# Changes in arterial stiffness index depending on the cardiovascular system condition

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***Abstract* – The paper deals with the measurement and processing of hemodynamic parameters for the purpose of primary screening of atherosclerosis in patients across the age spectrum. Parameters of cardiovascular system are measured using non-invasive methods widely applicable in clinical, ambulatory and home care. Processed results are based on a database of more than 200 signals collected during the last 3 years. The contribution includes a description of the principles of evaluation using several methods, and additionally mentions the risk of mistakes we commit when measuring oscillometric method used due to imperfections cuffs.**

***Keywords-ASI index, arterial stifness, haemodynamics parameters, blood pressure, oscillometry.***

## I. Introduction

One of the most common causes of death is nowadays cardiovascular disease. The basic premise of mortality decrease is their early detection and treatment. Primary risk factors for these diseases are usually high age, smoking, metabolic disorders, hypertension or diabetes mellitus.

The overall state of the cardiovascular system can currently be monitored through invasive or non-invasive imaging methods (CT, MRI). Other non-invasive methods of measurement (eg. VaSera device) give us only partial information, but for medical doctors, it is usually the primary clue to the fact that not all is as well as should be. The primary advantage of this method is the low price in comparison with advanced imaging methods and thus wider availability for doctors and also for home care.

The aim today is to maximize the amount of information that can be obtained by non-invasive methods. It appears that during the oscillometric blood pressure measurement is possible (with an appropriate arrangement) to obtain more hemodynamic parameters of the cardiovascular system than only a blood pressure. These parameters include the speed of propagation of the pulse wave, pulse wave amplification index and other derived parameters.

This text deals with the issue of non-invasive methods of diagnosis of cardiovascular disease, especially atherosclerosis of vascular walls, using arterial stiffness index.

Atherosclerosis is a serious cardiovascular disease, negatively affecting the function of the blood flow from several points of view - narrowing or closing of blood vessels, formation of thrombi or change the dynamic properties of blood. For this reason, current medicine deals with the possibility of early diagnosis and prevention of this disease.

## II. Arterial Stiffness Index (ASI)

ASI parameter is currently associated mainly with ambulatory arterial stiffness measurement called AASI (ambulatory arterial stiffness index), which is determined by the following procedure. The blood pressure is ambulatory measured for one day. From the mean systolic and diastolic pressure is determined the ratio, which is the determining factor. This method, despite its simplicity, is respected parameter for the indication of the cardiovascular disease.

This parameter is also defined in another way, based on the characteristics of oscillometric pulsations envelope obtained during the blood pressure measurement by the oscillometric method. In this area, however, the development of new algorithms continues and methods are still not uniform.

The Japanese company "Osachi" developed a device with advanced capabilities in diagnosis of blood circulation. Among other things, ASI is one of the parameters, which is based on structural properties of the envelope. Their technology is supported by the results of the study on animals. In the study, they generated artificial atherosclerosis in the test group rabbits and they compared the results with healthy animals. In this work, however, is not mentioned the success of measured results. Now, the device is used in practice.

The method is based on the physical properties of the blood vessel shown in Figure 1. Thus, healthy arteries that have completely different dependence on pressure yielding than diseased arteries. The envelope of the measured oscillation has a different waveform. Classification of typical envelopes is in Figure 2.

