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Development of an oximeter for neurology

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Abstract. Cerebral desaturation can occur during surgery manipulation, whereas other parameters vary insignificantly. Prolonged intervals of cerebral anoxia can cause serious damage to the nervous system. Commonly used method for measurement of cerebral blood flow uses invasive catheters. Other techniques include single photon emission computed tomography (SPECT), positron emission tomography (PET), magnetic resonance imaging (MRI). Tomographic methods frequently use isotope administration, that may result in anaphylactic reactions to contrast media and associated nerve diseases. Moreover, the high cost and the need for continuous monitoring make it difficult to apply these techniques in clinical practice. Cerebral oximetry is a method for measuring oxygen saturation using infrared spectrometry. Moreover reflection pulse oximetry can detect sudden changes in sympathetic tone. For this purpose the reflectance pulse oximeter for use in neurology is developed. Reflectance oximeter has a definite advantage as it can be used to measure oxygen saturation in any part of the body. Preliminary results indicate that the device has a good resolution and high reliability. Modern applied schematics have improved device characteristics compared with existing ones.

1. Introduction

During the surgery a reduction of oxygen saturation of the brain can occur, with the other controlled parameters change slightly. Prolonged intervals of cerebral anoxia may damage the central nervous system. General anesthesia has become safer in recent years due to the emergence of more reliable methods of control [1]. These technologies make it possible to identify early onset of adverse events and significantly reduce morbidity and mortality from the use of anesthetics [2, 3]. Quantitative assessment of physiological parameters permits to reduce the effects of the factors associated with a poor outcome. Pulse oximetry is a fast, noninvasive method for monitoring the oxygen saturation of a patient's blood. Pulse oximeter provides to diagnose problems in the respiratory and circulatory systems. Commonly used method for measurement of cerebral blood flow is the Kety-Schmidt method [4]. In this case, the patient inhales a mixture of O_2 and N_2O, and blood is sampled using invasive catheters.

Stimulation of the sympathetic nervous system leads to vasoconstriction and increased activity of the heart, while vagal activity to the heart is inhibited. At the same time some changes occur simultaneously: arterial pressure increases first, because of arterial constriction; then venous constriction displaces blood towards the heart and increases cardiac output and as a consequence stimulated heart increases the heart rate and the force of contraction. In the case of anesthesia the patient can not feel anything, but surgical intervention causes the typical sympathetic system reaction to pain.

Heart rate variability (HRV) may be used as an effective indicator of sympathetic tone and autonomic nervous system activation. In this case very low frequency in the HRV signal corresponds to both sympathetic and parasympathetic activity. At the same time higher frequency components correspond to only parasympathetic activation [5]. The aim of this study is to investigate the use of the reflectance pulse oximeter for remotely detecting a sudden sympathetic system changes.

2. Materials and experimental

To measure changes in sympathetic activity the reflectance pulse oximeter is developed. The block-diagram of the device is shown in Figure 1.

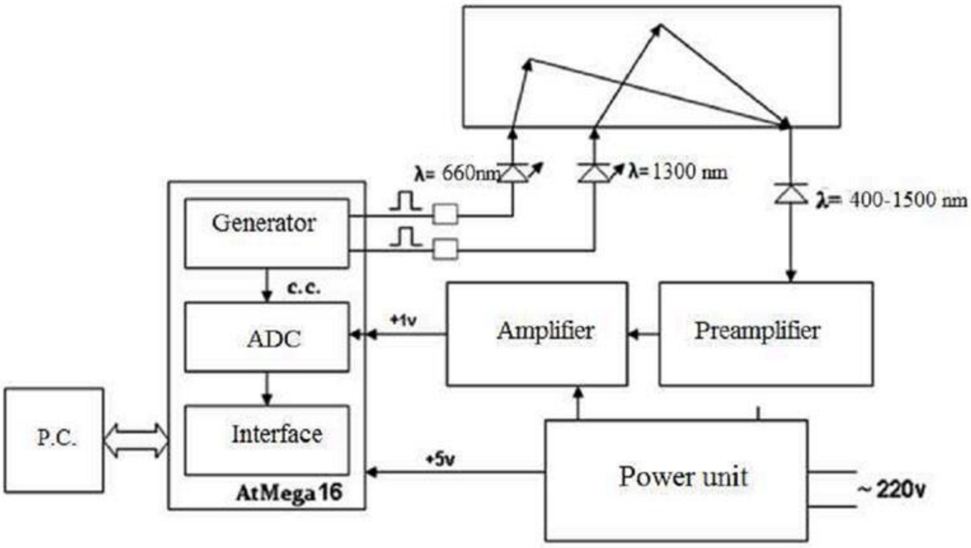

Figure 1. The block-diagram of the device

The main control element is a microcontroller Atmega16. The signal is processed by10 bit ADC. Each LED is controlled via a multiplexer. The main objective is to extract the AC signal with the exception of its constant part. This task is accomplished via an operational amplifier. The main contribution to the noise is ambient light with a frequency of 50 Hz and 100 Hz. Necessary information contained in the signal lies in the range of 0-30 Hz. Typically, LEDs are directly controlled by voltage. The disadvantage of this method is the dependence of the amplitude on the temperature of the LED. To eliminate his shortcoming the current source is designed. To improve the signal/noise ratio filtering is needed. As smoothing filter the moving window is selected. Such a filter is easily accomplished with macros.

