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APPRAISAL OF FUNCTIONAL STATE OF THE HUMAN RESISTANCE ARTERIES

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Abstract. The resistance arteries are playing a significant role in the control of circulation. They determine the functional state its most significant circulatory parameters both under the normal and pathological conditions. The present article contains results of a many years investigation of the functional state of the human resistance arteries during various pathologies, such as Raynaud's phenomenon, arterial hypertension, and II type diabetes mellitus. The investigation results were obtained with an original non-invasive technique developed in the laboratory of I. Beritashvili Institute of Physiology. Further usage of the technique will provide the specialists for a better understanding of the pathogenesis of various essential diseases.

Key words: resistance arteries, Doppler's effect, Raynaud's phenomenon, arterial hypertension, II type diabetes mellitus.

The resistance arteries located at the boundary of the systemic and regional circulatory beds are functioning like faucets and determine both the arterial pressure level and the rate of microcirculation in various parts of the body. In addition, development of various pathological and compensatory events in the peripheral blood flow and microcirculation is also related to the functional state of the resistance arteries.

Proceeding from this statements it is just the resistance arteries are the subject of diagnostic studies and of the therapeutic effects during various essential pathologies. This evidences how important is the efficient diagnostics of the functional states of human resistance arteries, especially when this must be the basis of the therapeutic effects eliminating the respective circulatory disturbances in the patients. The present work is a description of an original non-invasive technique for evaluation of the functional state of the resistance arteries functional state in the human hands. This technique was developed in the laboratory of I. Beritashvili Institute of Physiology and has been applied for an efficient diagnostics during some essential human pathology.

The principle of our technique for appraisal of the functional state of the resistance arteries is based on investigation of the standard postischemic (reactive) hyperemia that develops following a standard stoppage of the regional blood flow. Since the level of both the systemic arterial and venous pressures remains unchanged during one minute long period the blood flow in the radial arteries is directly dependent on the functional state of the resistance arteries of the hand, namely on the degree of their dilatation. Therefore, it becomes possible to judge their functional state proceeding from the dynamics of the blood flow in the appropriate radial artery.

The applied technique for the appraisal of the functional state of the resistance arteries should respond to the following requirements: (a) the obtained data related to the parameter under study should be direct and maximum precise; (b) the data should be quantitative; (c) the possible errors and artefacts should be minimized; (d) the technique should be easily applicable under the conditions of an ambulance and should not require a special and long-lasting training of the medical personal.

Under conditions of a stable systemic arterial pressure the velocity of the blood flow in the radial arterial reflects the functional state just of the resistance arteries of the appropriate hand. Therefore, proceeding from the blood flow velocity alterations after a standard blood flow stoppage in the patient's radial artery it is possible to judge the functional state of the resistance arteries in the same hand.

The blood flow velocity in the radial arteries was recorded with an ultrasound device while the arterial tone in the hand was revealed proceeding from the Doppler's effect. Its essence is well known to be related to the specific changes of the frequencies of the ultrasound, which are in turn dependent on the blood flow velocity in the appropriate artery. Therefore, directing the sound's signal toward the patient's radial artery at the angle of 45° and recording by the Doppler's device the reflected signal from the flowing bloods' erythrocytes, it is possible to determine the linear velocity changes of the flowing blood. These latters become evident proceeding from the shift of the falling and reflected signals of the respective resistance arteries, which originated from the ramifications of the radial artery under study.

In the present study we applied the ultrasound device "Dop 8/4" (Germany) with a frequency of 4 MG and an in-built recording device. For recording of the normal blood flow in the patients' radial arteries the transducer was placed at the wrist where the artery's audibility pulsations are maximal. By rising the pressure in the sphigmomanometer's cuff superimposed on the brachial artery over the systemic arterial pressure level the blood flow in the hand stopped just for one minute. After the subsequent lowering of the pressure to zero the authors recorded by the Doppler's device the blood flow during the postischemic hyperemia. Carrying out such functional tests is possible to be done both in the hospitals as well as in the ambulances and this does not arise disagreeable feelings for the patients.

For appraisal of the functional state of the patients' resistance arteries the authors use the term "resistance index". This latter represents itself the relationship of area between the course of the blood flow under the normal (background) conditions and the zero line during the time interval *t*. This latter was recorded in the period of the return of the increased postischemic blood flow to its initial value and reflects the amount of the flowing blood related to its initial value (Fig. 1). Thus, we recorded the amount of the flowing blood via the radial artery during the test since the curve represents itself the sum of discret values of the blood flow velocity ($S = \Sigma V_i$). The sizes of these areas – before ischemia and after it – differ, the one from the other, because of the significant increase of the blood flow during the postischemic hyperemia. The time of the blood flow restoration to its initial value reflects the dynamics of the functional state of the patients hand resistance arteries. The vascular resistance index is than calculated mathematically by using the following relation:

$$\frac{S_1}{S_2} = \frac{\sum V_{1i}}{\sum V_{2i}}, \qquad (1)$$

where S_1 is the area restricted by the curve of blood flow under the normal (initial) conditions and the zero line, S_2 is the area restricted by the blood flow curve in the postischemic period and the zero line, V_1 is velocity of the initial blood flow in the artery under study in the point *i* that acquires discrete values during the period t_1. V_2 is the blood flow velocity in the artery under study during the postischemic hyperemia in the point *i*, which accepts discreet values

