LECTURES

PREVENTION OF PERIOPERATIVE ISCHEMIC STROKE AFTER NON-CARDIAC AND NON-NEUROSURGICAL OPERATIONS IN THE LIGHT OF THE SCIENTIFIC STATEMENT AND GUIDELINES FOR THE SECONDARY PREVENTION OF ISCHEMIC STROKE AND TRANSIENT ISCHEMIC ATTACK AHA/ASA 2021. PART 1: DEFINITION, RISK FACTORS, PATHOGENESIS, PROGNOSIS, PRINCIPLES OF PRE- AND INTRAOPERATIVE PREVENTION

Kolomencev S.V. [1],
Yanishevskiy S.N. [1, 2],
Voznjouk I.A. [1, 3],
Tsygan N.V. [1, 4],
Litvinenko I.V. [1],
Shermatyuk E.I. [1],
Ilyina O.M. [5],
Kurnikova E.A. [6, 7],
Sergeeva T.V. [8, 9, 10]

[1] Kirov Military Medical Academy (Akademika Lebedeva str. 6, Saint Petersburg 194044, Russian Federation)
[2] Almazov National Medical Research Centre (Akkuratova str. 2, Saint Petersburg 197341, Russian Federation)
[3] Pavlov First Saint Petersburg State Medical University (Lva Tolstogo str. 6-8, Saint Petersburg 197022, Russian Federation)
[4] Petersburg Nuclear Physics Institute named by B.P. Konstantinov, National Research Centre "Kurchatov Institute" (Orlova Roshcha 1, Gatchina 188300, Leningrad Region, Russian Federation)
[5] Saint George City Hospital (Severnyi ave. 1, Saint Petersburg 194354, Russian Federation)
[6] City Hospital No. 26 (Kostyushko str. 2, Saint Petersburg 196247, Russian Federation)
[7] North-Western State Medical University named after I.I. Mechnikov (Piskarevsky ave. 47, Saint Petersburg 195067, Russian Federation)
[8] Saint Martyr Elizabeth City Hospital (Vavilovykh str. 14, Saint Petersburg 195257, Russian Federation)
[9] St. Petersburg State Pediatric Medical University (Litovskaya str. 2, Saint Petersburg 194100, Russian Federation)

ABSTRACT

Perioperative ischemic stroke is a potentially fatal complication that greatly increases the risk of poor outcome in surgical patients. Despite the relatively low prevalence among patients undergoing non-cardiosurgical and non-neurosurgical interventions (about 0.1–1.0 %), the total number of annually developing perioperative ischemic strokes in patients of this profile is high due to the large number of operations performed in the world. Since the publication in 2014 of the last fundamental work on the prevention of perioperative stroke, approaches to primary and secondary prevention, diagnosis, conservative and reperfusion treatment of ischemic stroke have been seriously modified. The numerous changes that have taken place have created the prerequisites for revising existing approaches to providing care for perioperative ischemic stroke. In 2021, updated documents of foreign researchers/associations on the problem of perioperative ischemic stroke in non-cardiac and non-neurosurgical patients were published. This review, which consists of two parts, presents current data that summarizes the most relevant information on this topic. The first part of the review outlines the general provisions on perioperative ischemic stroke (definition, risk factors, pathogenesis, predictive models), strategies for pre- and intraoperative prevention.

Key words: *perioperative stroke, non-cardiac and non-neurological surgery, perioperative complications, preoperative preparation, asymptomatic cerebral infarcts, intraoperative prevention*

[10] Saint Petersburg State University
(Universitetskaya emb. 7-9,
Saint Petersburg 199034,
Russian Federation)

Corresponding author:
Sergey V. Kolomencev,
e-mail: skolomencev@yandex.ru

For citation: Kolomencev S.V., Yanishevskiy S.N., Voznjouk I.A., Tsygan N.V., Litvinenko I.V., Shermatyuk E.I., Ilyina O.M., Kurnikova E.A., Sergeeva T.V. Prevention of perioperative ischemic stroke after non-cardiac and non-neurosurgical operations in the light of the Scientific Statement and Guidelines for the Secondary Prevention of Ischemic Stroke and Transient Ischemic Attack AHA/ASA 2021 Part 1: Definition, risk factors, pathogenesis, prognosis, principles of pre- and intraoperative prevention. *Acta biomedica scientifica*. 2023; 8(2): 103-116. doi: 10.29413/ABS.2023-8.2.10

Received: 10.10.2022
Accepted: 09.03.2023
Published: 05.05.2023

ПРОФИЛАКТИКА ПЕРИОПЕРАЦИОННОГО ИШЕМИЧЕСКОГО ИНСУЛЬТА ПОСЛЕ НЕКАРДИОХИРУРГИЧЕСКИХ И НЕНЕЙРОХИРУРГИЧЕСКИХ ОПЕРАЦИЙ В СВЕТЕ НАУЧНОГО ЗАЯВЛЕНИЯ И РЕКОМЕНДАЦИЙ ПО ВТОРИЧНОЙ ПРОФИЛАКТИКЕ ИШЕМИЧЕСКОГО ИНСУЛЬТА И ТРАНЗИТОРНОЙ ИШЕМИЧЕСКОЙ АТАКИ AHA/ASA 2021 г. ЧАСТЬ 1: ОПРЕДЕЛЕНИЕ, ФАКТОРЫ РИСКА, ПАТОГЕНЕЗ, ПРОГНОЗИРОВАНИЕ, ПРИНЦИПЫ ПРЕД- И ИНТРАОПЕРАЦИОННОЙ ПРОФИЛАКТИКИ

Коломенцев С.В. [1],
Янишевский С.Н. [1, 2],
Вознюк И.А. [1, 3],
Цыган Н.В. [1, 4],
Литвиненко И.В. [1],
Шерматюк Е.И. [1],
Ильина О.М. [5],
Курникова Е.А. [6, 7],
Сергеева Т.В. [8, 9, 10]

[1] ФГБВОУ ВО «Военно-медицинская академия им. С.М. Кирова» Министерства обороны Российской Федерации (194044, г. Санкт-Петербург, ул. Академика Лебедева, 6, Россия)
[2] ФГБУ «Национальный медицинский исследовательский центр им. В.А. Алмазова» Минздрава России (197341, г. Санкт-Петербург, ул. Аккуратова, 2, Россия)
[3] ФГБОУ ВО «Первый Санкт-Петербургский государственный медицинский университет имени академика И.П. Павлова» Минздрава России (197022, г. Санкт-Петербург, ул. Льва Толстого, 6-8, Россия)
[4] ФГБУ «Петербургский институт ядерной физики имени Б.П. Константинова», НИЦ «Курчатовский институт» (188300, Ленинградская область, г. Гатчина, мкр. Орлова роща, 1, Россия)
[5] СПб ГБУЗ «Городская больница Святого Великомученика Георгия» (194354, г. Санкт-Петербург, просп. Северный, 1, Россия)
[6] СПб ГБУЗ «Городская больница № 26» (196247, г. Санкт-Петербург, ул. Костюшко, 2, Россия)

