximeter in various fields of medicine, sports, and individual usage for human condition monitoring [12–14]. At present time only two means of diagnostics are exist in direct application (transmission and reflected pulse oximetry). The each of these methods has advantages and disadvantages, which
determines the areas of their most rational use [12-14]. For example, in case of the monitoring the patient's condition after surgery are using the reflected pulse oximetry. In case of the definition the reaction of human organism to extreme loads in sport are using the reflected pulse oximetry. For control the person of your health in during day are using the transmission pulse oximetry, etc.

Despite this, it is necessary are conducting the additional research for the common patterns establishing which in present time aren’t formulated. Also needed in technique of this method use in specific cases are make the additions and clarifications.

2. Features of the reflected and transmission pulse oximetry

The main advantage of the reflected pulse oximetry is possibility to place sensors practically on any part of the human body. This allows to make the more extensive diagnostics. For example, a person is placed in the stationary medical ward and his movement is restricted. The numerous sensors, installed throughout the human body, allows to obtain a reliable result about human condition after the analyzing the information. This result usually is confirmed by other devices (placed near the patient), which are used simultaneously with the reflected sensors of the pulse oximeter for monitoring the human condition [12].

It is not always expedient that one sensor used for control of person's condition, which is working at the reflected signal mode. The results of researches contain a large number of errors (failure in calibration of the sensor roughness of the skin surface, etc.) in case of the only one reflected signal is used during the measurement. As a result of the experiments conducted by various scientists it was established that the transmission pulse oximetry is much more accurate than the reflected in case of using one or two sensors for measurement.

The laser radiation, passing through the explored piece of skin tissue, absorbed unevenly, because of existence of vessels therein in case of diagnostics using a transmission pulse oximetry. The required value of oxygen saturation is calculated based on the difference within amplitudes of two transmitted rays. In the transmission pulse oximetry the measuring instruments (semiconductor laser and photodetector) must be located strictly opposite to each other. Therefore the measuring sensor usually located on an earlobe or fingers of the human hand. It is very convenient in case of self-monitoring of the human condition. It should be noted, personal usage of the transmission pulse oximetry (especially in the countries of Western Europe, the United States, Canada, Japan and South Korea) makes various research in this direction still relevant. The especially in the development of methods for assessing the reliability of results, measuring the oxygen content in the blood, the frequency of the pulse wave and form of this wave. Knowledge about the shape of the pulse allows to control the state of the whole organism from observing the heart work, how it fills vessels with blood.

The diagnosis of the human condition by the measured parameters of the pulse wave is difficult without usage of these methods. The main reason - various distortions of the waveform (artifacts). The variant of distortions in the recorded pulse wave during measurements is presented on the figure 1.
The averaging time of the pulse, we chose the standard equal to 10 seconds. In this case, the pulse wave period is 135-140 min$^{-1}$. Fronts, which correspond to the classic work of the heart, the pulse wave are not visible. The conclusion about the state of human health will be extremely negative. In some cases, this result is contrary to reality (the patient feels good, but measurements show a close state, for example, to a heart attack). In this situation, it is necessary quickly to establish the authenticity of measurement results obtained with the help of pulse oximeter or is necessary to establish presence of artifacts, which have created the distortions in the form of a pulse wave. The timely detection of artifacts during the diagnosis of the human organism state and the elimination of them occurrence reasons is one of the urgent tasks of modern pulse oximetry. In this paper, one of the possible methods for determining the reliability of measurement results when conducting a study of the state of human health with a pulse oximeter is proposed.

3. Method, results of experimental investigations and discussion

The currently for presence determining of artifacts and reducing then influence on the measuring result the developed techniques are suggesting in basis a following. Turn off the device, calm down, reinstall the sensors and take measurements again. Our experiments have shown low efficiency of these methods. To implement the experiments we used the models of a stationary and autonomous transmission-type pulse oximeter. Before recording of the indications, the optical sensors of the pulse oximeter were placed on two fingers of one hand of the person, which was sitting at the table. In this position of the person, the diagnosis of the person’s condition by this device usually perform. Results of the studies showed that the value of the signal-noise ratio reaches a maximum in case of the direction of propagation of laser radiation is perpendicular to the flow of blood in the vessel. As an example, in figure 2 shows the dependence of the amplitude ratio $A_I$ of the detected signal of the pulse wave to the angles $\alpha$ and $\varphi$.

![Figure 2](image)

**Figure 2 (a, b).** Dependence of $A_I$ on the position of the source of laser radiation relative to the plane of the finger where blood vessel is placed: (a) – the direction of laser radiation in the ZY plane changes, (b) - the direction of laser radiation in the ZX plane changes.
To define the angles $\alpha$ and $\varphi$ the blood vessel should be placed in the XY plane. The blood flows along it in the direction of X. The angle $\alpha$ determines the deviation of the direction of propagation of the laser radiation from the Z axis in the ZY plane. The angle $\varphi$ determines the deviation of the propagation direction of the laser radiation from the Z axis in the ZX plane. The analysis of the obtained results shows the presence of an optimal position of the sensor on the finger during the researches. In addition, it was found that for each person this position is different because of the blood vessels location (a feature of the body structure).

