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HUMAN VASCULAR AGE AND ASSESSMENT METHODS HARDNESS OF VESSELS

Annotation: A review of various methods for studying systemic arterial, local and regional vascular stiffness - a free foreteller of the development of cardiovascular diseases and cardiovascular death rate is presented. Although the determination of the velocity of propagation of the pulse wave (PWV) by the carotid-femoral method is the “reference” of research, the way founded on the contour estimate of the pulse wave are becoming more and more widespread. This is related to both the simplicity of the study itself and the possibility of simultaneous study of arterial stiffness and parameters of central hemodynamics - central aortic pressure and augmentation index.

Key words: vascular stiffness, pulse wave velocity, pulse wave contour analysis, augmentation.

In most developed countries, one of the leading causes of adult mortality is cardiovascular disease (CVD) [6,20]. An important role in their pathogenesis is played by a decrease in the elasticity of large arteries, an increase in vascular age and arterial stiffness [4,8]. If earlier it was believed that the great vessels are passive participants in the transport and redistribution of blood in the body, now they are rightfully considered an independently functioning organ with endocrine and paracrine functions [3,4,20].

The progress of many diseases of the cardiovascular system (CVS) is combined not only by functional transformations of arterial vessels [7], but also by frame pertubation of the arterial wall, a shift in the proportions between its components towards the accumulation of collagen and a decrease in elastic fibers, as well as the development of atherosclerosis [1,7,twenty].

All indicators characterizing arterial dysfunction are influenced by a variety of factors, the leading of which is blood pressure (BP) [6,20]. Its effect does not allow to fully establish what is the root cause of the increase in vascular rigidity: functional stretching of the vascular wall [2,3], structural remodeling [9,10] or atherosclerosis [20]. There was a need to create new parameters that could more effectively assess vascular stiffness.

Arteries have the following properties:

1. Arterial compliance (compliance, C) - an indicator of the change in volume (ʌV) in response to a change in pressure (ʌP): C = ʌV / ʌP [3,4].
2. Arterial extensibility (distensibility, D) - an indicator of the change in diameter in response to a change in pressure: D = ʌV / ʌP × V, where ʌV / ʌP - compliance. The extensibility depends on the inner and middle layers of the artery. At high pressure, the intima and media adequately expand and pull the outer lining of the arteries with them. Reaching a dangerous point, due to increased intravascular pressure, leads to the work of the outer shell as a limiter and a decrease in the extensibility of the arteries [3,4,6]
3. Stiffness of the artery (K) - the reciprocal of compliance: K = I / C = ʌP / ʌV - gives information about the internal elastic properties of the vessel [20].

4. Elasticity (E) - originally exploited measure of extensibility: E = ʌP × D / h × ʌD. It symbolizes the strength of the vascular wall 1 cm thick with a 2-fold increase in the caliber of the vessel, where D is the caliber of the vessel at rest,
ʌD is the change in the caliber of the vessel with a change in the tensile pressure ʌP, his the thickness of the vascular wall [20].

There are 2 methods for analyzing the elastic properties of the arterial wall [1,7]. Direct methods can be invasive or non-invasive. Invasive methods include angiography and arterial catheterization [1,7]. Non-invasive methods include transthoracic echocardiography (TT-echocardiography) and MRI [1,7]. Invasive methods for examining the distensibility of the aorta, affecting vascular catheterization, make it possible to most accurately assess elasticity using a built-in ultrasound transducer and micromanometer [2,11].

To date, the use of invasive methods of TT-EchoCG and MRI is limited, therefore non-invasive methods based on the calculation of surrogate parameters of arterial stiffness are increasingly being used. They are classified:

1.Determination of systemic arterial stiffness (this is based on a modified Windkessel model) - created to determine systemic arterial compliance - finding the absolute caliber of blood vessels at a certain pressure point, area method and method for calculating the ratio of stroke volume / pulse pressure. These methods of changing systemic arterial stiffness are based on theoretical conjectures that do not have sufficient substantiated arguments [2,3,4].

2. Determination of local vascular stiffness - allows you to directly determine the stiffness of the vascular wall. In this case, imaging methods are used, which allow to determine the pulse changes in the diameter of the arteries in response to pulse pressure changes. The main non-invasive method for determining the elastic properties of the arterial wall, measuring the diameter of the vessels and the thickness of the intima-media complex (ICIM) is an ultrasound study [3,4,15].

To identify pulse measurements of the artery caliber, TCIM, to study the hardness (rigidity) of the vessels, Echo-tracking systems are used, which determine the local velocity of pulse wave propagation (PWV), Young's elastic modulus [3,16].

