

# The importance of the study of central hemodynamics using volumetric compression oscillometry in clinical practice: resolved and unresolved issues

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## Abstract

The article discusses the promising possibilities of using the method of volumetric compression oscillometry in clinical practice, which allows to simultaneously determining 20 indicators of central hemodynamics. A comparative analysis with other research methods is presented herein, and the advantages of the presented method in the diagnostics of cardiovascular diseases are shown. The problematic issues in using this method and ways to solve them are considered herein.

## Keywords

Central hemodynamics, Volumetric compression oscillometry, Cardiovascular diseases, Arterial hypertension

## Imprint

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Cardiovascular diseases (CVD), according to the relevant WHO data, remain the leading cause of mortality worldwide. Arterial hypertension (AH) is considered as a separate disease and at the same time as a major risk factor for developing other cardiovascular diseases owing to its high occurrence rate and poor controllability, even in countries showing a high level of health care system functioning. The AH occurrence in the Russian Federation (in 2017) reached 39, 5% [1]. The risk of CVD-associated death doubles with every episode of surge of the systolic arterial pressure (AP) of 20 mmHg and the diastolic AP of 10 mmHg, from the starting level of 135/85 mmHg [2].

Despite the standardization to cover the AH diagnostics methods, the AH diagnosing in outpatient practice, especially at the initial stage of the disease, is a very difficult task. Rises in AP may be episodic, often at the time of the emotional, physical and stress-related overloads, while the normal AP in the same patients can be recorded at rest.

Thus, for example, some Polish researchers, basing on periodic examinations of 144 professional car drivers, middle-aged men  $50,2 \pm 9.3$  years, have detected arterial hypertension in 39 individuals (27.9%). However, during the ambulatory arterial pressure monitoring daily, arterial hypertension was diagnosed in 104 of 135 persons (73.8%) [3].

Some other researchers, including Russian scientists, believe that under the influence of various factors, initially some parameters of central hemodynamics (CH) are changed, and that only thereupon a persistent, steady increase in systolic and diastolic AP appears, i.e., hypertension develops [4,2].

On the other hand, an administrated medication should take into account pathogenetic mechanisms of the AH development which may be as follows: a prevailing increase in stroke volume, in the peripheral vascular resistance or a combination of both factors. During the AH treatment "an escape effect" often develops, which is associated with the CH restructuring, so that the treatment becomes ineffective.

All the above evidence dictates the need for searching for a new approach to the tactics in the AH treatment and follow-up: in addition to systolic and diastolic pressure the CH parameters are to be taken into account. At the same time, required is continuous monitoring of the CH parameters, since a single

measurement thereof cannot detect abnormalities due to lability of the hemodynamic parameters. The CH examination is usually performed with ultrasound technique to image the heart (Echocardiography), which involves applications of sophisticated ultrasound equipment, trained personnel and takes a lot of time. In this connection, the ECHO CG cannot be considered as a method belonging to the family of the CH monitoring techniques, especially if this examination is carried out regularly under the ambulatory conditions.

Today this problem can be successfully solved with the use of device CH HSS osm. GLOBUS, the hardware & software system designed and manufactured for noninvasive examination of central hemodynamics with the use of the method of volumetric compression oscillometry (VCO).

The problem of measurements of the main CH parameters in parallel with the use of a compact simple device has been first formulated in the framework of national Russian space mission programs. In order to provide medical monitoring of the cosmonauts' health state under the conditions of long-term space missions, required has been design and development of original diagnostics devices. The offered hemodynamics monitoring equipment designed for this purpose by the experts of the Institute of Biomedical Problems and the Institute of Aerospace Medicine is based on the conceptual ideas and methods developed by N.N.Savitskiy, 1956. [5].

Oscillometric devices used by orbital stations "Salyut" and "Mir" have demonstrated their capabilities, which are completely equivalent to those available in an in-hospital functional diagnostics unit furnished with the respective equipment to record the main CH parameters. CH HSS osm GLOBUS has been commercially manufacturing by Globus LLC, Belgorod, Russian for the last 15 years (see Figure 1 herein).