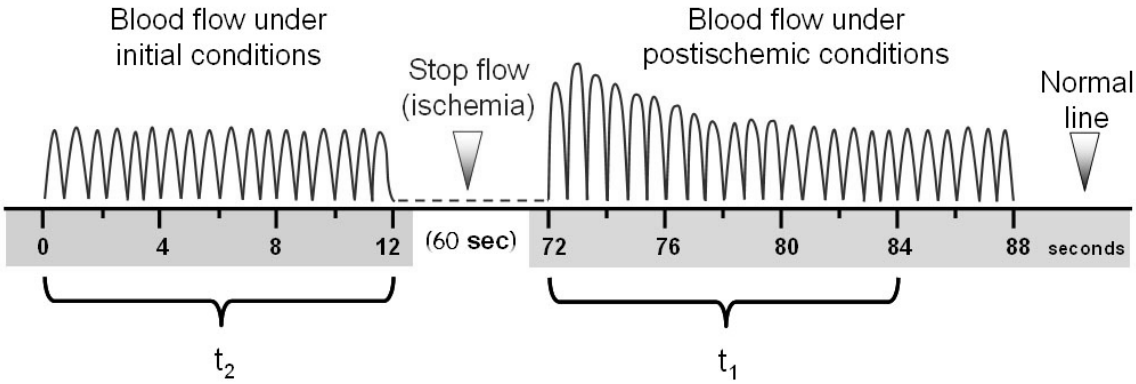

Fig. 1. Blood velocity curve under the normal conditions during temporary stop-flow and the subsequent postischemic hyperemia. The figure contains the curve of a healthy subject, 23 years old.

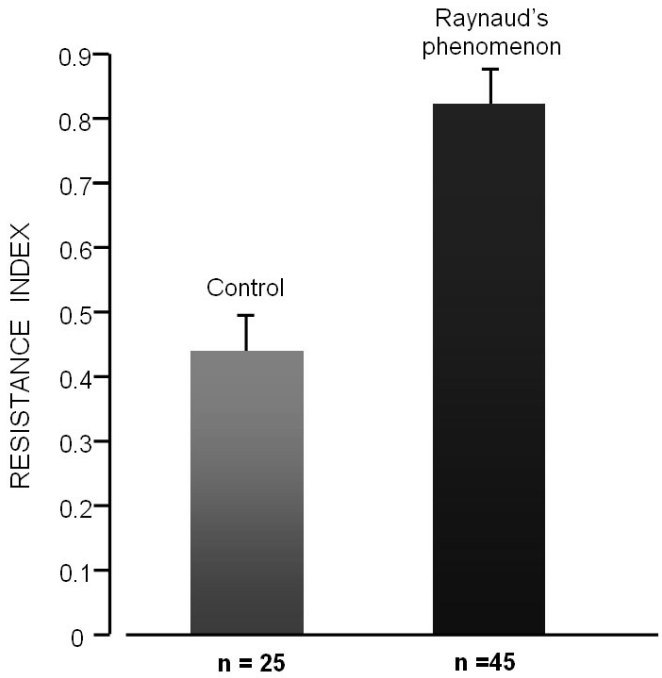

Fig. 2. Resistance index in a group of healthy subjects (n=25) and patients with the Raynaud's phenomenon (n=45).

during the time t_2. These mathematical calculations were carried out by using a special packet of programs of the textur analysis system of the TAS-plus of Leitz (Germany).

By applying the technique we have revealed the resistance value in the arteries of healthy people, i.e. the arithmetical mean of the resistance index of the appropriate people. Further, this value was used by us as a control parameter (n=25) in the healthy subjects of a mean age 35±8 years old where the approximate resistance index was found to be 0.43±0.082. Among the considered pathologies there were patients with the Raynaud's phenomenon (n=45) of a mean age 24±12 where the mean resistance index was 0.82±0.041 (Fig. 2). In addition, we studied a patients' group with the arterial hypertension (n=25) whose mean age was 45±3 years and the mean resistance index of the arteries was found to be 0.67±0.09 (Fig. 3). We investigated also a patients' group with the II type diabetes mellitus (n=65) whose mean age was 65±14 years and the mean resistance index equalled 0.55±0.079 (Fig. 4).

