A method for studying the dynamics of volumetric changes in the tissues of the human body

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SUMMARY

A system for recording quasiperiodic processes in the tissues of the human body has been developed. The principle of action is based on the differentiated reactions of various layers of tissues to occlusive effects (a model of functional or pathological restructuring). This approach makes it possible to analyze changes in both the state of fluid systems and micro- and macro-mobility of tissues. The indicators of functional rearrangements in this case are the spectra of periodic volumetric changes recorded in the tissues. The paper presents experimental data on wave processes observed at different constant levels of occlusion.

Key words: dynamics of volumetric measurements, body tissues, wave processes, levels occlusions.

RESUME

The method of research of a tissue condition and the quasi periodic processes occurring in different conditions of organism is represented. The method is based on model occluding exceptions of the contribution of different tissues in the common process of response to the external influence, shown as volumetric changes. Such approach allows analyzing changes as conditions of a system of a liquid exchange in tissues, and movements of soft tissues. Experimental data with the wave processes observable at different constant occlusion levels are represented. Thus occlusion pressure is considered as test influence on tissues of an organism. As parameters of the changed condition shows the changes of spectral characteristics of volumetric changes in tissues.

INTRODUCTION

In the tissues of a living organism, there are various processes associated with the movement of liquid substrates. They manifest themselves as changes in volume, shape and tension in tissues at all levels of organization. The processes that initiate movements in tissues are continuous and can be registered in certain ranges of amplitude-frequency characteristics reflecting volumetric changes in tissues. They are accompanied by the movement of liquid media in vascular systems and changes in elastic-viscous properties at the micro- and macroscopic levels. An important property of movements is the quasiperiodic repetition of processes. It is caused by the rhythm of heart contractions, respiration, regulatory influences of the nervous, endocrine and immune systems. Such processes are recorded in the form of high- and low-frequency wave components of signals of volumetric changes in tissues: Traube-Hering-Mayer waves, vascular regulation, thermoregulation and others. Occlusive influences (OS) are widely used in routine medical practice, for example, in procedures for measuring blood pressure (BP). In the process of measuring blood pressure, the pressure (Pm) in the shoulder cuff changes according to a certain law. During the decompression period, phenomena are manifested - Korotkov's tones, as well as the amplitude envelope of the signal of pulsating blood filling of the arteries, which are reproducibly recorded by the measuring equipment. Readout of information signals is performed in the linear decompression mode on the tissue of the shoulder region, and the displayed informative signs in them are used to determine blood pressure indicators. However, in Occlusive influences (OS) are widely used in routine medical practice, for example, in procedures for measuring blood pressure (BP). In the process of measuring blood pressure, the pressure (Pm) in the shoulder cuff changes according to a certain law. During the decompression period, phenomena are manifested - Korotkov's tones, as well as the amplitude envelope of the signal of pulsating blood filling of the arteries, which are reproducibly recorded by the measuring equipment. Readout of information signals is performed in the linear decompression mode on the tissue of the shoulder region, and the displayed informative signs in them are used to determine blood pressure indicators. However, in Occlusive influences (OS) are widely used in routine medical practice, for example, in procedures for measuring blood pressure (BP). In the process of measuring blood pressure, the pressure (Pm) in the shoulder cuff changes according to a certain law. During the decompression period, phenomena are manifested - Korotkov's tones, as well as the amplitude envelope of the signal of pulsating blood filling of the arteries, which are reproducibly recorded by the measuring equipment. Readout of information signals is performed in the linear decompression mode on the tissue of the shoulder region, and the displayed informative signs in them are used to determine blood pressure indicators. However, in During the decompression period, phenomena are manifested - Korotkov's tones, as well as the amplitude envelope of the signal of pulsating blood filling of the arteries, which are reproducibly recorded by the measuring equipment. Readout of information signals is performed in the linear decompression mode on the tissue of the shoulder region, and the displayed informative signs in them are used to determine blood pressure indicators. However, in During the decompression period, phenomena are manifested - Korotkov's tones, as well as the amplitude envelope of the signal of pulsating blood filling of the arteries, which are reproducibly recorded by the measuring equipment. Readout of information signals is performed in the linear decompression mode on the tissue of the shoulder region, and the displayed informative signs in them are used to dete depending on the level and duration of the compression on the tissues during measurements, the condition of the lymph and blood circulation in the tissues changes, which affects the state of the body. This can explain many of the known facts of differences in the results of blood pressure measurements obtained by different methods, as well as discrepancies in the results of a sequential series of measurements by the same method, on the same patient [1]. In works [1, 2], the understanding of the functional significance of occlusion for modeling the processes occurring under the influence of tissue compression is expanded. They take into account the peculiarity of the effect of compression on the state of various tissues and the manifestation of their volumetric changes.

