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Investigation of Microcirculatory in Resistive Arteries

Niashin I.

Multidisciplinary Science High School, New York, USA

Abstract

The article shows the physiological significance of resistive arteries in relation to blood flow. The article describes a new non-invasive method for assessing the functional state of resistive arteries, which indicates the resistance of resistive arteries. Microcirculation coefficient – resistance of resistive arteries is an easy-to-use diagnostic method for assessing circulatory problems. The article shows new normative indicators of the microcirculation index in young healthy men. And also shows the rheological indicators for the same group.

KEY WORDS: resistance index, resistive arteries, rheological properties

Introduction

The cardiovascular system consists of the heart and blood vessels – arteries, arterioles, capillaries, venules and veins, arterio-venous anastomoses. Its transport function lies in the fact that the heart ensures the movement of blood along a closed circuit of blood vessels. From the point of view of biomechanics, vessels are elastic tubes of various diameters. Distribution of total blood volume: 84% – in the systemic circulation, 9% – in the lesser circulation, 7% – in the heart [1]. In terms of elasticity, arteries are of the Elastic type. This is the aorta, the pulmonary artery; Muscular-elastic type – these are sleepy, subclavian, vertebral arteria; muscle type – these are the arteries of the limbs, trunk, internal organs. Veins are of the Fibrous type. They are muscleless. Veins of the hard and soft meninges (without valves); retina of the eye; bones, spleen, placenta. Veins are of the Muscular type: with muscle elements. These are the superior vena cava and its branches, veins of the face and neck; Veins are with an average development of muscle elements. These are the veins of the upper extremities. Veins are highly developed with strong muscle development. This is the inferior vena cava and its branches and veins of the lower extremities. The structure of arteries and veins is as follows: intima is the inner shell, media is the middle, and adventitia is the outer. All blood vessels are paneled from the inside with a layer of endothelium. All vessels have elastic, collagen and smooth muscle fibers. Their number in different vessels is different. They are not in true capillaries. Depending on the function performed, the following groups of vessels are distinguished: 1. Amortizing vessels – aorta, pulmonary artery. The high content of elastic fibers in these vessels causes a shock-absorbing effect, which comprises smoothing out of periodic systolic waves. 2. Resistive vessels – terminal arterioles (precapillaries) and, to a lesser extent, capillaries and venules. They have a small lumen and thick walls with developed smooth muscles, and offer the greatest resistance to blood flow. 3. Vessels-sphincters – terminal sections of precapillary arteriol. The number of functioning capillaries, that is, the area of the exchange surface, depends on the narrowing or expansion of the sphincters. 4. Exchange vessels – capillaries. The processes of diffusion and filtration take place in them. Capillaries are incapable of contractions, their diameter changes passively following pressure fluctuations in pre – and post-capillary resistive vessels and sphincter vessels. 5. Capacitive vessels are mainly veins. Due to their high elongation, veins are able to accommodate or eject large volumes of blood without significant changes in blood flow parameters, and therefore they play the role of a blood depot. 6. Bypass vessels – arterio-venous anastomoses. When these vessels are open, blood flow through the capillaries either decreases or stops completely [1,2,3]. We, as specialists in the study of hemodynamics and blood rheology, showed particular interest in the incomplete functional signs of resistive arteries that have been investigated. From the point of view of hemodynamics, blood circulation taps, which regulate the adequacy of blood circulation and ensure the required blood flow. Hemodynamic bases. The flow of blood through the vessels. The driving force of blood flow is the pressure difference between different parts of the vascular bed. Blood flows from a high-pressure area to a low-pressure area, from the high-pressure arterial section to the low-pressure venous section. This pressure gradient overcomes the hydrodynamic resistance due to internal friction between the liquid layers and between the liquid and the vessel walls, which depends on the size of the vessel and the viscosity of the blood. The flow of blood through any part of the vascular system can be described by the formula for the volumetric blood flow velocity. Volumetric blood flow velocity is the volume of blood flowing through the cross-section of a vessel per unit time (ml/s). Volumetric blood flow velocity Q reflects the blood supply to a particular organ. $Q= (P_2 – P_1)/R$, where Q is the volumetric blood flow velocity, $(P_2 – P_1)$ is the pressure difference at the ends of the vascular system, R is the hydrodynamic resistance. The volumetric blood flow velocity can be calculated based on the linear blood flow velocity through the cross-section of the vessel and the area of this section $Q = V \times S$, where V is the linear velocity of blood flow through the cross-section of the vessel, S is the cross-sectional area of the vessel. In accordance with the law of flow continuity, the volumetric blood flow velocity in a system of tubes of various diameters is constant regardless of the cross section of the tube. If a liquid flow through the tubes at a constant volumetric velocity, then the speed of movement of the liquid in each tube is inversely proportional to its cross-sectional area: $Q=V_1 \times S_1 = V_2 \times S_2$. The viscosity of blood is a property of a liquid, due to which internal forces arise in it that affect its flow. If the flowing liquid comes into contact with a stationary surface (for example, when moving in a tube), then the layers of liquid move at different speeds. As a result, a shear stress arises between these layers: the faster layer tends to stretch in the longitudinal direction, while the slower one retards it. Blood viscosity is determined by blood cells and plasma proteins. Under physiological conditions, a laminar blood flow is observed in almost all parts of the circulatory system. The liquid moves as if in cylindrical layers, and all its particles move only parallel to the axis of the vessel. Separate layers of liquid move relative to each other, and the layer immediately adjacent to the wall of the vessel remains motionless, the second layer slides along this layer, and the third layer over it, and so on. The result is a parabolic profile of the velocity distribution with a maximum in the center of the vessel. The smaller the diameter of the vessel, the closer the central layers of the liquid are to its stationary wall and the more they are inhibited as a result of viscous interaction with this wall. Due to the mean blood flow velocity is lower in small vessels. In large vessels, the central layers are located farther from the walls, therefore, as they approach the longitudinal axis of the vessel, these layers slide relative to each other with increasing speed. As a result, the average blood flow velocity increases significantly [2]. Under certain conditions, the laminar flow turns into a turbulent one, which is characterized by the presence of vortices, in which fluid particles move not only parallel to the vessel axis, but also perpendicular to it. In turbulent flow, the volumetric blood flow velocity is proportional to the square root of the pressure gradient. There are legalized principles of ultrasound examination. When studying them, the following are assessed: vessel permeability, vessel geometry, wall pulsations, vessel diameter; thickness, structure, uniformity of the wall; vessel lumen state.

