X-RAY ENDOVASCULAR TREATMENT OF «CRITICAL» THROMBOEMBOLISM OF THE PULMONARY ARTERY IN PATIENTS WITH ACUTE CEREBRAL BLOOD CIRCULATION BY HEMORRHAGIC TYPE

S.A. Fedorov[1*], *A.P. Medvedev*[1,2], *A.M. Khomenko*[3], *Yu.D. Brichkin*[1], *A.V. Deryugina*[4], *L.M. Tselousova*[2,5], *V.V. Pichugin*[1,2], *S.A. Zhurko*[1], *S. Kulkarni*[2], *D.A. Danilova*[4]

[1] Specialized cardiosurgical clinical hospitalnamed after academician B. A. Korolev, 603950, Russian Federation, Nizhny Novgorod, street Vaneeva, D. 209., E-mail: ps@skkbnn.ru;
[2] Privolzhsky Research Medical University of the Ministry of Health of the Russian Federation, 603005, Nizhny Novgorod, Minin and Pozharsky square. D. 10/1., E-mail: rector@pimunn.ru;
[3] N.A. Semashko Regional Clinical Hospital, 190 Rodionova St., Nizhny Novgorod, 603126, Russian Federation;
[4] National Research Lobachevsky State University of Nizhny Novgorod, 23 Prospekt Gagarina, Nizhny Novgorod, 603950, Russian Federation;
[5] Nizhny Novgorod Regional Clinical Oncology Dispensary, 11/1 Delovaya str., Nizhny Novgorod, 603093; E-mail: sekretar@nnood.ru.

* Corresponding author: sergfedorov1991@yandex.ru

Abstract. Purpose of the study: substantiation of indications and assessment of results X-ray endovascular treatment of «critical» PE in patients with acute hemorrhagic cerebrovascular accident. Material and methods: the study included 47 patients with acute violation of cerebral circulation for hemorrhagic and mixed types complicated by massive pulmonary thromboembolism of high risk, with «critical» manifestations of right ventricular failure. Depending on the method of PE treatment used, the patients were divided into 2 groups: the study group (17 people), in which endovascular mechanical fragmentation of thromboembols was performed, and the control group (30 people), in which only basic intensive therapy was used. Results: patients of the study group underwent thromboembolic fragmentation in order to transfer embolism of the trunk and the main branches into embolism of smaller branches of the pulmonary artery. Technical success of the procedure (destruction of the central thromboembolus) was achieved in 100% of the cases. 14 patients (82.4%) showed positive clinical dynamics in the form of an improvement in the general condition, a decrease in pressure in the pulmonary artery, and a decrease in the volume of the lesion of the pulmonary bed according to CT angiography. Three patients (17.6%) died in the early postoperative period. In the control group of 30 patients, 25 patients died, hospital mortality was 83.3%. Conclusion: the method of catheter endovascular fragmentation of thrombi for the treatment of «critical» pulmonary embolism in patients with acute hemorrhagic cerebrovascular accident leads to a rapid and safe decrease in pulmonary artery pressure.

Keywords: catheter endovascular fragmentation of blood clots, critical PE, hemorrhagic stroke.

List of Abbreviations

BSPAP – Baseline systolic pulmonary artery pressure
CT – computed tomography
MSCT – multispiral computed tomography
PE – pulmonary embolism

Introduction

Hemorrhagic stroke develops in 1-2 million people annually (Claeys *et al.*, 2019; Jimenez *et al.*, 2014; Sauvic & Sauvic, 2010), and these patients are most susceptible to the development of venous thromboembolic complications (Khripun *et al.*, 2015; Jaff *et al.*, 2011; Sharifi *et al.*, 2012). According to the frequency of development of pulmonary embolism (PE), the considered group of patients is second only to patients of oncological and orthopedic orientation (Kuntsevich *et al.*, 2012). According to a number of authors, the course of hemorrhagic stroke in 3–50% of patients is complicated, not fatal, but in 1.7–5% of cases- fatal PE (Tetri *et al.*, 2011).

