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COMMON CAROTID WALL ELASTICITY AND INTIMA-MEDIA THICKNESS EXAMINATIONS BY MEANS OF ULTRASOUND

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ABSTRACT

The aim of this study was to examine the relation between the intima-media thickness and the wall elasticity in the common carotid artery. A group of 40 persons (19 healthy and 21 with hypertension and/or atherosclerosis) aged 22 to 81 were diagnosed by means of ultrasound. A high correlation occurred between the wall stiffness coefficient α and the intima-media thickness ($r = 0.950$, $p<0.001$).

INTRODUCTION

Non-invasive measurements of large vessel walls are essential in modern medical diagnosis. Changes in the wall structure resulting from hypertension and atherosclerosis contribute to the increase of its stiffness and thickness [1, 5]. Ultrasonic measurements of vascular wall dimensions and its elasticity are carried out independently, owing to the different measuring techniques and applied apparatus. The wall thickness is assessed through analysis of ultrasonic picture with B-mode presentation [1, 3, 7]. Wall elasticity is examined by means of ultrasonic apparatus detecting changes in vascular diameter influenced by blood pressure changes [4, 5].

The paper presents the results of simultaneous ultrasonic measurements of wall elasticity and intima-media thickness in the common carotid artery which were carried out on a group of 40 persons (19 healthy and 21 with hypertension and/or atherosclerosis) aged 22 to 81.

METHOD AND EQUIPMENT

Wall elasticity in the common carotid arteries was determined by means of ultrasonic measurement of the maximum and minimum vascular diameter values and the systolic and diastolic pressure taken by cuff on the brachial artery. The subjects were examined in a lying position. The vascular wall elastic properties were evaluated through the following coefficients: compliance coefficient CC, distensibility coefficient DC and stiffness coefficient α. They are formulated as follows:

$$CC = \frac{\pi\left(D_{\max}^2 - D_{\min}^2\right)}{4\left(P_s - P_d\right)} \tag{1}$$

$$DC = \frac{D_{\max}^2 - D_{\min}^2}{D_{\min}^2\left(P_s - P_d\right)} \tag{2}$$

$$\alpha = \frac{D_{\min}^2}{\left(D_{\max}^2 - D_{\min}^2\right)} \ln\left(\frac{P_s}{P_d}\right) \tag{3}$$

D_{max}, D_{min} being the maximum and minimum vascular diameter values for the systolic P_s and diastolic P_d blood pressure respectively.

Simultaneously with the elasticity coefficients the intima-media thickness (IMT) was measured in the same vessel cross-section. The examinations were performed using the VED system designed by the authors from IFTR PAS. The apparatus comprised a pulse system tracking displacement of vascular wall with measurement precision of up to 7 µm. The inner diameter was determined through digital time measurement

