Pulse Transition Time in heamodynamic measurement

methods, problems, hardware equipment and first results

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Abstract – **This contribution deals with the Pulse Transition Time (PTT) as a marker that can predict some cardiovascular problems. The PTT is calculated from the ECG and PPG signals measured on a finger. The PTT is a parameter that is dependent mainly on aortic length (alternatively patient's height) and blood pressure. It means that there is no general criteria how to assess the PTT value without the knowledge of additional information about the patient. This contribution is focused on the hardware design and realization, the methodology of measurement and shows the first results of the PTT measurement. Data processing and their evaluation is described as well. It could be stated that the PTT is a valuable parameter for the cardiovascular system monitoring.**

Keywords – Pulse Transition Time, haemodynamic parameters, ECG, PPG.

I. INTRODUCTION

Today, the most common causes of death are cardiovascular diseases. The basic assumption for the decrease of mortality is their early detection and treatment. The main risk factors are usually high age, smoking, metabolic disorders, hypertension, and diabetes mellitus.

It is possible to monitor the overall state of the cardiovascular system either through invasive or noninvasive and imaging methods (like CT, MRI). Non-invasive measurements give us only a partial information, but it says to doctors the initial information that there is something wrong. The advantage of these methods is that intervention to patient is needed and also the low price in comparison with advanced imaging techniques. It makes it wide available for doctors and home care.

The main aim is to maximize the amount of information which can be obtained with minimum non-invasive measurement methods. One of such parameters is a Pulse Transition Time (PTT). It is the propagation time of a pulse wave measured between two sites of the artery. Because it is beat-to-beat measurement type, we can monitor immediately the vascular condition.

The pressure waveform comes from the ejection of blood from the left ventricle and propagates with a velocity much greater than the forward movement of the blood itself. The speed of the pressure wave is directly proportional to the blood pressure. The PTT is highly dependent on the vascular condition which indicates the Moens-Korteweg equation. So it gives information about the distensibility, which is inversely proportional to the stiffness. It can be assumed that young people, having more flexible arteries, have the PPT longer.

For measuring PTT, we need to record the synchronous ECG and PPG signals.

A. ECG (electrocardiogram)

The electrocardiogram (ECG) is an interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the outer surface of the skin.

We need to measure ECG signal for synchronization with cardiac cycle. ECG is tied to exact cardiac state and it is why this signal is suitable. For the PPT calculating, we can fix reference point like R-wave, corresponding with specific part of cardiac cycle and related to other measured signals.

For our purpose, it is enough to measure only one ECG lead with at least two electrodes.

B. PPG (photoplethysmogram)

Optically obtained plethysmogram is a volumetric parameter of peripheral vessels. Infrared LED diode illuminates the skin and photodiode measures changes in light absorption.

II. HARDWARE DESCRIPTION

The hardware design of the system is composed of several modules in one board. The composition is shown on block diagram in Figure 1.

For PTT measurement is enough to record ECG and PPG signal, but for verification of calculated PTT in relation to cardiovascular system condition, we measure also blood pressure during both inflating and deflating the cuff. From these signals, we can calculate not only PTT, but also Pulse Wave Velocity (PWV), Augmentation Index (AI) or Cardio-Ankle Vascular Index (CAVI). For the measurement of CAVI, we can use the second PPG module to obtain signal from the ankle. It can help to calculate propagation time between two sides.
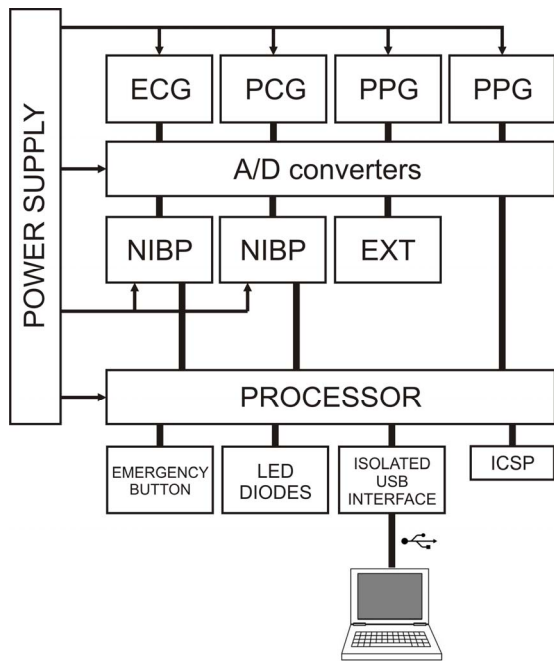
Figure 1. Block schematics of the device

