Review

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The Three Most Discussed Questions in Carotid Artery Surgery. Review of Russian and Foreign Studies in the Last Five Years

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ABSTRACT This literature review analyzes Russian and foreign publications over the past five years on the three most discussed issues related to carotid artery surgery: 1.Which is more effective: eversion carotid endarterectomy or conventional carotid endarterectomy with patch closure? 2. Which is better: carotid endarterectomy (CEE) or carotid angioplasty and stenting (CAS)? 3. How soon after the development of ischemic stroke should cerebral revascularization be performed?

The authors of the article came to the following conclusions: 1. According to the majority of large studies and meta-analyses, conventional CEE with patch closure is associated with a higher risk of internal carotid artery restenosis compared to eversion carotid endarterectomy. Single-center trials with small samples of patients do not find statistical differences between the outcomes of applying both surgical techniques. 2. Large multicenter randomized trials are required to address the effectiveness of CEA and CAS in symptomatic and asymptomatic patients. To date, there has been no consensus on this matter. 3. CEE and CAS can be equally effective and safe in the most acute and acute periods of ischemic stroke when performed in the presence of a mild neurological deficit and the ischemic brain lesion not exceeding 2.5 cm in diameter. Nevertheless, the choice of treatment strategy should be made strictly personalized by a multidisciplinary council based on the experience of the institution and current recommendations.

Keywords: carotid endarterectomy, eversion carotid endarterectomy, conventional carotid endarterectomy, patch, restenosis, aneurysm, carotid angioplasty and stenting, acute period of stroke, COVID-19, SARS-CoV-2

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ACVA – acute cerebrovascular accident
ASP – atherosclerotic plaque
CAC – carotid artery calcification
CAS – carotid angioplasty and stenting
CCA – common carotid artery
CEA – carotid endarterectomy
CI – confidence interval
ICA – internal carotid artery
MI – myocardial infarction
OR – odds ratio
RCT – randomized clinical trial
RR – risk ratio
TIA – transient ischemic attack

INTRODUCTION

The history of carotid endarterectomy (CEA) lasts more than half a century [1–5]. Today, this is the most common open surgery on the arterial bed, both in Russia and abroad [6, 7]. Current guidelines set strict standards for the performance of this intervention [6, 7]. However, for a number of problems, the "scales" still do not find their balance [6, 7].

The purpose of this literature review was to analyze domestic and foreign publications over the past 5 years on the three most discussed issues of carotid surgery.

CONVENTIONAL OR EVERSION TECHNIQUE?

Eversion and conventional CEA with patch closure are the most popular and studied surgical techniques [6–8]. The former involves cutting off the internal carotid artery (ICA) at the orifice, followed by endarterectomy through eversion and its reimplantation in the original place [6–8]. The latter is performed using a longitudinal arteriotomy of the common carotid artery (CCA) with a transition to the ICA, open endarterectomy, and patch implantation [4, 6–8]. The pros and cons of both methods are well known [4, 6–8].

Eversion CEA does not always guarantee reliable fixation of the intima or atherosclerotic plaque (ASP) behind the endarterectomy zone. As a result, ICA thrombosis may develop after blood flow restart [9–13]. The conventional CEA, in turn, not only requires from the institution additional expenses for patches purchase, but is also known for the fact that after patch angioplasty the lumen of the CCA and ICA expands [14–16]. This leads to the development of turbulent blood flow, the risk of parietal thrombosis, neointima hyperplasia, and subsequent restenosis [14–16]. Moreover, body reaction to a synthetic or biological patch may be that of rejection type (donor-recipient conflict) [16]. This trend is accompanied by an enhanced inflammatory response, making a significant contribution to the development of vessel lumen loss processes [16]. Despite the above facts, a comparative analysis of the two CEA techniques has been in the trend of vascular surgeons' interests during all those years.

Bokeria L.A. et al. analyzed the treatment of 60 patients from 2009 to 2015. The authors concluded that ICA restenoses in the late postoperative period are most often diagnosed after conventional CEAs [9].

