ARTERIAL PULSE WAVE ANALYSIS DURING COLD PRESSOR TEST IN PATIENTS WITH BORDERLINE HYPERTENSION

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Abstract: During this study the changes of arterial pulse wave during cold pressor test (CPT) in patients with hypertension were investigated. There were studied 21 patients, aged 22 to 64 years. Patients were divided into two groups: with normal and high blood pressure. Signals were detected by piezoelectric sensor. Measurements of signals consisted of two sessions: normal conditions used for baseline wave and measurement with applying cold pressor test. For signal analyzing ratio of signal peaks P1/P2 was used. The analysis was divided into two parts. First of all it was compared influence of cold pressor test within each group: with normal blood pressure and with high blood pressure. And also influence of CPT was compared between both groups. During this research there were found two significant values (Table 2).

The preliminary results show that it is possible to use pulse wave analysis for noninvasive indirect estimation of elastic properties of blood vessels.

Keywords: pulse wave, hypertension, cold pressor test, arterial compliance, arterial stiffness, elastic properties.

Introduction

Pulse wave analysis helps to study large-artery damage, a major contributor to cardiovascular disease, which is the common cause of mortality and morbidity in industrialized countries. This high incidence emphasizes the importance of early evaluation of the arterial abnormalities, which constitute the common lesion of major organ damages due to cardiovascular risk factors [1,2].

Several studies conduced with various groups of population showed significant correlations or powerful interactions between pulse wave velocity (PWV) (and other parameters concerning arterial wall properties) and the so-called “major” cardiovascular risk factors, such as hypertension, high cholesterol level, diabetes and smoking. Impaired vascular compliance and a concurrent rise in vascular rigidity are the central pathogenetic processes and the first step leading to fatal cardiovascular events in many cases of hypertension and hyperlipidaemia patients [3]. Several methods can be used to analyze the structure and function of the large arteries. Among the noninvasive methods of evaluating arteries, pulse wave analysis can be used as an index of arterial elasticity and stiffness.

A cold pressor test (CPT) is a classical experiment in which mostly deal with related physiological changes. During CPT, the sympathetic nervous system is stimulated; arteriolar vasoconstriction occurs and blood pressure increases, and skin blood flow decreases [4]. The pulse wave waveform conveys important information about the cardiovascular system. The goal of the study was twofold: 1) to evaluate whether pulse wave shape is modified by CPT, and 2) compare the changes in the radial arterial pulse shape during CPT in normotensive patients and in patients with borderline hypertension.

Method and procedure

Signal measurements were obtained from 21 subjects (14 male, 7 female); their mean age was 39 (range 22-64).

Ten subjects were with borderline hypertension and eleven were normotensive patients. Normotension is defined as systolic blood pressure ≤130 and diastolic blood pressure ≤90 mmHg. Borderline hypertension (BHT) is defined a diastolic blood pressure (DBP) >90 mmHg.

The pulse detector was previously developed by our team and is composed of a piezoelectric sensor (MLT 1010 pulse transducer, AD Instruments).

Measurements were performed in a laboratory. Each subject rest relaxed in laboratory for more than five minutes before the CPT experiments begin. Blood pressure was measured by a standard cuff at the left upper arm just before the measurements.

During the study signals were acquired in parallel from left and right hands. First, we measured the radial pulses as the baseline pulse of the subject while seated on a chair continuously for five minutes. Secondly, right

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hand was immersed in the 10°C water for five minutes. Thirdly, the right hand was taken out of the water, dried, and kept in the air without covering for five minutes. During these three five-minute periods the radial pulses of the subjects on both hands were measured. All measurements began after 30 seconds stimulus.

