Endovascular treatment results in patients with large cerebral artery occlusions in a metropolis. Moscow Stroke Registry data over 2019

Skrypnik D.V.[1, 3], Anisimov K.V.[3], Botsina A.Yu.[3], Kiseleva T.V.[2], Grachev S.P.[1, 3], Shamalov N.A.[2], Vasilyeva E.Yu[1, 3], Shpektor A.V[1, 3]

[1]A.I. Evdokimov Moscow State University of Medicine and Dentistry, Ministry of Health of Russia, Moscow;
[2]Federal Center of Brain and Neurotechnologies, Federal Biomedical Agency, Moscow;
[3]I.V. Davydovsky City Clinical Hospital, Moscow Healthcare Department, Moscow
[1]20, Delegatskaya St., Build. 1, Moscow 127473, Russia; [2]1, Ostrovityanov St., Build. 10, Moscow 117997, Russia;
[3]11, Yauzskaya St., Moscow 109240, Russia

Objective: *to assess results from the Stroke Network created on the basis of the Infarction Network in the metropolis Moscow for endovascular treatment in patients with occlusion of the large cerebral artery (the internal carotid artery, the M1 and M2 segments of the middle cerebral artery, and the main artery).*

Patients and methods. *A total of 742 thromboextractions were performed in patients with ischemic stroke in Moscow Stroke Network hospitals in 2019. The final analysis included 729 patients aged 25 to 97 years (mean age, 71 years); of them there were 370 (50.8%) men and 359 (49.2%) women. The selection criteria for endovascular treatment for ischemic stroke were consistent with those set out in the 2015 American Heart Association/American Stroke Association (AHA/ASA) guidelines, which included a pre-stroke modified Rankin Scale (MRS) score of 0–1; ⩾18 years of age; a National Institutes of Health Stroke Scale (NIHSS) score of ⩾6; and an Alberta Stroke Programme Early CT score (ASPECTS) ⩾6. The angiographic results were assessed using the Thrombolysis in Cerebral Infarction (TICI) scale. The clinical outcomes were measured with the NIHSS and the MRS.*

Results and discussion. *Successful recanalization (TICI 2b/3) was achieved in 547 (75%) patients. The predominant technique for thromboextraction was thromboaspiration that was used in 376 (51.6%) patients. Combined procedures (the co-use of an aspiration catheter and a stent retriever) were the second most commonly used – in 231 (31.7%) patients. By the end of the 20th day, good functional recovery (MSR 0–2 scores) was observed in 213 (29.2%) patients. The 20-day mortality rate was 31.8%.*

Conclusion. *The successfully functioning Infarction Network in Moscow was used to create the Stroke Network for treatment in patients with ischemic stroke and large cerebral artery occlusion, the clinical results of which are comparable to large European registry studies.*

Keywords: *ischemic stroke; cerebral artery occlusion; endovascular recanalization; thromboextraction; thromboaspiration; stroke network; metropolis.*

Contact: *Dmitry Vladimirovich Skrypnik;* ***dvskrypnik@gmail.com***

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Endovascular methods of ischemic stroke (IS) treatment have become a standard option for patients with acute occlusion of large cerebral arteries [1–4]. Results of the randomized trials in 2015 showed obvious benefits of endovascular thrombectomy in comparison with conservative therapy [5–9]. The emergence of the evidence base caused the system-level changes in the stroke therapy approach, as it was necessary to provide well equipped care units, as well as to arrange a new route for eligible patients from the moment of the first emergency call to the catheterization laboratory (cath lab). Due to the addition of the endovascular component, the interdisciplinary interactions became more complicated, which raised the requirements to the interdisciplinary team organization. Only in the framework of smoothly running interaction between all components of the system it becomes possible to implement this highly efficient and technologically advanced method.

There have been different approaches to the implementation of endovascular stroke treatment in the clinical practice of different regions, depending on the existing medical infrastructure and access to neurointerventional service. There are descriptions of different routing (Drip-Ship [10], MotherShip [11], Drip-and-Drive [12], and others); each one has its own advantages and disadvantages. This article describes our experience and the results of the implementation of our methods of endovascular thrombectomy in IS patients in Moscow.

Materials and methods. ***Stroke network arrangement.*** In Moscow, we organized a network of comprehensive stroke centers (Stroke Network) for implementation of endovascular thrombectomy. Moscow Myocardial Infarction Network with its long experience became the basis for the Stroke Network.

There were 28 vascular centers functioning in Moscow at the time of the program development; they included departments for patients with acute cerebrovascular accidents (ACA) – neurological intensive care units, early rehabilitation wards, as well as radiology departments (CT/MRI). Most centers (23 out of 28) were a part of the Myocardial Infarction Network and included cath labs. The most frequently used operation type in the catheterization labs of the city vascular centers was percutaneous

coronary interventions, while the experience in performing neurointerventional procedures was extremely limited, and often was lacking at all. Only one center within the framework of the city healthcare system had a specialized unit for neurointervention.