III. MEASUREMENT

Depending on measured signals, two systems of reference point are possible. We can use either ECG or PCG (phonocardiogram) synchronization with pressure waves. If we use ECG, subsequent figure shows the measured times.
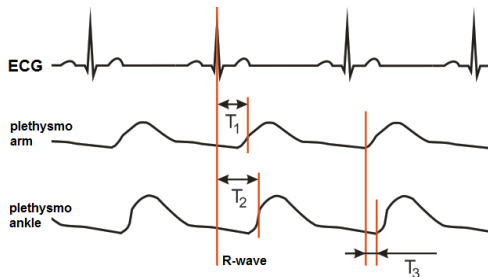

Figure 2. ECG synchronization

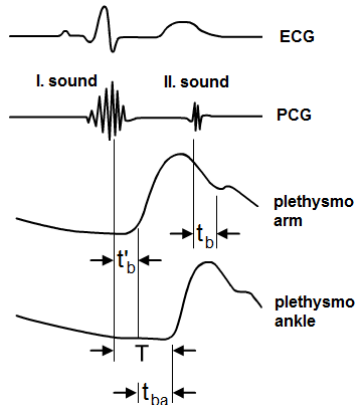Figure 3 shows measured times during PCG synchronization of signals.

Figure 3. PCG synchronization [3]

In our data processing, we used the R-peak of the ECG signal as a reference point. The second indicated point was a minimum of PPG signal measured on a finger.

The measurements were carried out in two stages. In the beginning, 36 students of FEE CTU (of whom 12 women and 24 men) were measured. Average age was (23,4 ± 4,75) years. The second stage of measurement took place in Malešice Retirement Home in Prague. There were measured 26 people in total, including 24 women and 2 men. This disparity is due to the distribution of nursing home occupants where is significant preponderance of women. The average age of the second group was (82,4 ± 10,3) years.

For evaluating the measured signals, we have information about physical parameters, lifestyle and health of the patients. It is why a questionnaire was made. Everyone filled out this questionnaire prior to measurement and all these information have been completely anonymised and saved together with signals under ID number. We collected data about age, height, weight and arm circumference above the elbow and wrist. We wanted to know last two answers to verify correct size of cuff. We also investigated the extent to eat fatty foods and drink alcohol, next question was whether ever come into contact with drugs and whether they smoke (and if so, for how long time). Finally, we investigated the health condition. We asked for blood pressure (rather low or high), whether they suffer from diabetes and if so, how it is its treated. We were also interested in any cardiovascular, respiratory or other illness, and how the disease is treated. The measured signals and a questionnaire from one person were marked with one identical unique ID.

During measurements the patients were sitting. We took care that the patient was in complete calm and silent. The majority of patients were measured twice with a spacing of at least ten minutes. This time lag is necessary for recovering the artery after inflating and deflating the cuff during the oscillometry pulsations measurement.

IV. DATA PROCESSING

The ECG signal was measured using a standard three-lead configuration. We used Lead II to detect R-wave peak. The PPG sensor was placed on the finger. The PTT was detected between R-wave peak and the initial upstroke point of the pulse wave. [2] The signal was sampled at 400 Hz.
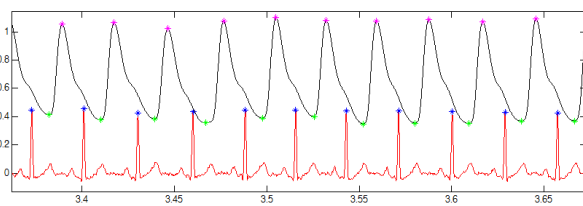

Figure 4. ECG and PPG signals in one plot

We calculated PTT for all the signals in our database. All the signals are approximately one minute

long and the PTT is calculated on every heartbeat. The time variability of the results is not considered. For each signal is calculated the median value that represents the whole signal in subsequent statistics.