Quite a large number of works have been devoted to the prevention of PE in patients with hemorrhagic stroke; however, the problem of treating this formidable disease against the background of hemorrhagic stroke is far from a final solution (Khripun *et al.*, 2015). Acute pulmonary thromboembolism arteries – an urgent state of the cardiovascular system due to occlusive lesion of the pulmonary arteries, accompa-

nied by acute and life-threatening but potentially reversible right ventricular insufficiency (Claey *et al.*, 2019). As a rule, these are patients with massive lesions of the pulmonary arterial bed. The likelihood of survival of these patients depends on the early restoration of blood flow through the pulmonary arteries.

To date, the main methods of reperfusion of the pulmonary artery basin include: first, it is thrombolytic therapy as the «gold standard» of reperfusion; second, surgical embolectomy of pulmonary arteries; third, endovascular treatment methods (Medvedev *et al.*, 2021; Andriyashkin *et al.*, 2015; Piazza, 2020). However, in the group of patients with homeric stroke, the use of routine thrombolytic therapy is absolutely contraindicated, and the high operational risk in open surgery pushes us to use the endovascular method of treatment as a less invasive and traumatic procedure.

Catheter fragmentation of thromboemboli is the simplest and an effective method of minimally invasive recanalization of the pulmonary arteries. Immediate redistribution of blood clots occluding blood flow from the main pulmonary arteries to the lobar and segmental branches reduces dangerous afterload on the right ventricle, which, in most cases, is a life-saving action in critical patients with acute cerebrovascular accident (Schmitz-Rode *et al.*, 2012).

Purpose of the study: Substantiation of indications and assessment of results X-ray endovascular treatment of «critical» PE in patients with acute hemorrhagic cerebrovascular accident.

Materials and Methods

In total, the study included 47 patients with acute cerebrovascular accident of hemorrhagic and mixed types, complicated by massive high-risk pulmonary thromboembolism, with «critical» manifestations of right ventricular insufficiency. In the control group (30 people), only basic therapy was used with the prescription of fractionated / unfractionated heparins in order to passively reduce the thrombus and decline its volume by preventing the accumulation of fibrin conglomerates on the existing thrombus.

The inclusion criteria for the study were:

1. CVA by hemorrhagic type;
2. «Critical» PE with very high risk (PESI > > 125);
3. Embolism of the trunk and main branches of the pulmonary arteries;
4. Acute right ventricular failure;
5. The impossibility of using other methods of pulmonary reperfusion of the arterial bed (thrombolytic therapy, open pulmonary embolectomy).

Clinical and functional indicators of patients in the study groups are presented in Table 1.

Decision on the advisability of endovascular intervention was made on the basis of a council consisting of a doctor, neuroresuscitation specialist, cardiorheumatologist, specialist in endovascular diagnosis and treatment, anesthesiologist.

All patients in the study group underwent fragmentation of the thromboembolism with a modified Pig-Tail catheter in order to transfer embolism of the trunk and main branches into

Table 1

Clinical indicators of the studied patients

Indicator	Study group (*n* = 17)	Control group (*n* = 30)
Male/Female	7/10	13/17
Age	57,95 (S = 8,0) (43–72 years)	63,2 (S = 7,87) (50–78 years)
PE severity according to PESI classification (points)	Class V (152 ± 22)	Class V (150 ± 24)
Operational risk (ASA physical status classification)	ASA V	ASA V
Baseline systolic pulmonary artery pressure (mmHg)	70,53 (S = 4,53)	69,2 (S = 9,46)

S – Standard deviation. BSPAP – Baseline systolic pulmonary artery pressure

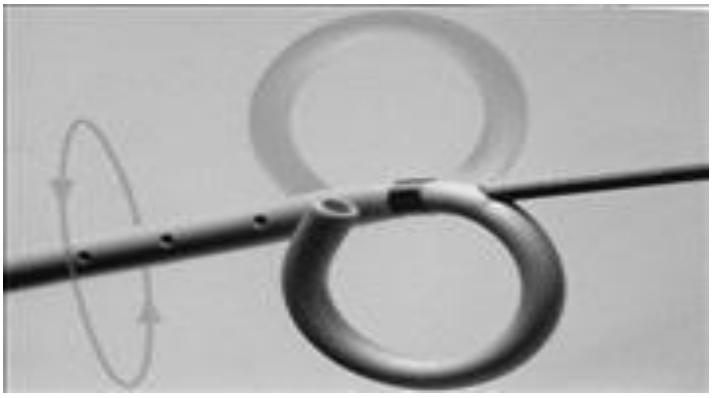

Fig. 1. Rotary Pig-Tail catheter for thromboembolic fragmentation in pulmonary arteries