The CH examination device is a medical instrument designed and manufactured for applications both by intuitive users and for examinations of in- and out-patients. The device is approved for the use by the Russian Federal Service for Health Supervision, validated, appropriately registered and certified; an appropriate Russian national Certificate of Conformity and Certificate of Product have been issued [6].

An assessment of the recorded CH parameters can be performed by an intuitive user at home or under the outpatient conditions with a simple method



Figure 1. Portable automated hardware & software system for noninvasive examination of central hemodynamics: CH HSS device (Device CH HSS osm GLOBUS).

of arterial pressure measurement conducted with an upper-arm cuff oscillometric instrument, which is connected with a portable device capable of assessing pulse oscillations in the brachial artery walls under the conditions of rising pressure in the pneumocuff.

The received signal in the form of an oscillogram is subjected to analytical and mathematical processing, upon the results of which the major CH parameters are determined. An example of a hemodynamics data record is presented in Figure 2 herein.

The obtained CH parameters can be divided by convention into 4 groups as follows:

1. Types of AP: systolic AP (SAP), diastolic AP (DAP), true systolic AP (TSP), mean AP (MAP), stroke AP (strAP is a difference between SAP and TSP), pulse AP (pAP), pulse AP velocity;
2. Vascular characteristics: linear blood flow velocity (LBFV), pulse wave propagation velocity (PWPV), vascular system compliance (VSC), total and specific peripheral vascular resistance (TPVR, SPVR);
3. Cardiac activity indices: cardiac output (CO), stroke volume (SV), cardiac and stroke indices (CI, SI), volumetric ejection rate (VER), left ventricular contraction capacity (LVCC), energy consumption per liter of blood circulation (EC);
4. Types of blood circulation: hyperkinetic, eukinetic and hypokinetic circulation types, differentiated by three characteristics as follows: SI, CI and TPVR.

## Компьютерная осциллометрия гемодинамики

**Ям-ва М.Е.**  
Ф.И.О.

**АД 81/53**

Дата измерения **26.05.2009**

Время **15:54**

Диагноз

**Перитонит**

**Ж 34 170 75**  
Пол Возраст Рост Вес

Информация

Условия

**реанимационные мероприятия**

### Результаты исследования

#### Артериальное давление

			Фактически	Норма (рабочее) <sup>1</sup>	Оценка
1	АД систолическое	мм рт.ст.	81	100 - 139	Гипотензия.
2	АД диастолическое	мм рт.ст.	53	60 - 89	Гипотензия.
3	АД боковое	мм рт.ст.	66	90 - 110	Отклонение -27 %
4	АД среднее	мм рт.ст.	66	75 - 85	Отклонение -12 %
5	АД пульсовое	мм рт.ст.	28	35 - 50	Отклонение -20 %
6	Скорость пульс. АД	мм рт.ст.	245	200 - 600	Норма ■■■■■
7	АД ударное	мм рт.ст.	26	20 - 40	Норма ■■■■■

