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inferior vena cava collapsibility index as a non-invasive method of assessing the volemic status of patients during spine interventions

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Objective. To prove the possibility of using non-invasive diagnostics of the volemic state of postoperative patients using ultrasound assessment of inferior vena cava collapsibility index. Methods. The study included 67 patients who underwent transpedicular fixation of the spine with laminectomy. Volemic status was determined for all participants in two ways: by catheterization of the central vein and determination of central venous pressure, as well as by ultrasound examination of the inferior vena cava and calculation of inferior vena cava collapsibility index. Results. According to the results of the invasive assessment of central venous pressure, patients were divided into 3 groups: group I (patients in hypovolemic state, n = 31), group II (patients in euvolemic state, n = 25) and group III (patients in hypervolemic state, n = 11). The average values of central venous pressure indicators in patients of these groups were statistically significantly different from each other (p < 0.01). The difference between the mean values of the inferior vena cava collapse index in the respective groups was statistically significant (p < 0.01). A reliable inverse correlation of very high strength was found between the indicators of inferior vena cava collapsibility index and central venous pressure (p < 0.05). Conclusions. Determination of the patient's volemic state is an extremely important tool for the correct selection of the fluid volume management. Ultrasound assessment of volemic status has a number of advantages, such as the non-invasiveness of the method, wide availability, low price and speed of execution. According to the results of our study, the possibility of using inferior vena cava collapsibility index to assess the volemic status of patients has been demonstrated.

Мета. Довести можливість застосування неінвазивної діагностики волемічного стану післяопераційних пацієнтів за допомогою ультразвукового оцінювання індексу колабування нижньої порожнистої вени. Методи. У дослідження включено 67 пацієнтів, яким було проведено транспедикулярну фіксацію хребта з ламінектомією. Усім хворим визначали статус волемії двома способами: шляхом катетеризації центральної вени та вимірюванням центрального венозного тиску, а також за допомогою ультразвукового дослідження нижньої порожнистої вени і розрахунку індексу колабування нижньої порожнистої вени. Результати. Після проведення інвазивної оцінки центрального венозного тиску пацієнтів було поділено на 3 групи: I — стан гіповолемії, n = 31; II — стан еуволемії, n = 25; III — гіперволемії, n = 11. Середнє значення показників центрального венозного тиску у хворих цих груп статистично вірогідно відрізнялось між собою (p < 0,01). Статистично вірогідною була відмінність між середніми значеннями індексу колабування нижньої порожнистої вени у відповідних групах (p < 0,01). Між показниками індексу колабування нижньої порожнистої вени та центрального венозного тиску виявлено достовірний зворотний, дуже високої сили, кореляційний зв'язок (p < 0,05). Висновки. Визначення волемічного стану пацієнта є надзвичайно важливим інструментом для правильного вибору об'єму інфузійної терапії. Ультразвукове оцінювання волемії має низку переваг, таких як неінвазивність методу, широка доступність, низька ціна та швидкість виконання. За результатами проведеного нами дослідження продемонстровано можливість застосування індексу колабування нижньої порожнистої вени для оцінювання волемічного статусу пацієнтів. Ключові слова. Волемічний статус, центральний венозний тиск, індекс колабування нижньої порожнистої вени.

Key words. Volemic status, central venous pressure, collapsing index of the inferior vena cava

Introduction

Correct assessment of the volemic state of patients in the postoperative period is often of critical importance. After all, the volume of correctly selected infusion has a direct effect on systemic perfusion and can prevent the development of multiple organ failure and reduce mortality [1].

It is not always easy to determine the volume of the infusion. Sometimes there is a discrepancy between intravascular volume and arterial pressure, or between intravascular and extravascular volumes. For example, severe vasoconstriction can increase blood pressure in a hypovolemic patient. Some patients have low blood pressure, but at the same time they have an overload of intravascular volume due to cardiac dysfunction. Therefore, due to low specificity and sensitivity, it is not worth relying only on physical examination indicators and laboratory findings [2].

A European survey of anesthesiologists and intensive care physicians showed that more than 90 % of specialists use the central venous pressure (CVP) indicator to select the infusion volume [3].

Invasive determination of CVP makes it possible to more reliably assess the patient's volemic state. Central venous pressure reflects its value in the right atrium, which, in turn, is a determining factor in the filling of the right ventricle. Therefore, CVP is a good indicator of right ventricular overload. In order to evaluate it through the subclavian or jugular vein, a catheter is inserted so that its tip is in the right atrium. Normally, CVP is 8.0–12.0 cm of the water column. Its decrease indicates hypovolemia, and its increase indicates hypervolemia [4, 5].

This invasive method can have the following complications: arrhythmia; damage to the heart chamber or central vessels (both arteries and veins); nerve plexuses and trunks; pneumothorax; hemothorax; hematoma; infection; thrombosis; occlusion; pulmonary embolism and post-thrombophlebitic syndrome due to catheter installation; superior vena cava syndrome [6].

Determining the diameter and collapsing index of the inferior vena cava using ultrasound diagnosis allows for a quick and, most importantly, non-invasive assessment of the patient's volemic status.