РЕЗЮМЕ

Периоперационный ишемический инсульт является потенциально смертельным осложнением, многократно увеличивающим риск неблагоприятного исхода у пациентов хирургического профиля. Несмотря на относительно низкую распространённость среди пациентов, подвергающихся некардиохирургическим и ненейрохирургическим вмешательствам (около 0,1–1,0 %), общее число ежегодно развивающихся периоперационных ишемических инсультов у пациентов данного профиля является высоким ввиду большого числа выполняемых в мире операций. С момента опубликования в 2014 г. последней фундаментальной работы на тему профилактики периоперационного инсульта подходы к первичной и вторичной профилактике, диагностике, консервативному и реперфузионному лечению ишемического инсульта были серьёзно модифицированы. Произошедшие многочисленные изменения создали предпосылки к пересмотру существующих подходов к оказанию помощи при периоперационном ишемическом инсульте. В 2021 г. в свет вышли обновлённые документы зарубежных исследователей/ассоциаций, посвящённые проблеме периоперационного ишемического инсульта у пациентов некардиохирургического и ненейрохирургического профиля. В настоящем обзоре, состоящем из двух частей, представлены современные данные, обобщающие наиболее актуальную информацию по данной теме. В первой части обзора изложены общие положения о периоперационном ишемическом инсульте (определение, факторы риска, патогенез, модели прогнозирования), стратегии пред- и интраоперационной профилактики.

Ключевые слова: *периоперационный инсульт, некардиохирургическое и ненейрохирургическое оперативное вмешательство, периоперационные осложнения, предоперационная подготовка, асимптомный церебральный инфаркт, интраоперационная профилактика*

[7] ФГБОУ ВО «Северо-Западный государственный медицинский университет имени И.И. Мечникова» Минздрава России (195067, Россия, г. Санкт-Петербург, Пискаревский просп., 47, Россия)
[8] СПб ГБУЗ «Городская больница Святой преподобномученицы Елизаветы» (195257, г. Санкт-Петербург, ул. Вавиловых, 14, Россия)
[9] ФГБОУ ВО «Санкт-Петербургский государственный педиатрический медицинский университет» Минздрава России (194100, г. Санкт-Петербург, ул. Литовская, 2, Россия)
[10] ФГБОУ ВО «Санкт-Петербургский государственный университет» (199034, г. Санкт-Петербург, Университетская наб., 7-9, Россия)

Автор, ответственный за переписку:
Коломенцев Сергей Витальевич,
e-mail: skolomencev@yandex.ru

Для цитирования: Профилактика периоперационного ишемического инсульта после некардиохирургических и ненейрохирургических операций в свете Научного заявления и Рекомендаций по вторичной профилактике ишемического инсульта и транзиторной ишемической атаки AHA/ASA 2021 г. Часть 1: Определение, факторы риска, патогенез, прогнозирование, принципы пред- и интраоперационной профилактики. *Acta biomedica scientifica*. 2023; 8(2): 103-116. doi: 10.29413/ABS.2023-8.2.10

Статья поступила: 10.10.2022
Статья принята: 09.03.2023
Статья опубликована: 05.05.2023

INTRODUCTION

Perioperative ischemic stroke (PS) is a potentially fatal complication in patients undergoing any surgical intervention, multiplying the risk of unfavorable outcome many times over. For example, after non-cardiac and non-neurosurgical surgery, the 30-day risk of mortality increases 8–10-fold with absolute mortality rates of 21 to 26 % [1–3]. Despite the fact that historically the problem of PS became the most obvious in cardiovascular surgery due to the relatively high prevalence of this complication in cardiac surgery patients (2–10 % depending on the type of surgery [4]), at present the task of PS prevention and treatment is extremely relevant for patients of any surgical profile. Although the proportion of PSs in patients undergoing non-cardiac and non-neurological interventions is relatively low (0.1 % to 1.0 % depending on the type of surgery; see Table 1), the total number of PSs developing annually in this category of patients is high due to the large number of operations performed worldwide and represents a significant public health burden. More than 250 million surgical procedures are performed annually worldwide [3]; major surgeries are performed annually in 4 % of the world's total population [5]. Given a total European population of more than 500 million, the annual number of major interventions is estimated at 19 million, with 5.7 million surgeries (30 %) performed in patients at increased risk of cardiac complications. In the United States, more than 5 million patients over 45 years of age undergo non-cardiac surgery each year, with an estimated number of PSs of more than 25,000 cases per year [3]. In Russia, there has also been a steady increase in the number of surgeries performed annually over the last few years: in 2005 – 8,735 thousand, in 2010 – 9,277 thousand, in 2015 – 9,882 thousand, in 2016 – 9,974 thousand, in 2017 – 9,943 thousand, in 2018 – 10,020 thousand [6]; and the estimated number of PSs in Russia may be as high as 15,000–20,000 per year. PSs increase the length of stay and the probability of discharge to a long-term care facility [2, 7, 8].

PS prognosis, prevention, and treatment are currently receiving considerable attention. The greatest focus has traditionally been on investigating the issues and reducing the risks of PS in cardiac surgical patients. As of publishing the article, the main document on PS prevention among patients in this category is Scientific Statement from the American Heart Association 2020: Considerations for Reduction of Risk of Perioperative Stroke in Adult Patients Undergoing Cardiac and Thoracic Aortic Operations [9]. The basic document covering the problem of PS in non-cardiac and non-neurological patients for a long time was Perioperative Care of Patients at High Risk for Stroke during or after Non-Cardiac, Non-Neurologic Surgery: Consensus Statement from the Society for Neuroscience in Anesthesiology and Critical Care edited by G.A. Mashour et al. [10]. In 2021, a new American Heart Association/American Stroke Association (AHA/ASA) scientific statement, «Perioperative Neurological Evaluation and Management to Lower the Risk of Acute Stroke in Patients Undergoing Noncardiac, Nonneurological Surgery» was published summarizing current thinking about the problem of PS in patients after non-cardiac and non-neurological surgeries. Furthermore, new AHA/ASA Guidelines for the Secondary Prevention of Ischemic Stroke and Transient Ischemic Attack [11] were published in 2021, complementing the AHA/ASA Scientific Statement 2021 in terms of PS prevention issues. The multi-part review presents data summarizing information from these two documents. The first part of the review outlines the general background of PS (definition, risk factors, pathogenesis, prediction models, preoperative and intraoperative prevention strategies). The following parts of the review will outline the current principles of antithrombotic therapy in the perioperative period, diagnosis and treatment of PS.

Definition and risks of perioperative ischemic stroke. Perioperative stroke can be defined as any embolic, thrombotic, or hemorrhagic cerebrovascular event with motor, sensory, or cognitive dysfunction lasting at least 24 hours, occurring during surgery or within 30 days of surgery. As with non-perioperative cerebrovascular events, most PSs are ischemic rather than hemorrhagic. The incidence of PS in patients undergoing noncardiac, non-neurosurgical surgeries ranges from 0.1 % to 1.0 %, according to the following retrospective studies [10] (Table 1).