#### Сердечная деятельность

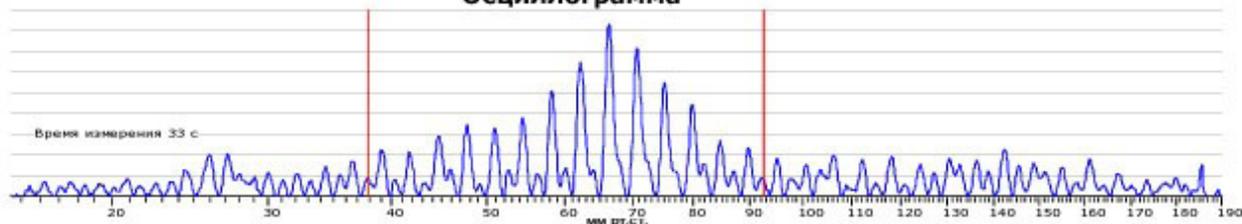
1	Пульс	уд./мин	110	60 - 80	Отклонение +38 %
2	Сердечный выброс	л/мин	3.8	4.2 - 5.9	Отклонение -10 %
3	Сердечный индекс	л/(мин·кв.м)	2.1	2.3 - 3.2	Отклонение -9 %
4	Ударный объем	мл	43	55 - 83	Отклонение -22 %
5	Ударный индекс	мл/кв.м	23	30 - 45	Отклонение -23 %
6	Объемная скорость выброса	мл/с	143	160 - 300	Отклонение -11 %
7	Мощность сокращений ЛЖ	Вт	1.3	2.0 - 4.5	Отклонение -35 %
8	Расход энергии на 1 л СВ за минуту	Вт	11.3	9.0 - 12.7	Норма ■■■■■

#### Сосудистые показатели

1	Скорость кровотока лин.	см/с	31	28 - 50	Норма ■■■■■
2	Скорость пульсовой волны	см/с	785	600 - 1000	Норма ■■■■■
3	Податливость сосуд. системы	мл/мм рт.ст.	1.49	1.03 - 2.35	Норма ■■■■■
4	Общее периф. сопр. сосудов	дин·с/см	1113	1579 - 1789	Отклонение -30 %
5	Удельное периф. сопрот.	усл. ед.	31	38 ±6%	Отклонение -14 %

\*1 Условия применения нормативов: "В покое"

#### Осциллограмма



#### Медицинское заключение

Гипотензия.

Гипокинетический тип гемодинамики. Избыточная проходимость прекапиллярного русла.

Врач В.Ермаченко

Тел/факс 8-910-406-49-85

Исследование проведено прибором КАП ЦГосм-"Глобус"

Figure 2. An example of hemodynamics data record issued upon hemodynamic examination

## Aims

The aim of this study is to assess applicabilities and capabilities offered by device CH HSS osm, the hardware & software system for noninvasive examination of central hemodynamics with the method of volumetric compression oscillometry (VCO) in clinical practice on the basis of the relevant data evidence available in Russian national publications.

## Methods

A survey and an analysis of the Russian publications available at [www.e-library.ru](http://www.e-library.ru), [www.ncbi.nlm.nih.gov](http://www.ncbi.nlm.nih.gov) / [pubmed](http://pubmed) with the use of keywords have been conducted.

## Results

### 1. Comparison and comparability of the CH parameters' investigation results with other methods

Comparative characteristics of several methods of CH calculation are shown in Table 1 herein (the data

evidence reported from <http://gemodinamika.ru> with supplements).

As seen from the above table, the advantages of the VCO method are as follows: noninvasiveness, rapid simultaneous measurement of 20 hemodynamic parameters, a simple automated procedure of measuring, its accessibility and availability to the population.

Published are several papers, where assessments of the central hemodynamics with the use of the CH HSS osm GLOBUS device employing the oscillometric methods are found to be in a good agreement with the results of other applicable methods applied to the hemodynamic examinations.

In the paper by V.A. Mazurok, 2017, compared have been the reproducibility of cardiac output indices measured by the classical technology of pre-pulmonary thermodilution and those calculated according to VCO using device CH HSS osm GLOBUS [7]. 200 parallel measurements have been recorded (100 measurements with each method) in 7 cardiac sur-

Table 1  
Comparative characteristics of several methods of central hemodynamics calculation\*

