

Portable Device Use for Arterial Stiffness Determination as a Control Method at the Recovery Stage of Rehabilitation

Wykorzystanie przenośnych urządzeń do określania sztywności tętnic jako metoda kontrolna podczas rehabilitacji

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SUMMARY

Aim: To create a device for PWPV evaluation which would be cheap and could be easily used not only at the inpatient but also at the restorative outpatient and health-resort stages of rehabilitation.

Materials and Methods: The clinical examination included 90 people who were randomized into the group of observation (n=75) with patients of AH various degrees. 15 practically healthy persons were involved into the control group. PWPV was measured using a specially designed device according to the generally accepted carotid-femoral technique.

Results: Our results showed that the PWPV of healthy persons measured using original device failed to differ statistically from the literature reference values and indicated the correspondence of the measurements we obtained with the data received using traditional apparatus. Out data of original PWPV measurement obtained from examined and treated patients do not differ from the results obtained in wide range of patients aged from 40 to 70 years with the 1st -2nd stages of AH.

Conclusions: We described an efficacy of PWPV determination using an original device. The use of the proposed device does not contradict with the generally accepted method of vascular stiffness measuring and studying. The results obtained on it are comparable with the data of the most used stationary device SphygmoCor for these purposes. The prospects of the device using are without the limitations in patients with vascular diseases at the stage of rehabilitation.

Key words: vascular wall, arterial hypertension, stiffness, treatment efficacy, rehabilitation

Słowa kluczowe: ściana naczyniowa, nadciśnienie tętnicze, sztywność, skuteczność leczenia, rehabilitacja

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INTRODUCTION

It is well known that with age there is a change in the elastic properties of large arterial vessels. When studying blood vessels biomechanical properties one should attract special attention to pulse wave propagation velocity (PWPV) – an arterial vessels elastic-viscous state indicator. It just accurately reflects biological age and demonstrates a close relationship with chronological age in combination with other criteria reflecting a slow or accelerated type of aging of an certain individual [1, 2]. Discussing the vascular aging one should assume that especially the progressive increase in large arteries stiffness is its central marker [3, 4].

According to authors, an increase in stiffness and a decrease in elasticity of large arteries plays an important role in the pathogenesis of many cardiovascular diseases (CVD) and primarily in the arterial hypertension (AH) development [5, 6]. We know that blood pressure increase causes changes in the vascular wall together with arteriolosclerosis development which can result in arterial stiffness increase [7]. Thus, the vascular wall remodeling is associated both with age and with hereditary and other risk factors for CVD development i.e. hypertension, smoking, hypercholesterolemia, carbohydrate metabolism disturbances, etc. [8, 9]. Arterial stiffness evaluation is recommended by vascular specialists to detect the asymptomatic target organ damage as well as for CVD prevention as additional information for their development risk assessment [10, 11]. Experts also emphasize that PWPV increase is not only an independent predictor of cardiovascular complications but also their most reliable prognostic marker [12, 13].

The principle of PWPV determination is to register two pulse waves in different areas with a known distance (L) to measure the transit time (t) from the beginning of the first wave increase in the nearest area to the initial point till the second wave initiation at the distal end of the arterial vessels and is calculated by the formula:

$$PWPV = \frac{L\ (m)}{t\ (s)}$$

This indicator integrates the geometry and elastic properties of the vessel that described by the Moens-Korteweg formula in accordance to which it follows that PWPV increases with increasing the vascular wall both stiffness and thickness [14]. Therefore, PWPV is significantly higher in the vessels of the muscular type at a young and mature age: for example, PWPV in the aorta (Se) equals to 4-6 m/s while in the peripheral arteries of the muscular type (Sm) it equals to 8-12 m/s.

Analyzing abovementioned it becomes clear that the level of arterial stiffness is important for potential risks evaluation in patients with CVD and especially with arterial hypertension as the most common nosological index among them. PWPV determination becomes even more important at the outpatient and recovery stages of rehabilitation as an effective method of cardiovascular risks preventing at the early stages of disease manifestation.