Using the US National (Nationwide) Inpatient Sample (NIS) from 2004 to 2013, N.R. Smilowitz et al. reported that despite an overall decrease in the composite of major adverse cardiovascular and cerebrovascular events in non-cardiac surgery, the incidence of PS increased during this period from 0.52 % in 2004 to 0.77 % in 2013. A trend toward increased PS risk was evident for both men and women and among different races and ethnic groups. Of note, all of these studies did not independently clinically evaluate patients with PS, nor did they always use magnetic resonance imaging (MRI) to accurately temporally assess the ischemic event, so the true number of PSs may be higher or lower than in the data reported by the investigators [12].

Common risk factors for perioperative stroke. Numerous studies have consistently identified elderly age, kidney disease, and prior transient ischemic attack/stroke as key risk factors for PS. Risk factors such as myocardial infarction within the previous 6 months, atrial fibrillation, arterial hypertension, chronic obstructive pulmonary disease, current smoking, female gender, and diabetes mellitus were also identified as independent, further increasing the risk of PS. There is evidence that patients who underwent emergency surgery or certain types of surgery (head and neck, thoracic, intra-abdominal, vascular, transplant, orthopedic surgeries) were at higher risk of developing PS [12].

Asymptomatic cerebral infarct. Asymptomatic cerebral infarcts, sometimes referred to in the English-language literature as covert or silent strokes, are acute cerebral ischemic events without clinical manifestations. Cerebral infarctions are usually detected by neuroimaging techniques

TABLE 1

THE INCIDENCE OF PERIOPERATIVE ISCHEMIC STROKE AFTER NON-CARDIAC AND NON-NEUROSURGICAL OPERATIONS

Types of surgeries	PS, all patients, % (*n*)	PS, patients of or over 65 years of age, % (*n*)
Bateman B.T. et al. (2009); Nationwide Inpatient Sample		
Hip replacement surgery (*n* = 1,568)	0.4 (6)	0.5 (5)
Lung resection (*n* = 1,484)	0.3 (5)	0.7 (5)
Colon resection (*n* = 33,426)	0.4 (130)	0.7 (100)
Mashour G.A. et al. (2011); American College of Surgeons–National Surgical Quality Improvement Program		
Bile duct surgery (*n* = 43,289)	0.1 (36)	0.2 (23)
Breast removal surgery (*n* = 36,793)	0.0 (16)	0.1 (11)
Hernia surgery (ventral/umbilical/postoperative/other) (*n* = 32,638)	0.1 (28)	0.3 (21)
Inguinal hernia surgery, including usage of surgical mesh made from plastic (*n* = 26,448)	0.1 (17)	0.1 (10)
Appendectomy (*n* = 26,046)	0.0 (6)	0.2 (4)
Bariatric esophageal and gastric surgeries (*n* = 23,766)	0.0 (5)	0.0 (0)
Extracerebral and neck tumors (*n* = 20,057)	0.0 (7)	0.1 (3)
Thoracic/femoral small vessel surgery (*n* = 5,883)	0.0 (2)	0.1 (1)
Small intestine – resection/stoma (*n* = 5,860)	0.5 (27)	0.6 (14)
Small intestine – lysis of adhesions, others (*n* = 5,683)	0.3 (17)	0.7 (14)
Diagnostic studies of abdominal organs (*n* = 5,760)	0.5 (26)	0.9 (18)
Surgical management of pancreatitis (*n* = 4,832)	0.3 (15)	0.5 (10)
Limb amputation (*n* = 4,800)	0.8 (37)	1.1 (29)
Gastric surgeries (*n* = 4,749)	0.3 (16)	0.7 (12)
Esophageal surgeries (*n* = 4,635)	0.0 (1)	0.1 (1)
Hysterectomy (*n* = 4,454)	0.1 (3)	0.2 (2)

TABLE 1 (*continued*)

Types of surgeries	PS, all patients, % (*n*)	PS, patients of or over 65 years of age, % (*n*)
Arthroscopy (*n* = 4,255)	0.0 (0)	0.0 (0)
Spinal surgeries (*n* = 3,480)	0.1 (4)	0.3 (3)
Abdominoperineal resection (*n* = 3,169)	0.0 (0)	0.5 (5)
Knee surgeries (*n* = 2,970)	0.1 (4)	0.2 (4)
Anorectal abscess (*n* = 2,508)	0.0 (0)	0.0 (0)
Simple skin and soft tissue surgeries (*n* = 2,383)	0.3 (6)	0.6 (4)
Coloanal anastomosis (*n* = 2,293)	0.2 (4)	0.2 (2)
Liver surgeries (*n* = 2,144)	0.3 (6)	0.8 (6)
Anorectal resection (*n* = 2,103)	0.0 (1)	0.0 (0)
Surgeries for bone fractures (*n* = 2,065)	0.1 (3)	0.3 (3)
Skin and soft tissue biopsies (*n* = 2014)	0.1 (2)	0.2 (1)

and are catamnestically associated with the development of cognitive impairment, dementia, increased risk of recurrent stroke, and increased mortality. The incidence of perioperative asymptomatic cerebral infarcts varies according to the type of surgery and is probably higher in patients undergoing vascular or cardiac surgery. The detection rate of asymptomatic cerebral infarcts after carotid endarterectomy (CEA) can be as high as 17 %, and 30–50 % after internal carotid artery (ICA) stenting or cardiac surgery. The development of asymptomatic cerebral infarcts after ICA stenting was also associated with an increased risk of recurrent cerebral ischemic events, with this risk increasing with the number of areas of silent infarctions. According to a prospective multicenter pilot study by M. Mrkobrada et al. (2016), in 100 patients over 65 years of age after non-cardiac surgery, the incidence of asymptomatic cerebral infarcts based on postoperative MRI was 10 %. In the larger multicenter prospective Neurovision study, asymptomatic cerebral infarct was diagnosed in 7 % of patients based on routine MRI scans of 1,114 patients performed on days 2–9 after elective non-cardiac surgery. Among these patients, the risk of cognitive decline during 1-year follow-up was almost 2-fold higher compared with patients without evidence of asymptomatic cerebral damage. The incidence of perioperative delirium was also higher in the perioperative asymptomatic cerebral infarct group [12].

Pathogenesis of perioperative ischemic stroke. In patients undergoing cardiac surgery, nearly 2/3 of ischemic strokes are the result of emboli from proximal sources: either as a result of direct manipulation of the heart/major arteries or intraoperative performance of the bypass pump, or as a result of the development of delayed complications such as atrial fibrillation or myocardial infarction (MI). In patients who have undergone non-cardiac surgery or intervention on great vessels, the cause of PS is less clear. Stroke subtypes were not established in most studies because many of the earlier studies did not include advanced diagnostic tests such as MRI or vascular imaging. PS mechanisms suggested for patients undergoing non-cardiac and non-neurosurgical operations may include hypotension/low blood flow states, previously undetected large artery stenosis, tissue hypoxia associated with anemia, thromboembolism (including cardiac and transcardiac), fat embolism, and increased coagulation/thrombosis in the setting of systemic inflammation, endothelial dysfunction, and discontinuation of antithrombotic drugs preoperatively [12].