The multi-site measurement and analysis system is shown in Figure 1. For piezoelectric signal measurements piezoelectric sensors (MLT 1010 pulse transducer, AD Instruments) were used (Fig. 1, block 1). The laboratory instrument for signal acquiring, amplifying was designed. The piezoelectric signals were recorded simultaneously for 5 minutes during each measurement session at a sampling rate 500 Hz. A National Instruments data acquisition board (DAQ) PCI-MIO-16E-1 (block 3) to digitize the signals locally and transmit the digital data to the personal computer in this system was used.

Signals are directed to the DAQ board where acquisition and analog-to-digital conversion take place. Once data is acquired and received it is possible to process and manipulate it using LabVIEW software packet (block 4).

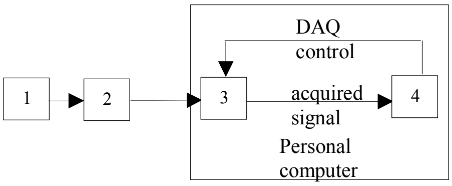

Figure 1: Block diagram of the equipment.

Analysis

The waveform analysis was performed to assess the pulse wave characteristics. The waveforms were analyzed offline using LabVIEW programs. The computer program displayed the incoming waveform on the screen of the computer. The minimum and maximum peaks of pulse wave signal (further P1 and P2) were used as marks for signal analysis and comparison (Figure 2). To locate necessary points of signal 3 markers were used. Point V was used as baseline for peaks P1 and P2.

The length of each the recorded signal was 5 minutes. It means that at an average pulse rate, the number of the pulses in one recorded signal is 400. The process of transition from one pulse to another was manual, which allowed editing of any poorly recognized pulse landmarks. A 5 minutes period of pulses were manually extracted for the analysis. The pulses were smoothed using a digital low-pass filter (16 Hz) and high-pass filter (8 Hz) to remove the low frequency baseline. Due to the patients' movements or irregular breathing anomalous pulses were rejected from the analysis.

For each 5 minutes signal we calculated values for peaks P1 and P2. Then ratios P1/P2 mean was calculated. Lately were found their average values (Table 1).

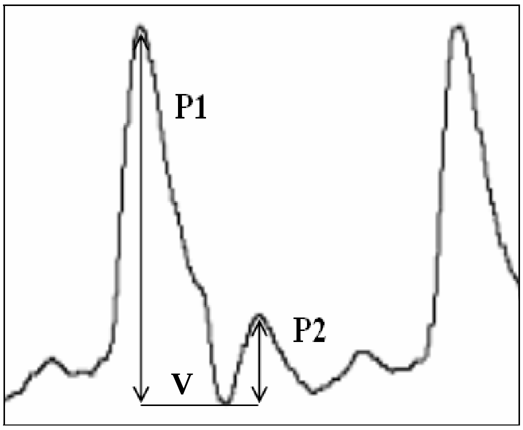

Figure 2: Pulse wave characterizing maximums
Axis x – time, seconds.
Axis y – amplitude, volts

Results

For all subjects for both hands at the normal conditions and during the cold pressor test ratios P1/P2 were calculated and their averages were found (Table l).

Table 1: P1/P2 ratios' average values

	P1/P2
Patients with normal pressure	2,5
Patients with high pressure	3,05
Patients with normal pressure under CPT	2,9
Patients with high pressure under CPT	3,1

This method allows the analysis of wave reflections by using the changes in the shape of the pulse wave. The pulse wave is shown as manifesting an incisura point dividing the pulse wave into two peaks: P1 and P2. Those peaks have been described as indicating two different waveform components on the recorded pressure: a forward, or incident, wave (corresponded to the peak P1) and a backward, or reflected, wave (corresponded to the peak P2). The peak P2 is interpreted as the result of the reflected wave coming back from peripheral sites of reflection and is responsible for a late increase in pulse wave and systolic blood pressure (SBP).

To see graphically how ratio P1/P2 changes with increase of blood pressure diagram was composed on the following graph (Figure 3).