However it should be noted the vascular wall functional condition can now be non-invasively evaluated only using magnetic resonance, computed tomography and ultrasound methods. These methods and equipment are quite expensive, difficult to operate and many of them are not available on the Ukrainian market. There are no analogous domestic manufacturers and the available foreign devices are rare used in well-equipped private clinics and only at the stationary stage of rehabilitation.

AIM

The aim of the present work was to create a device for PWPV evaluation which would be cheap, easy to use, not bulky and finally could be used not only at the inpatient but also at the restorative outpatient and sanatorium-resort stages of rehabilitation. The additional aim of the work was to perform the comparative investigation of PWV indexes obtained using our original device with the reference literature data in healthy people and in patients with arterial hypertension determined with the help of SphygmoCor device.

MATERIALS AND METHODS

The clinical examination included 90 people. These persons were randomized into the group of observation (n=75) in which the patients with AH various degrees were involved. 15 practically healthy persons were involved into the control group for PWPV indexes verification. The examined patients were hospitalized at the cardiology clinic of the Military Medical Clinical Center of the Southern Region (Odesa).

We used the following criteria of patients' inclusion into the clinical investigation: the patient's informed agree to the study and the presence of hypertension of various degrees. Exclusion criteria were the following: the 3rd degree of hypertension, cardiac rhythm and conduction disturbances, any forms of atrial fibrillation, rheumatological diseases with vascular damage, acute coronary syndrome, type 1 or 2 diabetes mellitus, internal organs chronic diseases in the stage of subcompensation and decompensation, oncological diseases.

Table I. PWPV normal values depending on age (according to [16])

Age, years	PWPV, m/s (median (10th - 90th percentile)
Less 30	6,1 (5,3-7,1)
30-39	6,4 (5,2-8,0)
40-49	6,9 (5,9-8,6)
50-59	8,1 (6,3-10,0)
60-69	9,7 (7,9-13,1)
Above 70	10,6 (8,0-14,6)

The average age of healthy individuals was 23.40±1.96 years, among them there were 8 men and 7 women. The average age of patients with hypertension (from 28 to 59 years) was equal to 42.4±7.8 years, among them were 44 men and 31 women.

PWPV was measured using a specially designed device (Patent of Ukraine No. 145472) according to the generally accepted carotid-femoral technique [15]. These device was composed of strain gauge pulse sensors, an analog-to-digital converter and a personal computer with software. Mechanosensitive sensors were applied on the skin surface in the area of the carotid (the 1st sensor) and femoral (the 2nd sensor) arteries followed by simultaneous recording of two pulse waves, and then PWPV was calculated from the data obtained.

For PWV reference values we used the normal indexes obtained in a population study by P. Boutouyrie et al. (2010) for the European population taking into account age and blood pressure (Table 1) [16].

The results are presented as M±m, where M is the arithmetic mean, m is the error of the mean. The data obtained were calculated statistically using 'Statistica 10.0' program. The Shapiro-Wilk test was used to test the groups for the Gaussian distribution. Assuming the obtained normal distribution the further statistical calculation was performed using One Way Analysis of Variance (ANOVA-test). The minimum statistical probability was determined at $p<0.05$.

RESULTS

One of the main tasks for our original device introducing into practice was to compare the obtained PWPV values with the known referent indexes in patients of the same age and pathology – in our study, patients with the 1st degree of AH. The comparison of the obtained results was carried out with the literature data of PWPV measurement using the SphygmoCor device which is the most accurate and commonly used device at the stationary stage of rehabilitation. The results obtained are presented in Table 2.