The criteria for choosing comprehensive stroke centers for the Stroke Network, in addition to territorial ones, were the work of radiology department (CT/MRI) and 24/7 angiography services, the number and the percentage of cases of systemic thrombolytic therapy carried out for all IS patients in the hospital per year, and the experience of medical staff of the neurological service. Before launching the program, training was arranged for neurologists, interventionalists, and radiologists. The training of specialists included classes in simulation centers (using computer simulators and stream models), practicing the techniques on animals in the laboratories, as well as workshops and master classes in European centers with a large number of neurointerventional procedures. Besides, neurologists and anesthesiologists of the stroke departments were trained to use the rating scales – National Institute Health Stroke Scale (NIHSS), and Modified Rankin Scale (mRS).

The Moscow Department of Health developed a clinical protocol that regulated the procedure for providing care to stroke patients for all links of the network to standardize the work of the Stroke Network Centers.

The principle of operation of the Stroke Network was based on the prehospital selection of patients with a severe neurological deficit and, accordingly, with a greater probability of large cerebral artery occlusion. The Los Angeles Motor Scale (LAMS) was chosen for an impartial evaluation of neurological symptoms severity [13, 14].

This scale consists of three items, and the assessment of the stroke severity on this scale takes less than one minute. In addition to the neurological deficit severity, the time from the stroke onset and the level of consciousness were also taken into account (Fig. 1). If the criteria for prehospital selection were met, the patient was transferred to one of the comprehensive stroke centers for possible endovascular treatment with hospital prenotification. In other cases, a standard scheme of medical transportation to the nearest stroke center was provided.

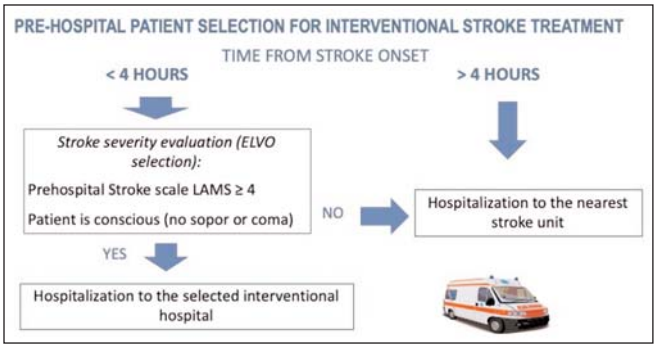

Fig. 1. *Scheme of prehospital selection of patients for comprehensive stroke centers of the Stroke Network*

In addition to the introduction of new algorithms for ambulance, the intrahospital routing of stroke patients was also changed. On the one hand, it was required to minimize the time for intrahospital movements, on the other hand, – to include additional methods in the diagnostic algorithm to identify occlusion of a large cerebral artery. In the Stroke Network centers, a patient with stroke symptoms, bypassing the general admission department, was forwarded directly to the neuroimaging room (CT or MRI), where non-invasive angiography and, if necessary, perfusion studies (CT or MR-perfusion) were performed. If a patient met the selection criteria for endovascular treatment, he was transported directly to the cath lab, bypassing the intensive care unit. Besides, the comprehensive clinical protocol regulated the possibility to start systemic thrombolytic therapy directly in the neuroimaging room, which made it possible to shorten the time from the patient admission to the beginning of reperfusion therapy.

The selection criteria for patients for endovascular treatment of IS were consistent with recommendations of American Heart Association/American Stroke Association (AHA/ASA) 2015 [15]:

a) pre-stroke mRS – 0 to 1;
b) M1 or ICA occlusion;
c) age i18 years;
d) NIHSS i6;
e) ASPECTS i6;
f) arterial puncture within 6 hours from the stroke onset.

Endovascular interventions in patients, who did not meet the criteria listed above (occlusions of other localization, low NIHSS score, premorbid mRS score > 1, etc.) were performed after the risk/benefit ratio estimation by a local council of physicians.

After the publication of the results of the DAWN and DEFUSE 3 studies in 2017, it became possible to perform thrombectomy in patients admitted within 6 to 24 hours from the stroke onset, if the criteria for inclusion in the studies were met [16, 17].

In 2017, the Stroke Network included eight comprehensive stroke centers. Due to the increase in the volume of interventions in 2018, the number of centers was increased to nine, and in 2019 – to 11 hospitals. In 2016, before the start of the interventional stroke program in Moscow, 59 thrombectomies were performed. Then, already in the first years of the network operation, their number increased to 307, and in 2019 it reached 742 cases in one year (Fig. 2). This article presents the results of the Moscow Stroke Network in 2019.

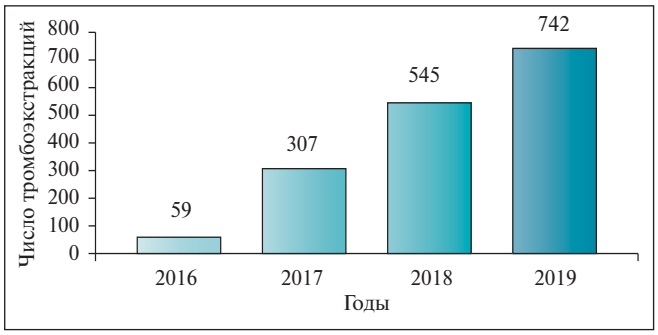

Fig. 2. *The number of thrombectomies in IS patients in the period 2016–2019*

Patient characteristics. In 2019, 742 thrombectomies were performed in IS patients in Moscow. Due to the lack of complete data, 13 patients were excluded from the analysis. The final analysis included 729 patients aged 25 to 97 years (average – 71 years), of which 370 were men (50.8%) and 359 – women (49.2%). Most of the interventions (639 thrombectomies; 87.7%) were performed in the comprehensive hospitals of the Stroke Network.