V. FIRST RESULTS

We calculated PTT with the described method for a total of 62 signals. The main task was to verify the theory about the influence PTT on the cardiovascular system condition. We assume that younger people have the CVS condition better than older ones.

On figure 5 and 6, we can see the histogram of absolute values of calculated PTT in seconds measured on young people and older people These values are absolute values in seconds, regardless of the heart rate.
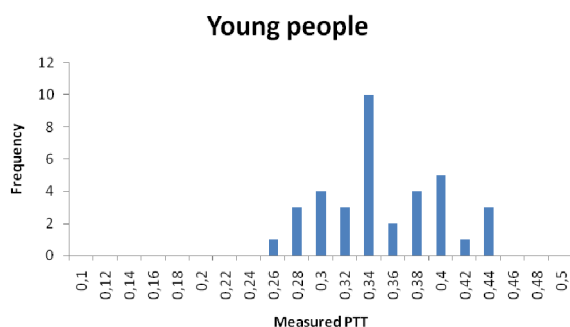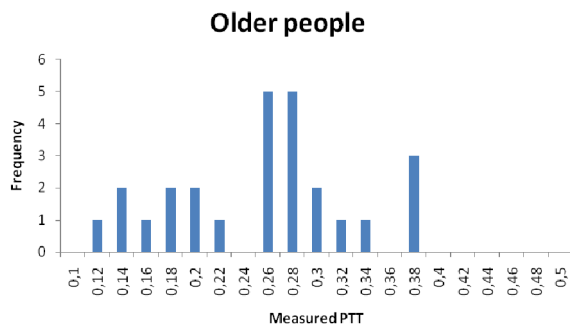

Figure 5. PTT measured on young people

Figure 6. PTT measured on older people

Next two figures shows relative value of PTT relative to heart rate. It should show the actual ratio between PTT time and heart beat period which is more objective parameter to compare. In this statistics is considered neither the length of the arterial tree nor the blood pressure.

We can see the significant difference between these two categories. This difference is given by cardiovascular system condition. It is apparent from Bramwell-Hill and Moens–Korteweg equations that say about pulse wave velocity (PWV) relative to distensibility of blood vessels. Simply said, PWV is higher when the vessels are more rigid.
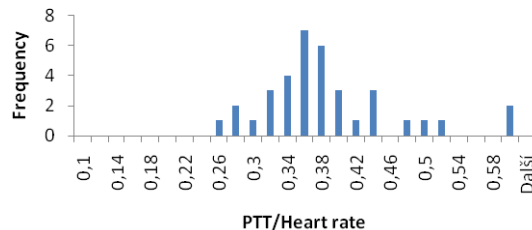

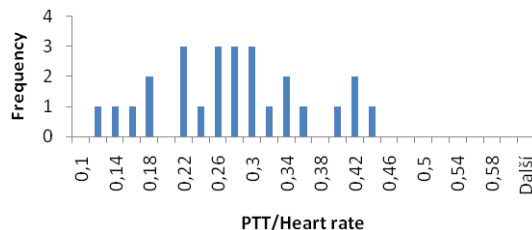Figure 7. Relative PTT time to heart rate for young people

Figure 8. Relative PTT time to heart rate for older people

VI. CONCLUSION

The method for measuring the pulse transition time (PTT) was described. We used PPG signal with synchronization on R-wave peak of ECG. First results confirmed the theory about the influence of the cardiovascular state to PTT. We measured two groups of people with diametrically different age and we can see the differences in results. Typical PTT for older people in age of (82,4 ± 10,3) years is (246 ± 73) ms. Typical PTT for young people in age of (23,4 ± 4,75) years is (322 ± 45) ms. PTT was measured as the time between R-wave peak and the initial upstroke point of the pulse wave.

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