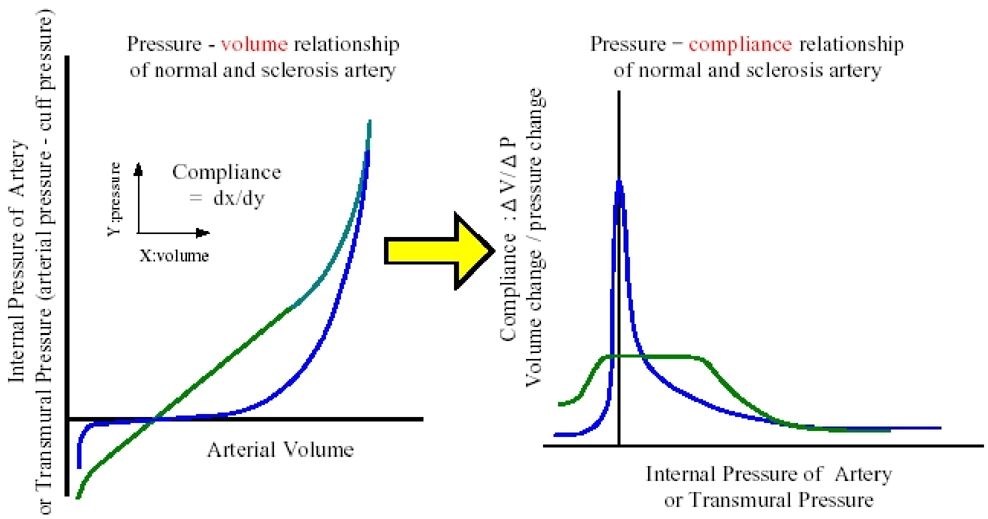


Figure 1. The relationship between pressure and volume (left), and pressure and flexibility (right)

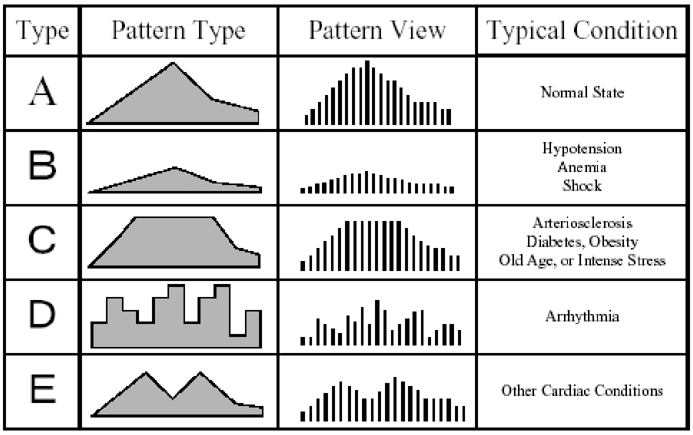


Figure 2. Classification of envelope shapes of oscillometric pulsations - used in CardioVision device

## III. Signal Database

Our database contains more than 270 signals from approximately 180 people. The significant part of the signals comes from people in the age between 60 and 90 years. These data are very important for us, because many of these people is suffering from some hemodynamic problem. As contrast of these people, young students often representing healthy people with no troubles. The signal database consists of CSV files with measurements and the questionnaires. In the questionnaire people are asked about their sex, age, height, weight, arm circumference, life style (fat diet, alcohol, drug use, smoking) and known health problems (high/low blood pressure, heart problems, respiration problems, diabetes mellitus, medicaments).

The measurements were carried out on a device that enables several different biological signals to be captured synchronously. The measuring system is equipped with electronics for dual–channel measurements of oscillometric pulsations during inflation and deflation of the cuff, for dual–channel measurements of the photoplethysmography curve by the transmissive method, and also for a 4–electrode sensing electrocardiogram together with a phonocardiogram. This system was developed specifically for the purposes of making such measurements.

## IV. Results

In the questionnaire obtained during the data collection is larger number of parameters. During processing, we tried to include as much as possible and draw conclusions about correlation with the measured parameter. Estimated correlations for the intention are the following: the presence of cardiovascular disease, BMI (Body Mass Index), weight, diabetes mellitus and more. It is assumed that this parameter should not be dependent on blood pressure (unlike the PWV). For each dependency is necessary to build test of statistical significance:

- Regression analysis - Hypothesis H0: Parameter ASI is independent of the compared parameter. The alternative hypothesis H1: Parameter ASI is dependent on the compared parameter. The significance level for all tests is chosen 5%, and the result is evaluated on the basis of p-values.