In the publication of Dudanov I.P. et al. a lower risk of complications after eversion CEAs was also confirmed [10]. The study included 122 patients, among them 30 patients underwent patch angioplasty of the arteriotomy site. During 3 years of follow-up after conventional CEAs, the total number of complications reached 33.3%. Among them, ICA thrombosis was diagnosed in 2 cases, ICA restenosis in 2 others, and myocardial infarction (MI) in 1 case. After eversion CEAs, the combined endpoint reached 9.8%, and restenosis of the arteriotomy site was visualized in 1 patient [10].

Grinev K.M. et al. analyzed their own experience in performing various CEA techniques over 25 years [11]. In the long-term follow-up period, hemodynamically significant ICA restenosis after patch angioplasty was noted only in 5.6% of cases. The authors concluded that the eversion type of operation is the most preferable [11].

In the study by Kazantsev A.N. et al. devoted to the outcomes of different CEA types in one patient with bilateral ICA stenosis, the following conclusions were drawn. Both techniques showed comparable quality of treatment. However, an increase in the number of restenoses persisted after CEAs with patch closure: 17.3% versus 9.3% [12]. In their other work, Kazantsev A.N. et al. analyzed the outcomes of 1493 conventional and 637 eversion CEAs after 48.8±19.6 months. Restenosis (4.2% versus 2.1%, p=0.02) and thrombosis/occlusion of the reconstruction zone were more often visualized after patch implantation (5.2% versus 5.3%, p=0.01) [13].

A high risk of ICA restenoses after conventional CEAs was also determined by Darvish N.A.M.A. et al. The authors came to the conclusion that the eversion CEA should be the method of choice [17].

Gavrilenko A.V. et al. conducted a meta-analysis of existing studies on this topic [18]. 1718 eversion and 1954 conventional CEAs were included. The authors found out that the development of ICA restenosis (p=0.006) and in-hospital/remote acute cerebrovascular accident (ACVA) (p=0.005/p=0.000) is most often observed after patch angioplasty of the arteriotomy site [18].

The largest Russian study comparing two CEA techniques was conducted under the scientific supervision of Belov Yu.V. [19]. The multicenter study included 25,106 patients operated on between February 1, 2006 and September 1, 2021. In the long-term follow-up period (124.7±53.8 months), death from all causes (p<0.0001), death from stroke of the ischemic type (p<0.0001), non-fatal stroke of the ischemic type (p <0.0001), restenosis of the ICA (p<0.0001) were most often diagnosed after conventional surgery with patch angioplasty of the reconstruction zone [19].

Therefore, most studies in Russia favor eversion CEA techniques. But what are the trends abroad?

One of the questions concerning a higher risk of ICA restenosis after conventional CEAs was the patch type. However, numerous studies have shown that its nature does not affect the immediate and long-term surgical outcomes. Leonore F.T. et al. compared 168 outcomes of CEA using xenopericardial patches and 174 synthetic ones [20]. The incudence of hemodynamically significant restenosis on the 301st day of observation was 5.16% and 4.11% (p=0.55), respectively [20].

In their meta-analysis of randomized trials, Texakalidis P. et al. analyzed outcomes of utilizing synthetic, autovenous and biological patches in 3234 patients [21].

Risk of 30-day stroke (risk ratio - RR 1.00; 95% CI (confidence interval) 0.45–2.19; I 2=0%), transient ischemic attack (TIA) (RR 1.14; 95% CI, 0.41-3.19; I 2 = 0%), MI (RR 0.75; 95% CI 0.14-3.97; I 2 = 0%), death (RR 0.53 ; 95% CI 0.21–1.34; I 2 = 0%), wound infection (RR 1.84; 95% CI 0.43–7.81; I 2 = 0%), carotid artery thrombosis (RR 1.47; 95% CI 0.44–4.97; I 2 = 0%) and distant stroke (RR 2.33; 95% CI 0.76–7.10; I 2 = 0%), death (RR 1.09; 95% CI, 0.65-1.83; I 2 = 0%), restenosis more than 50% (RR, 0.48; 95% CI, 0.19-1.20; I 2 =0%) were similar in the synthetic and venous patch groups [21].Comparison of outcomes of the using biological and synthetic patches also did not show statistically significant differences in terms of 30-day stroke (RR 1.44; 95% CI 0.19-10.79; I 2 \u003d 12.7%), TIA (RR 1, 05; 95% CI, 0.11-10.27; I 2 = 0%) and death (RR 4.01; 95% CI, 0.46-34.85; I 2 = 0%) [21].

