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BLOODLESS ESTIMATION OF BIOMECHANICAL PROPERTIES OF HUMAN CAPACITIVE VESSELS

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UDC 612.147.3-072.7

KEY WORDS: rheoplethysmography; interelectrode resistance; elasticity, of vessels; orthostatic test; capacitive vessels.

Determination of the state of the veins has not yet found its true place in functional investigations of the human cardiovascular system. Information on the elasticity of capacitive vessels is particularly deficient. The writer has perfected an apparatus and method for the bloodless determination of the elasticity of the limb veins [1, 2], and the results obtained are described below.

EXPERIMENTAL METHOD

The subject was placed on a table which could be tilted into the orthostatic (vertical) position. Rubber ring electrodes, connected to a two-channel rheoplethysmograph, were secured to the upper and lower thirds of the legs of the subject in the horizontal position. After measurement of the original values of interelectrode resistance, the two legs, which were at the foot end of the table, were simultaneously lowered; under these circumstances the lower limbs were flexed at the knee practically to a right angle (test 1). Changes taking place under these conditions in the interelectrode resistance were recorded for 2 min, after which the limbs were returned to their initial positions. Similar measurements were carried out during lowering of the limbs alternately (test 2). The investigation was completed with the orthostatic test (test 3). During this procedure the subject, together with the table, was tilted passively into the near-vertical position (an angle of 75° to the horizontal). Typical tracings of rheoplethysmograms are illustrated in Fig. 1.

Elasticity was determined immediately after the subject or his limbs had been tilted into the vertical position, and 30, 60, and 120 sec later. The calculation was done by the following equation:

$$B = \frac{\Delta R}{R \Delta P},$$

where B is elasticity; R and ΔR interelectrode resistance and its change; and ωP is the change in hydrostatic pressure caused by the change in position of the limb in the verticle direction from the level of the heart.

This method was used to investigate 45 clinically healthy persons and 35 patients with a clinical diagnosis of varicose veins. The healthy subjects included 25 men aged 15 to 43 years and 20 women aged from 15 to 42 years; the patients included 15 men aged from 18 to 49 years and 20 women aged from 15 to 64 years.

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 89, No. 5, pp. 632-634, May, 1980. Original article submitted April 19, 1979.

 0007-4888/80/8905-0708$07.50

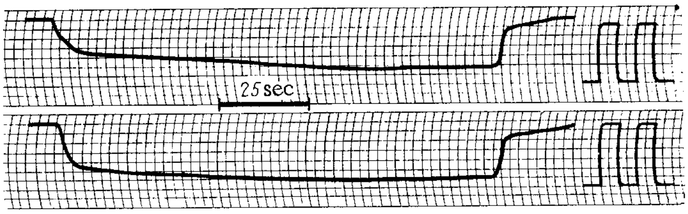

Fig. 1. Rheoplethysmogram of right (top) and left (bottom) leg of human subject during simultaneous passive tilting of both lower limbs from horizontal into vertical position by flexion at the knee. On right — calibration marker 5 Ω.

TABLE 1. Elasticity of Capacitive Vessels of the Leg (in 10^{-2} m^2/N) in Healthy Subjects (M ± m)

Time after change in position of limb	Test 1		Test 2		Test 3	
	men	women	men	women	men	women
	1,52±0,08	1,44±0,11	1,72±0,07	1,50±0,11	0,14±0,01	0,12±0,01
30 sec	1,92±0,08	1,78±0,12	2,20±0,09	1,95±0,13	0,24±0,02	0,20±0,02
60 sec	2,06±0,09	1,93±0,12	2,36±0,09	2,12±0,13	0,28±0,02	0,23±0,02
120 sec	2,30±0,10	2,10±0,13	2,53±0,09	2,24±0,14	0,33±0,03	0,29±0,02

TABLE 2. Elasticity of Capacitive Vessels of the Leg (in 10^{-2} m^2/N) of Patients with Varicose Veins (M ± m)

Time after change in position of limb	Test 1		Test 2		Test 3	
	men	women	men	women	men	women
	1,27±0,10	1,28±0,17	1,73±0,16	1,50±0,19	0,25±0,04	0,40±0,04
30 sec	1,47±0,14	1,58±0,18	1,92±0,18	1,93±0,20	0,44±0,05	0,58±0,05
60 sec	1,57±0,17	1,66±0,20	2,12±0,20	2,03±0,22	0,51±0,05	0,66±0,06
120 sec	1,73±0,20	1,81±0,21	2,29±0,21	2,11±0,23	0,59±0,07	0,71±0,07

EXPERIMENTAL RESULTS AND DISCUSSION

It will be clear from Table 1 and immediately after both legs were lowered the elasticity of the vessels of the healthy subjects was 1.5×10^{-2} (men) and 1.4×10^{-2} (women) m^2/N. This value was a little higher when the right and left legs were lowered alternately $(1.5\text{-}1.7) \times 10^{-2}$ m^2/N, but the difference between them was at the level of statistical significance. After 30, 60, and 120 sec, the volume of the lowered limb continued to increase a little, so that the calculated values of elasticity reached $1.7 \times 10^{-2}\text{-}2.3 \times 10^{-2}$.

A completely different result was obtained in the orthostatic test. Immediately after the patient's body had been tilted into the vertical position the volume of the leg increased much less than during alternate or simultaneous lowering of the limbs, and the calculated values of elasticity were only $(0.12\text{-}0.14) \times 10^{-2}$ m^2/N. The ratio of elasticity in the orthostatis test to its value during isolated lowering of the leg was only 12-15%.

Elasticity measured immediately after isolated lowering of the legs approximately reflects the increase in volume of the capacitive vessels under the influence of the raised hydrostatic pressure. Toward the end of the 2nd minute it increased somewhat, reflecting relaxation of the walls of the veins and (to a very small degree) the commencing increase in the outflow of fluid from the vessels into the surrounding tissues. For practical purposes the elasticity after the increase in hydrostatic pressure changed slowly and gradually, and for that reason any of the measurements (i.e., the one carried out immediately or after 30-120 sec) could be used to characterize the elasticity of the veins.

The decrease in elasticity in the orthostatic test revealed by this method is of the greatest interest. It reflects the well known phenomenon of a reflex increase in vascular tone during a change in position of the human body from horizontal to vertical. Because of it, the rigidity of the walls of the capacitive vessels rises sharply, thus preventing excessive pooling of blood in the vessels of the lower limbs.

In patients with varicose veins the values obtained for elasticity of the vessels during isolated lowering of the legs differed only a little from those for healthy subjects (Table 2). There was only a tendency toward an increase in rigidity of the veins in the patients according to the results of test 1. By contrast, in the orthostatic test the elasticity of the vessels of these patients was 2 or 3 times greater than that of the healthy subjects. This suggests that in varicose veins it is not so much a change in the initial elasticity of the veins as a disturbance of their ability to reduce their elasticity when the patient's body assumes the vertical position, on account of weakening of vasoconstrictor reflexes. In other words, regulation of the elasticity of the veins or partial loss of their ability to constrict is affected to a greater degree than their fundamental biomechanical properties. This is in good agreement with investigations of responses of the cardiovascular system of such patients during the orthostatic test [3].

The results thus show that the elasticity of the capacitive vessels of the limbs in healthy subjects and patients can be determined by a bloodless, time-sparing, and sufficiently accurate method, and that this method can be recommended for function tests of the cardiovascular system for various purposes and under different conditions.

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