Perioperative stroke risk stratification. Numerous cardiovascular risk stratification tools have been used to predict perioperative complications, including the Revised Cardiac Risk Index (RCRI), the MI or Cardiac Arrest Calculator, and the American College of Surgeons Surgical Risk Calculator (ACS-SRC), but all of these tools have not been developed specifically for PS risk prediction. Two other risk assessment scales, CHADS2 and CHA2DS2-VASc, were originally developed and validated to predict the annual risk of stroke in patients with nonvalvular atrial fibrillation; however, it has been shown that they predict the perioperative risk of stroke in cardiac surgery patients even in the absence of atrial fibrillation.

The effectiveness of these tools in PS risk stratification was retrospectively evaluated by ACS investigators in a large cohort of patients (n = 540,717) undergoing noncardiac surgery using the US National Surgical Quality Improvement Program registry. The proportion of patients with PS in the studied sample was 0.27 %, and the highest frequency was observed in patients undergoing vascular surgery or neurosurgery. The ACS surgical risk calculators and the MI/cardiac arrest risk calculator demonstrated greater high predictive accuracy than other risk prediction models, even though they were not designed to predict stroke risk. The AHA/ASA 2021 Scientific Statement recommends a uniform approach for identifying patients at increased risk of PS using the ACS web-based surgical risk calculator [13]. It would be advisable to discuss the results of the prognosis with patients to inform them about the risks and to make joint decisions about surgery, with the caveat that this calculator, although not directly predicting the risk of stroke, can identify patients at high risk of serious complications in general, including those with a high probability of stroke in the perioperative period [12].

Timing of surgical interventions after previous stroke. Patients with previous ischemic stroke are at increased risk of PS. In this case, the risk of PS depends on the length of time between the history of stroke and the surgery performed. In 2014, M. Jørgensen et al. analyzed the data of the Danish National Patient Registry and reported an increased risk of ischemic stroke and other serious adverse cardiovascular events (MI and death due to other cardiovascular causes) in patients who underwent non-cardiac surgery after a previous stroke (Table 2) [12].

Patients who underwent elective non-cardiac surgery within 3 months of stroke had the highest risk of ischemic stroke. Although the risk of serious adverse cardiovascular and cerebrovascular events, 30-day mortality, and ischemic stroke was higher in patients undergoing non-cardiac surgery within 12 months of a previous stroke overall, the increased odds ratio for each of these end points leveled off by about month 9. Using the same data, these authors also showed that patients who underwent emergency non-cardiac surgery within 3 months of a previous stroke were more than 20 times more likely to develop PS. Similar temporal trends in PS risk have been observed after stroke in patients who did not undergo surgery, but the absolute event rates in these studies of perioperative patients were higher than in observational studies or clinical trials among unoperated patients with recent transient ischemic attack or nondisabling stroke. Although evidence of an association between timing of surgery and stroke risk is limited

TABLE 2

ADJUSTED ODDS RATIO OF PERIOPERATIVE ISCHEMIC STROKE STRATIFIED BY TIME BETWEEN HISTORY OF ISCHEMIC STROKE AND SURGERY

Indicators	Number of strokes, *n*	Number of follow-ups, *n*	Stroke rate, %	Odds ratio (95 % CI)
No history of ischemic stroke	368	474,046	0.078	1
Ischemic stroke (age undetermined)	210	7,137	2.94	16.24 (13.23–19.94)
Ischemic stroke < 3 months ago	103	862	11.95	67.60 (52.27–87.42)
Ischemic stroke from 3 to 6 months ago	21	469	4.48	24.02 (15.03–38.39)
Ischemic stroke from 6 to 12 months ago	16	898	1.78	10.39 (6.18–17.44)
Ischemic stroke ≥ 12 months ago	70	4,908	1.42	8.17 (6.19–10.80)

Note. 95 % CI – 95 % confidence interval.

to only these two studies, the AHA/ASA, to reduce the risk of perioperative stroke in patients undergoing non-cardiac surgery, suggests delaying elective non-cardiac surgery for at least 6 months and, if possible, even 9 months after a previous stroke [12].

Extracranial carotid artery stenosis. The AHA/ASA Guidelines for the Secondary Prevention of Ischemic Stroke and Transient Ischemic Attack recommend that patients with a high degree of extracranial stenosis (> 70 %) and ipsilateral symptoms of ischemic stroke or transient ischemic attack within the past 6 months undergo CEA or ISA stenting. Patients with moderate symptomatic stenosis (50–69 %) are also considered for revascularization surgery if the surgical risk is < 6 %. It is important to consider that performing carotid artery stenting and CEA is itself associated with cardiovascular risks. For example, carotid artery stenting is associated with a slightly higher risk of stroke and CEA with a slightly higher risk of MI. Recommendations for patients with known asymptomatic high-grade ISA stenosis who are to undergo non-cardiac and non-neurosurgical interventions are ambiguous. However, patients with known asymptomatic high-grade ISA stenosis (> 70 % by ultrasound or > 60 % by selective angiography) should be considered candidates for CEA and ISA stenting if the perioperative risks of stroke, MI, and death are < 3 %, according to the 2021 AHA/ASA guidelines. Planned surgical procedures may be delayed if carotid revascularization treatment is planned (for symptomatic or asymptomatic high-grade carotid stenosis), but the optimal duration of this delay is unknown and may be determined predominantly by the timing of the most recent cerebrovascular event (no earlier than 6–9 months after a previous stroke) [12].

The European Stroke Organization (ESO) guidelines published in the European Stroke Journal in 2021 regarding stroke prevention in patients with carotid atherosclerosis, in accordance with meta-analyses of randomized controlled trials on primary stroke prevention, recommend surgical intervention on the ISA when asymptomatic stenosis is 60–99 % [14]. CEA is favored as the surgical intervention. The relative risk (RR) of stroke ipsilateral stenosis after CEA compared with optimal medical therapy is 0.79 (95 % confidence interval (95% CI): 0.59–0.90), equivalent to a reduction of 19 cases per 1,000 patients. There was also evidence that post-CEA reduced the risk of stroke in any cerebral blood supply basin (RR = 0.74; 95% CI: 0.59–0.92). Perioperative safety of surgical interventions is currently of special concern, and European guidelines define the borderline rate of perioperative stroke or death for patients with asymptomatic stenosis as 2 % [15]. For secondary stroke prevention, there is strong evidence regarding the need for surgery at 70–99 % ISA stenosis (RR = 0.37; 95% CI: 0.27–0.50, corresponding to a reduction of 169 cases per 1,000 patients) and moderate strength evidence regarding the efficacy and safety of interventions at 50–69 % stenosis (RR = 0.82; 95% CI: 0.58–1.15, corresponding to a reduction of 29 cases per 1,000 patients). CEA is recommended as surgery for all patients having 50–99 % stenosis. For the group of patients younger than 70 years of age, stenting with angioplasty is recommended as an alternative. Patients with ISA stenoses < 50 % are not currently recommended to undergo surgery in routine practice. The timing of interventions is determined by the following decisions: the minimum is within the next 2 weeks after stroke (i. e., at the first medical center where the stroke patient is located); the maximum is up to 6 months, and the patient's disability should not exceed a mRS score of 3 [14].