Despite the fact that the nature of the patch does not affect CEA outcome, there is evidence of one important disadvantage of this method – namely an infection of the arteriotomy site with the formation of an aneurysm [22–25]. If that is the case, it is necessary to perform a repeated intervention with resection of the latter, secondary surgical debridement, and subsequent ICA prosthetic repair [22–25]. Failure to comply with these measures may lead to the development of angiosepsis and arrosive bleeding [22–25]. Thus, having studied this side of the issue, the main focus of the scientific community was also aimed at comparing the outcomes of conventional and eversion surgical techniques.

In their large meta-analysis Paraskevas K.I. et al. included the outcomes of 16249 eversion and 33251 conventional CEAs [26]. The eversion technique was associated with a significant reduction in 30-day mortality (RR 0.46; p<0.0001), stroke (RR 0.58; p<0.0001), death from stroke (RR 0.52; p <0.0001), death from stroke or MI (OR 0.50; p<0.0001) and late ICA restenosis (odds ratio — OR 0.49; p=0.032) compared with patch angioplasty [26].

In a study by Chen G.Z. et al. 211 eversion and 230 conventional CEAs were analyzed [27]. The authors showed that the incidence of ICA restenoses and deaths during the long-term follow-up period did not significantly differ (p=0.86 and p=0.17, respectively) [27].

Maguire S.C. et al. presented the results of 114 conventional and 90 eversion CEAs [28]. Within 7 years, the authors did not obtain statistically significant differences in the incidence of complications between the samples [28]. However, it was noted that the duration of operation and ICA clamping was significantly shorter when performing eversion technique, which reduces the risk of intraoperative stroke [28].

Dakour-Aridi H. et al. conducted an analysis of data from the Vascular Quality Initiative registry, including 30-day and 1-year outcomes of 12,050 eversion and 83,676 conventional CEAs [29]. Although there was no statistical difference in ICA restenosis, the authors found out that the eversion technique was associated with lower rates of stroke and death after 30 days (OR 0.72, 95% CI 0.54–0.95, p=0.02) and after 1 year (RR 0.75, 95% CI 0.58–0.97, p=0.03) [29].

In the work by Cheng S.F. et al., the authors compared the results of three types of CEAs: group 1 (n=511) — CEAs with patch closure; group 2 (n=232) — primary closure; group 3 (n=47) — eversion CEAs [30]. The cumulative rates of restenosis ⩾50% after one year were 18.9%, 26.1%, and 17.7%, respectively; and after 5 years, 25.9%, 37.2%, and 30.0%, respectively. There was no difference in risk between the eversion and conventional CEA groups (RR 0.90, 95% CI 0.45–1.81; p=0.77) [30]. Primary closure had a higher risk of restenosis than the conventional technique (RR 1.45, 95% CI 1.06–1.98; p=0.019). Cumulative restenosis rates ⩾70% did not differ between primary closure and patch angioplasty (12.1% vs 7.1%, RR 1.59, 95% CI 0.88–2.89; p = 0.12), and between patch angioplasty and eversion endarterectomy (4.7%, heart rate 0.45, 95% CI 0.06–3.35; p=0.44) [30].

Meyer A. et al. compared the results of 585 CEAs with patch angioplasty and 274 eversion CEAs [31]. There was no difference in the incidence of postoperative complications [31].

Lazarides M.K. et al. conducted a large meta-analysis (4440 patients) evaluating the outcomes of various CEA techniques: 431 eversion CEAs, 973 autovenous patching, 948 PTFE patching, 828 Dacron patching, 828 xenopericardial patching, 258 polyurethane patching [32]. After eversion CEAs, a statistically lower number of 30-day postoperative stroke, deaths, and ICA restenoses in the long-term follow-up period was registered [32].