During breathing, negative intrathoracic pressure increases the return of venous blood to the heart and reduces the diameter of the inferior vena cava (IVC). At the end of exhalation, the intrathoracic pressure rises to zero, reducing the return of venous blood to the heart. Under these conditions, the diameter of the LV reaches its maximum value. These physiological features serve as the basis for calculating LV collapsing index (IC LV) [7]:

$$IC = ((IVCmax - IVCmin) / IVCmax) \times 100\ \%.$$

Purpose: to prove the possibility of using non-invasive diagnosis of the volemic state of postoperative patients using ultrasound assessment of the index of collapsing of the inferior vena cava.

Material and methods

The study involved 67 patients who underwent transpedicular fixation of the spine (thoracic, lumbar and sacral divisions) with laminectomy. All study participants were of legal age and had a central venous catheter in place for the purpose of conducting infusion and transfusion therapy and determination of volemic status. Among the examined patients, the share of men was 47.8 % (32/167), and women — 52.2 % (35/67). The average age of the patients was (47.08 ± 9.30) years.

Informed consent was obtained from all patients, and they were assured that the identities of the respondents would remain anonymous. The study was approved by the Bioethics Commission of Uzhgorod National University (Protocol No. 1 dated 29.09.2022).

Exclusion criteria from the study were: pregnancy, organic heart disorder, arrhythmia, pulmonary hypertension, prolonged artificial lung ventilation in the postoperative period, unsatisfactory visualization of the inferior vena cava, increased intra-abdominal pressure, refusal to participate in the study.

All patients underwent a comprehensive clinical examination, which included the collection of demographic and anthropometric data, physical examination and the collection of venous blood for laboratory analysis, as well as chest X-ray, electrocardiographic and echocardiographic studies. Combined general anesthesia (inhalation/non-inhalation) was performed. Extubation was performed on the operating table after surgery. The criteria for central venous catheterization were: the need to control CVP, the potential need for long-term infusion-transfusion therapy and ensuring reliable venous access in the case of thin peripheral veins, the need to regularly obtain venous blood samples. Assessment of the volemic status was carried out in all subjects within 6–12 hours after the operation.

To determine the level of CVP, catheterization of the internal jugular vein was performed under the control of ultrasonography. Measurements were made at the end of exhalation, with the patient lying on the back, and the pressure sensor was set to zero in the middle of the chest: for the CVP indicator, it is less than 8 cmH2O patients were considered hypovolemic; between 8–12 cmH_2O — euvolemic, and in CVP > 12 cmH_2O — hypervolemic.

Echocardiographic assessment was performed immediately after invasive determination of the CVP level to ensure the same volemic status of the patient for both study methods.

All ultrasound examinations were performed by the same physician throughout the study using a GE Vivid E9 device with a transthoracic echocardiographic sensor. Before determining the diameter of the IVC, the doctor was not informed about the hemodynamics and CVP parameters. The anteroposterior diameter of the inferior vena cava was measured from the subcostal window proximal to the confluence of the hepatic veins, using "frozen" images at the end of inspiration and expiration, as shown in Fig. 1. Measurements were performed during normal spontaneous inhalation and exhalation of patients, trying to avoid Valsalva maneuvers [8–10].

Statistical processing of the obtained results was carried out on a personal computer using the Office Excel 2010 and Statsoft Statistica 12.0 software packages. The discrepancy was considered probable if its value was equal to or greater than 95 % ($p < 0.05$). Statistical analysis of materials, summarization of results and generalization of conclusions was carried out by the method of variational statistics, taking into account average values (mode, median, arithmetic mean) and average error (M ± m) with assessment of the reliability of values according to the Student's t-criterion, as well as with the determination of the correlation coefficient according to using the paired Pearson method to identify relationships between the obtained indicators.

Results and their discussion

Among all 67 examined patients, the average value of the diameter of the inferior vena cava at the end of expiration was (14.7 ± 6.2) mm (IVC max), at the end of inhalation — (9.4 ± 6.2) mm (IVC min). The average value of the IC LV was (42.2 ± 16.3) %, and the CVP indicator was (7.2 ± 4.6) cmH2O.

According to the results of invasive assessment of CVP, patients were divided into 3 groups: I — hypovolemic state, n = 31; II — euvolemia, n = 25 and III — subjects in a state of hypervolemia, n = 11. The average value of the indicator of IC IVC in Group I patients was statistically significantly different from the average value of the same indicator of the patients of Groups II and III ($p < 0.01$). Moreover, the mean values of IC IVC in patients of Groups II and III differed ($p < 0.01$) (Table). Such results of statistical analysis indicate that there are statistically significant differences between indicators of non-invasive assessment of volemia.

The graphic display obtained during the correlation-regression analysis of the relationship between the indicators of the IC IVC and CVP is presented in Fig. 2. A reliable inverse, very strong, correlation relationship ($p < 0.05$) was revealed, confirming the possibility of using non-invasive evaluation volemic state in patients who do not require central venous catheterization for other indications.