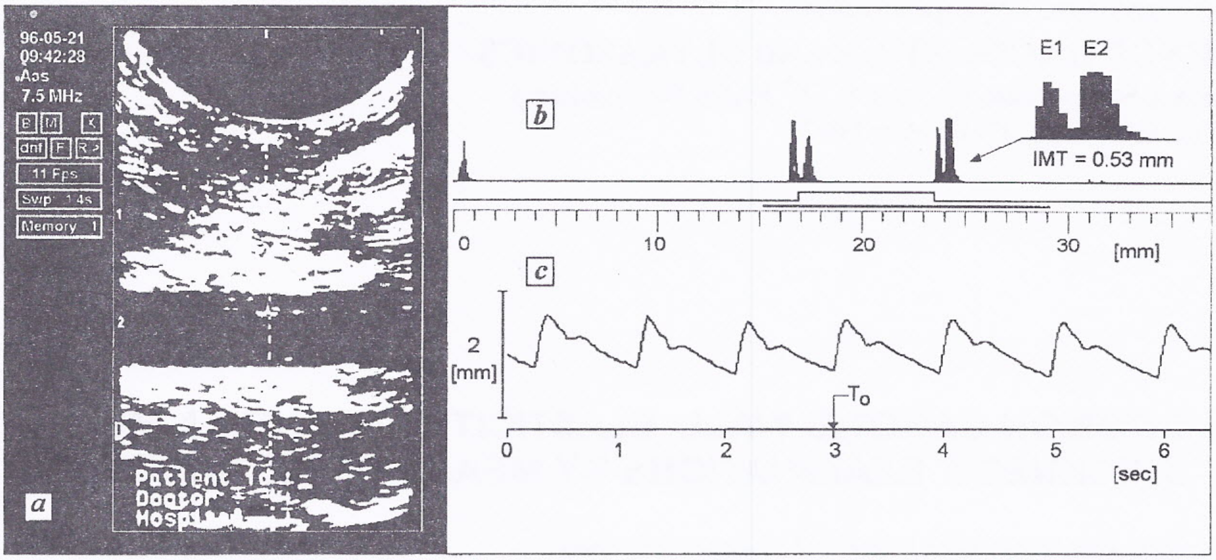


Fig. 1. The data presented in the course of the measurements in the common carotid artery : *a*) longitudinal ultrasound image of the artery, b) echoes from the wall of the artery, c) artery diameter variations; E1, E2 - echoes from the inner and outer vascular wall layer; IMT - intima-media thickness; T_o- the time of registering the echoes.

between chosen echoes (RF signal) received from the inner vascular wall layer. The frequency of transmitted ultrasound was 6.75 MHz. The wave was focused at 1 to 3 cm below the skin surface. The longitudinal resolution of the apparatus obtained by model examination was 0.33 mm in water. The measured data were displayed on the screen of an IBM PC (fig.1b-c) connected on-line with the ultrasonic equipment and stored in the computer memory. The intima-media thickness was determined on the basis of the echo outline pictures.

The reproducibility of the measurements was tested on a control group of 10 healthy persons aged 23 to 30. For two examiners in one measurement session the coefficient of variation CV in examining the intima-media thickness and vascular wall elastic properties was as follows: 11.84 ± 0.18% for IMT (mean IMT = 0.45 mm), 10.01 ± 0.13% for stiffness coefficient α, 12.85 ± 0.73% for distensibility coefficient DC and 14.73 ± 0.14% for compliance coefficient CC measurements.

RESULTS

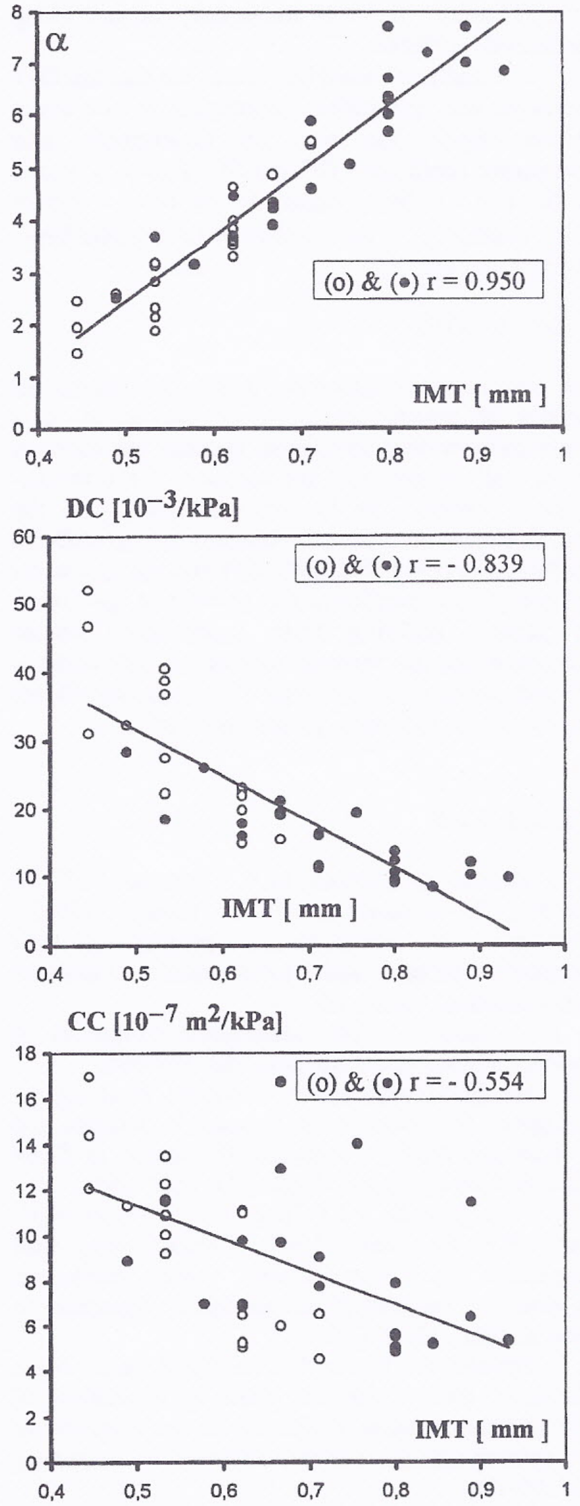
The measurements were carried out in the common carotid arteries of 40 persons (19 female, 21 male) aged 22 to 81 (mean age 49.9) of whom 19 were healthy, 3 were suffering from hypertension, 9 were suffering from atherosclerosis and a further 9 from both.