embolism of smaller branches of the pulmonary artery, followed by pulmonary angiography control. The technique consists of a selective catheterization of the pulmonary arteries from puncture of the right-sided jugular or subclavian access.

The angiographic guidewire was introduced into the thrombus, and then a modified Pig-Tail catheter was installed in the pulmonary artery 5–6 F (Fig. 1.) (Schmitz-Rode & Günther, 1995). Angiographic guidewire at the distal catheter exits through the lateral holes rather than the end holes. The annularly bent inner end of the catheter, located next to the guidewire, during rotational movements around the guidewire passed through the thrombus, the guidewire fragments the thromboembolus.

One day after the intervention, all patients underwent echocardiographic control, on the seventh day – CT angiographic control. The conclusion about the effectiveness of the procedure was made on the basis of a set of data from examination methods, as well as the dynamics of the clinical picture.

Statistical data processing was performed using Microsoft Office Excel. Categorical variables are expressed as a percentage; constant variables are expressed as M ± SD, where M is the mean, SD is the standard deviation. The main characteristics and hospital outcomes for the two groups were compared with the results using the Student's criteria.

The study was carried out in accordance with the standards of Good Clinical Practice and the principles of the Helsinki Declaration of 1975 and its revised version from 2000. Prior to inclusion in the study, written informed consent was obtained from all participants, and the study itself was approved by the Local Ethics Committee.

Results

All studied patients were assigned to the V class according to the ASA classification (a patient whose death can be expected within the next 24 hours with or without surgical intervention). According to the PESI classification (2014), class V was defined in all patients (130–174 points), which is associated with an extremely high risk of death (10–24%).

The patients of the study group underwent thromboembolic fragmentation in order to move the embolism of the trunk and main branches into embolism of the smaller branches of the pulmonary artery. The technical success of the procedure (destruction of the central thromboembolus) was achieved in 100% of cases. 14 patients (82.4%) showed positive clinical dynamics in the form of an improvement in the general condition, a decrease in pressure in the pulmonary artery, and a decrease in the volume of pulmonary lesions according to CT angiography.

The dynamics of systolic pressure in the pulmonary artery before and after the endovascular intervention is shown in Fig. 2. Three patients (17.6%) died in the immediate postoperative period. Mortality was due to the initial severity of the patient's condition. In the control group 25 out of 30 patients died, the hospital mortality rate was 83.3%.