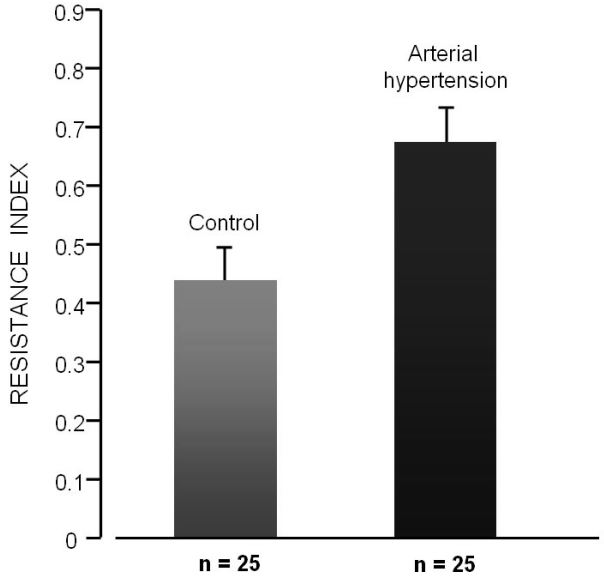

Fig. 3. Resistance index in a group of healthy subjects (n=25) and patients with the arterial hypertension (n=25).

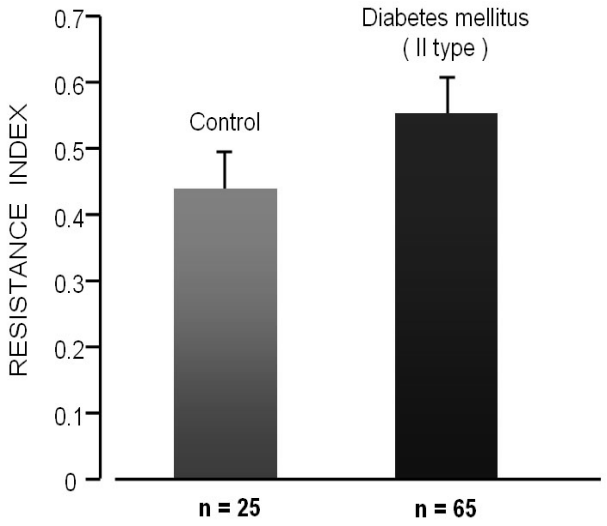

Fig. 4. Resistance index in a group of healthy subjects (n=25) and patients with the II type diabetes mellitus (n=65).

Proceeding from our studies it became possible to find out that during such a vascular pathology as the Raynaud's phenomenon the resistance index was significantly higher than in the control group. This corresponds to the data described in the articles related to the pathogenesis of this disease [1, 2]. According to these data, the resistance index investigated with other techniques during the same pathology was higher than under the normal conditions [4, 6, 8], and this evidences for the reliability of the technique developed by us.

The resistance index was higher by about 50 per cents in the investigated hypertensive patients as compared to the healthy control subjects. This indicates that in addition to the hemorheological changes the vascular tone is increased significantly during hypertension [3, 5, 7]. We have also found an increase of the resistance index during the II type of diabetes as compared to the same index in the control group. This evidence for the availability of changes of the resistance arteries functional state in the both hands probably also belongs to the other parts of the body, thus showing on the appropriate circulatory complications during diabetes mellitus (e.g., during the angiopathies, myocardial infarcts, etc.).

Proceeding from the foregoing, the investigation of functional behavior of the resistance arteries demonstrates that this approach might be very significant for the diagnostics of appropriate pathologies and for the well-timed appraisal of the blood supply to various parts of the patients bodies. The investigations that are going on in the same direction will provide for a better understanding of the pathogenesis of various pathologies related to the blood supply to various parts of the human body. The described technique might be applied for detailed studies of various diseases related to disturbances of the resistance arteries physiological tone and its disturbances.

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ОЦЕНКА ФУНКЦИОНАЛЬНОГО СОСТОЯНИЯ РЕЗИСТИВНЫХ АРТЕРИЙ У ЧЕЛОВЕКА

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Резистивные артерии играют важную роль в регуляции кровообращения. Они определяют функциональное состояние наиболее важных циркуляторных параметров как в нормальных, так и в патологических условиях. Статья содержит результаты многолетних исследований функционального состояния резистивных артерий человека при разных патологиях, таких как болезнь Рейно, артериальная гипертензия и сахарный диабет II типа. Результаты настоящих исследований были получены с помощью неинвазивной методики, разработанной в лаборатории физиологии и патологии Института физиологии им. И.С. Бериташвили. Дальнейшее использование этой методики обеспечит специалистов лучшим пониманием патогенеза различных важных заболеваний.

Ключевые слова: резистивные артерии, функциональная диагностика, эффект Допплера, индекс резистивности, лучевая артерия.

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