Peculiarities of pulse arrival time revealed in human arms by imaging photoplethysmography

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The pulse arrival time (PAT), defined as the time difference between the R-peak of an electrocardiogram (ECG) and the onset of an increase in blood pressure at the periphery, is a useful tool for assessing the functional state of the cardiovascular system. PAT depends on many factors such as the structure of the vessels network, vessel diameter, wall stiffness, blood pressure, heart rate, etc. [1]. Either pressure or optical sensors are used for clinical assessment of PAT. In recent years, there has been a significant increase in interest to developing devices for cuffless estimation of blood pressure (BP) based on a photoplethysmography (PPG) and ECG techniques, which measure PAT to use it as a surrogate for BP [2]. The PPG signal in these systems is recorded directly from the patient's skin using a contact sensor affixed on distal part of the body (fingertip, forearm, earlobe, etc.), which can cause discomfort [3]. In addition, any contact-type sensor affects the blood flow in the contact area, which is often not evaluated and not taken into account, despite the well-known fact that any skin contact may affect cutaneous microcirculation. The aim of our work was to study how stable PAT is with changes in microvascular blood flow parameters, caused by the controlled local hyperemia.

The study was carried out using a multimodal system, which includes imaging photoplethysmography synchronized with ECG, and described in detail in our recent paper [4]. This technique allows us to measure PAT together with the perfusion index (PI). The skin of the subject's forearm with a transparent heater placed on it, was illuminated by green light-emitting diodes, and an image of the forearm was recorded by a video camera. The baseline lasted 5 minutes with the heater turned off, then the skin was heated up to ~40°C during 150 s and maintained at this temperature for 15 minutes, followed by 25-minute relaxation. Images of the forearm and the heater were recorded continuously and synchronously with ECG. The recorded signals were processed using a specially developed algorithm [4]. PAT in the area under study was calculated as the time between the R-peak of ECG and a minimum of the PPG waveform in every cardiac cycle.

A total of 52 volunteers, men, aged 48±10 years, were examined. The perfusion index and PAT values were assessed over a pair of time intervals: baseline (b) 10:140 s and heating (h) 520:650 s. It was found that in the baseline $PI_b = 0.25$ (0.1; 1.0) a.u. (here and further, the data is presented as median (quartile 1; quartile 3)), $PI_h = 1.50$ (0.6; 3.4) a.u., $P < 0.001$; $PAT_b = 200$ (136; 253) ms, $PAT_h = 142$ (74; 207) ms, $P < 0.001$. The median PAT difference between the baseline and heating stage was 58 ms or ~30%. Correlation analysis of the evolution of the parameters PI and PAT revealed their strong negative relationship (r = -0.75). At the same time, the heart rate of all the subjects remained unchanged throughout the experiment. In conclusion, we have shown for the first time that local changes in the microcirculatory perfusion significantly affect PAT against the background of unchanged heart rate.

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