Table 1. **Patient baseline characteristics (n=729)**

Characteristics	Value
Sex, n (%):	
male	370 (50.8)
female	359 (49.2)
Age, years, Me [25; 75 percentiles] (min–max)	71 [62.0; 79.0] (25–97)
Prior stroke, n (%)	102 (14)
Stroke etiology, n (%):	
atherothrombotic	204 (28.0)
cardioembolic	306 (42.0)
unspecified etiology	208 (28.5)
other known etiology (ICA or MCA dissection)	11 (1.5)
NIHSS score on admission, Me [25; 75 percentiles] (min–max)	16 [12.0; 20.0] (1–39)
Stroke Network Center, n (%):	
Comprehensive hospital	639 (87.7)
Other hospitals	90 (12.3)

Table 2. **Time characteristics of patients (n=729)**

Characteristics	Value
Time from the ambulance call to admission to the hospital («103 – hospital»), min, Me [25; 75 percentiles] (min–max)	53 [44.0; 62.3] (31–150)
Distribution of patients in time from the stroke onset to admission to the hospital, n (%):	
<4.5 h	555 (76.1)
4.5–6 h	77 (10.6)
6–24 h	33 (4.5)
>24 h	7 (1.0)
Time of the stroke onset is unknown (including wake-up stroke)	57 (7.8)
Time from admission to hospital to arterial puncture, min, Me [25; 75 percentiles] (min–max)	85 [60.0; 117.0] (30–593)
Time from the arterial puncture to recanalization, min, Me [25; 75 percentiles] (min–max):	
total	60 [40.0; 93.5] (15–320)
in comprehensive hospitals	60 [39.0; 90.0] (15–290)
in other hospitals	80 [55.0; 95.0] (25–320)

Table 3. **Cerebral blood flow at the end of the procedure (n=729)**

TICI	Number of patients, n (%)
TICI 0	84 (11.5)
TICI 1	42 (5.8)
TICI 2a	44 (6.0)
TICI 2b	114 (15.6)
TICI 3	433 (59.4)
Unavailable data	12 (1.6)

Note. TICI (Treatment in Cerebral Ischemia) – perfusion recovery scale.

Table 4. **Occlusion localization (n=729)**

Localization	Number of patients, n (%)
M1-segment MCA	301 (41.3)
M2-segment MCA	118 (16.2)
ICA	165 (22.6)
Tandem lesion	90 (12.4)
Posterior circulation	41 (5.6)
Other lesions	14 (1.9)

Table 5. Techniques of thrombectomy (n=729)

	Value
Technique, n (%):	
Balloon guide thrombectomy with stent retriever (BGT)	99 (13.6)
Aspiration	376 (51.6)
Combined techniques	231 (31.7)
Other techniques	23 (3.2)
Number of passes, Me [25; 75 percentiles] (min–max)	2 [1; 3] (1–11)
Type of anesthesia (n=642)*:	522 (81.3)
sedation	120 (18.7)
general anesthesia	

Note. * – number of patients with available data.

The total NIHSS score on admission ranged from 1 to 39 (average – 16). In 204 (28.0%) cases, an atherothrombotic pathogenetic variant was diagnosed; in 306 (42.0%) cases – cardioembolic; in 208 (28.5%) patients – of unspecified etiology. In 11 (1.5%) patients, stroke was caused by dissection of the internal carotid artery (ICA) or middle cerebral artery (MCA). Detailed characteristics of the patients are presented in Table 1.

In most cases, the time from the stroke onset to admission to the hospital did not exceed 4.5 hours – in 555 (76.1%) patients. In the period from 4.5 to 6 hours, 77 (10.6%) patients were admitted; from 6 to 24 hours – 33 (4.5%) patients. In 57 (7.8%) patients the time of the stroke onset was unknown (including wake-up stroke). Seven patients (1.0%) were treated beyond 24 hours from the stroke onset (Table 2).

Angiographic results and clinical outcomes. Successful recanalization (TICI 2b / 3) was achieved in 547 (75%) patients (Table 3). In most cases (301 patients, 41.3%), occlusion of the M1 segment of the MCA was diagnosed. Thrombectomy was rarely performed in patients with occlusion of the arteries of the vertebrobasilar arterial system (41 patients, 5.6%). Lesions of the cerebral circulation are presented in Table 4.

Most of the interventions (81.3%) were performed using conscious sedation (Table 5). The predominant technique for thrombectomy was thromboaspiration which was used in 376 (51.6%) patients. Combined techniques (simultaneous use of an aspiration catheter and a stent retriever) were the second most frequently used procedure – 231 patients (31.7%). Variants of the thrombectomy techniques used are presented in Table 5.