Based on the possibilities of obtaining data on the state of various tissues of the body, we set the task of conducting special studies at different constant levels of compression on the tissues of the shoulder region, surrounded by an occlusive cuff, and analyzing their volumetric changes. As a result, a targeted effect is created on the lymphatic vessels, the blood supply of the veins, arteries, as well as the tissues surrounding the vessels.

PURPOSE OF THE STUDY

The aim of the study is to register macroscopic volumetric changes in body tissues using a specialized hardware-software complex in research, which allows dosing the compression effect on tissues, registering the dynamics of their volumetric change. Assessment of quantitative indicators reflecting the dynamics of volumetric changes for the diagnosis of manual and osteopathic medical techniques.

MATERIALS AND RESEARCH METHODS

The studies were carried out on a homogeneous group of twenty-one practically healthy people (8 men and 13 women) aged 18 to 26 years, with different body types. To register volumetric changes in tissues, a shoulder compression cuff was used, which serves as a volumetric transducer. The change in pressure in the cuff is caused by the integral effect of volumetric changes in the entire set of body tissues in the sub-cuff space. It is created by simultaneously contributing to volumetric changes in these tissues. In turn, the action of external pressure is set and controlled by technical means. The cuff creates a controlled occlusal effect (OS), consistently eliminating the contribution of individual tissues from their total recorded volumetric change. Volumetric transducer, starting from low constant pressure levels, the interstitial fluid is displaced. As the pressure in the cuff rises in the body space underneath it, the blood and lymphatic capillaries are sequentially squeezed, and then the venous and arterial vessels. In fig. 1 shows a generalized diagram of the interaction of structural and functional elements of body tissues in the sub-cuff space affected by occlusal tests. The occlusion of these vessels is created by the pressure transmitted from the cuff in steps with stops at constant levels selected in accordance with the data on the pressure in different vessels [3]. and then venous and arterial vessels. In fig. 1 shows a generalized diagram of the interaction of structural and functional elements of body tissues in the sub-cuff space affected by occlusal tests. The occlusion of these vessels is created by the pressure transmitted from the cuff in steps with stops at constant levels selected in accordance with the data on the pressure in different vessels [3]. and then venous and arterial vessels. In fig. 1 shows a generalized diagram of the interaction of structural and functional elements of body tissues in the sub-cuff space affected by occlusal tests. The occlusion of these vessels is created by the pressure transmitted from the cuff in steps with stops at constant levels selected in accordance with the data on the pressure in different vessels [3].

Rice. 1. Diagram of hydromechanical interactions of tissues under the occlusal cuff.

The pressure P is transmitted by the occlusal cuff$_m$ through the skin surface to the entire volume of the tissue system in the space under the cuff.

When choosing a method for processing recorded signals reflecting volumetric changes in tissues, it was taken into account that a significant number of processes occurring in tissues are quasiperiodic. The recurrence is caused primarily by variable heart rate and breathing cycles. The compression created on the tissue changes the ongoing processes and leads to an adaptive response and new conditions for the functioning of tissues, changing the ratio of rhythmic components.

The software "Measurement and Automation Explorer, National Instruments" was used to control the registration of measuring signals. The MPX-5050DP sensor (Motorolla) was selected as a pressure transducer. Sampling of analog electrical signals proportional to pressure and transmitted to a personal computer was carried out with a 16-bit analog-to-digital converter (ADC) DAQCard-6036E (National Instruments). The ADC is installed in the PCMCIA port of the computer. The sampling rate of the recorded signals was set at 100 Hz.

To study the periodicity of wave processes in the tissues of the shoulder in a sequential series of experiments in the cuff, constant pressure levels were set in the range of P_m(const) = 3 ... 120 mm Hg The variable component of the pressure signal at each OF stage was recorded for 3 min.

Spectral analysis of signals is applied in the processing of recorded signal records. For this, the tools of the MatLab software package were used, with a calculation using the fast Fourier transform (FFT) algorithm and a resolution of 4096 counts. The calculated spectra make it possible to single out the main frequency components of periodic processes and to determine the relative contribution of the governing biophysical mechanisms, or external factors responsible for their manifestation. In our work, we used these advantages of spectral signal processing.