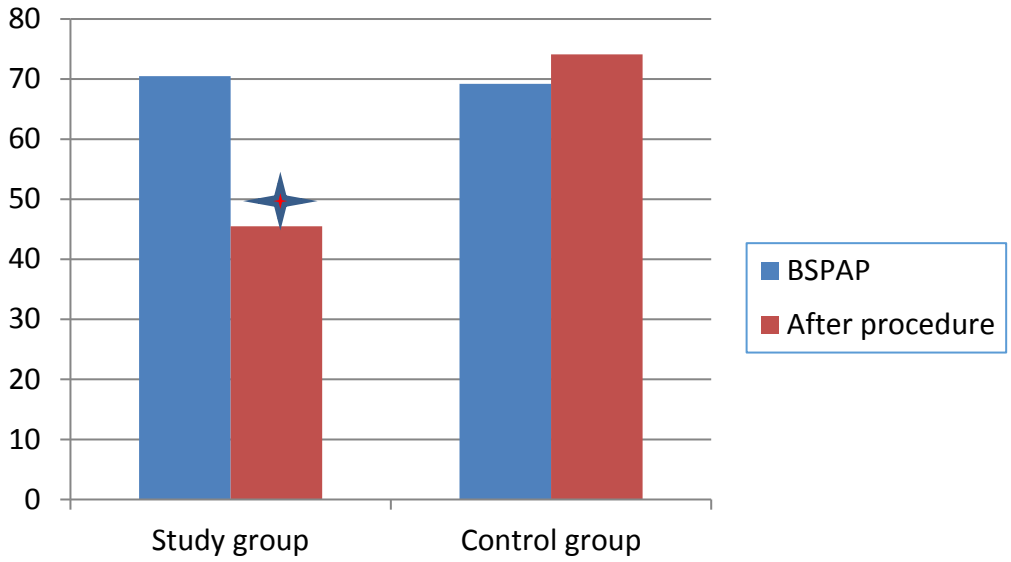

Fig. 2. Dynamics of systolic pressure in the pulmonary artery before and after the procedure

In the long-term (after 6–9 months) there were no lethal outcomes in the study group. With echocardiographic control after 6–9 months, signs of pulmonary hypertension persisted in 11 (64.7%) patients.

We present a case of successful treatment of «critical» PE in a patient with hemorrhagic stroke by means of endovascular destruction of thromboemboli in the main branches of the pulmonary artery.

Patient N.; 56 years old. Was in the Neurological intensive care unit (neuroICU) for hemorrhagic stroke in the pool of the middle cerebral artery on the right. On the 8th day from the episode of hemorrhagic stroke, there was a sharp deterioration in the patient's condition, which was assessed as extremely severe. The degree of impairment of consciousness on the Glasgow coma scale is 13 points (stunning). Severe hypoxemia Sat O_2 = 84% against the background of oxygen inhalation through nasal catheters. Arterial hypotension - blood pressure 90/50 mm Hg, despite inotropic stimulation of the myocardium. Heart rate – 110–120 beats per min. According to Echocardiography, stenotic blood flow through the pulmonary arteries, dilatation of the cavities of the right heart and left atrium are recorded. Hypertrophy of the left ventricle. Relative mitral valve insufficiency with moderate regurgitation (grade 2), tricuspid valve with severe regurgitation (grade 3). Signs of high pulmonary hypertension. Hydropericardium. PV – 55%; SPAP – 79 mm Hg.

According to MSCT with pulmonary angiography: detected thrombotic masses in the distal pulmonary artery with obstruction of their lumen (Fig. 3).

The presence of thrombotic masses in the distal pulmonary arteries with obturation of their lumen.

A consultation was held in the presence of an anesthesiologist-resuscitator, cardiologist, cardiovascular surgeon, neurologist and X-ray endovascular diagnostics and treatment of diseases of the heart and blood vessels. Due to the critical condition of the patient (ASA – V class) as a result of the development of massive PE, which complicated the course of hemorrhagic stroke by absolute contraindications to thrombolytic therapy and inability to perform an open thromboemboloectomy due to high risk of surgery, it was decided to perform catheter destruction of thromboemboli for health reasons in the main branches of the pulmonary artery. Mechanical fragmentation of thromboemboli with a Pig-Tail catheter (6 F) (Fig. 4).

After completing the procedure, the patient's condition improved: systolic pressure in the pulmonary artery decreased from 79 to 57 mm Hg, Sat O_2 increased to 92-94%, EF – up to

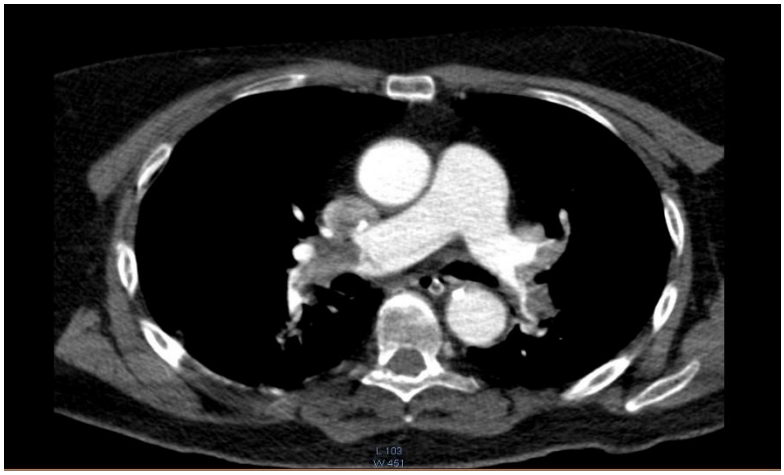

Fig. 3. MSCT-angiography of the pulmonary arteries of patient N; 56 years old

Fig. 4. Introduction of the rotary fragmentation Pig-Tail for fragmentation of thromboemboli in the pulmonary arteries. Fragmentation thromboemboli in the pulmonary arteries with Xray endovascular control of improved blood flow