So we can conclude that both Russian and foreign medical communities have not still come to a common denominator as to which CEA technique is the most optimal. However, the results of large multicenter studies and meta-analyses clearly demonstrate that the conventional technique with patch angioplasty of the arteriotomy site is associated with the highest risk of ICA restenosis in the late postoperative period. Nevertheless, additional prospective randomized studies are required to finally identify the best method of brain revascularization in the presence of hemodynamically significant ICA stenosis.

CAROTID ENDARTERECTOMY OR CAROTID ANGIOPLASTY AND STENTING?

According to the current Russian recommendations, CEA is the method of choice in the presence of hemodynamically significant ICA stenosis [6]. However, with the development of endovascular technologies, carotid angioplasty and stenting (CAS) has become an alternative option for revascularization [33, 34].

Speaking of symptomatic patients, the latter may be preferable to open intervention when there is a high surgical risk for CEA [6]. CAS is also possible in asymptomatic patients, but only in medical institutions with high operational activity and the level of complications corresponding to the existing "quality standards" [6].

Nevertheless, according to the 2017 European Society for Vascular Surgery Guidelines, CEA continues to be the “gold standard for revascularization” (Class IIa; Level of Evidence: B) [7, 35]. However, CAS may be considered in some cases as the procedure of choice (Class IIb; Level of Evidence: B) if one or more clinical/imaging characteristics are present that may be associated with an increased risk of late ipsilateral stroke (cerebral infarction of embolic origin, a history of contralateral stroke, etc.) provided that the perioperative stroke/mortality rate is <3%, and the patient's life expectancy is >5 years [7, 35].

Against this background, disagreements between vascular and endovascular surgeons regarding the effectiveness of one or the other correction method do not subside. Constant improvement of interventional technologies, modernization of stents and drug supply in some cases make it possible to be doubtful about the position of CEA as the surgery of choice.

Stolyarov D.P. et al. in their publication demonstrated the outcomes of 132 CEAs and 137 CASs. No deaths were recorded. There were no differences in the incidence of stroke (1.5% and 4.5%, respectively, p=0.13). Damage to the cranial nerves was diagnosed only after CEAs (7.6%, p=0.001) [36].

Khafizov T.N. et al. analyzed immediate outcomes of 353 CEAs and 242 CASs. The incidence of postoperative stroke in the 1st group reached 2.3%, in the 2nd group — 3.7% [37]. The authors concluded that both methods have comparable efficacy and safety [37].

Cui L. et al. conducted a meta-analysis of 5 randomized clinical trials (RCTs) involving 3901 patients [38]. The authors found out that the risk of any type of stroke during the periprocedural period was significantly lower in patients after CEAs (RR 0.53; 95% CI 0.29–0.96) [38].

Bokeria L.A. et al. analyzed the results of treatment of 256 patients. Depending on the type of operation, three groups were formed: 1 — eversion CEA, 2 — conventional CEA, 3 — CAS [39]. ICA restenosis in the 1st group reached 2.1%, in the 2nd - 4.3%, in the 3rd - 1.6%. The findings of the study demonstrated that patching is the least preferred method of reconstruction, while eversion CEA and CAS showed comparable safety and efficacy [39].

Bazylev V.V. et al. analyzed the results of 522 CASs and 386 CEAs. The incidence of stroke in both groups was comparable (1.7% and 1.04%, respectively, p=0.5) [40]. No deaths or hemorrhagic transformations were recorded [40].

Batchelder A.J. et al. conducted a systematic review and meta-analysis of 20 RCTs. The 30-day mortality/stroke rate was significantly higher after CAS in seven RCTs involving 3467 asymptomatic patients (RR 1.64, 95% CI 1.02–2.64) and in 10 RCTs involving 5797 symptomatic patients (RR 1.71, 95% CI 1.38–2.11) [41]. The incidence of restenoses was the highest after CASs and reached 10%. Also, after CASs, the maximum number of ischemic strokes + TIA was recorded (23% versus 9%) [41].