Parameters	Methods		
	Invasive method: thermodilution	Echocardiography	Oscillometry CH HSS osm GLOBUS
Accuracy of cardiac output calculation	High level	Medium level (KK = 0.86-0.9)	Medium level (KK = 0.85-0.9)
Capability to measure mean hemodynamic AP	Not available (computed)	Not available (computed)	Available
Capability to measure actual values of the AP levels	Available	Not available	Available
Methodology complexity of the method	Very high	High	Low
Invasiveness of the method	Yes	No	No
Measurement technology costs	Very high	High	Low
Duration of the measurement procedure	1 hour and over	30 minutes and more	Less than 1 minute
Simultaneous determination of indices	Not available	Not available	Available
Requirements for medical staff training and qualification	High (physician)	High (physician)	Medium level (nurse)
Suitability of the method for screening	Yes	No	Yes
Stress test applicability	Yes	Yes	Yes
Availability and accessibility to the population	No	No	Yes
Specific requirements for the examination conditions	Narcosis, pulmonary ventilation, (anesthesia), surgery	Lying position	Not applicable
Applicability of continuous automated monitoring	No	No	Yes
Applicability of continuous automated monitoring	No	No	Yes

\*According to the data published on <http://gemodinamika.ru> with supplements

gery patients in their early post-operation period. The mean values of cardiac output parameters measured with thermodilution and VCO have been found comparable:  $5.41 \pm 0.12$  vs.  $5.33 \pm 0.13$  l min<sup>-1</sup>, respectively; cardiac index values of  $2.93 \pm 0.13$  vs.  $2.92 \pm 0.94$  l·min<sup>-1</sup>·m<sup>-2</sup>, accordingly. The mean error in CO and CI is approximately 10%. The author concludes that VCO may be used to calculate CO in cardiac surgery patients that is very important for this category of patients. When interpreting the obtained indices, the limitation for any method on the CO calculation, based on an estimation of the pulse wave, should be taken into consideration.

Comparable results have been obtained by V.A. Degtyaryov, 2015, by analyzing the CO data delivered with VCO and those produced with the thermodilution method in patients with acute myocardial infarction both during their scheduled examinations and under the conditions, when admitted to hospital [8]. For this purpose, a total of 70 investigation procedures have been completed. The CO value obtained using the thermodilution method has been recorded to be  $4.986 \pm 0.222$  l/min versus  $4.76 \pm 0.48$  l/min delivered with the VCO method, so that the correlation coefficient has been found to be 0.92 [8].

In the paper by Trivozhenko A.B. et al., 2019, the expert Doppler echocardiography has been applied as the reference technology to assess the accuracy of the VCO method. The method has demonstrated an allowable accuracy in measuring SV ( $\pm 15\%$ ), with consistent displacements ( $\pm 1.96$  standard deviations) in the estimation to describe agreement between two quantitative measurements produced by two techniques according to the Bland-Altman plotting. A close correlation between the oscillometric peak blood flow velocity has been detected in the brachial artery and the Doppler velocity of the blood flow at the aortic mouth ( $p < 0.001$ ;  $r = 0.85$ ). A similar correlation has been observed between the aortic Doppler spectrum integral and the peak arterial flow velocity measured with VCO ( $p < 0.001$ ;  $r = 0.68$ ) [9].

Researchers S.Y. Ivanov and N.I. Livshits, 2015, have compared accuracy of arterial pressure measurements obtained with the auscultatory technique and the VCO method. For this purpose, 50 patients having hypotension, the normal pressure level and mild / moderate arterial hypertension have been tested. Daily blood pressure monitor "Kardiotechnika 04-AD3" (CJSC "INCART", Russia) has been used as the refer-

ence technique. In parallel with the automatic monitor pressure measuring, two experts have measured AP with the help of a dual phonendoscope according to the "blind" method assessing the first and fifth phases of Korotkoff sounds, reading the pressure digits in the cuff displayed on the device screen.

When using the oscillometric method, a more significant difference of -1.8 mmHg for SAP and 0.8 mmHg for DAP (SD 5.0 and 5.2 mmHg, respectively) has been observed. Thus, the arterial pressure measurement by the Korotkoff method delivers more accurate results than using the oscillometric method. However, in about 6% of patients the AP measurement by the Korotkoff tones seems to be more difficult due to the presence of hollow low-amplitude sound tones. The oscillometric method for this sort of patients appears to be more preferable. Thus, the accuracy may be higher with the simultaneous use of both methods [10].