The median NIHSS score by the end of the first day was 12 [6.0; 19.0]. Good functional recovery by the end of the 20th day

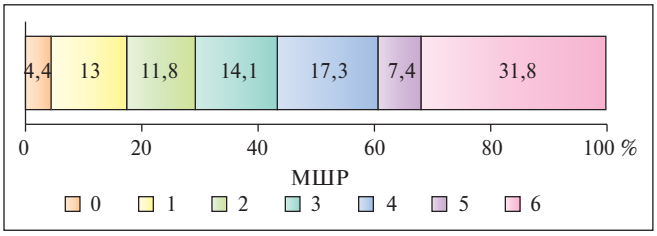

Fig. 3. *The degree of functional recovery on the 20th day according to mRS*

(mRS 0–2) was observed in 213 (29.2%) patients. The 20-day mortality rate was 31.8%. Clinical outcomes are shown in Fig. 3.

Discussion. ***Organizational aspects of the «Stroke Network».*** The introduction of the method of endovascular thrombectomy for IS into routine clinical practice is a task that requires systemic measures. In some regions of the countries with high availability of neurointerventional units (Germany, the Netherlands, France), already existing specialized centers were used to introduce the new method. Nevertheless, in some regions, the number of interventional neuroradiologists turned out to be too small for round-the-clock (24/7) work of the departments, therefore thrombectomy could be performed only during working hours [18], and in some regions such specialists were completely unavailable [19].

Even in the countries with a developed neurointerventional service, there is a problem of uneven distribution of specialists throughout the territory: they are mainly concentrated in urban academic centers. For example, in the United States, only 50% of the population lives within one hour (by land transport) from stroke centers with the possibility of performing endovascular thrombectomy [20]. According to experts, even the addition of 20 centers per state with an ideal territorial location will leave 1/3 of patients out of one-hour-reach by land transport [21].

Increasing the number of specialized neurointerventional departments is a difficult task that requires not only the launching of new operating rooms, but also training of specialists, starting with the most basic principles of endovascular surgery. Such a laborious process will require significant financial resources as well as time. In addition, the question arises about the expediency of creating a large number of neurointerventional centers, since the need for other neurointerventional procedures, in addition to those used in IS, may not be so great.

To address the issue of the lack of specialists, the involvement of interventionalists of related fields (interventional cardiologists, radiologists, vascular surgeons) is actively discussed [18, 19, 21, 22]. The positive side of this approach is that the stroke team involves specialists who routinely work with emergency vascular pathologies, for which time and team interaction are critical. Among all specialists in related fields, interventional cardiologists seem to be the most suitable for the endovascular treatment of stroke. Performing percutaneous coronary interventions requires a high level of proficiency in catheter techniques (including catheterization of atypically located coronary arteries, performing bypass grafting, and working in an elongated aorta or brachiocephalic arteries). Manipulations on the coronary circulation occur under conditions of constant movement of the arteries, while the patient is conscious.

However, interventional cardiologists are limited in fundamental knowledge about the pathophysiology of vascular diseases of the brain, cerebrovascular anatomy, and the specificity of endovascular approaches for interventions on intracranial arteries. Nevertheless, the training of such specialists in a narrow section of the neurointerventional direction should be much faster than training new personnel from scratch. At the same time, a large number of functioning cath labs with good territorial coverage will significantly improve the availability of endovascular care for patients with stroke.

Small prospective registry studies have shown that clinical outcomes in patients after thrombectomy performed in cardiac departments can be no worse than in specialized neurointervention centers [23, 24]. The problem of the lack of fundamental neurological knowledge among interventional cardiologists was solved by the involvement of a multidisciplinary team that included a neurologist and a radiologist.

At the time of Moscow stroke program development, there was a problem of a lack of specialized neurointerventional personnel. In the system of hospitals of the Moscow Department of Health, only one neurointerventional department functioned, and the number of doctors in this department did not allow it to work 24/7. At the same time, the Myocardial Infarction Network had been operating in Moscow for many years, each hospital of which was equipped with a cath lab and personnel for round-the-clock percutaneous coronary interventions. The Myocardial Infarction Network covered the entire territory of Moscow with accessibility of less than 60 minutes by land transport from any point. The hospitals of the Myocardial Infarction Network were vascular centers, each of which, in addition to the cath lab, cardiac intensive care units and cardiology departments, had radiology departments (CT / MRI), departments for patients with stroke, and the staff with experience in systemic thrombolytic therapy. Thus, the key elements for the provision of endovascular care for patients with stroke were in each of the hospitals of the Myocardial Infarction Network.

The next step in the development of the stroke program was the choice of a scheme for organizing the endovascular stroke service: to use all hospitals of the Myocardial Infarction Network or to choose only one or several centers to which all patients with diagnosed occlusion of a large cerebral artery would be sent. The accumulation of patients in one center would certainly contribute to the rapid accumulation of experience, but the load on such a center would be excessive. In addition, it was unrealistic to provide one-hour transport accessibility to one center from all districts of Moscow. If all hospitals of the Myocardial Infarction Network were used for endovascular treatment of stroke, this could lead to an extremely low number of cases per hospital and, accordingly, a slow accumulation of experience. It is known, that in centers with a small number of thrombectomy performed, clinical outcomes are worse than in centers with a large number of patients [25].