Brott T.G. et al. analyzed the long-term outcomes of CEAs and CASs in a sample of 4775 patients [42]. The authors proved that the incidence of complications and ICA restenosis in both cohorts did not differ during 12 years of follow-up [42].

Chernyavsky M.A. et al. studied one-year outcomes of 232 CASs, 90 conventional CEAs and 142 eversion CEAs [43]. Despite the fact that the results were comparable, the authors noted a greater increase in the number of adverse cardiovascular events and ICA restenoses after patch implantation [43].

In a study by Bracale U.M. et al. a comparison of two-year outcomes of CEAs (n=86) and CASs (n=33) with a double-layer micromesh stent was made in a retrospective format [44]. The highest number of deaths was recorded after endovascular procedures (p=0.03). No statistically significant differences were found for other types of complications [44].

Matsumura J.S. et al. conducted an analysis of two large RCTs, including the results of treatment of 2544 asymptomatic patients [45]. The authors found out that the development of MI is more typical for patients after CEA (0.6% versus 1.7%, p=0.01). No statistical difference was obtained for other complications [45].

Qureshi A.I. et al. studied the incidence of ICA restenosis 10 years after CASs and CEAs [46]. No statistically significant differences were found. The mean survival without repeated revascularization was 8.2±0.1 years and 8.0±0.1 years, respectively (log-rank test p=0.0823) [46].

Speaking of the choice between CAS and CEA, Vinogradov R.A. proposed focusing on the severity of atherosclerotic plaque (ASP) calcification in the ICA [47]. Thus, with its degree up to 30%, it is recommended to perform CAS, from 31 to 70% - CAS or CEA, and more than 70% - only CEA. The author explains this approach by the fact that severe ASP calcification in the ICA can prevent full stent deployment [47]. Stent implantation under these conditions is characterized by the presence of residual stenosis, the risk of distal embolism and arterial dissection [47].

We would like to pay special attention to the importance of carotid artery calcification (CAC) factor. CAC is a well-known marker of atherosclerosis and is associated with high levels of morbidity and mortality. It is now believed that vascular calcification is an active enzymatically regulated process, including dystrophic calcification and endothelial dysfunction at an early stage [48-52]. This induces a pathogenic inflammatory response leading to calcium phosphate deposition in the form of microcalcifications, resulting in ASP formation, which eventually become unstable [48-52]. If inflammation ceases, hydroxyapatite crystals begin to form, resulting in macrocalcifications that help maintain plaque stability [48–52]. Since CAC may be asymptomatic, it is essential to detect it at an early stage using diagnostic imaging. CAC score is calculated by means of computed tomography angiography, a confirmatory test allowing surgeons to study ASP composition and calculate CAC score [48-52].

Returning to the problem of choice between CAS and CEA, it must be remembered that the latter is most often performed utilizing eversion or conventional technique with patch angioplasty of the arteriotomy site [53–55]. Summarizing the above studies, it is important to note that in the overwhelming majority of cases, the authors compare the total cohort of open surgeries with the endovascular technique. However, this is not correct. As noted in the previous section of this article, patch implantation is most often associated with an increased risk of ICA restenosis due to dilatation of the reconstruction zone and arterial lumen with deformation of the physical properties of the blood flow [15, 16, 19, 56].

Against this background, in a study by Raptis A. et al. the results of 3D computer modeling of the reconstruction zone after conventional CEA and CAS were presented [57]. The authors showed that, as a result of the open intervention, there is indeed a large dilatation of the arterial lumen, its tortuosity and curvature, which aggravates all the physical characteristics of the blood flow and is associated with a greater risk of ICA restenosis compared to CAS [57]. Therefore, CAS is preferable to CEA with patch closure.

Of particular interest are CEA and CAS outcomes in asymptomatic patients older than 75 years. On the one hand, according to the recommendations, endovascular revascularization cannot be the operation of choice in this situation [6]. On the other hand, high surgical risk suggests that CEA performance will be characterized by a higher incidence of postoperative adverse cardiovascular events [6, 58].

