Research Article
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Possibilities of Surgical Treatment of Pulmonary Embolism in Patients After Spinal Surgery

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AIM OF STUDY Comprehensive assessment of clinical and hemodynamic results of surgical treatment of high- and intermediate-high risk of pulmonary embolism in a group of patients who underwent spinal surgery.

MATERIALS AND METHODS The analysis of the results of open surgical treatment of pulmonary embolism in high- and intermediate-high-risk patients after neurosurgical operations on the spine in the period from 2013 through 2019. The study group included 5 patients. The average age of patients was 59.74±3.42 years. The Wells index was 9.2±2.4. The Pesi index of the studied patients was in the range of 100–126, which allowed them to be classified as a high-risk group of 30-day mortality (class IV). Clinical manifestations of pulmonary embolism developed on average by 5.8±1.08 days after the initial neurosurgical intervention. The calculated pressure in the pulmonary artery was 56.6±8.22 mm Hg. In all cases, surgical intervention was performed for emergency indications, in conditions of artificial blood circulation, without aortic compression during the main stage of the operation.

RESULTS The 30-day survival rate of patients was 100%. Among non-lethal postoperative complications, acute cardiovascular failure and hepatic-renal failure prevailed, which were levelled by the time the patients were transferred to a cardiac hospital. In 1 patient, the early postoperative period was complicated by the development of exudative pericarditis with cardiac tamponade, which required a finger revision of the anterior mediastinum, its drainage for 2 days. In all cases, there was an improvement in the condition of patients, in the form of increased tolerance to physical activity. The estimated pressure in the pulmonary artery at the time of discharge was 24.69±8.03 mm Hg.

CONCLUSIONS Surgical treatment of acute pulmonary embolism of high- and intermediate-high risk of early death in a group of patients with a neurosurgical profile is a highly effective and reliable method with great prospects for application.

Keywords: pulmonary embolism, spinal surgery, postoperative complications

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ALV – artificial lung ventilation

BP – blood pressure

CAD – coronary artery disease

DS – duplex scanning
DVT – deep vein thrombosis
ECG – electrocardiography
Echo-CG – echocardiography
FC – functional class
HLM – heart-lung machine
IVC – inferior vena cava
MSCT – multislice computed tomography
SVC – superior vena cava
TLT – thrombolytic therapy
VTEC – venous thromboembolic complications

INTRODUCTION

Pulmonary embolism (PE) in the clinic of surgical diseases is an urgent problem associated with a steady increase in morbidity and extremely high mortality [1]. The incidence of postoperative PE after standard surgical interventions in the absence of adequate prophylaxis can reach 28–33% [2]. According to the Framingham study, PE defines up to 15.6% of all in-hospital and 6–25% of all postoperative mortality [3]. Pulmonary embolism is the leading cause of death in surgical hospitals, determining a high percentage in the structure of pathological diagnoses [3, 4]. In particular, in vascular surgery, it determines 4.1% of deaths, in abdominal surgery - 14.3%, in purulent surgery - 33.3%, reaching 30.7% in the group of neurosurgical patients [4]. This trend is associated with the higher risks of neurosurgical patients in relation to the development of venous thromboembolic complications (VTEC), which is associated with the involvement of all three components of the Virchow triad in the pathological process [5]. According to published data, the average incidence of deep vein thrombosis (DVT) of the lower extremities in neurosurgical patients is 25–30%, and the incidence of subsequent PE is 3–7% [6]. At the same time, one should remember about the large number of asymptomatic forms of PE, which, due to the severe somatic status of neurosurgical patients, elude the physicians, determining a large number of pathological findings. Thus, according to a number of researchers, clinical verification of DVT, confirmed by X-ray examination methods, takes place in 159 cases per 100,000 population vs 123 cases of DVT, which were established on sectional material [7]. The situation with PE verification seems to be much worse, which is recognized in 19 cases per 100,000 patients, and in 139 cases is a sectional finding [7]. According to the results of pathologic-morphological studies carried out on the basis of N.N. Burdenko Institute of Neurosurgery, PE as a cause of death occurs in 7-10 cases annually, despite the implementation of preventive measures [9]. The urgency of the problem is associated with the increasing volume of surgical interventions from year to year, as well as the progressively increasing severity of the operated patients. So, the modernization of the healthcare system, the introduction of the latest technical devices, as well as the development of microsurgical manuals determine an increase in the proportion of extremely difficult patients who are on the verge of operability, which subsequently leads to a long period of rehabilitation with all the complications that result from this. Thus, according to the data of domestic registers, more than 10,000,000 operations are performed annually on the territory of the Russian Federation, including more than 200,000 interventions on the central and peripheral nervous systems [10]. Given these numbers, it is easy to imagine the scale of the problem. If we talk about the contribution of PE in the structure of mortality after performed neurosurgical interventions, then its share is about 30% [11]. This state of affairs is determined by the underestimation of the importance of adherence to thromboprophylaxis measures in the high-risk group of patients.