Quantitative parameters are very important for clinical practice:

- peak systolic blood flow velocity (S);
- end diastolic blood flow velocity (D);
- time-averaged maximum blood flow velocity (TAMX);
- time-averaged mean blood flow velocity (Fmean, TAV);
- peripheral resistance index, or resistivity index, or Pource-lot index (RI).
  RI=S–D/S;
- pulsation index, or index, or Gosling index (PI). PI=S–D/Fmean;
- spectral expansion index (SBI). SBI=S–Fmean/S x 100%;
- systolic-diastolic ratio (SD).

The spectrogram is characterized by many quantitative indicators, however, most researchers prefer the analysis of the Doppler spectrum based on not absolute, but relative indices [2]. Described by us, above is the features of the study of hemodynamics in the arterial network. Features of hemodynamics in the veins are as follows. Fluctuations in the velocity of blood flow in the great veins are associated with breathing and cardiac contractions. These fluctuations increase as you approach the right atrium. Fluctuations in pressure and volume in veins located near the heart (venous pulse) are recorded by non-invasive methods (using a pressure transducer) [1,4,5,6]. Compression of the vein lumen by the sensor leads to complete compression of the lumen. In the case of partial or complete thrombosis, the lumen of the vein is not completely compressed by the sensor or not compressed at all. In the study of the venous system, in contrast to the arterial, fewer parameters are assessed. In our early works, we paid special attention to the intimate media layer for the evaluation of blood in general. All the methods described are especially laborious, requiring special additional qualifications and experience from the meeting. For these methods, sophisticated equipment, specialized clinics and offices are required. The methods are financially expensive. But not only had these questions prompted us to develop a particularly interesting method for evaluating blood circulation. This is a method for studying the functional state of resistive arteries. In our early work, we paid particular attention to the intimate media layer for blood flow assessment [7]. But this is a very painstaking process. At the moment, all methods are laborious, requiring special additional qualifications and experience from the doctor. These methods require sophisticated equipment, specialized clinics and offices. The methods are financially expensive. These and other questions prompted us to develop a new method for assessing blood circulation. This method is based on the study of the functional state of resistive arteries, determines the coefficient of microcirculation. This article is methodological, overview and includes experimental data. The article presents a new method for studying the functional states of resistive arteries in order to diagnose somatic health in young men.

Methods

The study included 53 healthy young people aged 22.4 ± 5.4 years. By means of special questionnaires, according to the analysis of the general blood picture (HumanCount, Germany), as well as by measuring the total arterial pressure (“Pulse” manometer, Russia), the condition of all volunteers was assessed, which corresponded to the definition of somatic health (“practically healthy”). The apparatus was used to study the functional state of resistive arteries at the site of pulsation using a standard test, measuring the coefficient of resistance of resistive arteries.