RESULTS AND DISCUSSION

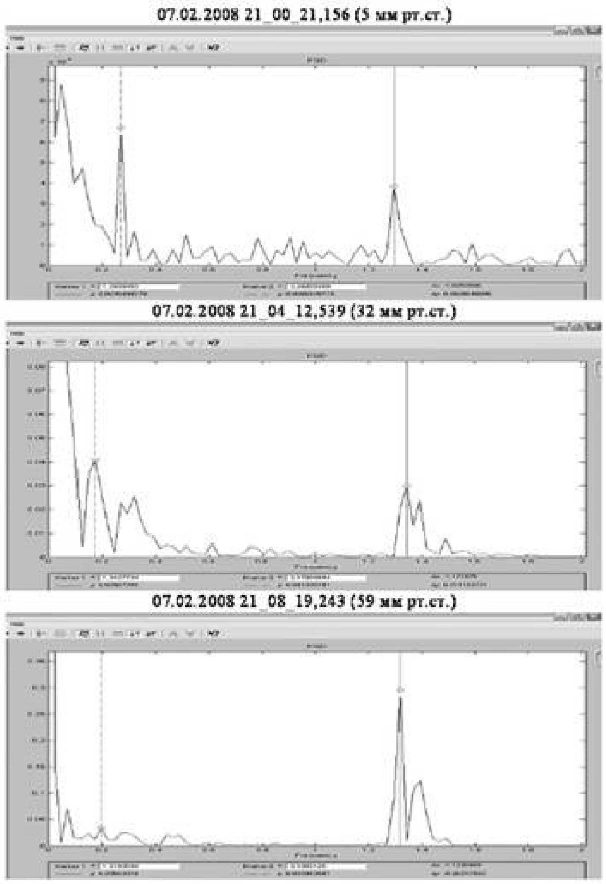
A common feature of the tissue reaction during OS is the manifestation of volumetric changes transmitted in the form of pressure exerted on adjacent tissues and the cuff. Due to the difference in the rheological properties of tissues, the total effect of the changes is non-linear. Changes to varying degrees are manifested in different layers of tissues at the same levels of external OM. Occlusion causes lymphohemodynamic changes in the limb, which accompanied by adequate changes in the elastic-viscous properties of adjacent tissues. First of all, this is the redistribution of fluid compartments, which is accompanied by local movements of aqueous media and changes in the intercellular space (cells and matrix). In the same area, as the pressure rises, the nature of the lymph and blood circulation changes due to the local compressive effect, as a result of which the tissue compliance also changes.

The volumetric transducer registers these processes as an integral reaction. As mentioned above, to differentiate the response of different tissue layers and fluid media to OM, an occlusion level was created that corresponded to the objectives of the experiment. Each level of occlusion is due to the need to exclude the contribution of certain tissues from the general recorded process due to the excess pressure in the cuff of the pressure level in them. The basis of the compression control and data processing algorithm was the physical mechanism of pressure gradients in the investigated operating systems. Due to the use of a volumetric transducer, the functional activity of tissues, the pressure in which exceeds the level of occlusion, was not disturbed in studies. This technique provided the possibility of performing controlled compression.

In fig. 2 shows examples of spectrograms of the power density (PSD) of the variable component of the signal Pm (t) at three constant levels of OB on the tissue of the shoulder region. Digitized marks on the vertical axes of the graph - SPD values, mm Hg. st.2 / Hz, horizontal - frequency, Hz. At all levels of external pressure on the tissue of the shoulder region, spectrograms show various harmonics in the high-frequency (in the range 1.2 ... 1.4 Hz) and low-frequency (below 0.6 Hz) regions.

They reflect the dynamics of volumetric changes in fast and slow wave processes identified in the simultaneous reaction of tissues. The high frequency peak and its frequency band are associated with the work of the heart. They correspond to the heart rate and the range of its variation, which are determined in an independent electrocardiographic study. Low-frequency components of the spectrum reflect slow wave processes in the shoulder tissues, including the modulating effect of respiratory waves, possible manifestation of higher order waves (Traube-Hering-Meier [7–10], reflection and superposition of waves) and other physiological mechanisms.

From the spectrograms (Fig. 2) it follows that at each pressure stage Pm (const), as it increases from 5 to 59 mm Hg. Art., the low-frequency spectral components of the processes in the tissues of the shoulder are less pronounced in comparison with the high-frequency peaks. This is due to the excess of occlusal pressure over the level of normal functioning of structures involved in slow wave processes. The spectrograms also show changes in both the absolute values of the peak levels and the ratios between them. In all cases of studies, the recorded low-frequency processes corresponded to the frequency range of waves 6 ... 14 / min. This range corresponds to the primary respiratory mechanism known in the practice of osteopathic medicine [5, 6]. Table 1 shows the statistical data of the results of studies of the volumetric state of the tissues of the upper limb, obtained from the processing of the power density spectra of the variable component of the cuff pressure signal at a constant level of 30 mm Hg. The data refer to the group of practically healthy subjects: the background state and after the lymphatic drainage (on the forearm) and orthostatic functional tests. In all states of the organism, the spectra contain: high-frequency peak F_{treble} (pulse component), as well as low-frequency harmonics F_{LF} in the region of 0.05–0.2 Hz. The amplitude of low-frequency harmonics decreases with increasing external pressure and during functional tests. After lymphatic drainage, an increase in harmonic amplitudes is observed in the low-frequency region of the spectrum (Table 1). There are also obvious changes in relation to the initial state of the characteristics of the orthostatic functional test: an increase in F_{treble} and a change in the index (A) of the amplitudes of the high and low frequency components. The rearrangements that take place are caused by an increase in volume in the low pressure vascular bed.