In turn, speaking about the difficulties of the primary verification of the correct diagnosis, which determines the lightning-fast progressing cardiac catastrophe, it should be said about a much more serious problem, namely, the choice of the treatment method [12]. To date, the arsenal of practicing physicians includes the following methods for restoring blood flow in the pulmonary artery system. According to the national clinical guidelines, as well as the recommendations of the European Association for Cardio-Thoracic Surgery *(EACTS)*, thrombolytic therapy (TLT) is the gold standard for reperfusion of the pulmonary circulation in the group of high and intermediate-high risk patients [1, 3]. If it is impossible to carry out the latter, and also due to its ineffectiveness, it is recommended to perform an open surgical intervention - thromboembolectomy from the pulmonary artery [2]. Conservative treatment, which consists of antithrombotic drugs, has low clinical efficacy in this group of patients and can only act in

addition to the main methods of treatment [3]. All the variety of methods used for reperfusion of the pulmonary artery is lost in the group of patients in whom pulmonary embolism is a complication of the early postoperative period. Thus, the presence of absolute contraindications for TLT often confuses the doctor and delays the time needed to perform a vital intervention. This approach is determined by the lack of publicly available data on the possibilities of open surgery in a group of patients with severe morbid status. In the context of the above, we analyzed the surgical treatment of patients with pulmonary embolism who had previously undergone surgery on the spine.

Aim of study: comprehensive assessment of the clinical and hemodynamic results of surgical treatment of PE of high and intermediate-high risk in the group of patients who underwent spine surgery.

MATERIAL AND METHODS

The study is based on the experience of surgical treatment of pulmonary embolism in 5 neurosurgical patients who were operated on at B.A. Korolyov SCCH from 2013 to 2019. There were no gender epidemiological features in the general group of patients. So, there were about the same number of men and women, it was 2 and 3, respectively. The age of the studied patients ranged from 43 to 62 years, and averaged 59.74 ± 3.42 years. It should be noted that all the patients were included in the group of high and intermediate-high risk and had previously undergone surgery on the spine. The structure of neurosurgical interventions is presented in Table 1.

Table 1

Structure of neurosurgical interventions

Types of neurosurgical interventions	*n*
Microsurgical plasty of the spinal canal	1
Removal of a herniated disc	2
Reconstruction of the lumbar spine associated with injury in a traffic accident	2

The morbid background of the patients was associated with both the severity of the postoperative period and the presence of concomitant pathology. The type of the latter certainly had a significant impact on the number and severity of complications in the early postoperative period, and also influenced the chosen management tactics. Among the comorbidities, arterial hypertension, DVT of the lower extremities, and type 2 diabetes mellitus prevailed. The structure of concomitant pathology is presented in Table 2.

Table 2

Premorbid status of operated patients

Gender, *n*	
male	2
- female	3
Average age, years	
- male	47 ± 3.12
- female	56 ± 4.7
Comorbidity, n	
- arterial hypertension	5
- deep vein thrombosis of the lower extremities	5
- type 2 diabetes mellitus	3
Cardiac ischemia	3
- obesity	3
The degree of circulatory failure, n	
II B (*NYHA*)	5
III functional class according to Vasilenko-Strazhesko	2
IV functional class according to Vasilenko-Strazhesko	3

At the time of admission to a cardiac surgery hospital, the main complaints were severe shortness of breath with minimal physical exertion, severe weakness, tachycardia (heart rate from 100–150 beats/min), chest pain in 3 patients. In 3 cases, systemic arterial hypotension was noted with a maximum arterial pressure (BP) up to 85/50 mm Hg, which required vasotonic support and cardioprotective therapy starting from the moment of hospitalization in the clinic. The test for the gas composition showed a decrease in arterial blood saturation below 90%, which determined oxygen therapy starting from the admission ward.