The coefficient of resistance of resistive arteries was denoted by the letter M, was calculated by the formula $M=(V_{pix} / V_{phon}) x100\%$, where V_{pix} is the volumetric blood flow velocity at the site of pulsation on the wrist after a standard ischemia with a duration of 1 min; V_{phon} is the rate of volumetric background blood flow at the site of pulsation on the wrist without exposure. The coefficient of resistance of resistive arteries was measured as a percentage [7]. The measurement was based on a comparison of the blood flow velocity in postischemic (reactive) hyperemia resulting from a standard 60 cessation of local blood flow with the background blood flow at the site of pulsation at the wrist. Standardized ischemia was induced by compression of the brachial artery, the blood flow curve was analyzed using a texture analysis apparatus (TAS-plus, Germany). Following the Helsinki convection about scientific research, the participants were informed about the inclusion of the depersonalized method in the study, an informed consent was drawn up, which was signed by all volunteers included in the study addition to measuring the functional state of resistive arteries, we investigated the intravascular state of the blood, which forms the flow laminarity, or its turbulence [8]. Specifically, we measured the rate of erythrocyte aggregation [9], the rate of erythrocyte deformability in [10], plasma viscosity according to existing certified techniques [11].

Results

When solving this problem, we studied a group of actually healthy young people. We examined all members of the group, the resistance of resistive arteries, the index of erythrocyte aggregation [EAI], the index of erythrocyte deformability [EDI], plasma viscosity. This comprehensive study enables us to study the vascular and extravascular factors that shape microcirculation and blood flow. The statistically processed data showed that EAI, EDI and blood viscosity in the group of young people corresponded to the existing control (normative) values. See table 1. Also, a homogeneous series of values of the functional value of resistive arteries was obtained, i.e. the resistance coefficient series did not have extrema and the scatter of values was minimal. This gave us the opportunity to conclude that the study of the functional state of the arteries is a diagnostic tool. To check the validation of our new method, we examined patients with hemodynamic disorders with arterial obstruction syndrome: patients with stenosis (n = 8) and patients with occlusion (n = 9). All patients were examined for resistance of resistive arteries. 1. Syndrome in violation of arterial patency of varying degrees: patients with stenosis (n = 5) and patients with occlusions (n = 5); 2. Syndrome of arteriovenous shunting (n = 6); 3. Syndrome of arterial vasodilation (n = 5).

Discussion

According to the literature, a decrease in the linear blood flow velocity can be recorded up to the deformation zone, and the peripheral resistance indices can be increased. In the deformation zone, there is an increase in the blood flow velocity, more often during bends, or multidirectional turbulent flow – in the case of loops. Behind the deformation zone, the blood flow velocity increases, the peripheral resistance indices decrease. Since deformities develop for a long time, adequate collateral compensation develops.

As a result, the resistance measured by our method turned out to be adequate, the one that was investigated by complex technological methods.

It occurs in the presence of arteriovenous fistulas, malformations. Changes in blood flow are noted in the arterial and venous bed. In the arteries proximal to the shunting site, an increase in the linear blood flow velocity, both systolic and diastolic, is recorded, the peripheral resistance indices are reduced. A turbulent flow is observed at the shunting site, its value depends on the shunt size, the diameter of the adducting and draining vessels. In the draining vein, the blood flow velocity is increased, often noted “arterialization” of venous blood flow, manifested by a “pulsating” Doppler curve. Having determined the resistance of resistive arteries in these patients with a new method, we obtained the same results.

This leads to a decrease in peripheral resistance indices and an increase in blood flow velocity in systole and diastole. It develops in systemic and local hypotension, hyper perfusion syndrome, “centralization” of blood circulation (shock and terminal states). In contrast to arteriovenous shunting syndrome, arterial vasodilation syndrome does not cause characteristic disorders of venous hemodynamics [1, 2]. Research by our method showed similar results.

Thus, within the framework of the grant, the results obtained can be interpreted as confirmation of a new diagnostic method with the aim of introducing and expanding this method into clinical medicine. Knowledge of the structure of the walls of blood vessels, their functions, the characteristics of hemodynamics in the arteries and veins is necessary for the successful prevention of hemodynamic disorders and proper treatment. Work in this direction is very timely, since the latest approaches in biomedicine include minimizing financial costs, patient safety and reducing the risk of errors on the part of the doctor. A new method for assessing the resistance of resistive arteries by examining the functional state of resistive arteries is safe, easy to implement and does not require large expenses against the background of high information content.

Table 1. Rheological properties in young men group. M – arithmetic mean of a row; m – arithmetic mean deviation from the mean of row. Row consists of 53 healthy young men

Parameters	M	m
EAI	23.5	0.2
EDI	2.0	0.02
Plasma viscosity	1.2	0.015

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