

Carotid Endarterectomy with Autoarterial Remodeling of Bifurcation of the Common Carotid Artery and Carotid Endarterectomy with Patch Closure: Comparison of Methods

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Background: The objectives of our research were to identify whether the new method of carotid endarterectomy (CEA) with autoarterial remodeling of bifurcation of the common carotid artery (ARBCCA) influences daily parameters of blood pressure and heart rate (HR) while monitoring them on a daily basis and to assess the efficacy of the suggested method. *Materials and methods:* It is a prospective randomized comparative study. The first group ($n = 100$) included patients that underwent ARBCCA, the second group ($n = 100$) included patients that underwent “classic” CEA with xenopericardial patch closure.

Diurnal Holter recording of blood pressure and (HR) was performed before and after the surgical treatment in both groups. *Results:* Surgical treatment in both groups leads to an increase of HR, arterial hypertension time index by systolic blood pressure, and arterial hypertension time index by diastolic arterial blood pressure. The damage of carotid artery bulb increases sympathetic innervation and causes dysregulation of the baroreceptor mechanism. *Conclusions:* In our study, we did not reveal a significant difference in the incidence of postoperative hypertension and the dependence of HR on the choice of surgical technique. Thus, the proposed ARBCCA method does not lead to an increased risk of pre-existing arterial hypertension development. A significant difference is found out on the parameter of the clamping time of carotid arteries in favor to ARBCCA group. Another advantage of the suggested technique is the number of restenosis greater than 50% during the 2-year follow-up (4 [4%] cases (ARBCCA group) versus 12 [12%] cases [“classic” CEA], respectively, $P = .037$).

Key Words: Carotid endarterectomy—postoperative hypertension—stroke prevention—diurnal Holter

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Introduction

Currently carotid endarterectomy (CEA) is the main surgery that is performed to prevent ischemic stroke during hemodynamically significant stenosis bifurcation of common carotid artery (CCA).¹⁻⁴ There are 2 most used types: classic endarterectomy that is performed through longitudinal

incision of CCA and internal carotid artery (ICA) endarterectomy with auto-/xeno-/allo-pericardium patch closure. The second type is called eversion endarterectomy. It is performed after cut-off of ICA from bifurcation of CCA with subsequent removal of plaque from ICA ostium.

Numerous studies show that having all things equal, eversion endarterectomy in the long run leads to the

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decrease of the number of restenosis. However, ICA intersection leads to carotid glomus malfunctions and interruption of intramural sympathetic fibers. This results in increase of blood pressure (BP) in early postoperative period that requires additional correction of antihypertensive therapy. Thus, the incidence of hypertension after open surgery of carotid artery varies from 9% to 38%, while during stenting this parameter varies from 18.8% to 56.1%.⁵⁻⁸

In this context, the surgery of carotid artery is unique because it can influence the baroreflexes function^{9,10} directly by surgical damage of baroreceptor nerves,^{11,12} or by disruption baroreceptor mechanism due to damage of carotid artery bulb.¹³⁻¹⁶ This consequently leads to hemodynamically instable postoperative period. During eversion CEA, ICA is intersected through a carotid bulb. The incision of sinus nerve, including longitudinal nerve fibers in the end leads to decrease in sensitivity of baroreceptors in the early postoperative period.¹⁷⁻¹⁹ The researchers state that saving of sinus carotid nerves (baroreceptor glomus) during CEA decreases the risk of postoperative hypertension and development of postoperative hemodynamics related to complications (hemorrhagic stroke, postoperative hematoma, and myocardial infarction).²⁰⁻²²

We are offering a new method of CEA (autoarterial remodeling of bifurcation of the common carotid artery [ARBCCA]) that allows to avoid the usage of biological and synthetic patches, besides it gives the opportunity to assess the efficacy of the endarterectomy performed and the condition of dorsal wall of ICA.

The clinical assessment of this method in early and later postsurgery period is provided in the randomized research "ClinicalTrials.gov No NCT03027752 – Pilot Study of ARBCCA". In this research, we have assessed the influence of glomus incision on the change of daily parameters of BP and heart rate (HR) in the early postoperative period and taking into consideration the received data we have evaluated the efficiency of the offered method.

Considering that in the course of the suggested surgery there is longitudinal incision of the carotid glomus fibers, we decided to make a comparative analysis of changes in BP and HR in the both groups: the first group where patients underwent CEA according to the suggested method (ARBCCA) and the second group where CEA with patch closure ("classic" CEA) was performed.