Objective assessment: patients were aggravated by the fact of immobilization of the lower extremities, as well as the symptoms caused by the previous intervention. Calculations on the *Wells* scale showed a high clinical likelihood of developing PE, with an average of 9.2 ± 2.4. The *Pesi* index of the studied patients ranged from 100–126, which made it possible to assign them to the high risk group of 30-day mortality (class IV).

The analysis of the materials of the primary documentation showed that mentioned clinical symptoms developed on average 5.8 ± 1.08 days (from 2 to 9 days) after the primary neurosurgical intervention. The early postoperative period, threatened by the development of fatal hemorrhagic complications, served as an absolute contraindication to TLT, and also determined the urgency of performing open surgery due to progressive right ventricular failure. However, despite all the above risks, TLT found its application in one patient against the background of cardiac arrest and ongoing resuscitation measures. It should be noted that in the situation under consideration, TLT helped save the patient's life, but did not allow performing hemodynamically significant reperfusion in the pulmonary artery basin, which was an indication for open intervention.

In terms of clinical examination of patients admitted to our clinic for open surgery, we used standard research methods. These include: general laboratory examinations, electrocardiography (ECG), transthoracic echocardiography (EchoCG), multislice computed tomography with intravenous contrast (MSCT), duplex scanning of arteries and veins of the lower extremities (DS), as well as X-ray endovascular techniques if indicated.

For the establishment of a true diagnosis, as well as verification of indications for surgery, the results of MSCT are of the highest priority. With the help of the latter, we noted intra-trunk location of the clot with a volume of pulmonary obstruction of more than 50% in all cases, the presence of intracardiac location of embolus in 2 patients, in addition, MSCT allowed us to assess the absence of a hemodynamic effect from previously performed TLT (Fig. 1).

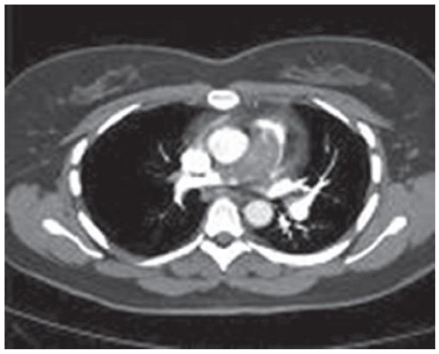

Fig. 1. Central pulmonary embolism in the trunk and lobar branches of the pulmonary artery

An extremely important point is the study of the peripheral vascular system, which we also assessed according to MSCT data. In addition, the assessment of the peripheral bed of the pulmonary artery basin was carried out using pulmonary angiography, used in 4 cases, as an addition to the selective coronary angiography, the indications for which were determined by the age of the operated patients and concomitant coronary artery disease (CAD). In one case, we were forced to abandon this extremely important method of examination due to the absence of a "therapeutic window" due to the extremely severe morbid status of the patient. Analyzing the recordings of the obtained angiograms, we revealed a bifurcational location of the clot in 4 patients, in one case - a right-sided lower lobe lesion. Miller's index in the considered group of patients was 27–32 points.

The ECG results did not allow to verify the pathognomonic symptoms of PE, but showed signs of overloading of the right chambers of the heart, repolarization changes and block of the right bundle branch in 2 patients. Transthoracic echocardiography is of the highest priority among the non-invasive research

methods in patients with PE. With the help of the latter, we revealed systolic overload of the right chambers of the heart (dilatation of the right ventricle), signs of pulmonary hypertension (the calculated pressure in the pulmonary artery was 56.6 ± 8.22 mm Hg), signs of embolism in progress in two patients, as well as assessed the tricuspid valve regurgitation (Fig. 2).