For the most rational use of available resources various routing schemes for stroke patients are used in the world practice. The Drip-Ship scheme assumes that the patient is admitted to a specialized hospital through an intermediary hospital, in which he undergoes the initial examination and thrombolytic therapy [10]. These intermediary centers cover a much larger area and, as a rule, are closer to the patient. If the occlusion of a large artery is not detected, the treatment continues in the local stroke department. Unfortunately, the time spent on the initial examination at the local hospital, organizing the transfer and transportation to the intervention center, repeated examination and neuroimaging, preparation for the intervention and the operation itself lead to

Table 6. **Comparison of clinical results and register, %**

Indicators	Stroke Network	Hamburg - Eppendorf	TGSRET	Praque-16	mrClean Registry	mrClean study
mRS ≤2	29.2	26.1	37	40	38	33
Mortality	31.8*	29.8**	29**	35**	29**	21%**
Any intracranial hemorrhages	15.2	17.4	13.2	–	–	–
TICI 2b/3	75	72	83	72	58.7	58.7

Note. * – day 20 mortality; ** – 3 months mortality.

Table 7. **Lesion localization according to registries, %**

Localization	Stroke Network	Hamburg-Eppendorf	Praque-16	mrClean Registry	mrClean study
M1 and M2 segments of MCA	57.5	54.5	44	70.3	73.8
ICA (including tandem lesions)	35	29.2	44	27.7	25.7
Vertebrobasilar arterial system	5.6	16.3	11	–	–

Table 8. **Distribution of good clinical outcomes among the Stroke Network Centers**

Number of patients with good recovery (mRS 0–2), %	Number of hospitals*	Total number of interventions in these hospitals
40–45	4	256
30–35	3	208
17–21	4	129
<17	2	80

*This analysis included centers with more than 20 interventions performed.

unacceptable delays in reperfusion [18]. According to O. Nikoubashman et al. [26], in almost a quarter of patients (24.2%), a large infarction zone is formed during transportation from an intermediary hospital to the endovascular center, which makes further reperfusion inappropriate. The authors agreed that thrombectomy should, if possible, be performed in the hospital where the patient was initially hospitalized.

An alternative MotherShip scheme involves some kind of prehospital selection, which is most often done using clinical scales. In this case, a patient with a probable occlusion of a large cerebral artery is evacuated directly to a hospital with a neurointerventional unit, bypassing the nearest intermediary hospitals [11]. The STRATIS registry has shown that direct routing of patients with occlusion of a large cerebral artery to the endovascular center has better outcomes than those with admission through intermediary hospitals [27]. Nevertheless, the time to transport such a patient to the intervention center may be prolonged due to territorial characteristics. Since the prehospital diagnosis of large cerebral artery occlusion is imperfect, the time from the stroke onset to systemic thrombolytic therapy in patients with lesions of small-caliber arteries will increase.

Considering the problems of such a large metropolis as Moscow, with intensive traffic and high availability of cath labs, an alternative option was chosen – to use a network of hospitals for endovascular treatment of stroke, but to choose among them priority hospitalization centers (comprehensive centers). This made it possible, on the one hand, to form centers with a high flow of patients, and on the other, it allowed to perform thrombectomy in other hospitals of the network, if a suitable patient was initially hospitalized there.

Discussion of the results of the network. An increase in the number of procedures. The start of the Stroke Network operation led to a significant increase in the number of interventions performed. Such a rapid introduction of the new methodology was facilitated by the experience of hospitals in working with urgent vascular pathologies: on the part of interventionalists – performing percutaneous coronary interventions in patients with acute coronary syndrome, and on the part of neurologists – conducting systemic thrombolytic therapy in patients with stroke. Despite the almost zero experience in endovascular stroke treatment by the time the program was launched in 2017, the preparatory work made it possible to establish cooperation between the units that had not interacted before. The key aspects of the organizational measures were the preparation of the medical infrastructure for new patient routing schemes, training of multidisciplinary teams and financial support of the treated cases.

The fact that most of the interventions (87.5%) were performed in comprehensive centers indirectly confirms the effectiveness of prehospital selection. Of course, the Los Angeles Motor Deficit Severity Scale, like any other prehospital clinical scale, has its own limitations with regard to the diagnosis of large cerebral artery occlusion. Nevertheless, the targeted evacuation of patients with the most severe neurological deficits to selected hospitals made it possible to increase the concentration of patients suitable for thrombectomy and contributed to a rapid increase in experience, while the T103 – hospitalУ time (53 minutes from the emergency call to hospitalization) did not exceed the average time in the city for patients with stroke.

The steady annual growth in the number of procedures required the inclusion of new comprehensive centers in the network. At the same time, the potential for increasing the number of thrombectomies remains high. According to various estimates, from 7% to 10% of all patients with IS admitted to hospitals are suitable for thrombectomy in accordance with the AHA / ASA selection criteria [28, 29]. Using advanced imaging protocols, the proportion of eligible patients can increase to 16% [28]. Extrapolating these data to the population of Moscow, it can be assumed that the number of patients eligible for thrombectomy can range from 2000 to 5000 per year.