Intracranial stenosis. Asymptomatic intracranial stenosis (50–99 % as measured by selective angiography) carries a 15 % risk of recurrent stroke within the first year after the event, but the overall risk of PS in this patient population remains unknown. Stroke prevention in a patient with intracranial stenosis is non-surgically managed with antithrombotic therapy and careful modification of risk factors. Intracranial stenosis stenting is accompanied by an increased risk of hemorrhagic complications, and the experience of using these operations among patients who did not receive conservative medical treatment is limited by a small number of follow-ups. A small retrospective study by D. Blacker et al. (2003) of patients with severe intracranial stenosis of vertebral or basilar arteries who underwent surgical intervention (vascular, cardiac or general) showed that the PS rate in the studied group was 6 % [12].

Patent foramen ovale. Patent foramen ovale (PFO) is present in 25 % of the population and is not associated with any morbidity among most people. However, data from three recent clinical trials (Søndergaard L. et al., 2017; Mas J. et al., 2016; Saver J. et al., 2017) support the potential association between PFOs and cryptogenic stroke in patients aged < 60 years and the benefit of PFO closure in selected patient groups. In a retrospective study of more than 150,000 patients undergoing non-cardiac surgery under general anesthesia, Ng et al. (2018) found that a diagnosis of PFO established preoperatively significantly increased the likelihood of PS. These patients had more severe PSs and were more often accompanied by involvement of large vascular territories with the formation of extensive zones of ischemic damage. In a large study of patients undergoing a total hip replacement; from the US National (Nationwide) Inpatient Sample, the risk of PS was 29 times higher (7.14 % vs. 0.26 %; $p < 0.001$) among patients with atrial septal defect/PFO compared with controls. Thus, there is a need for further research to develop optimal approaches for PS prevention in the population of individuals with PFO. If there is evidence of the need for surgery to close the PFO, it should be considered before elective surgery is performed; and urgent and emergent surgical interventions should not be delayed to address the PFO [12].

β-blockers. In 2008, a large randomized controlled trial regarding the use of β-blockers in POISE perioperative conditions (Effects of extended-release metoprolol succinate in patients undergoing non-cardiac surgery) revealed a tendency to increase the number of PSs, possibly associated with arterial hypotension against the background of metoprolol administration, while no such dependence was shown for other β-blockers. However, in 2017, M. Jørgensen et al. based on a large cohort study found no difference in the risk of overall mortality or serious adverse cardiac events when using different subtypes of β-blockers.

The AHA/ASA 2021 Scientific Statement on Perioperative Ischemic Stroke Prevention in Patients after non-Cardiac and non-Neurosurgical Operations, citing the 2014 ACC/AHA Guideline on Perioperative Cardiovascular Evaluation And Management Of Patients Undergoing Noncardiac Surgery: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines) supports the continuation of β-blockers in patients who have already been taking β-blockers for an extended period of time prior to surgery. These guidelines also suggest that β-blockers should be offered to patients with established high cardiac risk based on preoperative evaluation or in the presence of ≥ 3 risk factors according to RCRI, but even in these cases β-blockers should not be started on the day of surgery [12].

Statins. To reduce the risk of cardiovascular events, patients already taking statins are advised to continue perioperative therapy prior to non-cardiac surgery. Multiple cohort studies (Berwanger O. et al., 2016; London J. et al., 2017; Ma B. et al., 2018) and the results of a recent meta-analysis of patients undergoing non-cardiac surgery (study groups included vascular surgery and neurosurgery) show that the use of statins in the perioperative period leads to significant reductions in postoperative MI, death from cardiac causes, de novo atrial fibrillation, and all-cause mortality, including myocardial injury and stroke. However, none of these studies showed a significant reduction in the risk of PS [12].

Arterial blood pressure. Maintaining appropriate perfusion of the heart, brain, and other vital organs is the cornerstone of anesthesia management. A significant number of anesthesiologists commonly use a mean arterial pressure (MAP)[1] of 60 mmHg and a systolic BP of 100 mmHg as the threshold, assuming that in healthy individuals without cerebrovascular disease, cerebral blood flow is maintained within a range of 60 to 150 mmHg. Intraoperative drop in BP is a very common event, with episodes of drop in MAP below 20 % of baseline occurring in 90 % of surgical procedures. There are currently about 140 different definitions of intraoperative hypotension, but the most common are: a decrease in systolic BP < 80 mmHg and a decrease in systolic BP more than 20 % below baseline.

Hypotension can be considered a modifiable risk factor for PS. However, most studies that have examined the causal relationship between intraoperative hypotension and perioperative strokes have inconclusive evidence, with the exception of the results of the POISE study (2008).

Currently, there is insufficient evidence defining target values of intraoperative BP levels that reliably prevent the development of cerebral ischemia. At the same time, there is evidence of BP thresholds associated with target organ damage and mortality. A 2018 systematic review reported a modest increase in the risk of target organ damage and mortality (RR = 1.4–2.0) with a decrease in MAP < 65 mmHg lasting > 10 min, but no statistically significant associations between MAP thresholds and stroke were found. In 2017, the multicenter randomized controlled trial (INPRESS) (Effect of individualized vs standard blood pressure management strategies on postoperative organ dysfunction among high-risk patients undergoing major surgery: A randomized clinical trial) found that maintaining systolic BP fluctuations within 10 % of baseline was associated with a 30 % reduction in postoperative internal organ dysfunction. However, this study has been criticized because the BP targets in the control group were much lower than those used by most anesthesiologists. Nowadays, the Perioperative Quality Initiative Consensus Statement on Intraoperative Blood Pressure, Risk and Outcomes for Elective Surgery 2019 guidelines (concerning that systolic BP values < 100 mmHg and MAP < 60–70 mmHg may be associated with myocardial and renal damage) are the most convincing.

Recognizing the current lack of data to establish accurate intraoperative BP targets to reduce the risk of perioperative strokes, the AHA/ASA 2021 Scientific Statement suggests considering maintaining intraoperative MAP above 70 mm Hg. Although, there are no data on upper thresholds for intraoperative MAP in non-cardiac surgery, it is recommended to avoid excessive hypertension, which may cause myocardial ischemia, cerebral edema, or damage to other target organs. Also, the AHA/ASA 2021 Scientific Statement supports the recommendations of G.A. Mashour et al. (2014) that the BP difference between the brachial artery and the brain should be taken into account when performing surgery in the sitting position (e. g., shoulder, cervical spine surgery) [12].