If at device acquisition of appropriate sensor was not selected for the configuration of the finger, need to do following. Place an autonomous sensor on the other finger of this hand. If then readings will vary significantly it is necessary to carry out the orientation adjustment of fixed instrument sensor to the maximum signal-to-noise ratio. When the stationary device is on, smoothly to change the sensor position on a finger and to observe the amplitude change on the screen (until its value is maximum). In this case, all artifacts, which are determined by the angles $\alpha$ and $\varphi$, will become insignificant. To compare the readings for pulse and oxygen between the two devices. Is necessary to hold the breath if at the fronts of pulse wave, which is recorded on a stationary device, there are distortions. Our experiments allowed us to establish that the shape of rising and falling edges in the pulse wave should change in time breath hold for reliable measurements (even in the case of heart malfunction, etc.). The oxygen content in the blood and pulse values should change equally on two devices.

The changes in the structure of the pulse wave will not be significant (at breath hold) on the screen of the stationary device if the distortions caused by artifacts. In addition, there will be differences in the change in values (pulse and oxygen) on the two devices. In this case, the user need to calm down and reconfigure the stationary device. In some cases, it is necessary to increase the intensity of the laser radiation in the measuring sensor. It's related with that the blood vessel can be thin and the photo detector lacks a useful signal for reliable operation. The experimental results received by us shows, that in some situations the user the user must reduce the laser radiation intensity, since the saturation processes are introducing the distortions into the recorded pattern of the pulse wave. This fact has not previously considered in reliability determining of human health diagnosis results.

In figures 3-6, for example, shows the pulse wave shape in investigation the people of different age. In figures 3-6 (a) the results of reliable measurements (received on device screen) are presented. In figures 3-6 (b) the various failure options in device work or deterioration of human health are given.

**Figure 3 (a, b).** The pulse wave form - female, 52 years old: (a) influence of artifacts on signal registration is not significant; (b) errors in measurements.
The failure of device work (or measurement errors) can easily be qualified as a poor patient condition. A man with a personal control of his condition by pulse oximeter this result can cause a
nervous breakdown. After that, further measurements are meaningless. Then will reflect the nervous state of a person.

The use of the developed technique allowed us to determine a following. Using the method developed by us allows you to identify and eliminate errors, which are contributing to the artifacts appearance in the pulse wave. The presented results in fig. 3-6 (a) are confirmed this. The influence of artifacts on the measurement results became insignificant.

In addition, the obtained results showed that in case of presence of the parasitic pulses at the front of the decay and rise, the pulse oximeter gives the average values of the human pulse based on the measured intervals between these pulses. Operation of the device in such case leads to errors. Some models allow to increase the possibility of the data averaging period. In this case, incorrect measurements are "diluted" by the correct ones. It allows to decrease the summary error value, but not to completely eliminate it. In this case, there is a serious drawback in the operation of the device. The response of the device to sudden events slows down.

The obtained result, in contrast to the previously studies, makes it possible to detect various deviations in the work of the heart or the circulatory system of a person with a high degree of reliability with the help of the recorded distortions of the rising and falling peaks of the pulse wave characteristic. The appearance of additional peaks on the fronts of the pulse is associated only with some changes in the body and should be diagnosed with the help of additional equipment. The conducted studies with the help of such equipment in the cases of appearance of the distortions (in the form of peaks) on the fronts of the pulse wave confirmed the possibility of additional diagnosis of the work of the heart and circulatory system.

4. Conclusion

As a result of the performed experiments we have established the following. In most cases the appearance of artifacts are connected with that the pulse oximeter sensor parameters are adjusted to the data of the average person (exception is sensors for children). Proposed by us the technique shows, how to choose the sensor configuration for personal use. If the sensor squeezes the finger, hand or earlobe too much, outflow of blood from the tissues could be violated. This could lead to transmission of pulsation of the arterial blood to the veins. The pulse oximeter does not distinguish the pulsation of the arteries of the pulsation of the veins. Therefore, device calculations include the absorption of light by venous blood. In this case, final result could be underestimated.

In addition, the intensity and direction of the laser radiation must be selected so that most of the laser radiation penetrated through a dense skin layer and was detected after leaving the finger by photosensitive module. This would help to avoid errors connected with weak and unstable signals (in some cases this is due to human fatigue).

One more feature of using of a pulse oximeter was established. In case of the personal control of condition, a person should only use a pulse oximeter if he has previously established what values of the measured parameters of this device (only if the optical sensor on the finger is located correctly) correspond to his "comfortable" state. This would help to avoid a large errors number in time diagnostics.

5. References

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