Rice. 2. Examples of spectrograms of the power density (PSD) signal $P_m(t)$ for three constants OS levels on the tissue of the shoulder region.

Table 1

Испы-туемый	Воз-раст, лет	Исходн. ЧСС, Уд /мин	АД, мм рт.ст.		Телосложение	Фоновое состояние				После лимфодренажа предплечья				Ортостатическая проба			
			Р сист	Р диаст		Fв.ч, Гц	Fн.ч. min Гц	Fн.ч. max, Гц	A	Fв.ч, Гц	Fн.ч. min, Гц	Fн.ч. max Гц	A	Fв.ч, Гц	Fн.ч. min, Гц	Fн.ч. max, Гц	A
Л-ов	20	74	120	80	А	1,20	0,10	0,30	1,00	1,20	0,10	0,30	0,50	1,35	0,10	0,30	0,20
Зл-ов	25	66	130	70	А	1,05	0,05	0,20	0,50	1,05	0,05	0,20	1,00	1,20	0,05	0,30	0,17
Д-ев	26	86	120	75	Н	1,45	0,05	0,30	0,50	1,45	0,05	0,25	0,60	1,50	0,05	0,30	0,10
Ст-ва	23	70	130	70	Н	1,10	0,05	0,40	0,50	1,10	0,10	0,30	0,10	1,15	0,05	0,30	0,05
Р-ов	18	70	120	70	Н	1,15	0,05	0,20	0,60	1,15	0,05	0,40	0,50	1,30	0,05	0,30	0,05
А-ев	25	84	130	75	А	1,30	0,05	0,55	0,30	1,20	0,05	0,50	0,50	1,30	0,10	0,30	0,05
Ш-ва	21	78	110	70	Н	1,17	0,05	0,30	0,30	1,10	0,10	0,30	0,03	1,20	0,05	0,30	0,05
Ж-ва	22	64	115	75	Н	1,05	0,05	0,40	0,20	1,00	0,10	0,30	1,00	1,00	0,10	0,30	0,02
Е-ва	21	96	130	80	А	1,50	0,05	0,20	0,20	1,35	0,10	0,40	0,50	1,60	0,05	0,20	0,03
Д-ян	22	66	115	75	Н	1,20	0,05	0,25	0,10	1,15	0,05	0,30	0,20	1,35	0,05	0,30	0,10
Ст-в	23	60	130	80	Н	0,95	0,05	0,25	0,50	0,95	0,05	0,20	0,50	1,10	0,05	0,20	0,04
Ни-ва	25	76	110	60	Н	1,35	0,05	0,30	0,10	1,35	0,05	0,40	0,10	1,35	0,05	0,40	0,05
Но-ва	21	74	110	70	А	1,45	0,05	0,20	0,05	1,35	0,05	0,30	0,05	1,65	0,05	0,15	0,05
П-ая	22	78	110	60	Н	1,15	0,05	0,25	0,05	1,10	0,05	0,30	0,10	1,20	0,05	0,25	0,05
Б-ов	23	68	110	70	Н	1,10	0,05	0,50	0,10	1,05	0,05	0,30	0,10	1,20	0,05	0,10	0,05
Х-на	20	64	140	70	Г	1,05	0,10	0,20	0,05	1,00	0,05	0,15	0,05	1,40	0,05	0,30	0,05
М-ко	22	58	110	60	Н	1,10	0,05	0,30	0,30	0,95	0,05	0,40	0,30	1,20	0,05	0,10	0,05
М-ва	25	62	90	60	Н	0,95	0,05	0,30	0,50	1,00	0,05	0,10	0,05	1,05	0,05	0,20	0,05
К-ва	26	54	120	60	А	0,90	0,05	0,30	0,30	0,95	0,05	0,40	0,30	1,15	0,05	0,10	0,05
Б-ч	24	63	110	70	А	0,90	0,05	0,30	0,30	0,90	0,05	0,30	0,10	1,10	0,05	0,30	0,10
Ч-ва	22	60	120	70	Н	0,85	0,07	0,30	0,10	0,87	0,05	0,20	0,20	0,95	0,05	0,30	0,10
min знач.	18	54	90	60	-	0,85	0,05	0,20	0,05	0,87	0,05	0,10	0,03	0,95	0,05	0,10	0,02
max знач.	26	96	140	80	-	1,50	0,10	0,55	1,00	1,45	0,10	0,50	1,00	1,65	0,10	0,40	0,20
Ср. знач.	22,7	69,6	118,6	70,5	-	1,13	0,06	0,30	0,31	1,10	0,06	0,30	0,35	1,24	0,06	0,25	0,07
σ(x)	2,1	10,3	11,1	6,9	-	0,19	0,02	0,10	0,23	0,16	0,02	0,10	0,31	0,18	0,02	0,08	0,04
Δx	0,9	4,3	4,6	2,9	-	0,08	0,01	0,04	0,10	0,07	0,01	0,04	0,13	0,08	0,01	0,03	0,02

