

## INDICATOR OF STROKE VOLUME IN ESTIMATING PATIENT'S VOLEMIC STATUS IN THE CAROTID ENDARTERECTOMY

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▪ **The purpose of the study** is to determine the significance of variability index of the heart stroke volume in assessing the volemic status of patients during carotid endarterectomy. **Materials and methods.** The study included 60 patients who underwent carotid endarterectomy. The average age of patients is  $68 \pm 7.4$  years. The operation was performed under general anesthesia with mechanical ventilation. Cardiorespiratory interaction was studied. The parameters of the state of central hemodynamics were recorded before and after the functional hemodynamic test with the patient's legs raised. The patients were divided into 3 groups according to the change in the stroke volume of the heart on the test results. **Results.** The 1<sup>st</sup> group included 11 patients (18%), they have a volemia deficiency in combination with a decrease in myocardial contractility, 18 patients (30%) of the 2<sup>nd</sup> group suffered deficiency of volemia, and 31 patients (52%) having satisfactory hemodynamics were included into the 3<sup>rd</sup> group. The results of the test with raising of the legs demonstrated that the changes in the SVV indicator corresponded completely to the changes in stroke volume. It was revealed that, irrespectively of the initial state of hemodynamics, the index of variability of the heart stroke volume correctly reflected the state of the volemic status of patients during carotid endarterectomy. **Findings.** The rate of variability of heart stroke volume allows to evaluate the effectiveness of the infusion therapy and to control the volemic load during the carotid endarterectomy operation.

▪ **Keywords:** carotid endarterectomy; volemic status; cardiorespiratory interaction; variability of stroke volume of the heart.

## ПОКАЗАТЕЛЬ УДАРНОГО ОБЪЕМА СЕРДЦА ПРИ ОЦЕНКЕ ВОЛЕМИЧЕСКОГО СТАТУСА БОЛЬНОГО ПРИ ВЫПОЛНЕНИИ ОПЕРАЦИИ КАРОТИДНОЙ ЭНДАРТЕРЭКТОМИИ

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▪ **Цель исследования** — определить значимость показателя вариабельности ударного объема сердца в оценке волемического статуса пациентов при выполнении операции каротидной эндартерэктомии. **Материалы и методы.** В исследование было включено 60 пациентов, которым была выполнена операция каротидной эндартерэктомии. Средний возраст пациентов составил  $68 \pm 7,4$  года. Операция проходила в условиях общей анестезии с искусственной вентиляцией легких. Изучалось кардиореспираторное взаимодействие. Регистрировали параметры состояния центральной гемодинамики до и после функционального гемодинамического теста с подъемом ног больного. Изменение ударного объема сердца по результатам пробы было основанием для разделения пациентов на три группы. **Результаты.** Выявлены дефицит волемии в сочетании со снижением сократимости миокарда в 1-й группе — 11 пациентов (18 %), дефицит волемии во 2-й группе — 18 пациентов (30 %) и удовлетворительные показатели гемодинамики в 3-й группе пациентов — 31 больной (52 %). Изменения показателя SVV полностью соответствовали изменению ударного объема по результатам пробы

с подъемом ног. Выявлено, что независимо от исходного состояния гемодинамики показатель варибельности ударного объема сердца корректно отражает состояние волемического статуса пациентов во время операции каротидной эндартерэктомии. **Выводы.** Показатель варибельности ударного объема сердца позволяет оценивать эффективность проводимой инфузионной терапии и контролировать волемическую нагрузку при выполнении операции каротидной эндартерэктомии.

■ **Ключевые слова:** каротидная эндартерэктомия; волемический статус; кардиореспираторное взаимодействие; варибельность ударного объема сердца.

To provide satisfactory volemia in patients, intraoperative fluid therapy is used, which is necessary to maintain tissue perfusion during surgeries. Hypovolemia results in arterial hypotension, impaired peripheral microcirculation, oliguria, increased blood lactate, and also negatively affects consciousness level in the postoperative period. It is always necessary during surgery to decide whether additional intravenous infusion is necessary and to what extent. It is necessary to clearly determine whether the patient in this case has circulating blood volume (CBV) deficit and whether additional infusion to eliminate tissue hypoperfusion can lead to an increase in cardiac output necessary.

Generally accepted parameters in perioperative clinical assessment of hemodynamics includes electrocardiography (ECG), heart rate (HR), non-invasive measurement of blood pressure (NBP), and blood saturation ( $S_pO_2$ ). However, based on these parameters, such assessment cannot be recognized as absolutely adequate because it is impossible to accurately determine volume status and heart contractility (cardiac output, CO) [3]. Therefore, a dynamic (functional) approach to hemodynamic monitoring is currently recommended [2, 6]. Tests and parameters are used to implement such approach, through which the patient's sensitivity to the infusion load can be assessed. These tests and parameters include stroke volume variation (SVV), pulse pressure variation (PPV), systolic pressure variation (SVP), dynamic arterial elasticity index (PPV/SVV), inferior vena cava distensibility index, superior vena cava collapse index, end-expiratory occlusion test, positive end-expiratory pressure increase test, tidal volume (TV) increase test, standard infusion load test, minimum infusion load test, and passive leg lift test. Some of the tests are based on cardiorespiratory interaction, when the inspiration and expiration phases affect the preload amount and enable to assess changes in CO. Another approach presented is the trial intravenous fluid infusions in various volumes and autotransfusion. Thus, there is a group of tests that influences the cardiovascular system (CVS) and assesses changes in the patient's condition. Such tests need to be performed repeatedly. Another group of tests evaluate CVC continuously (online). These con-

trol indicators, such as SVV, PPV, and SVP, calculated.