Perioperative targeted (directed) therapy. Thirty years ago, W.C. Shoemaker et al. first outlined the principles of targeted therapy aimed at maintaining optimal target organ perfusion among high-risk surgical patients. Despite the controversy over its benefits, targeted therapy continues to be widely used in clinical practice. A 2013 Cochrane meta-analysis based on 31 randomized trials involving 5,092 participants found that administration of fluids and vasoactive agents aimed at increasing total blood flow did not significantly reduce mortality, but did reduce overall complication rates by 32 %, including 29 % reduction in the rate of renal failure and 49 % reduction in the rate of respiratory distress/acute respiratory distress syndrome. In 2014, the multicenter, randomized, controlled OPTIMISE (Effect of a perioperative, cardiac output–guided hemodynamic therapy algorithm on outcomes following major gastrointestinal surgery) trial reported a 6.8 % reduction in the postoperative absolute risk of complications and 30-day mortality (95% CI: 0.38–13.9 %; $p = 0.07$) in 734 high-risk patients undergoing major gastrointestinal surgery who received targeted therapy aimed at maintaining cardiac output. Although

[1] Calculation formula is as follows:
MAP = 1/3 × systolic BP + 2/3 × diastolic BP

the results of this study were not statistically significant on their own, their inclusion in the updated meta-analysis established the overall benefit of targeted perioperative hemodynamic support techniques (hazard ratio, 0.77 [95% CI: 0.71–0.83]). So far, no study of perioperative targeted therapy has demonstrated its effectiveness in preventing the development of perioperative stroke, which may be explained by the relatively low incidence of PS and insufficient sample size [12].

Transfusion of blood and its components in the perioperative period. Anemia is known to increase the risk of stroke in non-surgical patients and is associated with a higher risk of poor functional outcomes and mortality in patients with acute stroke. However, two large observational studies of patients undergoing non-cardiac surgery have not shown an increased incidence of adverse central nervous system outcomes among patients with preoperative anemia. Using data from more than 227,000 patients, K.M. Musallam et al. (2011) found that patients with moderate to severe anemia were 44 % more likely to experience mortality, 52 % more likely to experience cardiac complications, and 41 % more likely to experience respiratory complications compared to patients without anemia. However, no differences in central nervous system complications, including PS, were found. L. Saager et al. (2013) also reported similar findings using data on nearly 575,000 patients. Collectively, these studies form a somewhat confusing picture of anemia being a risk factor for stroke in the general population but not in patients undergoing non-cardiac surgery.

Although anemia is associated with higher rates of mortality and morbidity among patients undergoing non-cardiac surgery, observational studies have consistently demonstrated that patients who received blood transfusion in the perioperative period have worse outcomes compared to the group without hemotransfusion (Bernard A. et al., 2009; Glance L. et al., 2011; Ferraris A. et al., 2012; Karkouti K. et al., 2012; Aquina C. et al., 2017). However, the pooled results of randomized trials did not support this information, revealing an overestimation of the risks associated with performing hemotransfusion. A 2018 meta-analysis based on 37 randomized controlled trials involving > 19,000 patients showed that the risk of stroke, MI, congestive heart failure, renal failure, and 30-day mortality were not significantly influenced by hemoglobin thresholds before starting transfusion. The authors of the study believe that a major limitation of this meta-analysis is that it did not include enough information on patients with traumatic brain injury, acute coronary syndrome, or congestive heart failure to extend these recommendations to very high-risk patient populations. Patients with increased risk of PS are considered appropriate to be added to this same group by the AHA/ASA.

The AHA/ASA 2021 Scientific Statement, citing recommendations from the American Association of Blood Banks, suggests that a hemoglobin threshold of 80 g/L should be used to decide whether to initiate blood transfusions in patients with recent stroke or existing cerebrovascular disease. In light of the current uncertainty in guideline documents regarding the treatment and prevention of perioperative ischemic stroke, the AHA/ASA 2021 Scientific Statement suggests considering a transfusion threshold of 80 g/L for most patients with increased risk of stroke and a threshold of 90 g/L for patients with acute PS or a history of a cerebrovascular event due to severe carotid stenosis or occlusion. When considering initiating hemotransfusion in patients at high risk of stroke with higher hemoglobin values, the risks of noninfectious complications such as transfusion-associated circulatory overload (may occur in up to 5 % of transfusions) should be weighed against the unproven benefit of using a higher transfusion threshold [12].

Choice of anesthetic technique. The neuroprotective effects of anesthetics have been studied intensively over the past 50 years, but there is currently no evidence that anesthetics are neuroprotective, even though anesthetics have been found to reduce cerebral metabolic rate and mimic the effects of ischemic preconditioning. In 2018, representatives of the Perioperative Neurotoxicity Working Group, based on work sponsored by the American Society of Anesthesiology Brain Health Initiative, published a set of recommendations and stated that there is a lack of evidence for an increased risk of perioperative neurocognitive disorders with anesthetic gases. Current evidence suggests that anesthetics are neither neuroprotective nor neurotoxic, and that the choice of anesthetic is unlikely to affect the risk of stroke in the perioperative period [12].

A 2016 Cochrane meta-analysis of 31 randomized controlled trials (3,231 patients) compared neuraxial (spinal or epidural) versus general anesthesia in patients undergoing surgery for hip fractures. This meta-analysis did not report differences in 30-day mortality, heart attack or stroke rates, but concluded that the quality of evidence was too low and the sample size too small to draw any definitive conclusions. With an estimated stroke rate < 1 %, it may not be possible to design randomized controlled trials to reach conclusions about the superiority of local anesthesia over general anesthesia. Two large (528,495 and 182,307 patients) retrospective studies (Chu C. et al., 2015; Memtsoudis S. et al., 2013) did not demonstrate an advantage of neuraxial anesthesia over general anesthesia in the prevention of PS among patients undergoing hip surgery. In a 2017 meta-analysis, L.M. Smith et al. found no differences in 30-day mortality between groups of patients in whom neuraxial, combined (neuraxial and general), and general anesthesia were used for major surgery and limb surgery (appr. 1.1 million follow-ups). Neuraxial anesthesia was associated with a 60 % reduction in pulmonary complications, but no difference in cardiac complication rates compared with general anesthesia alone. Combined (neuraxial and general) and general anesthesia did not differ in the incidence of pulmonary or cardiac complications. However, this meta-analysis did not examine the association between local anesthesia and stroke. Thus, at present, the advantages of local anesthesia over general anesthesia in reducing the perioperative risk of ischemic stroke have not been proven [12].

Strategies for artificial lung ventilation (ALV). Given that hypocapnia can exacerbate cerebral ischemia, the injured brain may be particularly susceptible to its effects. These data suggest that it is prudent to avoid hypocapnia in patients at high risk of PS, and that hypocapnia may be exceptionally harmful for patients with PS. Artificial lung ventilation (ALV) using lower tidal volumes reduces mortality among patients with acute lung injury and acute respiratory distress syndrome. The use of ventilation protective modes has become a best practice for the care of critically ill patients. The use of ALV protective modes results in a lower incidence of serious pulmonary complications, sepsis, and death among patients undergoing non-cardiac surgery. Although the preventive effect of protective ALV regimens on the risk of PS has not been studied separately, it is believed that prevention of pulmonary complications may lead to fewer episodes of hypoxemia in the perioperative period and reduce the risk of stroke among high-risk surgical patients. In this regard, it is reasonable to apply protective ALV modes as part of the implementation of a general strategy to improve perioperative outcomes [12].