In addition to the widespread use of the DAWN and DEFUSE3 inclusion criteria, an increase in the number of procedures can be achieved due to more frequent thrombectomy in distal lesions (M2 and M3 MCA segments), as well as in patients with lesions localized in the vertebrobasilar circulation. In 2019, in Moscow, thrombectomy in occlusions of posterior circulation arteries was performed only in 5.6% of patients, and in lesions of the distal vascular bed – in isolated cases. Such technically complex operations will require a high level of performance of the entire multidisciplinary team. However, with experience, the number of such interventions will increase.

Discussion of clinical results. Comparison of the data with other registers. The angiographic and clinical data obtained as a result of the work of the Stroke Network were comparable with the data of international registry studies (Tables 6, 7). Registries

such as The German Stroke Registry Endovascular Treatment (TGSRET) [30], Hamburg–Eppendorf [31], mrClean Registry [32] included patients from large specialized centers with a large volume of operations performed by experienced interventional neuroradiologists. Clinical outcomes, according to the data of most international registries, are usually worse than in the Tbig fiveУ randomized trials in 2015 (mRS 6 – 9–18.4%; mRS 5–6 – 17–30.1 %, mRS 0–2 – 32.6–71.7%), as well as in the HERMES meta-analysis of these five studies (mRS 6 – 15.3%, mRS 5–6 – 21.5%, mRS 0–2 – 46%) [5–9, 33]. The patient cohort in registry studies tends to differ from that in randomized trials with strict inclusion criteria that increase the chances of a good outcome. In literature, this approach was compared to «cherry-picking»; it suited well for demonstrating treatment efficacy and validating the concept [34]. In real clinical practice, the results of randomized trials are applied to patients with characteristics different from the specially selected cohort of patients, which explains the difference in outcomes.

Despite little initial experience and lack of specialists, in the short period of operation of the Stroke Network it was possible to achieve results comparable with register studies with the participation of large specialized European centers. The high rate of angiographic success (TICI 2b/3 – 75%) confirms the fundamental possibility of learning the technique of IS thrombectomy by an endovascular cardiologist.

The limitations of the Moscow register include the absence of long-term results (on the 90th day from the stroke onset), which makes the comparison of data insufficiently complete.

In a detailed analysis of the results, attention is drawn to the difference in clinical outcomes among hospitals of the Stroke Network. Some hospitals show results that correspond to expert European and American centers (mRS 0–2 – 40–45%; mortality – 14.5–20.8%); at the same time, other hospitals show results worse than the average data of international registries (Table 8).

Such a significant difference in clinical outcomes between hospitals can be due to a large number of factors: deficiencies in interdisciplinary interaction, errors of patient selection stage, time factors, technical errors, insufficient experience of doctors, defects in anesthesia, and postoperative features. Some hospitals entered the Stroke Network only in 2019 and are still at the beginning of the learning curve, which may explain the lack of work experience and the low percentage of relatively good outcomes. Some experienced hospitals, on the contrary, began to work in a wider range of indications for thrombectomy and with technically difficult lesions. This, on the one hand, increased the number of operations, and on the other hand, influenced clinical outcomes. Such trends were reflected in the total number of patients with good outcomes (mRS score – 0–2) in 2019, compared with 2017 (29.2 and 32.5%, respectively).

This uneven distribution of clinical outcomes across hospitals shows the importance of monitoring network activity and continuing training programs involving all members of the multidisciplinary stroke team of each particular hospital.

Conclusion. Thus, based on the successfully functioning Myocardial Infarction Network in Moscow, the Stroke Network was created for the treatment of patients with IS and occlusion of a large cerebral artery, the clinical results of which are comparable with large European registry studies.

The developed algorithms made it possible to concentrate patients needing emergency endovascular care in selected comprehensive hospitals of the Stroke Network in Moscow, which led to an increase in the detection rate of strokes with occlusion of a large cerebral artery and an increase in the number of endovascular interventions.

REFERENCES

1. Володюхин МЮ. Внутриартериальная реперфузионная терапия у пациентов с острым ишемическим инсультом. Медицинский совет. 2015;(10): 4-5. [Volodyukhin MYu. Intra-arterial reperfusion therapy in patients with acute ischemic stroke. *Meditsinskiy sovet*. 2015;(10):4-5 (In Russ.)].

2. Крылов ВВ, Володюхин МЮ. К вопросу об организации рентгенхирургической помощи пациентам с острым ишемическим инсультом. Нейрохирургия. 2017;(2):60-5. [Krylov VV, Volodyukhin MYu. Organization of interventional surgery for patients with acute ischemic stroke. *Neyrokhirurgiya = Russian Journal of Neurosurgery*. 2017;(2):60-5 (In Russ.)].