Our results showed that the PWPV of healthy persons measured using original device were equal to 6.66±1.42 m/s that failed to differ statistically from the literature reference values [6.1 (5.3-7.1)] and indicated the correspondence of

Table 2. PWPV comparative analysis

Patients	PWPV, m/s (literature data) (M±m)	PWPV, m/s (original data) (M±m)	p
Healthy persons	6,1 (5,3-7,1)	6,66±1,42	
Patients (Chazova I.Ye.with co-authors) [17]	10,1±2,5	10,3±1,2	=0.943 >0.05
Patients (Liventseva M.M.with co-authors) [18]	10,1±0,3	10,3±1,2	=0.876 >0.05

Notes: p indicated significant differences of the investigated index compared with the same described in the literature data (criterion used – one-variant ANOVA + Krushkal-Wallis)

the measurements we obtained with the data received using SphygmoCor apparatus ($p>0.05$). It should be stressed that the age range of the studied group of healthy individuals corresponded to the age of the person in whom PWPV indexes were measured according to literature data – 23.4±1.96 years and "less than 30" years, respectively.

One could see that in the group of patients with the 1st stage of AH the PWPV index was 10.3±1.2 m/s exceeding the standard values (5.9-8.6 m/s) in their age group. These results coincide with the data of other authors showed that PWPV index increase in AH patients of the same age. The data obtained in the study Chazova I.Ye. co-authors (2018) revealed that PWPV index was also in the range of 10,1±2,5 m/s in patients aged from 40 to 70 years with the 1st-2nd stages of AH [17]. One could objectively see that these data do not differ from the results obtained using the original device ($p=0.943$ that is statistically <0.05). The correspondence of the measurements using the original device was also confirmed by the data of Livintseva et al. (2015) who showed PWPV equal to 10.1±0.3 m/s in patients with hypertension of the same age, and it should be stressed that there is no significant difference between the literature and our obtained data (10.3±1.2 m/s) ($p=0.876$) [18].

DISCUSSION

The investigation of blood vessels elastic properties becomes a highly informative predictor of cardiovascular accidents possible development. This dictates the need to determine the PWPV indicator as the "gold standard" for vascular stiffness studying not only at the inpatient but also at the outpatient, health-resort and recovery stages of rehabilitation.

The use of the proposed device does not contradict with the generally accepted method of vascular stiffness measuring and studying. The results obtained on it are comparable with the data of the most used stationary device SphygmoCor for these purposes.

The invention is quite convenient in operation, since the developed system is mobile which makes it possible to measure PWPV index at the patient's bedside at any time and determine risk factors with subsequent correction and treatment control. This device is also recommended for use as a screening method for population clinical examination to determine possible risk factors and prevent cardiovascular complications.

We believe that original device for arterial stiffness measuring does not have pronounced restrictions on technical application since we have indicated above its advantages and advantageous differences from similar devices and technologies currently used in the clinic. At the same time it is important to understand that relative limitations of original device and the method proposed clinical use are contraindications for certain groups of patients with vascular diseases which we indicated in chapter "Materials and Methods".

According to the prospects of the original technique with the developed device clinical use we note that these prospects are the best and most convenient and informative in patients with vascular diseases (in our case, with arterial hypertension) at the stage of rehabilitation. Using the original device we will achieve several effects: firstly, it will be easier to control the effectiveness of the therapy prescribed by doctors and, secondly, the actual data of the device can be an important factors in the vessels functional activity monitoring in certain patients at the rehabilitation stage which from a preventive point of view will allow to receive information about the possible developing pathology of the vascular wall.

CONCLUSIONS

With accordance to the aim of the present work we described an efficacy of PWPV determination using an original device.

The device constructed allowed to measure PWPV index in patients with AH throughout the whole epoch of their treatment and especially at the stage of rehabilitation which seems to be more effective and important.

The use of the proposed device does not contradict with the generally accepted method of vascular stiffness measuring and studying. The results obtained on it are comparable with the data of the most used stationary device SphygmoCor for these purposes.

The prospects of the device using are without the limitations in patients with vascular diseases (in our case, with arterial hypertension) at the stage of rehabilitation.

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