Publications demonstrating CEA outcomes in small patient samples tend to suggest that open surgery is safe for elderly patients [59, 60]. However, the only Russian multicenter study showed that death (p=0.037), MI (p=0.0006), ischemic stroke (p=0.03) and wound revision due to bleeding (p<0.0001) are most often diagnosed in patients older than 75 years [61]. In this situation, the question of the appropriateness of CAS in the older age group is particularly acute.

Mutaev M.M. et al. analyzed the outcomes of 52 CEAs and 17 CASs in patients older than 80 years. Ischemic strokes and deaths were not recorded. Both methods have shown their safety and efficacy [62].

Hammar K. et al. demonstrated the outcomes of CEAs and CASs in 7589 patients with mean age of 72 ± 8 years [63]. They proved that the category of patients over 80 years was characterized by an increased risk of developing stroke after stenting compared to open revascularization (RR 3.2; 95% CI 2.03–5.03) [63].

Mehta A. et al. conducted an analysis of CEA and CAS outcomes in a sample of 33,115 patients. The authors found out that CAS compared to CEA had a higher risk of both 30-day stroke/death (RR 1.78; 95% CI 1.10–2.89) and 1-year stroke/death (RR 1.85; 95% CI 1.35–2.54) in patients over 80 years [64].

Thus, there is no consensus both in Russia and abroad regarding the effectiveness of one or the other method of brain revascularization. This pattern applies to all characteristics of patients with precerebral atherosclerosis, regardless of age, symptomatic/asymptomatic, and the severity of the comorbid background. Some studies demonstrate the benefits of CEA, others show the benefits of CAS and vice versa. Ultimately, the choice in favor of one or the other treatment method should be made individually, based on the risk stratification for complications and the experience of the medical institution.

CAROTID ENDARTERECTOMY IN THE MOST ACUTE AND ACUTE PERIODS OF ACUTE CEREBROVASCULAR ACCIDENT

According to current guidelines, the presence of hemodynamically significant symptomatic ICA stenosis is an indication for cerebral revascularization [6, 7]. At the same time, CEA or CAS in this situation can be implemented if we are talking about a “minor” stroke without concomitant severe neurological deficit [6, 7].

Reconstructive intervention is allowed both in the most acute and acute periods of stroke [65–69]. Tarasov R.S. et al. presented the outcomes of 145 CEAs performed in the acute period of stroke. Among the complications, one stroke was recorded. MI and death were not observed [70].

Roussopoulou A. et al. compared CEA outcomes in two groups of patients: 1 — within 0–2 days after the development of ischemic stroke (n=63) and 2 — within 3–14 days (n=248). The 30-day incidence of stroke in the samples did not differ (7.9% vs. 4.4%, p=0.333) [71]. At the same time, the median length of hospital stay was shorter in case of urgent CEAs (6 days (interquartile range 4–6) as opposed to 10 days (interquartile range 7–14); p<0.001) [71].

Kazantsev A.N. et al. presented CEA outcomes depending on the period of stroke: most acute (1–3 days, n=24), acute (up to 28 days, n=493), early recovery (up to 6 months, n=481), late recovery (up to 2 years, n=115) [72]. The smallest number of complications was recorded in the acute and late recovery periods of ischemic stroke [72].

Borghese O. et al. presented the outcomes of 72 CEAs performed in the most acute period of stroke [73]. There were no hospital strokes, MI, or deaths. The combined endpoint (death/stroke/MI) was 5.5% at 30 days postoperatively [73]. The neurological deficit assessed on the National Institute of Health Stroke Scale (NIHSS) regressed by more than 2 points in 47.2% of cases [73].

Chisci E. et al. analyzed CEA outcomes at different times after the manifestation of a neurological event [74]. They came to the conclusion that the best results of revascularization were achieved in the acute period of stroke [74].

Zakirzhanov N.R. et al. presented a publication that described the outcomes of 32 CEAs performed up to 72 hours after stroke [75]. The comparison group was a sample of 48 patients operated on 4–14 days after the formation of the neurological event. In the study sample, 2 hemorrhagic transformations were recorded, in one case with a fatal outcome [75]. A new stroke of the ischemic type was diagnosed in one case in the comparison group. The authors concluded that emergency CEA was safe and effective [75].