3. Савелло АВ, Свистов ДВ. Внутрисосудистые вмешательства в острейшем периоде ишемического инсульта: результаты последних клинических исследований и практическая перспектива. Эндоваскулярная хирургия. 2015;2(3):15-23. [Savello AV, Svistov DV. Endovascular interventions in acute stroke: last randomized controlled trials review and practical perspectives. *Endovaskulyarnaya khirurgiya = Russian Journal of Endovascular Surgery*. 2015; 2(3):15-23 (In Russ.)].

4. Анисимов КВ, Манчуров ВН, Скрыпник ДВ и др. Технические аспекты эндоваскулярного лечения ишемического инсульта. Эндоваскулярная хирургия. 2018;5(1):30-42. doi: 10.24183/2409-4080-2018-5-1-30-42 [Anisimov KV, Manchurov VN, Skrypnik DV, et al. Technical aspects of endovascular treatment for ischemic stroke. *Endovaskulyarnaya khirurgiya = Russian Journal of Endovascular Surgery*. 2018;5(1):30-42. doi: 10.24183/2409-4080-2018-5-1-30-42 (In Russ.)].

5. Saver JL. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. *N Engl J Med*. 2015 Jun 11;372(24):2285-95. doi: 10.1056/NEJMoa1415061. Epub 2015 Apr 17.

6. Jovin TG. Thrombectomy within 8 hours after symptom onset in ischemic stroke. *N Engl J Med*. 2015 Jun 11;372(24):2296-306. doi: 10.1056/NEJMoa1503780. Epub 2015 Apr 17.

7. Goyal M. Randomized assessment of rapid endovascular treatment of ischemic stroke. *N Engl J Med*. 2015 Mar 12;372(11):1019-30. doi: 10.1056/NEJMoa1414905. Epub 2015 Feb 11.

8. Campbell BC, Mitchell PJ, Kleinig TJ, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. *N Engl J Med*. 2015 Mar 12;372(11):1009-18. doi: 10.1056/NEJMoa1414792. Epub 2015 Feb 11.

9. Berkhemer OA, Fransen PSS, Beumer D, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. *N Engl J Med*. 2015 Jan 1;372(1):11-20. doi: 10.1056/NEJMoa1411587. Epub 2014 Dec 17.

10. Silverman IE, Beland DK, Chhabra J, McCullough LD. The «drip-and-ship» approach: starting IV t-PA for acute ischemic stroke at outside hospitals prior to transfer to a regional stroke center. *Conn Med*. Nov-Dec 2005;69(10):613-20.

11. Ismail M, Armoiry X, Tau N, et al. Mothership versus drip and ship for thrombectomy in patients who had an acute stroke: a systematic review and meta-analysis. *J Neurointerv Surg*. 2019 Jan;11(1):14-9. doi: 10.1136/neurintsurg-2018-014249. Epub 2018 Oct 8.

12. Brekenfeld C, Goebell E, Schmidt H, et al. 'Drip-and-drive': shipping the neurointerventionalist to provide mechanical thrombectomy in primary stroke centers. *J Neurointerv Surg*. 2018 Oct;10(10):932-6. doi: 10.1136/neurintsurg-2017-013634.

Epub 2018 Feb 7.

13. Hastrup S, Damgaard D, Paaske Johnsen S, Andersen G. Prehospital Acute Stroke Severity Scale to Predict Large Artery Occlusion: Design and Comparison With Other Scales. *Stroke*. 2016 Jul;47(7):1772-6. doi: 10.1161/STROKEAHA.115.012482. Epub 2016 Jun 7.

14. Kidwell CS, Starkman S, Eckstein M, et al. Identifying stroke in the field. Prospective validation of the Los Angeles prehospital stroke screen (LAPSS). *Stroke*. 2000 Jan;31(1):71-6. doi: 10.1161/01.str.31.1.71

15. Powers WJ, Derdeyn CP, Biller J, et al. 2015 American Heart Association/American Stroke Association Focused Update of the 2013 Guidelines for the Early Management of Patients With Acute Ischemic Stroke Regarding Endovascular Treatment: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. *Stroke*. 2015 Oct;46(10):3020-35. doi: 10.1161/STR.0000000000000074. Epub 2015 Jun 29.

16. Albers GW, Marks MP, Kemp S, et al. Thrombectomy for Stroke at 6 to 16 Hours with Selection by Perfusion Imaging. *N Engl J Med*. 2018 Feb 22;378(8):708-18. doi: 10.1056/NEJMoa1713973. Epub 2018 Jan 24.

17. Nogueira RG, Jadhav AP, Haussen DC, et al. for the DAWN Trial Investigators, Thrombectomy 6 to 24 Hours after Stroke with a Mismatch between Deficit and Infarct. *N Engl J Med*. 2018 Jan 4;378(1):11-21. doi: 10.1056/NEJMoa1706442. Epub 2017 Nov 11.

18. Holmes DR, Hopkins LN. Interventional Cardiology and Acute Stroke Care Going Forward: JACC Review Topic of the Week. *J Am Coll Cardiol*. 2019 Apr 2;73(12):1483-90. doi: 10.1016/j.jacc.2019.01.033

19. Widimsky P. Thrombectomy for stroke by cardiologists. *Eur Heart J*. 2018 Sep 1;39(33):3018. doi: 10.1093/eurheartj/ehy442

20. Adeoye O, Albright KC, Carr BG, et al. Geographic access to acute stroke care in the United States. *Stroke*. 2014 Oct;45(10):3019-24. doi: 10.1161/STROKEAHA.114.006293. Epub 2014 Aug 26.