CONCLUSION

Thus, to reduce the risk of perioperative ischemic stroke, key risk factors (such as age, renal disease, history of transient ischemic attack/stroke), overall cardiovascular risk, and the type of elective surgery should be assessed before surgical intervention. It is possible to establish individual PS risk using the ACS-SRC online surgical risk calculator. In this case, a web interface should be used [13]. In patients who have had a recent ischemic stroke, elective surgery should be delayed for at least 6 months (preferably 9 months) from the date of the stroke. ISA revascularization (type of intervention is determined individually) should be performed in patients with symptomatic (stroke or transient ischemic attack within the last 6 months) carotid stenosis (>70 %) before elective surgery. Should evidence of the need for a PFO closing operation be obtained, consideration should be given to conducting it before the elective surgery is performed. It is necessary to continue previously prescribed therapy with antihypertensive drugs, statins in order to reduce the incidence of cardiovascular complications and overall mortality. One should refrain from prescribing β-blockers on the day of surgical intervention, provided that the patient has not taken them before.

When performing surgical intervention to reduce the risk of PS, it is necessary to: maintain intraoperative mean BP > 70 mmHg (especially in patients at moderate or high risk of PS); perform hemotransfusion at a threshold hemoglobin level of 80 g/L in patients with recent stroke or significant cerebrovascular disease (e. g., carotid or intracranial stenosis > 70 %); avoid hypocapnia during ALV and use protective ALV modes with lower tidal volumes (as part of an overall strategy to reduce postoperative complications); taking into account the lack of evidence on the benefits of different types of anesthesia for the prevention of PS, the choice of anesthesia should be based on the type of surgical intervention, the skills of anesthesiologists and the individual characteristics of the patient.

Conflict of interest

The authors of this article declare the absence of a conflict of interest.

REFERENCES

1. Mashour GA, Shanks AM, Kheterpal S. Perioperative stroke and associated mortality after noncardiac, nonneurologic surgery. *Anesthesiology*. 2011; 114(6): 1289-1296. doi: 10.1097/ALN.0b013e318216e7f4

2. Wang H, Li SL, Bai J, Wang DX. Perioperative acute ischemic stroke increases mortality after noncardiac, nonvascular, and non-neurologic surgery: A retrospective case series. *J Cardiothorac Vasc Anesth*. 2019; 33: 2231-2236. doi: 10.1053/j.jvca.2019.02.009

3. Weiser TG, Regenbogen SE, Thompson KD, Haynes AB, Lipsitz SR, Berry WR, et al. An estimation of the global volume of surgery: A modelling strategy based on available data. *Lancet*. 2008; 372: 139-144. doi: 10.1016/S0140-6736(08)60878-8

4. Tsygan NV, Andreev RV, Peleshok AS, Kolomentsev SV, Yakovleva VA, Ryabtsev AV, et al. Perioperative stroke in heart valve surgery: Pathogenesis, clinical findings, diagnosis, prevention, treatment. *Zhurnal nevrologii i psikhiatrii imeni S.S. Korsakova*. 2018; 118(4): 52-60. (In Russ.).

5. ESC/ESA guidelines on non-cardiac surgery: Cardiovascular assessment and management. *Russian Journal of Cardiology*. 2015; 8(124): 7-66. (In Russ.). doi: 10.15829/1560-4071-2015-08-7-66

6. Federal Service of State Statistics. *Health care in Russia. 2019: Statistical compendium*. Moscow; 2019. URL: https://rosstat.gov.ru/storage/mediabank/Zdravoohran-2019.pdf [дата доступа: 18.12.2022]. (In Russ.).

7. Smilowitz NR, Gupta N, Ramakrishna H, Guo Y, Berger JS, Bangalore S. Perioperative major adverse cardiovascular and cerebrovascular events associated with noncardiac surgery. *JAMA Cardiol*. 2017; 2: 181-187. doi: 10.1001/jamacardio.2016.4792

8. NeuroVISION Investigators. Perioperative covert stroke in patients undergoing non-cardiac surgery (NeuroVISION): A prospective cohort study. *Lancet*. 2019; 394(10203): 1022-1029. doi: 10.1016/S0140-6736(19)31795-7

9. Gaudino M, Benesch C, Bakaeen F, DeAnda A, Fremes S, Glance L, et al. Considerations for reduction of risk of perioperative stroke in adult patients undergoing cardiac and thoracic aortic operations: A scientific statement from the american heart association. *Circulation*. 2020; 142: e193-e209. doi: 10.1161/CIR.0000000000000885

10. Mashour GA, Moore LE, Lele AV, Robicsek SA, Gelb AW. Perioperative care of patients at high risk for stroke during or after non-cardiac, non-neurologic surgery: Consensus statement from the Society for Neuroscience in Anesthesiology and Critical Care. *J Neurosurg Anesthesiol*. 2014; 26(4): 273-285. doi: 10.1097/ANA.0000000000000087

11. Kleindorfer DO, Towfighi A, Chaturvedi S, Cockroft KM, Gutierrez J, Lombardi-Hill D, et al. 2021 guideline for the preven-

tion of stroke in patients with stroke and transient ischemic attack: A guideline from the American Heart Association/American Stroke Association. *Stroke.* 2021; 52(7): e364-e467. doi: 10.1161/STR.0000000000000375

12. Benesch C, Glance LG, Derdeyn CP, Fleisher LA, Holloway RG, Messé SR, et al. Perioperative neurological evaluation and management to lower the risk of acute stroke in patients undergoing noncardiac, nonneurological surgery: A scientific statement from the American Heart Association/American Stroke Association. *Circulation*. 2021; 143(19): e923-e946. doi: 10.1161/CIR.0000000000000968

13. *ACS risk calculator.* URL: https://riskcalculator.facs.org/RiskCalculator/index.jsp/ [date of access: 11.03.2023].

14. European Stroke Organization guideline on endarterectomy and stenting for carotid artery stenosis. *Eur Stroke J*. 2021; 6(2): I-XLVII. doi: 10.1177/23969873211012121

15. Eckstein HH, Kühnl A, Berkefeld J, Lawall H, Storck M, Sander D. Diagnosis, treatment and follow-up in extracranial carotid stenosis. *Dtsch Arztebl Int*. 2020; 117(47): 801-807. doi: 10.3238/arztebl.2020.0801

ЛИТЕРАТУРА

1. Mashour GA, Shanks AM, Kheterpal S. Perioperative stroke and associated mortality after noncardiac, nonneurologic surgery. *Anesthesiology*. 2011; 114(6): 1289-1296. doi: 10.1097/ALN.0b013e318216e7f4

2. Wang H, Li SL, Bai J, Wang DX. Perioperative acute ischemic stroke increases mortality after noncardiac, nonvascular, and non-neurologic surgery: A retrospective case series. *J Cardiothorac Vasc Anesth*. 2019; 33: 2231-2236. doi: 10.1053/j.jvca.2019.02.009

3. Weiser TG, Regenbogen SE, Thompson KD, Haynes AB, Lipsitz SR, Berry WR, et al. An estimation of the global volume of surgery: A modelling strategy based on available data. *Lancet*. 2008; 372: 139-144. doi: 10.1016/S0140-6736(08)60878-8

4. Цыган Н.В., Андреев Р.В., Пелешок А.С., Коломенцев С.В., Яковлева В.А., Рябцев А.В., и др. Периоперационный мозговой инсульт в хирургии клапанов сердца: патогенез, клиника, диагностика, лечение и профилактика. *Журнал неврологии и психиатрии им. С.С. Корсакова*. 2018; 118(4): 52-60.