65%. Subsequently – uncomplicated during the postoperative period.

Discussion

Patients with pulmonary embolism represent a very diverse group, differing, along with gender and age, in etiology and localization of the venous thrombus, severity of pulmonary arterial disorders blood flow and central hemodynamics, clinical manifestations of diseases preceding cardiopulmonary status, concomitant diseases aggravating the condition of patients and limiting or even preventing the use of necessary therapeutic measures. PE are aggressive in nature, do not always give the necessary clinical effect, can be accompanied by the development of various complications and side reactions; therefore, their use requires convincing argumentation.

The key pathogenetic mechanism of PE development is thromboembolic occlusion of the pulmonary arteries. In this regard, the modern patient management strategy requires an immediate decision on the exact localization of

thromboembolism and the method of restoring blood flow in the pulmonary arteries.

The most realistic way to restore pulmonary patency arteries are thrombolytic therapy or surgical intervention. In recent years, the role and place of surgical treatment of PE have changed significantly. Thanks to technological progress, the accumulated experience of surgeons and improving their qualifications, the indications for its implementation have expanded. Indications for surgery are considered thromboembolism of the pulmonary artery trunk or its main branches with shock, acute right ventricular failure, a significant decrease in arterial oxygen saturation in the presence of contraindications to thrombolytic therapy.

At this stage, a large number of scientific papers covering various aspects of prevention, diagnosis and treatment of PE have been published. However, the issues of treatment of pulmonary embolism in patients with hemorrhagic stroke, in critical condition, remain in the shadows. Our results suggest that the catheter fragmentation of thromboemboli is the simplest and most effective minimally invasive method of pulmonary artery recanalization.

According to the European Society of Cardiology, catheter fragmentation of thromboemboli is as effective as open embolectomy from pulmonary arteries. Moreover, this method can be used in patients whose condition precludes traditional surgery due to a high degree of risk, and the use of thrombolytic agents is associated with the risk of hemorrhagic complications.

A number of researchers (Karpenko et al., 2015) demonstrate significant experience in catheter fragmentation of thromboemboli in the pulmonary arteries in combination with local thrombolysis and indicating the high efficiency of this technique. The authors treated 164 patients with massive PE. Complete or significant dissolution of thromboemboli with normalization of systemic hemodynamics was achieved in 103 (63%) cases. Partial dissolution thromboemboli with stabilization of systemic hemodynamics were observed in 52 (32%) patients. And only 9 patients showed no clinical improvement.

In another multicenter study (Schmitz-Rode et al., 2000) catheter fragmentation thromboembolism was performed in 20 patients with massive PE (with lesions of the pulmonary arterial bed more than 50%). In 17 patients fragmentation of thromboemboli was supplemented by the introduction of thrombolytic drugs. Three patients had an absolute contraindication to thrombolytic therapy due to acute damage of the central nervous system (traumatic brain injury, brain tumor, neurosurgical operation). Two of these three patients survived. The overall mortality rate was 20% (4 out of 20 patients).

Among our patients (17 people) due to absolute contraindications (hemorrhagic stroke) thrombolytic therapy was not used. Of 17 patients, 3 died in the immediate postoperative period. The mortality rate was 17.65%.

Conclusion

Method of catheter endovascular fragmentation of thrombi for treatment of «critical» pulmonary embolism in patients with acute hemorrhagic cerebrovascular accident leads to a rapid and safe decrease in pulmonary artery pressure. Fragmentation of central embolism and displacement of thromboemboli to the periphery using a modified Pig-Tail catheter is a minimally invasive alternative to surgical embolectomy for extremely high risk of surgery and absolute contraindications to thrombolytic therapy.