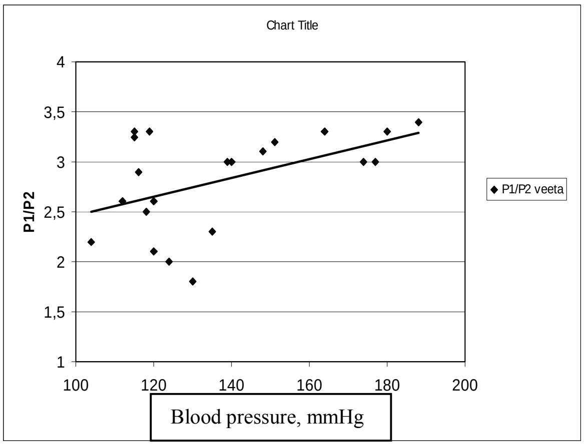

Figure 3: The relationship between P1/P2 and blood pressure

During this research the influence of cold pressor test was investigated in both groups: with normal and high blood pressure. On Figure 4 you can see the diagram how cold pressure test changes ration P1/P2 in the group of patients with normal blood pressure.

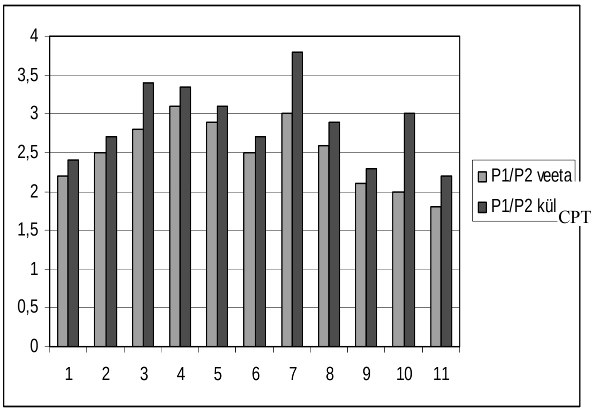

Figure 4: Change of ration P1/P2 under the CPT in patients with normal blood pressure
Axis x – patients with normal blood pressure
Axis y – P1/P2 ratio

On Figure 5 you can see the diagram how cold pressure test changes ration P1/P2 in the group of patients with high blood pressure.

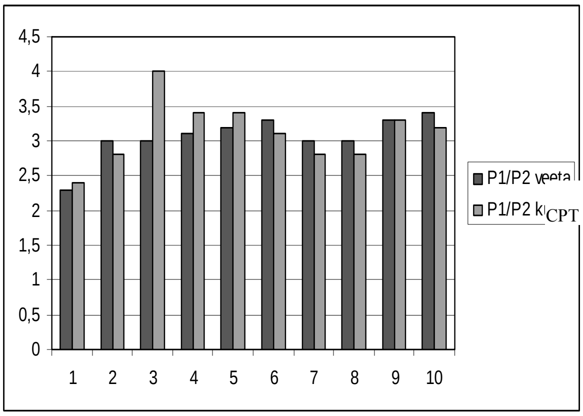

Figure 5: Change of ration P1/P2 under the CPT in patients with high blood pressure
Axis x – patients with high blood pressure
Axis y – P1/P2 ratio

As signals were acquired simultaneously for right and left hands during measurement session ratios P1/P2 were calculated for each hand and compared. In table 2 you can see the correlations of ratios P1/P2 between hands under different conditions. As you can see, under the CPT the correlation decreases. That might be explained by CPT applies only local effect on right hand, the signals of left hand become almost unchangeable.

Table 2: Correlation of P1/P2 ration for right and left hands

	P1/P2 for right hand	P1/P2 for right hand under CPT
P1/P2 for left hand	0,9	-
P1/P2 for left hand	-	0,65

Discussion

The main objectives of this study were: 1) to evaluate whether pulse wave shape is changing under cold pressor test and 2) to compare the changes in the radial arterial pulse during CPT in normotensive patients and in patients with borderline hypertension.

The analysis was divided into two parts. First of all influence of cold pressor test within each group: with normal blood pressure and with high blood pressure was compared. And also influence of CPT was compared between both groups.