Index A - the ratio of the maximum amplitudes of the pulse and slow-wave components of the spectrum.

Fv.ch - frequency of the peak of the pulse component.

Fn.ch.min - the lower limit of the frequency range of slow-wave components. Fn.ch.max - the upper limit of the frequency range of the slow-wave components of the spectrum. σ (x) - standard deviation; Δx - confidence interval with a probability of 0.95.

CONCLUSION

1. Occlusive effects cause reactions in tissues at the micro- and macrolevels, adequate compression. Volumetric rearrangements are associated with changes in lymph and blood circulation and compliance of the studied tissue sites.

2. The ratio of the amplitude-frequency characteristics of the spectra (their high-frequency and low-frequency components), obtained as a result of processing volumetric signals, are indicators of the named rearrangements.

3. The proposed research method can be used to assess the functional the state of tissues during medical and diagnostic manipulations in manual, osteopathic, and general medical practice.

LITERATURE

1. Chashchin A.V. "Assessment of hemodynamic processes of blood redistribution in the vascular upper limb system by methods of measuring blood pressure "// Izvestiya SPbGETU,

Biotechnical systems in medicine and ecology. Issue 2. - 2005. - P. 110-116.

2. Mokhov D.E., Chashchin A.V. "Non-invasive method of penetrating deep into the tissues of the body in the study of volumetric wave processes in them "// Manual therapy," No. 3 (31) 2008, 46-52.

3. Guyton A.K., Hall D.E. Medical physiology. - M .: Logosfera, 2008 .-- S. 1296.

4. Mokhov D. Ye., Chashchin A. V. "A method for examining cranial tissues and a device for it implementation "// Application for patent of invention 2007138894/20 (042551), prior. 21.10.07.

5. Sutherland WG The cranial bowl. A tretise relating to cranial mobility, cranial articular lesions and cranial technic. // Ed. 1. Free Press Co. Mankato, MN. 1939.

6. Nelson KE, Sergueef N., Lipinski CM, Chapman AR, and Glonek T. Cranial rhythmic impulse related to the Traube-Hering-Mayer oscillation: comparing laserDoppler flowmetry and palpation. // J. Am Osteopath Assoc, Mar 2001; 101: 163-173.

7. Traube L. Uber periodische Thatigkeits-Aeusserungen des vasomotorischen und Hemmungs-Nervencentrums. // Centralblatt fur die medicinischen Wissenschaften, Berlin. 1865: 3 (56): 881-885.

8. Hering E. Uber den Einfluss der Atumung auf den Kreislauf. I. Mittheilung. Uber Athembewegungen des Gefassystems. S. // Ber. Akad. Wiss. Wien. Math. - naturwiss. 1869; 2 (2) 60: 829- 856.

9. Mayer S. Studien zur Physiologie des Herzens und der Blutgefässe 5. Abhandlung: Über spontane Blutdruckschwaenkungen. // Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften in Wien. Mathematisch-naturwissenschaftliche Classe, Anatomie. 1876; 3 (74): 281-307.

10. Mokhov D. Ye., Chashchin A. V., Yesterday D. B., Erofeev N. P., “Registration and manifestation wave processes in body tissues in studies by volumetric method. " // Manual therapy, "№1 (29) 2008, 47-50.

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A method for studying the dynamics of volumetric changes in the tissues of the human body / D.E. Mokhov, A.V. Chashchin, N.P. Erofeev, D.B. Yesterday // Traditional Medicine. - 2009. - No. 2 (17). - pp. 14-18.

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