In the paper by S.A. Shidlovskaya et al., 2015, it is shown that in case of a pronounced stage of AH (stage III) the degree of the overread SAP obtained with the auscultatory Korotkoff method is fairly greater than it is the case with that delivered by VCO. The VCO method has been found to be more accurate for this category of patients. The difference between the AP readings measured by the Korotkoff and those obtained with the VCO method is an indicator of a pronounced aortic wall and artery lesion and, consequently, a predictor of an unfavorable outcome in patients suffering from AH. The value of the difference between the AP readings measured by the Korotkoff and those obtained with the VCO methods demonstrates the degree of actual resistance and stiffness of the vascular system [11].

The paper by M.S. Gerashchenko et al., 2016, offers an analysis of basic errors typical to the oscillatory methods involving the use of the pneumatic compensation cuff, on the basis of the applied the circuit design techniques employed for development of measuring instrumentation by LabVIEW. Shown are the prospects for the use of the hydro-cuff technology to generate oscillations for assessing hemodynamic parameters as well as a possibility of implementing a new class of devices to solve the topical task of evaluating the CH hemodynamic parameters [12].

In the paper by Y.G. Kuzminski and S.V. Shilko [13], 2014, on the basis of a single-dimensional biomechanical model of hemodynamics, confirmed is an efficacy of the primary diagnostics of the cardio-

vascular system condition, using an original software, which implements a mathematical analysis of the relevant oscillometric data. The screening conducted with the proposed method allows extending the capabilities of classical oscillometry and obtaining important data on the state of the heart and the blood vessels, including assessments of adaptation capabilities in human subjects (in particular, athletes) under the conditions of different physiological loads.

2. Many works are devoted to the CH investigations with employing the VCO method in healthy subjects [14], adolescents under various climatic conditions [16], university students [17, 18] and athletes [19] aimed at identification of the adaptation abilities in the organism and the CVD prevention

According to the data obtained by L.V. Shpak, E.S. Galoshina, 2013 presented in [14], when identifying the blood circulation type in normal subjects, with the mean age  $27.8 \pm 0.8$  years, at an optimal and normal AP ( $118.5 \pm 1.6 / 71.82 \pm 1.2$  mm Hg), more frequently (32%) recorded is the hyperkinetic type of blood circulation: SI  $46.75 \pm 1.92$ , CI  $3.5 \pm 0.05$ , TPVR  $1112.25 \pm 23$ ; then the eukinetic type (30%) follows: SI  $39.6 \pm 1.6$ , CI  $3 \pm 0.06$ , TPVR  $1170.5 \pm$ ; and less frequent appears the hypokinetic type (24%): SI  $36.2 \pm 2.5$ , CI  $2.8 \pm 0.08$ , TPVR  $1359.8 \pm 28.5$ , including the mixed type (14%): SI  $44 \pm 2.1$ , CI  $3.5 \pm 0.2$ , TPVR  $1297 \pm 44.4$ , that generally is consistent with the evidence data found in other studies [15].

L.I. Grechkina et al. in their investigations of systemic hemodynamics with application of the VCO method in male adolescents aged 13-16 in Magadan ( $n = 424$ ) and Moscow ( $n = 437$ ) offer their own classification of the following three types of the CH regulation: the cardiac type, the vascular type and the mixed (cardiovascular) type thereof. As to the cardiac type of the regulation, hemodynamics is maintained by increasing HR; under the vascular type of the regulation we can observe enhancing of the left ventricular contraction capacity and an increase in SV; the cardiovascular type involves both mechanisms as described above. The researcher believes that the most appropriate and well-balanced type of the systemic circulatory regulation are the cardiovascular and vascular types thereof.

Adolescents showing the cardiovascular type and especially the vascular circulation type have higher adaptation abilities of the cardiovascular system as

compared to those with the cardiac type, when even at rest a higher level of HR is found that requires a constant consumption of the organism energy resources.