3. Determination of regional (segmental) vascular stiffness allows the use of indirect methods. Mainly for determining the velocity of distribution of the pulse wave (PWV) in the central vessels, which is recognized as the "gold standard" for assessing vascular stiffness [2,18]. In second place are methods of pulse wave contour analysis, which determine the parameters of stiffness and parameters of central hemodynamics (cSAD, cPAD, augmentation and amplification indices) [4,5,6].

PWV is one of the first methods for studying the vascular system [17]. In 1929 G.F. Lang proved that PWV is a valid and reliable indicator of the elasticity of the aortic wall [1].

To determine the stiffness of the aorta, the carotid-femoral velocity of propagation of the pulse wave (PWVkf) is used [3,4,21]. The use of PWVKF was recommended by the European Consensus of Experts on Arterial Stiffness (2016) as a preclinical criterion for the defeat of great vessels in hypertension [20]. The critical value for determining the high risk of cardiovascular complications is recognized as the value of PWVkf> 10 m / s (European Society of Cardiology (EOC) / European Society for Arterial Hypertension (EOGH) (2016) [3,4,20].

СРПВ is determined by the "foot-to-foot" method. It consists in finding the time difference between the onset of the growth of the pulse wave in the carotid and femoral arteries (Dt). The distance (D) that the pulse wave travels is considered as the distance between the two registration points. PWV is calculated as the ratio of the distance D (in meters) to the time the wave overcomes this distance Dt (in seconds): PWV = D / Dt [3,4,21]. However, different devices use different methods for determining the distance. Of fundamental importance is the determination of the normative values of PWV, especially when conducting population studies and meta-analyzes (Fig. 1; Fig. 2) [15,22].

Most of the studies with the calculation of PWVKF were performed on the Complior apparatus (ArtechMedical, France). With the help of piezoelectric sensors, pulse waves are recorded at once in two points of the arterial tree. The device makes it possible to determine the rigidity of the aorta (carotid - femoral artery), upper arteries (carotid - brachial artery) and lower (femoral - posterior artery of the foot) limbs (Fig. 2) [13, 14].

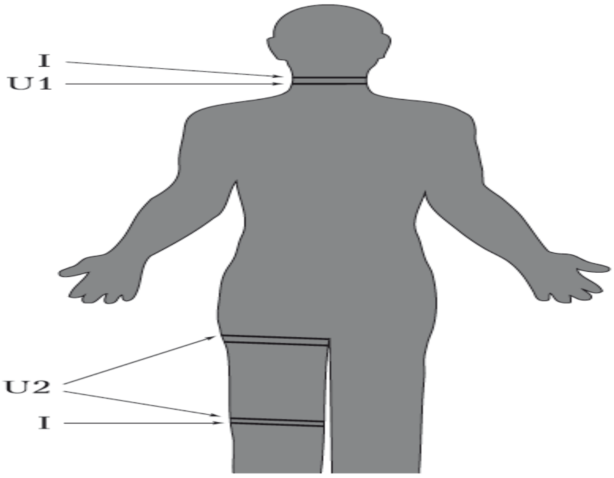

Fig. 1. Determination of PWVcfreograph "ReoKom" (Russia) (1, U1, U2 - placement of electrodes)

With the help of the SphygmoCor apparatus (AtCorMedical, Australia), pulse waves are recorded by a systematic high-precision applanation tonometer. Applanation tonometer is superimposed on the proximal (carotid) and, with a short interval, on the distal (femoral) arteries, while an electrocardiogram (ECG) is recorded at the same time. PWVKF is determined using the time of passage of the wave between the points of registration, determined using the R wave on the ECG. For this purpose, the time between the R wave on the ECG and the onset of pulsation is calculated.

Applanation tonometer is also used in the PulsePen device (Diatecne, Italy) [12,17]. The device calculates the central pressure in the aorta and the waveform in the arteries: carotid, femoral, brachial, radial, etc. The PulseTrace PWV device (MicroMedical, Great Britain) records alternate pulse waves in the carotid and femoral arteries, but using a Doppler probe and comparing it with the R-wave of the ECG, determines the PWVcf in the aorta. This method has a simplicity of research and is recommended for epidemiological studies [12,17].

Piezoelectric sensors for recording a pulse wave on the carotid and radial arteries, and volumetric sphygmography for the femoral artery is used in the Polyspektr device (NeuroSoft, Russia) [6,15]. At the same time, the ECG signal binding is used to calculate the onset of the pressure wave. By the delay of the contour of the wave of the femoral artery relative to the contour of the carotid artery, the propagation time of the pulse wave is calculated [4, 6].

Despite the high authenticity and reproducibility of the carotid-femoral method for determining PWV, recognized as the "standard" for assessing arterial stiffness [15,21], this method is accompanied by some difficulties in use, such as the complexity of recording pulse waves and ethical problems of recording a pulse wave on the femoral artery [19.21].