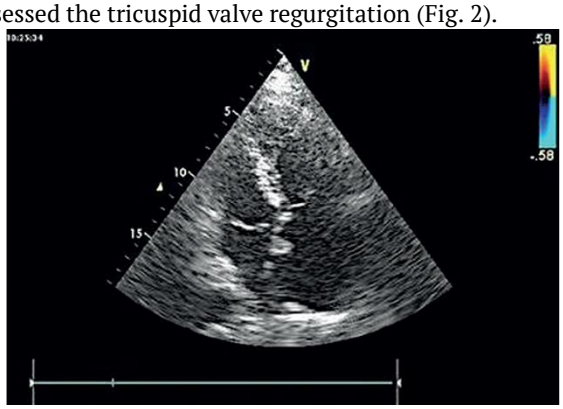

Fig. 2. Dilation of the right chambers of the heart, significant tricuspid regurgitation

Taking into account the fact that the inferior vena cava (IVC) system is the main source for the formation of the PE substrate in more than 70% of cases, the lower extremity vena cava is an obligatory method for the study of patients with PE. The source of embolism was the superficial femoral vein in 3 cases, the sural veins - in one case, and the ileocaval segment - in one case. In addition to the topical location of thrombus, we assessed the degree of flotation of its head, as well as its location. In the case of the transition of the floating thrombus head above the level of the inguinal ligament, we consider it reasonable to carry out retrograde ileocavagraphy in terms of objectifying indications for combined intervention. To select an active surgical tactic for patients with floating venous thrombus, we focus on the size of the floating head over 3.5 cm. It should be noted that when the floating head is located below the level of the inguinal ligament, we consider it reasonable to perform thrombectomy from the distal venous system with subsequent plication. If the ileocaval segment is involved in the process, then cava filter installation is the method of choice. In the studied group, we implanted a vena cava filter (*TrarEase, Sordis)* to a patient with a floating thrombus (head length of 4.8 cm) located at the level of the common iliac vein on the right.

After preoperative examination and preparation, open surgery was performed in all cases – thrombectomy from the branches of the pulmonary artery. We used a longitudinal median sternotomy as a surgical access, after that heart-lung machine (HLM) was connected. In all cases, isolated upper (SVC) and IVC cannulation was performed with 32 *F* and 36 *F* cannulas, respectively. After reaching the design capacity of the HLM, the IVC and SVC entries were clamped with loops pulled through during the preparatory stage of the operation. For embolectomy, an incision of the pulmonary artery trunk was performed 1.0 cm distal to the pulmonary artery valve, passing to its left branch (Fig. 3).

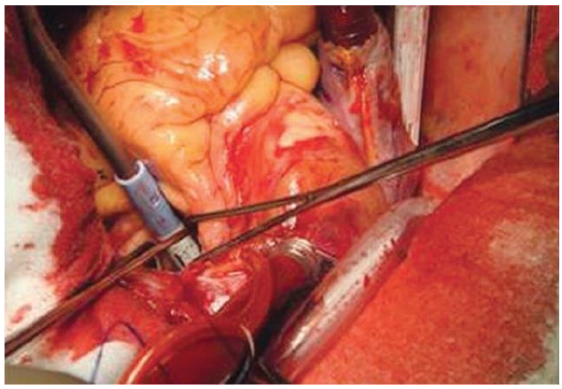

Fig. 3. Stage of thromboembolectomy from the pulmonary artery

Evaluation of the performed embolectomy was carried out according to the activity of obtaining retrograde blood flow. In two cases, retrograde perfusion of the pulmonary artery system was used, carried out by isolated cannulation of the upper right pulmonary vein. The pathogenetic rationale for the selected

aid was the presence of loose thrombotic masses occluding the lumen of the peripheral branches of the pulmonary artery, with an embolism period of up to 3 days. Fragments of removed clots are shown in Fig. 4.

Fig. 4. Removed thromboemboli

In two patients, the stage of embolectomy preceded the stage of the tricuspid valve plasty. The indication for reconstruction of the right atrioventricular valve was the presence of grade II – III tricuspid regurgitation. Taking into account the hemodynamic peculiarity of the right heart, as well as increased coagulation risks in patients, we consider it justified to use suture types of plastic of the tricuspid valve, bypassing the implantation of rigid support rings and flexible bands. In all cases, we performed *Batisto* suture plasty, which was supplemented with thrombectomy and debridement of the right heart in two cases. It should be noted that all surgical interventions were performed without clamping the aorta, in the course of parallel HLM perfusion. The duration of perfusion was 30.36 ± 6.43 minutes. After sealing the heart wounds and suturing the pericardiotomic wound, the patients were transferred to the intensive care unit (ICU) for postoperative treatment.