Factors that may influence the diameter of the IVC include the presence of pulmonary hypertension, hemodynamically significant tricuspid or pulmonary

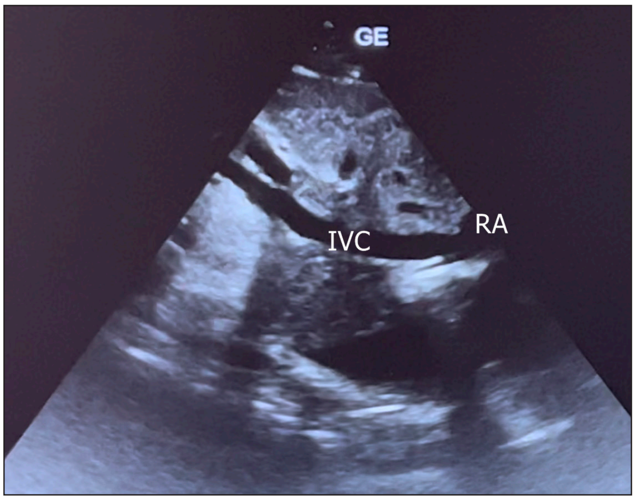

Fig. 1. Ultrasound image of the inferior vena cava along the long axis. inferior vena cava is the inferior vena cava, RA is the right atrium

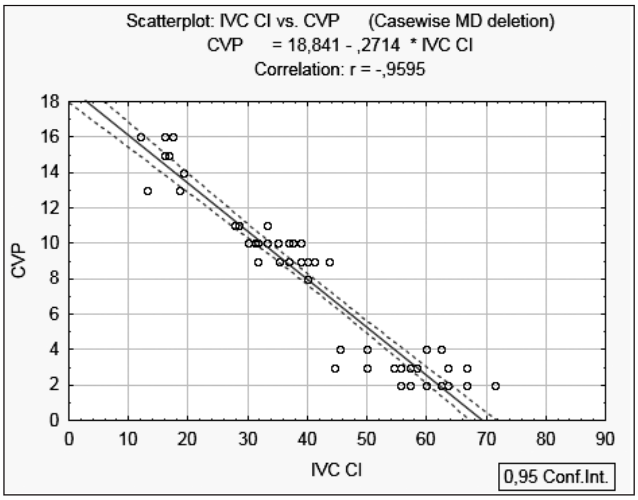

Fig. 2. Correlation-regression relationship between indicators of the index of collapse of the inferior vena cava and central venous pressure

Table

Indicators of central venous pressure in groups of examined persons

Indicator	Examination group			Reliability index	
	I — hypovolemic, n = 31	II — euvolemic, n = 25	III — hypervolemic, n = 11	t	p
IVC collapse index, %	57.3 ± 6.6	34.8 ± 4.5	16.4 ± 2.3	tI–II = 14.5 tI–III = 19.9 tII–III = –12.7	pI–II < 0.01* pI–III < 0.01* pII–III < 0.01*
CVP, cmH_2O	2.9 ± 0.7	9.8 ± 0.8	14.7 ± 1.1	—	—

Notes: n — number of patients; tI–II, tI–III, tII–III — Student's criterion when comparing the corresponding groups; pI–II, pI–III, pI–III — reliability of the difference in indicators of the respective groups; * — statistically probable difference when comparing indicators between the respective groups.

valve insufficiency, right ventricular dysfunction, and any condition with increased intra-abdominal pressure, such as individuals with morbid obesity or with moderate to massive ascites [4]. In addition to the above limitations for the use of non-invasive assessment of the state of volemia, there are still no clear criteria for the index of LV collapse to determine hypo-, hyper- or euvolemia. Thus, a number of studies showed that a decrease in the diameter of the IVC during the respiratory cycle by 50 % or more was strongly correlated with a low CVP [12, 13]. However, there is evidence that static parameters have low sensitivity and specificity for determining the state of volemia. It is about the fact that it is not recommended to evaluate only the maximum and minimum diameters of the IVC without calculating the IVC collapse index [14]. Dynamic parameters reflect the interaction of the heart and lungs and change during breathing and the cardiac cycle. In hypovolemic patients, dynamic indicators are more sensitive and better reflect the state of volemia compared to static parameters [15–17]. The majority of studies confirm the data that the IVC collapse index > 40 % indicates hypovolemia, and < 20 % indicates hypervolemia [16, 18, 19]. According to the results of our study, the indicators of the IVC collapse index coincide with these criteria: the average value of this indicator in the group of patients in a hypovolemic state was (57.3 ± 6.6) %, and in the group of patients with a hypervolemic state it comprised (16.4 ± 2 ,3) %.

Conclusions

Determination of the patient's volemic state is an extremely important tool for the correct selection of the volume of infusion therapy. Ultrasound assessment of volemia has a number of advantages: non-invasive method, wide availability, low price and quick performance. According to the results of our study, a very strong correlation was found between the invasive determination of CVP and the non-invasive evaluation of the IVC collapse index using ultrasound. Therefore, in patients who do not need central venous catheterization, it is sufficient to limit the non-invasive method using ultrasound to determine the volemic status.

Conflict of interest. The authors declare no conflict of interest.

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