SVV was used in this study as an indicator. It is calculated as the difference between stroke volume's (SV) maximum and minimum values during one breathing cycle or a fixed time interval divided by SV's average value.

No information was found on the use of the SVV indicator during carotid endarterectomy (CEAE) in the available literature.

**The study aims** to determine the significance of the indicator of heart stroke output variability in assessing the volume status of patients during CEAE surgery.

## Materials and methods

The study included 60 patients, including 48 men (80%) and 12 women (20%), who underwent CEAE surgery. The patients' average age was  $68 \pm 7.4$  years.

Vigileo monitors (Edwards Lifesciences, USA) and Nihon Kohden (Japan) were used for intraoperative hemodynamic monitoring. Invasive BP measurement was performed through the brachial or radial artery. The Nihon Kohden monitor was used to obtain data on invasive BP, HR, and hemoglobin oxygen saturation ( $S_pO_2$ ), whereas the Vigileo monitor was used to measure CO from the arterial blood pressure curve (APCO technology) of the Nihon monitor. The FloTrakSensor was used to connect the apparatuses. The heart's SV was measured first, then the stroke index (SI), cardiac minute output, cardiac index (CI), and stroke (systolic) blood volume variation (SVV) were calculated [5].

All patients received initial infusion therapy of 500 mL of balanced sterofundin solution. Premedication (fentanyl 0.1 mg and sibazone 10 mg), induction into anesthesia (propofol 2 mg/kg), relaxation (esmeron 0.6 mg/kg), and tracheal intubation was performed in the operating room. The patients were then transferred to artificial lung ventilation (ALV) using SIMV mode. TV was 10 mL/kg. Parameters of the initial state of central hemodynamics (CHD) were recorded by the monitors. After that, a functional hemodynamic test was performed by lifting the patient's legs  $45^\circ$  from the level of the operating

table. CHD parameters were recorded again after 1 min. The legs were lowered. The need and type of hemodynamic correction was determined based on the test results.

Statistical analysis was performed using the SPSS software. The data are presented by arithmetic mean values ( $M$ ) and standard deviation ( $s$ ) as  $M \pm s$ . Groups of parameters were compared by Student's  $t$ -test for normal distribution of data and  $t$ -test for dependent samples. In the absence of a normal distribution, nonparametric methods of analysis were used in the absence of normal distribution. The difference was considered statistically significant at  $p < 0.05$ .

## Results

The leg lift test was assessed based on changes in SV. According to the test results, the patients were distributed into three groups:

1. Patients with initial SV of up to 70 mL (SI up to 35 mL/m<sup>2</sup>) without significant (up to 10% of the initial) change in SV (SI), 11 patients (18%).
2. Patients with an initial SV of up to 70 mL (SI up to 35 mL/m<sup>2</sup>) had a significant (10% or more) increase in SV (SI), 18 patients (30%).
3. Patients with initial SV of 70 mL (SI 35 mL/m<sup>2</sup>) or more had changes in SV (SI) of varying severity, 31 patients (52%).

Table 1 shows the CHD indicators before and after the leg lift test.

Comprehensive assessment of the CHD was performed. Group 2 showed a deficiency of the CBV with preserved myocardial contractility. In group 1, changes in the CHD values indicated a deficiency of CBV and a decrease in the heart's

contractile ability. Hemodynamic parameters were found to be satisfactory in group 3.

The correspondence of the nature of SVV changes to the SV dynamics as a result of testing and additional intravenous volumetric infusion was assessed to determine the significance of the SVV indicator in assessing the patient's volume status.

Changes in SV and SVV during the leg lift test are shown in Table 2.

In group 1, change in SV and SVV was not statistically significant ( $p > 0.05$ ). A significant increase in SV ( $p = 0.002$ ) was accompanied by a significant decrease in SVV ( $p = 0.008$ ) in group 2, and the dynamics of SVV corresponded to the change in SV. No changes in SV ( $p = 0.262$ ) were recorded in group 3, however, the change in SVV was statistically significant ( $p < 0.05$ ).

According to the results of a comprehensive assessment of hemodynamics, the necessary infusion and cardiotoxic correction was performed. No correction was required in group 3.

The dynamics of SV and SVV after the necessary therapy in groups 1 and 2 are presented in Table 3.

A coordinated change in SV and SVV index was recorded during hemodynamic correction. With a statistically significant increase in SV in groups 1 and 2 ( $p < 0.05$ ), there was a significant decrease in SVV ( $p < 0.05$ ).