The study was carried out in accordance with *Good Clinical Practice* and the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment.

Statistical processing of the presented material was carried out using the licensed software package *"Statistica* 9.0*"*. Quantitative features are presented in the work as $M \pm s$, where M is the arithmetic mean, s is the standard deviation. When assessing the severity of the condition and the degree of risk of developing PE, the generally accepted classifications were used.

RESULTS

Despite the extremely severe morbid status of the operated patients, as well as the severity of the main and previous operations, we did not have any lethal outcomes upon discharge from the hospital, as well as within the first month after surgery. Thus, the 30-day survival rate was 100%. After transfer to the ICU, the patients underwent intensive therapy aimed at correcting residual pulmonary hypertension, as well as manifestations of cardiovascular and multiple organ failure. The duration of artificial lung ventilation (ALV) was 1.4 ± 0.8 days, followed by the transfer of patients to spontaneous breathing. An important link in postoperative rehabilitation is the selection of adequate anticoagulant therapy initiated by intravenous heparin therapy, followed by a switch to subcutaneous administration of low molecular weight heparins, combined with oral anticoagulants, and then isolated administration of oral anticoagulants to achieve the international normalized target ratio (MNO). Non-lethal postoperative complications were dominated by acute cardiovascular failure (ACVF), hepatic and renal failure, leveled by the time the patients were transferred to a cardiac surgery hospital. The average stay of patients in the ICU was 3 ± 0.8 days.

After the transfer of patients to a cardiac surgery hospital, multicomponent conservative treatment and breathing exercises continued. All patients were discharged in satisfactory condition on day 8–22 after surgery, which was largely determined by the severity of the comorbid pathology. Upon discharge from the hospital, patients noted an improvement in their general condition such as increased exercise tolerance, as well as the absence of manifestations of cardiovascular insufficiency. Speaking about the neurological status of the patients, it can be noted that upon discharge, the phenomena of moderate paresthesia persisted in the intervention area in 2 patients, in 2 cases there was a limitation of the range of motion in the lower extremities due to persisting pain discomfort in the area of neurosurgical intervention. The results of transthoracic echocardiography clearly demonstrated the hemodynamic effectiveness of the treatment, namely, the leveling of signs of right ventricular failure, the absence of pulmonary hypertension

(calculated pressure 24.69 ± 8.03 mm Hg), and an increase in the contractility of the left ventricular myocardium. Upon discharge from the hospital, the patients were transferred to outpatient treatment at the place of residence, with recommendations for anticoagulant, cardiac and phlebotonic therapy.

DISCUSSION

Currently, VTEC continues to be one of the most important causes of disability and mortality in the group of neurosurgical patients. Forced bed rest, due to the need to unload the spine in the postoperative period, is an important pathogenetic underlying reason for the development of VTEC, despite the whole range of preventive measures used. An extremely important point that determines the late diagnosis of VTEC is the disturbed afferentation of the nerve impulse due to damage to the peripheral nerve pathways, which hides the true picture of the developing pathology, due to the absence of patients' complaints as well. According to a number of studies carried out in a group of patients with injuries of the spine and long bones of the lower extremities, asymptomatic DVT was revealed in 90% of cases, complicated by PE in more than 10% of cases. In turn, PE, as a manifestation of an interdisciplinary catastrophe, is found on average in 2 patients per 1000 population in the group under 70 years of age, reaching 10–12 cases in the group of elderly patients. Thus, the results *of H. Takashi* [11], based on the material of surgical treatment of 100 patients with spinal injuries, demonstrated the incidence of DVT in 18% of patients, and PE - in 19%. In turn, *J.B. Hohl* [12], summarizing the results of a multicenter study, revealed the incidence of VTEC reaching 1.5%. At the same time, the share of clinically verified forms of PE is about 0.88%. Despite this, publications devoted to the problem under consideration are extremely few in number, and, as a rule, relate to the identification of risk factors for the development of VTEC in the interested group of patients. According to *A.J. Schoenfeld* [13], the latter include: the age of patients over 80 years old, overweight (body mass index> 25 kg/m^2), when the risk is score 3 or higher according to the *ASA* scale, as well as the duration of surgery over 261 minutes. Taking into account mentioned risk factors and prevention of VTEC recommendations, one can only say that the issues relating to the integrated prevention of DVT and PE in the group of patients with spinal injury, remain unsolved. The role of anticoagulant therapy in this group of patients has not been fully determined. Thus, one of the most formidable complications of surgical interventions on the spine is the development of epidural hematomas, accompanied by severe neurological disorders, which limits the range of currently available anticoagulant drugs to the use of enoxaparin sodium.