21. White CJ. Acute Stroke Intervention: The Role of Interventional Cardiologists. *J Am Coll Cardiol*. 2019 Apr 2;73(12):1491-3. doi: 10.1016/j.jacc.2018.12.071

22. Meng SW, Kuo RC, Yang HJ, et al. Recruiting an Acute Coronary Team to Perform Emergent Mechanical Thrombectomy in Acute Ischemic Stroke Patients: A Successful Case and Team Model in a Local Hospital. *Acta Cardiol Sin*. 2018 Jan;34(1):99-103. doi: 10.6515/ACS.201801_34(1).20170730A

23. Petr W, Koznar B, Peisker T, et al. Feasibility and safety of direct catheter-based thrombectomy in the treatment of acute ischaemic stroke. Cooperation among cardiologists, neurologists and radiologists. Prospective registry PRAGUE-16. *EuroIntervention*. 2017;13(1):131-6. doi: 10.4244/EIJ-D-16-00979

24. Guidera SA, Aggarwal S, Walton JD, et al. Mechanical Thrombectomy for Acute Ischemic Stroke in the Cardiac Catheterization Laboratory. *JACC Cardiovasc Interv*. 2020 Apr 13;13(7):884-91. doi: 10.1016/j.jcin.2020.01.232

25. Kim BM, Baek JH, Heo JH, et al. Effect of Cumulative Case Volume on Procedural and Clinical Outcomes in Endovascular Thrombectomy. *Stroke*. 2019 May;50(5):1178-83. doi: 10.1161/STROKEAHA.119.024986

26. Nikoubashman O, Pauli F, Schürmann K, et al. Transfer of stroke patients impairs eligibility for endovascular stroke treatment. *J Neuroradiol*. 2018 Feb;45(1):49-53. doi: 10.1016/j.neurad.2017.07.006. Epub 2017 Sep 18.

27. Froehler MT, Saver JL, Zaidat OO, et al. Interhospital Transfer Before Thrombectomy Is Associated With Delayed Treatment and Worse Outcome in the STRATIS Registry (Systematic Evaluation of Patients Treated With Neurothrombectomy Devices for Acute Ischemic Stroke). *Circulation*. 2017;136(24):2311-21. doi: 10.1161/CIRCULATIONAHA.117.028920

28. McMeekin P, White P, James MA, et al. Estimating the number of UK stroke patients eligible for endovascular thrombectomy. *Eur Stroke J*. 2017 Dec;2(4):319-26. doi: 10.1177/2396987317733343. Epub 2017 Oct 4.

29. Chia NH, Leyden JM, Newbury J, et al. Determining the Number of Ischemic Strokes Potentially Eligible for Endovascular Thrombectomy: A Population-Based Study. *Stroke*. 2016 May;47(5):1377-80. doi: 10.1161/STROKEAHA.116.013165. Epub 2016 Mar 17.

30. Alegiani AC, Dorn F, Herzberg M, et al. Systematic evaluation of stroke thrombectomy in clinical practice: The German Stroke Registry Endovascular Treatment. *Int J Stroke*. 2019 Jun;14(4):372-80. doi: 10.1177/1747493018806199. Epub 2018 Oct 22.

31. Deb-Chatterji M, Pinnschmidt H, Flottmann F, et al. Stroke patients treated by thrombectomy in real life differ from cohorts of the clinical trials: a prospective observational study. *BMC Neurol*. 2020 Mar 5;20(1):81. doi: 10.1186/s12883-020-01653-z

32. Jansen IGH, Mulder MJHL, Goldhoorn R-JB; MR CLEAN Registry investigators. Endovascular treatment for acute ischaemic stroke in routine clinical practice: prospective, observational cohort study (MR CLEAN Registry). *BMJ*. 2018 Mar 9;360:k949. doi: 10.1136/bmj.k949

33. Goyal M, Menon BK, van Zwam WH, et al. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. *Lancet*. 2016 Apr 23;387(10029):1723-31. doi: 10.1016/S0140-6736(16)00163-X. Epub 2016 Feb 18.

34. Goyal M, Simonsen CZ, Fisher M. Future trials on endovascular stroke treatment: the not-so-easy-to-pluck fruits. *Neuroradiology*. 2018 Feb;60(2):123-6. doi: 10.1007/s00234-017-1966-0

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Skrypnik D.V. https://orcid.org/0000-0001-7457-8057
Anisimov K.V. https://orcid.org/0000-0002-4532-4434
Botsina A.Yu. https://orcid.org/0000-0001-8159-6827
Kiseleva T.V. https://orcid.org/0000-0003-4913-351X
Grachev S.P. https://orcid.org/0000-0003-1539-4068
Shamalov N.A. https://orcid.org/0000-0001-6250-0762
Vasilyeva E.Yu. https://orcid.org/0000-0002-6310-7636
Shpektor A.V. https://orcid.org/0000-0001-6190-6808