An analysis of the distribution of their hemodynamic indices according to the blood circulation self-regulation type have demonstrated that the cardiac type is observed in 63.7% of the Magadan's students and 44.4% of the Moscow's students, the cardiovascular type has been identified in 26.9 and 41.2% of the cases, and the vascular type has been detected in 9.4 and 14.4 % of the cases, respectively, referred to the total number of all surveyed adolescents.

The authors thereof arrive at a conclusion that there are significant stresses in the performance of the cardiovascular system and reductions of its adaptation capabilities upon a long-term exposure to unfavorable environmental factors in the Far North in Russia that may result in the development of cardiovascular diseases.

In the study tests in 368 young men, students, the natives of the North-East of Russia, with the mean age of  $18.5 \pm 0.08$ , an analysis of the distribution of the individual values of the systemic hemodynamics index types employing the VCO method has shown that 48.1% of the adolescents has the cardiac type of the blood circulation self-regulation, 35.9% of them has demonstrated the cardiovascular type and 16.0% of the cohort have the vascular type thereof. The highest values of SAP, DAP, SV, LVCC and TPVR are typical to individuals with the vascular type of the regulation, and the respective lowest values have been found to be typical to individuals with the cardiac type thereof. Male adolescents with the cardiovascular type of the blood circulation self-regulation have the medium-level indices. At the same time, the values of HR, PWV and the Kerdo vegetative index have been reported to be the highest in young men with the cardiac type, and the respective lowest parameters have been recorded for the young individuals with the vascular type. The author comes to a conclusion that adolescents with the cardiovascular type and particularly with the vascular circulation CH type have higher adaptation abilities of the cardiovascular system as compared to those showing the cardiac CH regulation type, who have even at rest a high level of HR values that requires an interrupted use of the organism energy resources [16, 17].

### 3. Possibilities of using the VCO method in identification of a cardiovascular risk, clarification of pathogenesis of arterial hypertension and other CVDs

In research papers by Strakhova N.V., et al., 2013, clearly confirmed is the possibility of using the hemodynamics assessment with the VCO method in identification of a cardiovascular risk. Based on the conducted mathematical analysis, the authors therein propose to include the VCO indices in the cardiovascular risk scoring system. According to the conventional CVD risk factors with assessing 14 VCO indices, designed is a point risk scale capable of predicting a high and very high cardiovascular risk. A significant relationship between the VCO indices and the clinical course of AH has been detected. The most important criteria for an assessment of cardiovascular risks are the level of AP, PWV, LBFV, SPVR parameters and the qualitative characteristics of an oscillogram ("a bulge"). The last parameter indicates an increased vascular rigidity.

An increase in the total score according to the newly proposed scale by more than 20 points with a sensitivity of 95.6% and a specificity of 65.6% makes it possible to predict the presence of a high and very high cardiovascular risk and contributes to an early identification of this category of patients followed by taking preventive and therapeutic measures [20,21] well in time.

The same researchers in their further works have analyzed changes in the hemodynamic status with the use of the VCO method in patients with AH combined with postinfarction atherosclerosis that is of great importance in assessing the severity of the patient's condition, prediction and specification of the required medication. Detected is a significant relationship between the VCO indices and the cardiovascular complication risk factors as well as the presence of the postinfarction atherosclerosis. An increase in the PWV, LBFV, SAP VCO, MAP values and a decrease in the vascular compliance parameter, as determined by the VCO method, are predictors of an unfavorable clinical course of AH in combination with postinfarction atherosclerosis [22,23].

Ovsyannikov V.V. et al, 2014, 2015, based on the application of the VCO method, have detected higher values of the MO, SV, TPVR, PWV, LBFV parameters and a low compliance of the vascular system in case of combination of type 2 diabetes with AH in compari-

son with a group of AH patients without diabetes. The authors thereof conclude that the variations in hemodynamics of the different grades, detected in a patient with type 2 diabetes accompanied by AH with the VCO method, have a common pathogenetic element, namely the insulin resistance, should be considered as early indicators of a disorder in the elastic properties of the aorta [24, 25].

