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PRINCIPLES OF A PROTOTYPE MODEL OF A DEVICE FOR AUTOMATIC CONTROL OF CARDIO-PULMONARY RESUSCITATION PROCEDURES

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Abstract. The article is to present a prototype of a device intended for automatic control of the cardiopulmonary resuscitation outside the hospital. For the assessment of a patient's condition the device uses the vital parameters: respiratory noises and vibrations of the walls of the carotid arteries. The device is made in the form of a «surgical collar» and does not requires extra actions to fix the sensors to a patient's body. Resuscitation is performed with sound and light signals of different types for cardiac compressions and artificial respiration.

1 Introduction

Practically applied devices assess the correctness of ongoing resuscitation by means of indirect indicators, measuring the pressure force on the chest during compressions, or vertical offset. The feedback of a state of patient's vital functions during the procedure is only available on the bedside monitor. However, these conditions are only accessible in a medical institution. Ambulance and emergency personnel, mine-rescue workers and other professionals working in the field, do not have such assistance.

Thus, there is a significant demand in the development of easy-to-use, compact, reliable and low-cost self-powered devices for use outside hospitals for control of a resuscitated patient's vital functions and technical support during the cardiopulmonary resuscitation (CPR) procedure.

2 Research methods

Previously the design team proposed a layout of hardware and software for monitoring of CPR procedure [1].The device developed controlled the officially recommended evaluation items [2]: dynamic pattern of the diameter of the apple of the eye and air movement in the trachea. A video camera with the USB-output, fixed to the eye socket of the resuscitated patient, and a microphone installed in the larynx were used to take the readings.

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Subsequently, it was decided to abandon the use of video cameras, since fixing of sensors on the human body was excessively time consuming [3].

Currently, the developed device for CPR control is based on the analysis of acoustic signals recorded at the bifurcation of carotid arteries (blood flow noise and pressure pulse of vessel walls) and larynx (respiratory breath sounds). CPR procedures focus on the specifications developed by Russian experts and recommended by the Ministry of Health of Russia[2, 4, 5], as well as the recommendations of the European Resuscitation Council [6] for CPR and emergency aid in case of cardiovascular diseases.

The design of the device developed is similar to an orthopedic surgical collar with an inflexible splint for a cervical spine. This technical solution allows to perform a *Safar's Method* (opening the resuscitated patient's airway), and to begin intensive care [3] (Figure 1). Fast easy to put on device meets the principle of strict time limit, known in medicine of emergency conditions as *early access* and *early start*. It should be noted that the survival rate reduces by 10% each minute of the CPR delay [2].

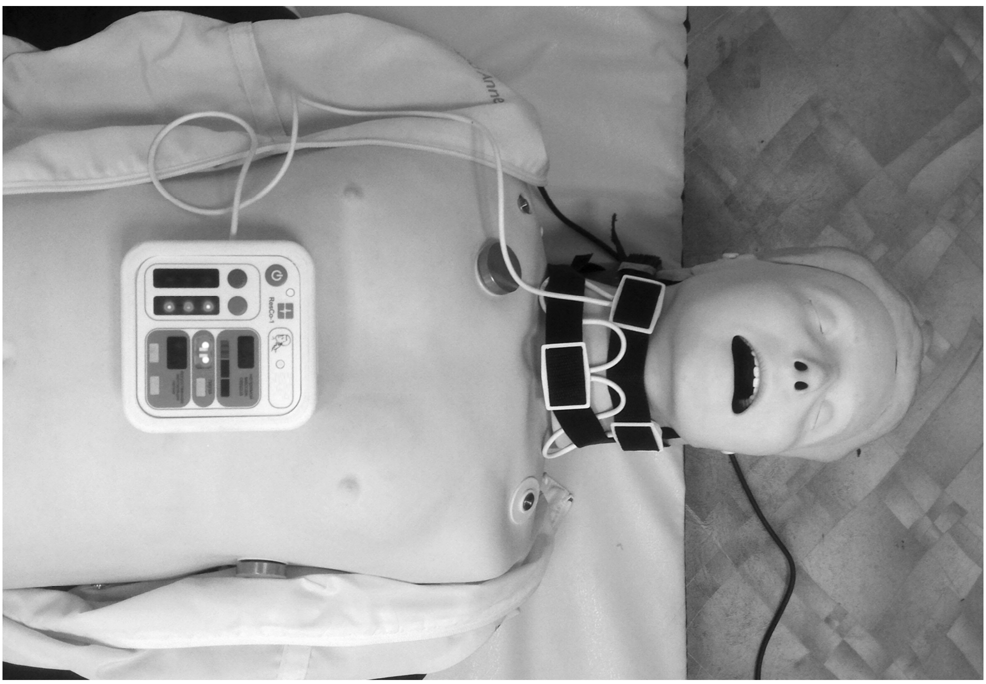

Figure 1. Model of the device attached to the manikin CPR.

In the place where the device is adjacent to the front of the neck there are three acoustic sensors: two on the left and right projections of the carotid artery, and one - in the larynx area (Figure 2). Each sensor is connected to the input of the converter *charge-voltage* with a shielded-conductor. After filtration a cable signal enters a multi-channel 12-charging analog-to-digital converter. The digitized signal is processed by a high-speed 32-charging microcontroller ARM Cortex M4, where algorithms of selection and recognition of respiratory and blood flow noise are implemented. Operation of the device is cyclical (Figure 3).