Table 1. The parameters measured in the group of 19 healthy persons.

Age [years]	P_s [mmHg]	P_d [mmHg]	D_{min} [mm]	IMT [mm]	α	CC [10^{-7} m^2/kPa]	DC [10^{-3}/kPa]
44.0 ± 17.9	119.7 ± 14.3	74.2 ± 8.0	6.78 ± 0.80	0.57 ± 0.08	3.31 ± 1.19	9.75 ± 3.52	27.64 ± 11.20

Table 2. The parameters measured in the group of 21 sick persons.

Age [years]	P_s [mmHg]	P_d [mmHg]	D_{min} [mm]	IMT [mm]	α	CC [10^{-7} m^2/kPa]	DC [10^{-3}/kPa]
55.4 ± 14.3	137.0 ± 20.7	77.1 ± 13.3	8.48 ± 1.31	0.73 ± 0.12	5.39 ± 1.55	8.42 ± 3.37	15.19 ± 5.74



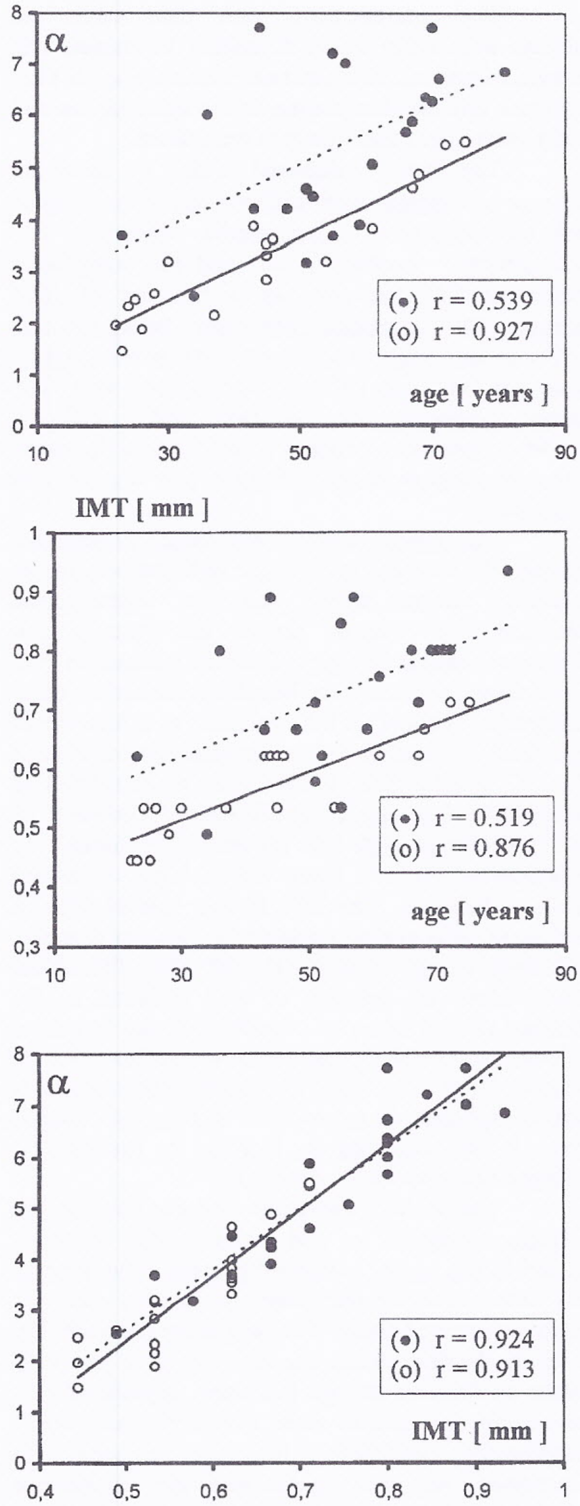


Fig. 2. The stiffness α, distensibility DC and compliance CC as a function of the intima-media thickness IMT of the artery wall determined in common carotid artery for healthy (o) and sick (•) persons. The solid lines represent the regression functions.

Fig. 3. The relation between stiffness α, intima-media thickness IMT of the artery wall and age of the examined persons determined in common carotid artery for healthy (o) and sick (•) persons. The solid and dotted lines represent the regression functions for healthy and for sick persons, respectively.

The measurements were done while the subjects were lying down, following 15 minute rest periods. Ultrasonic B-mode examinations (fig. 1*a*) did not show any stenotic plaque in the common carotid artery where the measurements were taken.

The results - depicted in fig. 2 - show the increase of vascular wall stiffness (α) to be coupled with the increase of intima-media thickness. The distensibility coefficient DC and the compliance coefficient CC decreased as a function of IMT increase. The correlation coefficient r between α and IMT was very high: 0.950 ($p<0.001$). It was slightly lower for IMT and DC ($r = -0.839$, $p<0.001$). The lowest correlation was for IMT and CC ($r = -0.554$, $p<0.001$). Tables 1 and 2 show the mean values of measurements in healthy and sick persons respectively.

The results show a significant dependence between the increase of vascular wall stiffness in the common carotid artery and the intima-media thickness. This may be due to the vascular wall structural changes bringing about an increase in both its thickness and stiffness. Results presented by other authors [3, 7] show an IMT increase as a function of age: from 0.3 mm to 1 mm between ages of 20 and 80. IMT greater than 1 - 1.2 mm is interpreted as pathologic (stenotic plaque) [3]. Results also show an IMT increase in high risk groups [1, 7] comprising hypertensive