In the paper by L.V. Shpak et al., 2013, we can find an evaluation of the evolution of hemodynamic parameters at the stage of the initial development of AH and at its further stages of increasing severity. Among the above indicators, TSP and MAP become the universal parameters as their recording is possible with the use of VCO only. The TSP dynamics serves as a possible pathogenic mechanism, which reflects the value of the pressure, to which the inner walls of the arteries is subjected under AH, that may be of a prognostic significance, and at the same time, it might be concluded that MAP can be a criterion for AH progression. The latter is particularly important because the MAP indicator is an integral value of all AP changes from the minimal to the true value, and this integral value is characterized by its significant constancy, when exposed to various stimuli, but demonstrates a reliable increase from AH grade 1 to grade 3 degree.

It is reported that in patients of AH grade 1 to 3 the vascular characteristics, the indicators of the cardiac activity are increased, while the vascular index, i.e. the vascular wall compliance, is decreased, that indicates the strengthening of the myocardial contractile function against the background of increasing the arterial walls tonic tension and the peripheral resistance in the resistive vessels. In this case, observed is a change in the formation of the cardiac hemodynamics types: the share of the hyper- and eukinetic types from AH grade 1 to grade 3 is decreased due to an increase in the occurrence rate of the mixed and especially hypokinetic variants thereof [14].

In another paper by the above mentioned authors an analysis of hemodynamics in patients with AH in their pre- and postoperative period is conducted. Regardless of the initial level, AP decrease occurs after surgery in all patients, but, in case of the corrected AP, it appears equally due to reducing the vascular and myocardial factor tension, and in case of the not corrected AP it takes place mainly due to the myocardial factor attenuation [26].

#### 4. Papers devoted to the AH treatment based on AP monitoring data obtained with VCO

The scope of these papers deals with an evaluation of efficacy of the AH treatment with the VCO method. M.V. Lozhakova, 2008, has evaluated the efficacy of the AH monotherapy with bisoprolol [27]. E.V. Pravdintseva et al., 2011 have assessed hemodynamics when administering angiotensin converting enzyme inhibitor to prevent cardiotoxic effect during chemotherapy [28].

D.I. Emelyanova et al., 2014 have evaluated differentiated administration of antihypertensive therapy in 110 pregnant females considering their type of central hemodynamics identified with the VCO method. The researchers have arrived at a conclusion that an assessment of hemodynamics in pregnancy, against the background of AH, is urgently required. In the absence of a differentiated approach to estimating hemodynamics, pregnant females with AH receive non-justifiable antihypertensive therapy, which, under the hyperkinetic type, may provoke a disproportionate development of the fetus / newborn. Unreasonable antihypertensive therapy under the eukinetic hemodynamics type may cause placental insufficiency, and that under the hypokinetic type may lead to an insufficient fetal weight. Therefore, it is recommended to use the VCO method for the purpose of identification of the CH type and selecting the proper pathogenetically grounded antihypertensive therapy in pregnant females [29].

The research paper by R.V. Gorenkov et al, 2019, treats outpatient examinations in 126 human individuals (mean age  $56.5 \pm 3.7$  years) with arterial hypertension. In accordance with the obtained initial hemodynamic data, the patients were administered with hypotensive agents of different groups: in case of an increase in SV: mainly selective beta-blockers; in case of an increase in TPVR: angiotensin converting enzyme inhibitors or angiotensin 2 receptor blockers or calcium antagonists; in case of an increase in both parameters: combination therapy. During such differentiated treatment, depending on hemodynamic parameters, in the majority of the patients (114 of 126, i.e. 90.5%) reported is a decrease in arterial pressure or reaching the target level thereof. The researchers conclude that hemodynamic monitoring with the VCO method allows providing a more accurate approach to the hypertension treatment and justify the proper selection of the required hypotensive drugs, as well as to

adjust the treatment based on the pathogenetic mechanisms of the AH development [30].