3. Results and discussion

The device was attached to the forehead of volunteer by using the elastic band. Then the measurements of oxygen saturation during normal breathing and breath delay for 30s were made. The results are shown in Figure 2. As can be seen from the graph a breath delay leads to a reduction in oxygen saturation.

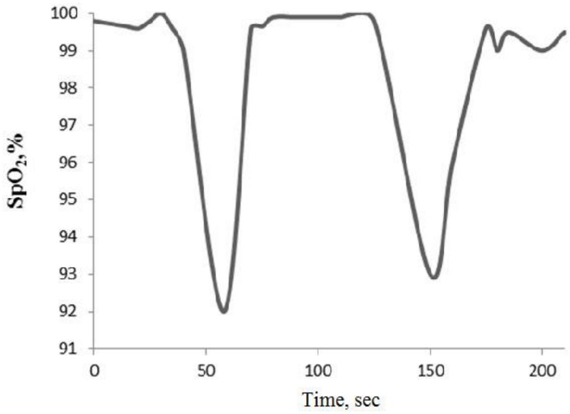

Figure 2. Typical view of hypoxia presence

A rapid change in sympathetic tone can be simulated by a sudden decrease in arterial pressure. The classic supine-standing experiment was performed. In this experiment, a person initially is in the supine position and then stands up suddenly. This rapid change in body position causes a sudden drop in arterial pressure due to the effects of gravity pulling blood into the lower extremities. This process activates the baroreceptor reflex, and as a consequence sympathetic arterial constriction and increased heart rate. The results are shown in Figures 3 and 4. It can be seen that the device detects the change in sympathetic tone confidently. After changing the body position the heart rate first decreases and then increases with subsequent return to the normal value.

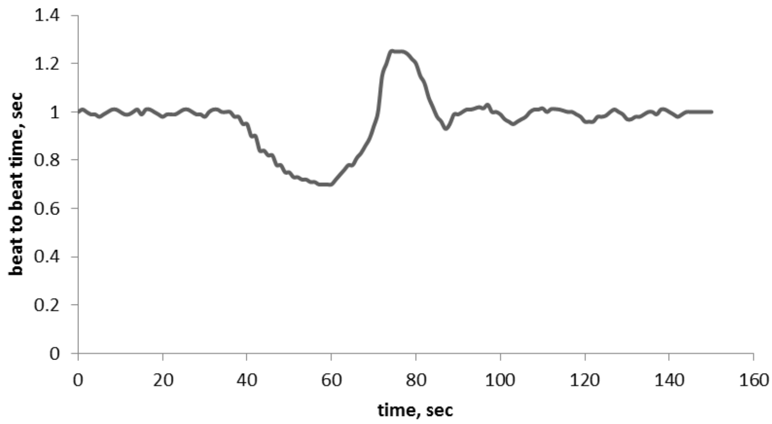

Figure 3. Beat-to-beat interval

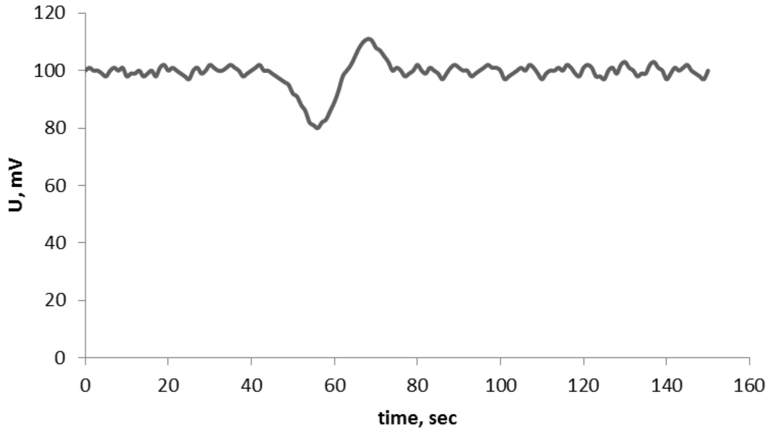

Figure 4. Peak value of PPG for each pulse

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Changing the PPG is delayed, which is necessary for the blood flow to reach the point of measurement.

4. Summary

The reflection pulse oximeter to detect sudden changes in sympathetic tone is developed. The device has a definite advantage as it can be used for measurement in any part of the body. Preliminary results indicate that the device reliably detects changes in sympathetic tone, has a good resolution and high reliability. Modern applied schematics have improved device characteristics compared with existing ones.

Acknowledgements
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