A diametrically opposite problem is the lack of prescriptions for wearing compression hosiery, due to the belief of a number of specialists in the inviolable effectiveness of modern anticoagulant therapy. Analyzing our own experience of observing patients with various forms of PE in a group of neurosurgical and traumatological patients, as well as the data of our colleagues, we consider that the only correct tactic in the rehabilitation of the above patients is a tactic based on both drug and non-drug mechanisms for regulating the parameters of the Virchow triad.

If we talk about early verification of DVT and PE in this extremely morbid group of patients, we consider it reasonable to conduct daily monitoring of the parameters of the hemostasis system, DS of the veins of the lower extremities, as well as transthoracic echocardiography in terms of increased “thromboembolic alertness”. The importance of the postulate under discussion is determined by the fact that patients, due to their objective status, will not always be able to inform the physician about the progressive deterioration of their condition. Assessment of the objective status may also not give the proper clinical result due to the concomitant spinal injury of lymphovenous insufficiency, as well as neuro-dystrophic disorders. The earliest possible verification of VTEC, assessment of the risks of sudden death, as well as topical diagnostics of the affected segment of the pulmonary arterial vessels, will make it possible to provide highly specialized care to patients in extremely serious condition in the shortest possible time.

We believe that the earliest possible hospitalization of patients with pulmonary embolism in specialized hospitals with experience in open surgery is justified. Early management of the obstruction of the pulmonary artery lumen will allow to neutralize the phenomena of developing and fulminant progressing right ventricular failure, which, in our opinion, is the key to a successful clinical result. Having accumulated experience in the surgical treatment of PE, we consider it reasonable to carry out the main stage of the operation in the course of parallel perfusion, without clamping the aorta, which makes it possible to neutralize a number of complications associated with the reperfusion syndrome of vital body systems. We consider the indications for open surgical intervention: massive PE of high and intermediate-high risk of death, with central location of thrombus obstructing the lumen of the pulmonary artery; with a calculated pressure in the pulmonary artery over 50 mm Hg, with progressive right ventricular failure, systemic

hypotension; with intracardiac location of thrombus, as well as the threat of the development of paradoxical embolism. The point about the impossibility of conducting TLT, as an indication for surgical intervention, we purposefully carried out beyond the limits of the regulated indications. Undoubtedly, TLT is currently the "gold standard" for achieving pulmonary artery reperfusion. However, taking into account the risks of hemorrhagic fatal complications, as well as the lack of a "therapeutic window", we consider thrombectomy more reliable and predictable way to restore hemodynamics in the pulmonary circulation. It should be noted that in the case of a fulminant course of pulmonary embolism, in the absence of the possibility of providing a specialized surgical aid, TLT, despite all possible risks, is the method of choice, which can prolong the patient's life due to its pathophysiological effect.

CONCLUSION

Compliance with comprehensive preventive measures and dynamic assessment of laboratory and instrumental examination methods will change the epidemiological characteristics of VTEC in a group of neurosurgical patients, and adherence to the phasing of specialized care and active surgical tactics will determine an increase in the survival rate of patients with high morbid status.

1. Thromboembolectomy from the pulmonary artery is a highly effective and reliable technique with predictable results in patients with a neurosurgical profile.

2. The basis of a successful surgical intervention is the active management tactics of the patients, which consists in performing the surgical intervention as early as possible after the onset of an episode of pulmonary embolism.

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