Despite the fact that the use of volumetric sphygmography to fix the pulse waves of the femoral artery greatly simplifies the research methodology, and also eliminates ethnic problems, but due to the fact that the femoral artery is located deep enough and is enveloped in a large amount of muscle mass, which reduces the accuracy of the calculation the actual beginning of the pulse wave [19,21,22].

With the help of continuous Doppler, the travel time of the wave between two points of the arterial tree is determined to calculate the PWV. The measurement is performed over the ostium of the left subclavian artery and in the area of the bifurcation of the abdominal aorta. The time distance is calculated automatically at the beginning of the rise in the pulse wave. This method makes it possible to more accurately calculate the PWV of the aorta in comparison with the carotid-femoral method [19,21].

Japanese scientists have proposed the simplest method of volumetric sphygmography for calculating PWV at points from the brachial artery to the ankle, which can be recreated in the VaSera-1000 (FukudaDenshi, Japan) and Colin VP-1000 (OmronHealthcare, Japan) devices [16,21]. It has been proven that the shoulder-ankle PWV (PWVPl) correlates well with aortic PWV, with the manifestation of coronary heart disease (IHD). This method makes it possible to determine not only PWVpl, but also the augmentation index (Alx) on the brachial and carotid arteries [16,21].

The disadvantage The calculation of any PWV is accompanied by a gap in view of the fact that it depends not only on the rigidity of the vascular wall caused by a change in its structure, but also on the level of mean blood pressure in the arterial system during the calculation of PWV (level of tensile pressure) [3,4,15]. There is another factor influencing the value of PWV - heart rate (HR). With an increase in heart rate from 60 to 90 per minute, the PWVkf indicator increases from 6.2 to 7.6 m / s. Because the vascular wall is represented by a viscoelastic material, its resistance to deformation increases with an increase in the rate of deformation of the vascular wall, which increases with an increase in heart rate [4,22]. This feature must be taken into account when interpreting the dynamics of PWV under exposure, leading to a change in heart rate [22].

Also, Japanese researchers have proposed a new indicator of stiffness - the cardio-ankle vascular index (CAVI) [16]. Which allows you to calculate the stiffness of the vessels, regardless of the level of stretching blood pressure, acting on the artery wall at the time of fixation of the pulse wave. This indicator is related to the presence and severity of coronary atherosclerosis, therefore it is recommended as its predictor [16,21]. CAVI is offered not only to identify vascular stiffness, but also to assess the severity of the atherosclerotic process [16,21].

At the moment, the method of contour analysis of the peripheral pulse wave, which is recorded using digital photoplethysmography, is widely used to calculate arterial stiffness (Fig. 3) [5, 6]. Registration of the peripheral pulse wave is based on the passage of infrared radiation through the finger. The amount of light is directly proportional to the volume of blood pulsating in the finger [4,5,6].

For this purpose, 2 devices are used: the Angioscan-01 device (Russia) and the PulseTracePCA device (Great Britain). They record the parameters of the central pulse wave, arterial stiffness, as well as biological age, which is calculated on the basis of the age index determined by mathematical models [5,6]. In turn, two more indices are calculated: 1) the reflection index RI is the percentage of the height of the systolic component to the height of the diastolic component of the peripheral pulse wave. RI shows the state of the tone of small arteries and the value of the pulse wave reflection [4,5,6]; 2) the stiffness index SI - analyzes the pulse wave velocity of large arteries and is calculated as the ratio of the patient's height to the time between the systolic and diastolic components of the wave [4,5,6]. These indicators show the distensibility of the arteries and the severity of atherosclerosis [12].

Fig. 3. Finger photoplethysmography

Moreover, methods based on the contour assessment of the pulse wave can be applied not only to the analysis of vascular stiffness, but also to fix the parameters of central hemodynamics, namely, to assess the level of cSBP, cPAD and AIx [12]. This is based on the fact that in the peripheral arteries and in the aorta, pulse waves have a similar shape.

The level of BP in the peripheral artery is determined by the calibration method, which is based on the fact that the mean and final DBP are approximately parallel in all large vessels. DBP is measured on the brachial artery, and the average pressure is calculated by the formula Avg = DBP + 0.4xPAD. Based on this formula, the PAP is calculated and the pulse wave is calibrated [4,12].

There is no doubt that these clinical studies on the study of pulse wave contour analysis are of great interest, due to a simple, reliable and effective diagnostic method for assessing arterial stiffness.

Conclusion

At present, to study the elastic properties of the vascular wall, the methods for assessing the regional stiffness of the arteries are most often used, which can be presented in the form of PWV or reflection waves of the great vessels. Although the first group of methods is the “gold standard” for assessing arterial stiffness, techniques based on pulse wave contour analysis are becoming more widespread. This is due to both the simplicity of the study itself and the possibility of simultaneous study of arterial stiffness and parameters of central hemodynamics - central aortic pressure and augmentation index.

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