It should be noted that despite an obvious advantage of the VCO method in early diagnostics of the disease and in selection of the proper justified medication therapy in AH patients, the scope of applications of the method remains unfortunately still not broad: VCO is mainly employed for the purpose of scientific research. It may be attributed to difficulties for a medical practitioner to assess twenty parameters of CH and make prompt decisions under limited time conditions scheduled for examination in outpatients.

A new approach to the issue of the AH treatment taking into account the hemodynamic data is presented by M.A. Yakushin, et al., 2017. The researcher has developed a PC-assisted expert system capable of making an optimal decision in selection of the most suitable hypotensive drug, considering the CH parameters obtained as a result from the examination with the VCO method. In addition to the considered CH parameters, the mechanism of action of a hypotensive drug, its side effects, patient's age and comorbidities are taken into account. Based on the above, immediately upon completion of the examination procedure, the software of device CH HSS osm GLOBUS delivers automatically recommendations on what specific drug can be administered by the doctor. This makes it possible to widely introduce this method in clinical practice, namely in an ambulatory health care unit.

Clinical efficacy of the proposed method has been confirmed for a cohort of 272 elderly patients (aged over 60) [31].

There are also some other features of the VCO use in the CH assessment. This sort of examinations should be carried out on a regular basis in order to accurately identify a tendency in CH in an examined individual. Besides, it should be mentioned that in the treatment of AH the phenomenon of "escape" from hypotensive therapy appears. SHD monitoring allows avoiding these phenomena and conducting an adjustment of medication therapy well in time.

A solution to this problem can offer telemedicine. Proposed is an automated systematic monitoring of CH indices recorded either at home or in ambulatory with further transfer of the recorded data to a specialized medical organization responsible for data accumulation, processing, storage and continuous analysis thereof with periodicity identified for each patient individually or as emergency measures.

The use of telemedicine and specialized medical PC-assisted instrumentation systems allow medical staff to support and monitor the health state in their patients remotely [31, 32, 33].

## Conclusions

The conventional arterial pressure measurement is not capable of delivering data on the mechanisms of the AH development, detecting early stages in the AH progression and predicting efficacy of hypotensive drug therapy and development of refractoriness to hypotensive therapy. In this regard, administration of an adequate drug therapy on the basis of the central hemodynamics indices determined with the VCO method in dynamics would be treated as a more accurate technique, which properly takes into account the pathogenetic mechanisms of the AH development, capable of achieving the specified targets and reducing CVD mortality.

## Research summary

1. The investigation of central hemodynamics with the VCO method is comparable with the generally accepted invasive technique and some other methods of central hemodynamics examinations.
2. The use of VCO is acceptable and reasonable provided that multiple VCO examination procedures are completed, since the hemodynamic parameters are labile.
3. The VCO method for assessing the central hemodynamics can be used for prediction of a cardiovascular risk under various human individual conditions: pregnancy, physical loads in athletes, anesthesia in case of surgery; comorbidities like arterial hypertension, diabetes, postinfarction cardiosclerosis etc.
5. The CH examination employing VCO makes it possible to adequately select the proper drug therapy, considering the identified type of blood circulation, and adjust the medication, if required.
6. Due to the complexity of the CH data interpretation, for the purpose of a wide application of VCO in clinical practice, a new software, capable of delivering assessed results and findings, should be developed.
7. To extend the scope of the applications of VCO in clinical practice it is necessary to involve capabilities and possibilities offered by telemedicine, which enable physicians to advise patients remotely, provide remote monitoring of their health status, and adjust their treatment, if required. It is especially applicable to elderly and disabled patients.

## Statement on ethical issues

Research involving people and/or animals is in full compliance with current national and international ethical standards.

## Conflict of interest

None declared.

## Author contributions

The authors read the ICMJE criteria for authorship and approved the final manuscript.

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