While analyzing literature data we could not find a single research that would analyze BP and HR in pre- and postoperative periods using objective hardware methods on the daily basis (daily analysis of BP and HR).

The objectives of our research were to identify whether the new method of CEA (ARBCCA) influences daily parameters of BP and HR while monitoring them on a daily basis and to assess the efficacy of the suggested method.

Materials and Methods

All patients underwent CEA under general anesthesia. Cerebral tolerance to ischemia was determined based on stump pressure (SP), cerebral oximetry (rSO_2), and the reduction of rSO_2 from baseline (ΔrSO_2) measurements during pilot cross-clamping of carotid artery, where ΔrSO_2 indicates the decreased percentages of rSO_2 levels relative to its original value (before the test occlusion). Indications for temporary shunt (TS) installation were the simultaneous decrease of SP less than or equal to 40 mm Hg, rSO_2 less than or equal to 40%, and an increase of ΔrSO_2 greater than or equal to 20%. In case of an isolated increase or decrease of these indicators a TS was not used. The levels of rSO_2 during pilot cross-clamping of carotid arteries were evaluated for 2 minutes from the start, using a near-infrared spectroscopy device (NIRS-SomaSensor) INVOS-5100 (Somanetics Corp., USA) simultaneously measuring rSO_2 in the frontal-temporal areas of the head on the operated and contralateral side.

In the first group (ARBCCA), CCA bifurcation is distinguished along the medial surface of the sternocleidomastoid muscle. ICA is mobilized 5-8 mm above the distal portion of the atherosclerotic plaque. The external carotid artery (ECA) is isolated at an identical distance with mobilization of the upper thyroid, lingual, facial, and occipital arteries. ECA is cut off at a 45° angle from the bifurcation with the CCA site (Fig 1).

After this, longitudinal arteriotomy is performed along the anterior medial surface of the ICA and posterolateral surface of the ECA. Then a sequential endarterectomy is performed from the ICA and ECA under visual control (Fig 2).

The final restoration of the lumen of the arteries is carried out by sewing their walls with each other side by side between ICA and ECA with a polypropylene 6/0 filament



Figure 1. First stage of the new method of carotid endarterectomy – intersection of the external carotid artery at a 45° angle.



Figure 2. Second stage of the new method of carotid endarterectomy – sequential endarterectomy from the ICA and ECA. Abbreviations: ECA, external carotid artery; ICA, internal carotid artery.

with 2 needles, while maintaining the integrity of all branches of ECA. The suture starts from the distal margin of the arteriotomic apertures of ICA and ECA and ends at CCA (Fig 3).

We have conducted a prospective randomized comparative study to analyze influence of CEA on HR and BP after the surgery that was studied with the usage of diurnal Holter recording of BP and HR. The data were collected in the period from 2016 to 2017 at the center of hybrid surgery of Meshalkin National Medical Research Centre (Novosibirsk, Russian Federation).

The selection was represented by 200 patients with hemodynamically significant stenosis of ICA that underwent CEA. Indication for surgery has been done according to the international recommendations: symptomatic stenosis more than 60% and asymptomatic stenosis over 70% according to NASCET. The type of CEA was defined randomly before the surgery. The research excluded patients with prosthesis of ICA, with hemodynamically insignificant stenosis of ICA, patients that had myocardial infarction less than 6 months ago and strokes less than 3 months ago, recent traumatic brain injury. Depending of the type of open surgery treatment ($n = 200$) all patients were divided into 2 groups. The first group included patients ($n = 100$; 50%), that underwent



Figure 3. Last stage of the new method of carotid endarterectomy – auto-remodeling the common carotid artery bifurcation.

CEA with ARBCCA, the second group ($n = 100$; 50%) was formed by patients that underwent “classic” CEA with xenopericardial patch closure.

According to the results of ultrasounds and CT angiography, all patients were analyzed on the basis of the following parameters: ICA stenosis, ICA diameter, CCA diameter, ICA flow velocity, CCA flow velocity, ICA plaque length, ECA patency, contralateral ICA patency, contralateral ICA stenosis, plaque structure, plaque surface, and Willisian circle condition.

All patients were subjected to diurnal Holter recording of BP and HR before the surgical treatment. Then 1 or another method of CEA was carried out. Control diurnal Holter recording of BP and HR was performed 1 day after the surgery and after the transfer of patients from intensive care unit to the department. The reason for this was the state of postnarcotic depression and the being in intensive care unit during the first day. At the same time, standard preoperative antihypertensive therapy was returned.