persons, those with a high cholesterol level or diabetics. The IMT is also greater than in healthy persons among people with vascular diseases, including atherosclerosis [1]. On the other hand results show an increase of wall stiffness in the common carotid artery as a function of age as well as in hypertensives [4, 5] and people with atherosclerotic changes [5]. The increase of vascular wall stiffness is mostly explained in terms of an increase of collagen fibres in the wall and an increase in the ratio of collagen fibres to elastin fibres [2].

The authors wanted to find out how are the stiffness coefficient α and intima-media thickness related to the age of examined persons. The analysis was carried out for the groups of healthy and sick persons described above. The results are shown in fig. 3. In the healthy group the increase of α and IMT values as function of age was very significant (the correlation coefficients were $r = 0.927$ and 0.876 respectively, $p<0.001$). In sick persons the dependence was very weak with the respective values of the correlation coefficient being $r = 0.539$ and $r = 0.519$ ($p<0.05$). This means that the structural changes that occur in vascular wall as a result of disease overshadow the symptoms of ageing. Nevertheless, the very high correlation between the value of α and the IMT for both groups is worth emphasising (the correlation coefficients were $r = 0.913$ and $r = 0.924$ for the healthy and sick group respectively, $p<0.001$).

Finally, it should be pointed out that the IMT correlates with the stiffness coefficient α to a much greater degree than with the distensibility and compliance coefficients DC and CC. This may be due to DC and CC being linked to the blood pressure value whereas α is independent of the systolic blood pressure changes [6].

CONCLUSIONS

The measurements carried out in the common carotid arteries of healthy and sick persons point to a statistically evident correlation between the increase of the wall stiffness and the increase of the intima-media thickness. The highest correlation with the wall thickness increase was observed for the stiffness coefficient α ($r = 0.950$, $p<0.001$) and the lowest for the compliance coefficient CC ($r = -0.554$, $p<0.001$). In persons suffering from hypertension and/or atherosclerosis the observed increase of wall stiffness (α) and intima-media thickness (IMT) was significant in comparison to healthy persons ($p<0.001$).

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