Differences in the ratios P1/P2 between and within groups were compared using the statistical program ANOVA (Table 3). This analysis tool performs a simple analysis of variance (ANOVA). The *p* means a P-value (Probability value) for rejection of the null hypothesis that the parameter is zero (i.e. not a significant linear factor). As a result of this work, two ratios were significantly different in terms of statistics at $p<0.05$ as shown in Table 3.

To compare how pulse wave changes with increasing of blood pressure we see that ratio P1/P2 is 22% higher for the group with high blood pressure. The difference of those values was found to be significant.

As you can see from the table 1 comparing changes of ratio P1/P2 for the patients with normal blood pressure in the normal condition or under the cold pressor test, the ratio P1/P2 become 16% higher under the CPT. The difference of those values was significant.

There were not found significant differences in ratios P1/P2 for the group with high blood pressure compare results under the normal conditions or under the CPT. The increase of ratio P1/P2 under the CPT constituted only 2%.

In fact, it is well established that the pulse wave must be analyzed as a superposition of two separate waves: the incident traveling wave from heart to periphery, and the reflected wave traveling from the periphery and the site of wave reflection to the heart [6,7]. The incident wave depends on the left ventricular ejection and the arterial stiffness, whereas the reflected wave is related to arterial stiffness and the potential sites of wave reflection. Depending on different reasons (increased blood pressure, high level of cholesterol, etc) the pulse wave velocity might change, causing change f pulse wave shape [9-11]. This characteristic change in the shape of the pulse wave is attributed to an increase in aortic stiffness and pulse wave velocity, with earlier return of reflected waves from peripheral sites [12]. During CPT as a consequence of increasing of in peripheral resistance the arteriolar site of reflection becomes closer to the heart and contributes to enhance the impact of backward wave to the arterial pulse, mostly to the systolic part of pulse [5]. Also it is well known that the pulse wave velocity is influenced not only by the arterial physical properties but also by the level of blood pressure [8].

Thus, due to the increase in blood pressure we can reasonably assume that pulse wave velocity increases significantly and contributes to the enhancement of reflection waves. Finally, the global effect of wave reflections in both groups showed the changes of ratios P1/P2.

Table 3: Significance of difference in two groups

	P1/P2 in patients with normal pressure	P1/P2 in patients with high pressure
P1/P2 in patients with high pressure	P<0,05	-
P1/P2 in patients with normal pressure under CPT	P<0,05	-
P1/P2 in patients with high pressure under CPT	-	p>0,05

Conclusions

CPT is the classic test of sympathetic activity causing arterial vasoconstriction resulting an increase in blood pressure. In the present study we showed that CPT was responsible for changes pulse wave shape causing increasing of ratio P1/P2 characterizing pulse wave mean peaks.

In this research were investigated pulse wave changes with increase of blood pressure and under the influence of “cold pressure” test. There were 21 subjects, used to measure the piezoelectric signal. The results showed that with increasing of blood pressure significantly changes pulse wave shape. Also “cold pressor” test significantly affected pulse wave in group with normal blood pressure. In group with hypertension this influence was insignificant.

In previous studies was observed pulse wave shape changes during the CPT as in healthy so in hypertension patients. So, our interest was using special amplitude markers and ratios to evaluate how they reflect changes in pulse shape during cold pressor test.

The ratio P1/P2 (see figure 2) was dependent of blood pressure. Also CPT causes the changes of pulse wave indicating in increasing of ratio P1/P2. So, to summarize the preliminary results show that it is possible to use pulse wave analysis for noninvasive indirect estimation of elastic properties of blood vessels.

Further tests in a clinical environment are necessary to classify various pathological conditions with the pulse wave analysis. We suggest that this type of analysis can provide a simple inexpensive and noninvasive means for studying changes in the elastic properties of the vascular system with the age and disease.

Acknowledgment

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