- T-test of mean values conformity - Hypothesis H0: Mean values of the parameter ASI in two different groups are identical. Double-sided alternative hypothesis H1: Mean values of the parameter ASI in two different groups are different.

For statistics processing were chosen only signals without artifacts so we can consider normal distribution for t-test.

### A. Dependency of ASI on Body Mass Index

In this test, p-value is 0.0204. On the significance level 5%, we can reject the null hypothesis and say that the ASI and BMI are not independent. On the following figure we can see a plot with regression line.

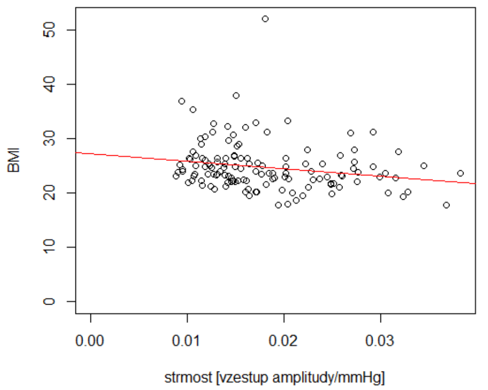


Figure 3. Graph of the slope of the onset of the patients. The black points are measured data, the red line is linear regression

### B. Dependency of ASI on patients age

To visualize this relationship, we choose two approaches. The first is direct plot with points and the regression line and the distribution of patients into two groups: "old" and "young" and show each in boxplot graph. The border of these two groups is taken as 60 years.

For this test p-value is 3.89e-10 At the level of significance we can reject the null hypothesis and say that the ASI and age are not independent. The plot with regression line is shown on figures 4 and 5.

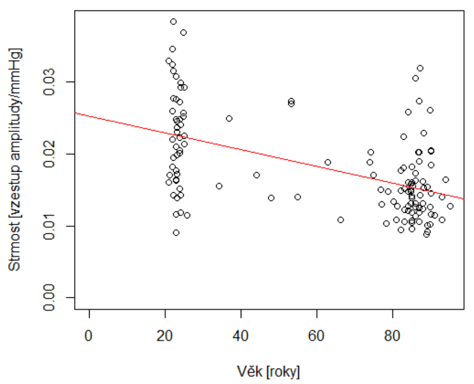


Figure 4. The distribution of ASI parameter to the age

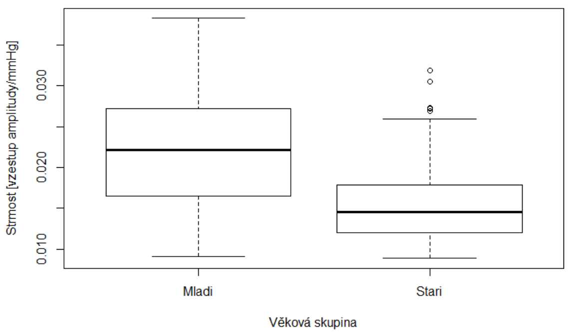


Figure 5. The distribution of ASI parameter to the age - boxplot view

At older people can generally be considered worse condition of the vascular system. A result of this test can be considered to support this.

### C. Dependency of ASI on MAP

Regression analysis of ASI depending on the value of MAP is very interesting. For this test appeared p-value of 5.96e-9. At the level of significance we can reject the null hypothesis and say that the ASI and MAP are not independent. This correlation can be explained by the connection between atherosclerosis and pressure. This does not mean that the pressure of the patient directly affects the value of ASI - it seems to be a secondary phenomenon.

## V. SUMMARY

The results above show that the calculated parameter ASI changes as a result of several different causes. The main objective was to determine whether the parameter value affects the vascular status. Since we do not have any objective measurement or examination, it must be based on data that was available. Therefore we assumed worse condition of the vascular system in the elderly, which is in different age groups visible difference in the values of the parameter.

Another measure can be BMI from which it can be assumed that patients with overweight have a worse condition of the vessel wall. This dependence is visible, but not very significant.


## ACKNOWLEDGMENT

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