References

ANDRIYASHKIN V.V., LEBEDEV I.S., VIRGANSKY A.O., ORLOV B.B. & KIRIYENKO A.I. (2015): How to choose a rational method of treatment of pulmonary embolism. *Pulmonary embolism* **2**, 80–85.

CLAEYS M.J., VANDEKERCKHOVE Y., COSYNS B., VAN DE BORNE P. & LANCELLOTTI P. (2020): Summary of 2019 ESC Guidelines on chronic coronary syndromes, acute pulmonary embolism, supraventricular tachycardia and dislipidaemias. *Acta Cardiologica* **10**, 1–8.

JAFF M.R., MCMURTRY M.S., ARCHER S.L., CUSHMAN M., GOLDENBERG N., GOLDBAHER S.Z. ET AL. (2011): Management of massive and submassive pulmonary embolism, ilieofemoral deep vien thrombosis, and chronic thromboembolic pulmonary hypertension: a scientific statement from the American Heart Association. *American Heart Association. Circulation* **123**, 1788–1830.

JIMENEZ D., KOPECHA D., TAPSON V., BRIESE B., SCHREIBLER D., LOBO J.L. ET AL. (2014): Derivation and Validation of Multi-marker Prognostication for Normotensive Patients with Acute Symptomatic Pilmonary Embolism. *Am.J. of Respir. And Crit Care Med.* **6**, 718–726.

KARPENKO A.A., ANDRIYASHKIN V.V., AN E.S., BALASHOV A.V., SON D.A., LEBEDEV I.S. & KIRIYENKO A.I. (2015): Surgical interventions for the treatment and prevention of pulmonary embolism. *Pulmonary embolism*, 123–167.

KHRIPUN A.I., ALIMOV A.N., PRYAMIKOV A.D., MIRONKOV A.B., ASRATYAN S.A., PETRENKO N.V. & ABASHIN M.V. (2015): Diagnosis and prevention of venous thromboembolic complications in patients with hemorrhagic stroke. *Thoracic and cardiovascular surgery* **3**, 10–17.

KUNTSEVICH G.I., MAKSIMOVA YU.V. & POPOVA L.A. (2012): Thrombosis of the veins of the lower extremities in the dynamics of acute disorders of cerebral circulation. *Angiology and vascular surgery* **18**(2), 77–81.

MEDVEDEV A.P., FEDOROV S.A., TROFIMOV N.A. & TSELOUSOVA L.M. (2021): Errors in the diagnosis and treatment of pulmonary embolism. *Cardiology and cardiovascular surgery* **14**(1), 54–59.

PIAZZA G.J. (2020): Advanced Management of Intermediate- and High- Risk Pulmonary Embolism: JACC Focus Seminar. *Am Coll Cardiol*, **76**(18), 2117–2127.

SAUVIC D. & SAUVIC L. (2010): Vein thromboembolsim prevention in stroke patients. *Med. Pregl.* **63**, 220–6.

SCHMITZ-RODE T. & GÜNTHER R.W. (1997): Apparatus for fragmentation of a lung embolus. *Germanpatent DE G 9409863.8, US patent 5,630,823, PCT WO 95/35066.*

SCHMITZ-RODE T., JANSSENS U., DUDA S.H., ERLEY C.M. & GÜNTHER R.W. (2000): Massive pulmonary embolism: percutaneous emergency treatment by pigtail rotation catheter. *Journal of the American College of Cardiology* **36**(2), 2154–2163.

SHARIFI M., BAY C., SKROCKI L., RAHIMI F. & MEHDIPOUR M. (2013): "MOPETT" Investigators. Moderate pulmonary embolism treated with thrombolysis (from the "MOPPET" Trial). *Am. J. Cardiol.* **11**, 273–277.

TETRI S., HAKALA J., JUVELA S. ET AL. (2008): Safety of low-dose subcutaneous enoxaparin for the prevention of venous thromboembolism after primary intracerebral haemorrhage. *Thromb. Res.* **2**, 206–212.