5. Рекомендации ESC/ESA по предоперационному обследованию и ведению пациентов при выполнении внесердечных хирургических вмешательств 2014. *Российский кардиологический журнал*. 2015; 8(124): 7-66. doi: 10.15829/1560-4071-2015-08-7-66

6. Росстат. *Здравоохранение в России. 2019: Статистический сборник*. М.; 2019. URL: https://rosstat.gov.ru/storage/mediabank/Zdravoohran-2019.pdf [дата доступа: 18.12.2022].

7. Smilowitz NR, Gupta N, Ramakrishna H, Guo Y, Berger JS, Bangalore S. Perioperative major adverse cardiovascular and cerebrovascular events associated with noncardiac surgery. *JAMA Cardiol*. 2017; 2: 181-187. doi: 10.1001/jamacardio.2016.4792

8. NeuroVISION Investigators. Perioperative covert stroke in patients undergoing non-cardiac surgery (NeuroVISION): A prospective cohort study. *Lancet*. 2019; 394(10203): 1022-1029. doi: 10.1016/S0140-6736(19)31795-7

9. Gaudino M, Benesch C, Bakaeen F, DeAnda A, Fremes S, Glance L, et al. Considerations for reduction of risk of perioperative stroke in adult patients undergoing cardiac and thoracic aortic operations: A scientific statement from the american heart association. *Circulation*. 2020; 142: e193-e209. doi: 10.1161/CIR.0000000000000885

10. Mashour GA, Moore LE, Lele AV, Robicsek SA, Gelb AW. Perioperative care of patients at high risk for stroke during or after non-cardiac, non-neurologic surgery: Consensus statement from the Society for Neuroscience in Anesthesiology and Critical Care. *J Neurosurg Anesthesiol*. 2014; 26(4): 273-285. doi: 10.1097/ANA.0000000000000087

11. Kleindorfer DO, Towfighi A, Chaturvedi S, Cockroft KM, Gutierrez J, Lombardi-Hill D, et al. 2021 guideline for the prevention of stroke in patients with stroke and transient ischemic attack: A guideline from the American Heart Association/American Stroke Association. *Stroke.* 2021; 52(7): e364-e467. doi: 10.1161/STR.0000000000000375

12. Benesch C, Glance LG, Derdeyn CP, Fleisher LA, Holloway RG, Messé SR, et al. Perioperative neurological evaluation and management to lower the risk of acute stroke in patients undergoing noncardiac, nonneurological surgery: A scientific statement from the American Heart Association/American Stroke Association. *Circulation*. 2021; 143(19): e923-e946. doi: 10.1161/CIR.0000000000000968

13. *ACS risk calculator.* URL: https://riskcalculator.facs.org/RiskCalculator/index.jsp/ [date of access: 11.03.2023].

14. European Stroke Organization guideline on endarterectomy and stenting for carotid artery stenosis. *Eur Stroke J*. 2021; 6(2): I-XLVII. doi: 10.1177/23969873211012121

15. Eckstein HH, Kühnl A, Berkefeld J, Lawall H, Storck M, Sander D. Diagnosis, treatment and follow-up in extracranial carotid stenosis. *Dtsch Arztebl Int*. 2020; 117(47): 801-807. doi: 10.3238/arztebl.2020.0801

Information about the authors

Sergey V. Kolomencev – Cand. Sc. (Med.), Head of the Neurology Unit, M.I. Astvatsaturov Department and Clinic of Nervous Diseases, Kirov Military Medical Academy; e-mail: skolomencev@yandex.ru, https://orcid.org/0000-0002-3756-6214

Stanislav N. Yanishevskiy – Dr. Sc. (Med.), Associate Professor at the M.I. Astvatsaturov Department of Nervous Diseases, Kirov Military Medical Academy; Head of the Research Laboratory for Neurology and Neurorehabilitation, Chief Research Officer at the Research Laboratory of Technologies for Predicting the Risk of Developing Cardiovascular Complications, Almazov National Medical Research Centre, e-mail: yanishevskiy_sn@almazovcentre.ru, https://orcid.org/0000-0002-6484-286X

Igor A. Voznjouk – Dr. Sc. (Med.), Professor, Deputy Chief Physician for Neurology, Pavlov First Saint Petersburg State Medical University; Professor at the M.I. Astvatsaturov Department of Nervous Diseases, Kirov Military Medical Academy; e-mail: voznjouk@yandex.ru, https://orcid.org/0000-0002-0340-4110

Nikolay V. Tsygan – Dr. Sc. (Med.), Docent, Deputy Head of the M.I. Astvatsaturov Department and Clinic of Nervous Diseases, Kirov Military Medical Academy; Leading Research Officer, Petersburg Nuclear Physics Institute named by B.P. Konstantinov, National Research Centre "Kurchatov Institute"; e-mail: 77tn77@gmail.com, https://orcid.org/0000-0002-5881-2242

Igor V. Litvinenko – Dr. Sc. (Med.), Professor, Head of the M.I. Astvatsaturov Department and Clinic of Nervous Diseases, Kirov Military Medical Academy; e-mail: litvinenkoiv@rambler.ru, https://orcid.org/0000-0001-8988-3011

Evgeny I. Shermatyuk – Senior Clinical Resident at the Neurology Unit, M.I. Astvatsaturov Department and Clinic of Nervous Diseases, Kirov Military Medical Academy; e-mail: sherma1@mail.ru, https://orcid.org/0000-0002-4163-1701

Oksana M. Ilyina – Head of the Primary Vascular Department, Saint George City Hospital; e-mail: ksanil55@yandex.ru, https://orcid.org/0000-0002-1195-186X

Elena A. Kurnikova – Cand. Sc. (Med.), Associate Professor at the Department of Hematology and Transfusiology, North-Western State Medical University named after I.I. Mechnikov; Deputy Chief Physician – Head of the Regional Vascular Center, City Hospital No. 26, e-mail: kurnikovaelena221281@yandex.ru, https://orcid.org/0000-0002-6405-1646

Tatyana V. Sergeeva – Cand. Sc. (Med.), Deputy Chief Physician for Neurology, Saint Martyr Elizabeth City Hospital; Associate Professor at the Department of Medical Rehabilitation and Sports Medicine, St. Petersburg State Pediatric Medical University; Teaching Assistant at the Department of Neurosurgery and Neurology, Saint Petersburg State University, e-mail: tatyana_serg@mail.ru, https://orcid.org/0000-0003-2949-6268