Figure 2. The piezoelectric sensor.

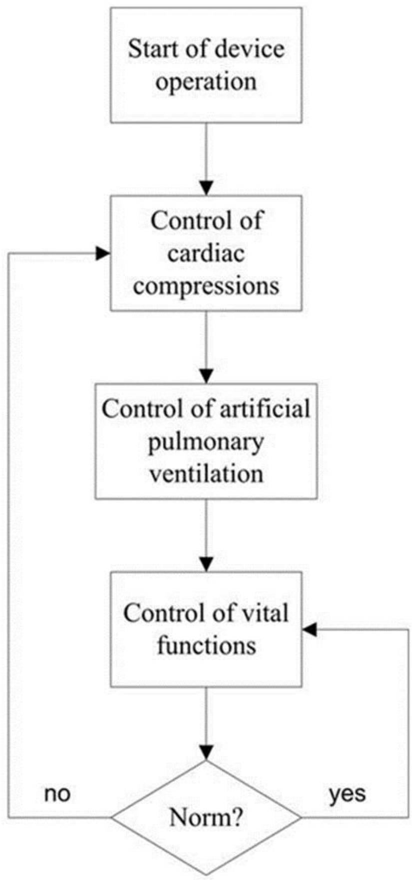

Figure 3. Operation algorithm of the device for CPR monitoring.

The implementation of the algorithm is as follows. After placing the device on the neck of the resuscitated patient and switching it begins to control sensors status (presence of signals) and starts the timers of CPR control subsystems. The CPR control mode consists of three phases [2, 5].

Phase 1: Control of cardiac compressions. The goal is to ensure the blood supply to the brain. Control of the CPR procedure is performed by transmitting 30 short signals with a frequency of 1 kHz and an interval of 600 ms to a built-in speaker. This corresponds to the recommended intensity of chest compression of 100...120 times a minute [2, 5]. The end of the cycle of cardiac compressions is indicated by a signal of double duration. To set the rate of artificial pulmonary ventilation process two signals with frequency of 500 Hz are given to to the built-in speaker.

Phase 2: control of artificial pulmonary ventilation. The goal is oxygen saturation of blood. According to the recommendations [2, 5], at this stage the rescuer has to do two acts of artificial respiration mouth-to-mouth with a duration from 1 second with an interval of 3 seconds. The built-in speaker receives two signals with a frequency of 500 Hz.

Phase 3: control of vital functions. Signals from the acoustic sensors are recorded and analyzed. Upon occurrence of independent heart rates in the carotid arteries periodic signals with low frequency (15…100 Hz), corresponding to pulse fluctuations of the vascular wall. Upon occurrence of breathing in the area of the larynx of the resuscitated patient periodic breathing noises of medium frequency range (300...800 Hz), corresponding to the respiratory cycles *inhale – exhale,* are recorded. Cycle time monitoring of vital functions is 5 seconds (recommended no more than 10 seconds [2, 5]). In case the device did not register any spontaneous breathing and heart contractile activity (Norm?), phase 3 is followed by a continuous signal with a frequency of 1 kHz, warning about the beginning of a new CPR cycle and demanding to start cardiac compressions.

In case, if the device recorded signs of spontaneous breathing and heartbeats, the device automatically switches from CPR control mode to Control of vital functions mode. It is followed by monitoring the patient's spontaneous breathing and heartbeats. According to current recommendations [2, 5], the criteria of the CPR ending are awakening of a patient, opening of his/her eyes, and normal breathing, observed visually and aurally. If signals of the functions stop coming from sensors for 15 seconds, the device prevents the occurrence of a critical situation with a three-time longer signal automatically returns to the CPR control mode. For the convenience of the resuscitation team audio signals generated by the device are accompanied by super-bright red and green LEDs.

In order to display breathing and heart beats it was decided not to use a color LCD-display due to: 1) complexity of data perception in bright light; 2) data redundancy; 3) mechanical fragility of the display.

In the absence of signals of vital functions on the device sensors both indicator lights are red. The appearance of typical noise of blood flow and respiration observed during cardiac compressions and artificial pulmonary ventilation procedures leads to periodic yellow light signals, synchronized with the recorded signals. Independent breathing and heartbeats are indicated by periodic green light signals, also synchronized with the recorded signals. For the reporting of the CPR procedure performed device immediately begins to protocol signals received the time of their transmission. To store the date and time of current signals the device uses real-time clock as a part of the microcontroller. It continues to function even when the device is powered off. The report of proceedings is saved to the nonvolatile backup memory and, if necessary, can be sent to the doctor's computer work station via USB, decrypted, and presented in a printing form.

3 Conclusion

During the study performed a layout of the device for quick assessment the vital functions of the affected and to some extent control the course of cardiopulmonary resuscitation procedures outside a medical institution has been developed.

Correct CPR procedures performed by rescuers without medical education, but under the control of professional ones increase the chances of survival of a victim by approximately fifty percent [4, 7]. The developed device is intended for replacing (to some extent) a specialist's control of the CPR procedure.

In the future, a voice synthesizer will be included in the device for autonomous CPR control.

Acknowledgement

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