Summarizing the presented data, it should be noted that one of the problems that hinders surgeons from active surgical treatment in an urgent mode is the risk of hemorrhagic transformation of the ischemic focus. On the one hand, the latter can develop against the background of hyperperfusion syndrome after blood flow restart [76–78]. On the other hand, a number of authors have proven that damage to the carotid glomus during CEA can lead to its formation, which will be accompanied by unstable hemodynamics and a tendency to hypertension [78]. In their study, they analyzed the results of 214 glomus-sparing (group 1), 145 conventional (group 2), and 158 eversion (group 3) CEAs [78]. Their work demonstrated that glomus-sparing CEAs are not accompanied by the development of any adverse cardiovascular events [78].

Thus, CEAs performed in the most acute and acute periods of stroke most often demonstrate optimal results. Although there is still no consensus on this matter. Against this background, the works devoted to CAS under these conditions are of interest.

Ermolaeva T.V. et al. demonstrated that in a sample of 30 patients CASs were not accompanied by the development of any adverse cardiovascular events [79]. Moreover, there was a significant regression of neurological symptoms [79].

Limaye K. et al. compared CAS outcomes in the most acute (n=39) and acute (n=58) periods of ischemic stroke [80]. In the first one, there was a predominance of all postoperative complications (15.3% versus 3.4%, p=0.05) [80]. The incidence of restenosis in both groups reached comparable values after 13.7 months of follow-up (8.1% vs. 9.1%, p=0.8) [80].

Kazantsev A.N. et al. presented the results of 312 CASs in the most acute period of stroke [81]. In the hospital follow-up period, 1.92% of deaths, 1.6% of MI, 1.6% of non-fatal strokes, 2.2% of “silent” strokes, 0.64% of hemorrhagic transformations, 0.32% of ICA thromboses were detected [81]. In view of the fact that the presented data corresponded to those limits of stroke and deaths incidence established by the current recommendations, the authors came to the conclusion about the effectiveness and safety of CAS in the urgent mode [81].

Therefore, studies on CAS performed in the most acute phase of stroke also demonstrate the lack of certainty about the effectiveness and safety of this revascularization strategy under these conditions.

It should be noted that by now there has been a tendency for the prevalence of publications assessing CEA and CAS outcomes in isolation from each other. Along with this, there are not enough works comparing the outcomes of both methods.

Khripun A.I. et al. analyzed the outcomes of 20 CEAs and CASs performed in the period from 2 to 7 days after the development of ischemic stroke [82]. No complications were recorded in the postoperative period [82]. The authors specified that the success of revascularization was associated with the absence of severe neurological deficit (no more than 3 points on the Rankin scale) and the size of the ischemic focus in the brain of no more than 4 cm [82].

Altman D.A. et al. presented the outcomes of 32 CEAs and 20 CASs within a period of several hours to 2 weeks from the onset of stroke [83]. In both groups, one case of postoperative ischemic stroke was registered. No other complications were recorded [83].

In 2021, the first multicenter Russian study was published, assessing the outcomes of CASs (group 1, n=312) and CEAs (group 2, n=357) performed in the urgent mode [84]. The inclusion criterion was the presence of a mild neurological deficit (NIHSS score from 3 to 8) and an ischemic focus in the brain, not exceeding a diameter of 2.5 cm [84]. Statistically significant differences were obtained in the incidence of hemorrhagic transformations (0.64% vs. 3.6%, p=0.001) and "silent" hemorrhagic transformations (0% vs. 7.3%, p=0.001) [84]. The authors came to the conclusion that CEAs in the most acute period of stroke are associated with the development of complications in every fifth patient, and CAS is the most optimal method of revascularization [84].

Cui C.L. et al. analyzed the outcomes of CASs and CEAs performed at different moments from the onset of stroke in 18,643 patients [85]. The highest rates of deaths + stroke were recorded after the endovascular procedure: 4.0% in the CEA group and 6.9% in the CAS group, p=0.01 — 0–2 days after the development of ischemic stroke; 2.5% in the CEA group and 3.8% in the CAS group, p=0.05 — 3–14 days after ischemic stroke; 1.6% in the CEA group and 2.8% in the CAS group, p=0.003 — 15–180 days after the development of ischemic stroke [85].