## Discussion

The respiratory variation of the SV can be measured directly by using the Vigileo/FloTrac TM monitor (Edwards Lifesciences) [7]. SVV is a functional hemodynamic variable. SV changes are based on cardiorespiratory interaction, that

Table 1 / Таблица 1

### Hemodynamic indicators before and after the test with the legs raised Показатели гемодинамики до и после теста с подъемом ног

Indicators	Group 1		$p$	Group 2		$p$	Group 3		$p$
	before	after		before	after		before	after	
HR	97 ± 12.2	94 ± 11.1	0.156	64 ± 6.5	66 ± 7.8	0.128	67 ± 10.5	68 ± 8.6	0.714
SV	54 ± 2.3	54.3 ± 5.1	0.898	62.3 ± 2.8	75.7 ± 4.3	0.002	83.8 ± 12.5	85.2 ± 10	0.262
SI	27 ± 2.3	28.3 ± 4.4	0.576	32 ± 2.7	38 ± 4.21	0.002	42.4 ± 7.7	43 ± 6	0.295
CI	2.34 ± 0.1	2.73 ± 0.4	0.341	2.01 ± 0.31	2.4 ± 0.31	0.042	2.79 ± 0.31	2.78 ± 0.30	0.611
TPVR	1392 ± 301	1604 ± 456	0.21	1844 ± 431	1884 ± 515	0.647	1361 ± 274	1479 ± 285	0.001
BP <sub>av</sub>	89 ± 10.8	98 ± 15.4	0.216	91 ± 17.3	114 ± 19.4	0.004	93 ± 11.2	104 ± 10.6	0.001
SVV	18 ± 0.7	16.3 ± 0.8	0.31	20.8 ± 3.6	11.5 ± 5.2	0.008	12.4 ± 4.7	8.9 ± 2.3	0.025

Note. TPVR — total peripheral vascular resistance. For other abbreviations, see the text.

Примечание. ОПСС — общее периферическое сосудистое сопротивление. Расшифровку других аббревиатур см. в тексте.

Table 2 / Таблица 2

Changes in stroke volume and SVV after the test with the legs raised  
Изменения ударного объема и SVV после пробы с подъемом ног

Group	Parameter	Before	After	<i>p</i>
1	SV	54 ± 2.3	54.3 ± 5.1	0.898
	SVV	18 ± 0.7	16.3 ± 0.8	0.31
2	SV	62.3 ± 2.8	75.7 ± 4.3	0.002
	SVV	20.8 ± 3.6	11.5 ± 5.2	0.008
3	SV	83.8 ± 12.5	85.2 ± 10	0.262
	SVV	12.4 ± 4.7	8.9 ± 2.3	0.025

Table 3 / Таблица 3

Change in stroke volume and SVV after the treatment  
Изменение ударного объема и SVV после коррекции

Group	Parameter	Before	After	<i>p</i>
1	SV	54 ± 2.3	69.1 ± 6.1	0.019
	SVV	18 ± 0.7	12.6 ± 0.8	0.038
2	SV	62.3 ± 2.8	73 ± 5.1	0.008
	SVV	20.8 ± 3.6	12 ± 3.7	0.013

Note. For abbreviations, see the text.

Примечание. Расшифровку аббревиатур см. в тексте.

is, they are determined by fluctuations in intrathoracic pressure. The patient must be under ALV with a TV of 8–15 mL/kg to get a more accurate measurement of the indicator. On inspiration, the venous return to the heart decreases and SV also decreases. Cardiac preload is restored and cardiac output is increased after exhalation. The greater the difference in SV during inhalation and exhalation on ALV is, the higher its value of variation. Consequently, CBV deficit is more pronounced [1, 4]. Parameter sensitivity is 86% and the specificity is 85%. The closer the SVV figure is to 10%, the lower the volemic deficit is [2].

**The study aims** to determine the significance of the SVV indicator in assessing the patient's volume status during CEAE surgery. For this, the correspondence of the nature of SVV change to SV dynamics as a result of the leg lift test and additional intravenous infusion was assessed. Changes in the parameter completely coincided with the nature of SV dynamics. In group 1, change in SV and SVV was not statistically significant ( $p > 0.05$ ) based on the result of the leg lift test. This indicated CBV deficiency and the presence of a decrease in the heart's contractile ability. The therapy provided an increase in SV and a decrease in SVV ( $p < 0.05$ ), which also properly characterized the patient's condition. In group 2, a significant increase in SV was accompanied by a significant decrease in SVV ( $p < 0.05$ ).

The dynamics of the SVV corresponded to the change in SV. No changes in SV were revealed in group 3 ( $p = 0.262$ ). These results confirm the previously published data on the study of these parameters [2, 4]. Results of the study revealed that the indicator of heart SVV correctly reflects the volemic status, regardless of the initial state of hemodynamics. By measuring it, the ongoing infusion therapy and dynamic control of patients' volemia, including during CEAE surgery, can be assessed. These conclusions coincide with the opinions of other authors [2, 5, 7].

## Conclusions

1. The variation indicator of the cardiac stroke output enables to perform the correct dynamic control of the patients' volemic status.
2. This allows to evaluate therapy efficacy during CEAE surgery.

*The authors declare no conflict of interest.*

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