Discussing the problem of emergency CEAs, one cannot fail to mention new circumstances that turned the world of modern medicine upside down over 2 years ago. We are talking about patients with COVID-19. The SARS-CoV-2 virus is known to be capable of causing coagulopathy and endotheliitis [86–88]. Both processes lead to thrombotic complications of various localization and destabilization of ASP [86–88]. Since the current Russian and foreign recommendations had been created long before the start of the pandemic, there was no consensus and rules for providing primary vascular care to this cohort of patients [6, 7]. Nevertheless, in the case of symptomatic non-occlusive ICA thrombosis against the background of the novel coronavirus infection, existing indications for CEA can be used if there is no severe neurological deficit and extensive ischemic focus in the brain [89]. However, despite the fact that ICA thrombosis under conditions of COVID-19 can be observed in a quarter of cases, there is a shortage of publications on emergency surgery for this condition [90].

Foreign literature provides only few observations of CEA in the most acute period of stroke against the background of ICA thrombosis in patients with COVID-19 [90–94]. As a rule, publications report a successful outcome of revascularization if there is no severe course of COVID-19 and local anesthesia is used [90-94]. According to the authors, avoiding general anesthesia with the transition to mechanical ventilation prevents the development of pulmonary barotrauma, which ensures a favorable prognosis for the postoperative period [90–94]. In Russia, according to elibrary.ru, there are only three publications devoted to this problem. In the first one, the authors report a successful CEA in a patient with local occlusive ICA thrombosis in the presence of unstable ASP and retrograde filling of the artery [89]. The optimal outcome of revascularization, according to the surgeons, was associated with the use of local anesthesia and the installation of two drains, which contribute to the prevention of hemorrhagic complications under conditions of virus-induced coagulopathy [89].

In the second publication, the authors analyzed treatment outcomes of 43 patients of this profile, comparing them with the outcomes of 89 pre-COVID CEAs [90]. The groups were comparable in terms of the incidence of all cardiovascular events. However, in the cohort with COVID-19, a hematoma in the intervention area developed more often (11.6% vs. 1.1%, p=0.02) [95]. The authors came to the conclusion about the efficacy and safety of CEA in the most acute period of stroke against the background of ICA thrombosis under conditions of COVID-19 [95].

The third publication on this topic analyzed the results of operations for extended atherosclerotic lesions of the ICA and parietal thrombosis in 49 patients with a positive PCR test for the presence of SARS-CoV-2 [96]. No complications were recorded in the postoperative period. Neurological deficit on the NIHSS scale regressed from 10.5±3.5 points to 6.5±1.5; p=0.001. The authors confirmed the effectiveness of this treatment strategy [96].

Summarizing the data of the presented section, it should be noted that certainty regarding the use of CEA and CAS in the urgent mode has not yet been achieved. It also remains unclear which of the two methods of revascularization is the most optimal. In this regard, the approach to choosing a treatment strategy for this cohort of patients can only be personalized and selected by a multidisciplinary council based on the experience of the institution and current recommendations.

CONCLUSION

1. According to the majority of large studies and meta-analyses, conventional carotid endarterectomy with patch angioplasty of the arteriotomy site is associated with a higher risk of internal carotid artery restenosis compared with the eversion technique. Single-center studies with small samples of patients do not find statistical differences between the results of using both methods of surgery.
2. Large multicenter randomized trials are required to address the effectiveness of carotid endarterectomy and carotid angioplasty with stenting in symptomatic and asymptomatic patients. To date, there has been no consensus on this matter.
3. Carotid endarterectomy and carotid angioplasty with stenting can be equally effective and safe in the most acute and acute periods of acute cerebrovascular accident when implemented in conditions of mild neurological deficit and ischemic focus in the brain, not exceeding 2.5 cm in diameter. Nevertheless, the choice of treatment strategy should be made strictly personalized by a multidisciplinary council based on the experience of the institution and current recommendations.

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