We evaluated such parameters as the maximal HR (HR max), the minimal HR (HR min), the average HR (HR mean), the minimal systolic BP (SBP min), the average systolic BP (SBP mean), the maximal systolic BP (SBP max), average systolic BP (SBP mean), minimal and maximal diastolic BP (DBP min, DBP max), average diastolic BP (DBP mean), the arterial hypertension time index by systolic BP (AHTI SBP), the arterial hypertension time index by diastolic arterial BP (AHTI DBP), HR variability, severe arterial hypertension (with elevation of systolic BP over than 180 mm Hg), and night variability of systolic and diastolic BP (night-peaker, nondipper).

The length of follow-up was 24 months. The follow-up visit consisted of physical examination, duplex scan of the carotid arteries at 6, 12, and 24 months.

We applied the Shapiro-Wilk W test to verify the normality of the quantitative data distribution. Normally distributed quantitative data are presented as the mean \pm standard deviation, the abnormally distributed data are presented as a median with a 95% confidence interval (CI). The statistical significance of the difference between groups was determined with the help of the Mann-Whitney U test quantitatively and with the help of accurate 2-sided F test qualitatively. We used the Wilcoxon signed-rank test for the intragroup analysis of dependent quantitative data and McNemar's test for qualitative features. Probability values less than .05 were considered significant.

Our study was approved by Local Ethics Committee of Academician E.N. Meshalkin, National Medical Research Center, Ministry of Public Health of the Russian Federation, and all patients entered the study after the procedure of informed consent.

Results

The patients' demographic and clinical characteristics of both groups are shown in Table 1. Based on the gender,

Table 1. The patients' demographic and clinical characteristics of both groups

Characteristics	Group 1 (ARBCCA), n = 100	Group 2 ("classic" CEA), n = 100	P value
Gender, n (%) female/male	F 23 (23)/M 77 (77)	F 18 (18%)/M 82 (82%)	.49
Age, years	65.5 (62; 71.5)	65 (60; 70)	.44
Smoking, n (%)	58 (58)	61 (61)	.67
Asymptomatic stenosis n (%)	75 (75)	73 (73)	.57
Symptomatic stenosis n (%)	25 (25)	27 (27)	
Coronary heart disease, n (%)	84 (84)	80 (80)	.58
Arterial hypertension, n (%)	93 (93)	90 (90)	.61
Bronchial asthma, n (%)	7 (7)	14 (14)	.17
Peripheral artery disease, n (%)	44 (44)	54 (54)	.20
Diabetes mellitus, n (%)	26 (26)	20 (20)	.40
Blood cholesterol level, mmol/l	5.42 (4.50; 6.25)	4.95 (2.67; 10.70)	.004
Atherogenic index	3.55 (2.70; 4.75)	3.80 (2.80; 4.80)	.48

Abbreviations: ARBCCA, autoarterial remodeling of bifurcation of the common carotid artery; CEA, carotid endarterectomy.

symptoms, the level of heart failures, and the presence of arterial hypertension there is no significant difference in the groups.

Arterial hypertension was diagnosed in 93 (93%) patients in ARBCCA group and in 90 (90%) patients in "classic" CEA group ($P = .61$). Antihypertensive therapy received by patients before and after operations is given in Table 1a. In the early postoperative period (while a patient was in the intensive care unit (ICA)) angiotensin-converting enzyme inhibitor Enalaprilat was given as an intravenous bolus (.625-1.25 mg every 6 hours) for arterial hypertension correction. In the postoperative period, all patients returned to the basic antihypertensive therapy.

According to the data presented (Table 2), the groups had no differences in the main parameters, such as the percentage (%) of ICA stenosis (76% and 74% correspondingly, $P = .15$), diameter of ICA in mm (3.8 mm and 3.6 mm correspondingly, $P = .30$), the blood flow velocities in ICA in m/s (2.36 m/s and 2.60 m/s correspondingly, $P = .19$), the blood flow velocities in CCA in m/s (1.65 m/s and 0.69 m/s correspondingly, $P = .07$), the length of atherosclerotic plaques in mm (26 mm and 29 mm correspondingly, $P = .74$). Groups had also no significant differences in morphology and condition of atherosclerotic plaque surface, and in Willisian circle condition.

The groups were comparable in all diurnal Holter recording of BP and HR parameters with the only 1 exception –

the variability of systolic BP at night. In the second group, there were 15% more night-peaker/nondipper patients than in the first group (51% in the first group and 66% in the second group, $P = .04$; Tables 3 and 4).

We found statistically significant difference between 2 groups in the AHTI SBP using intergroup analysis of parameters based on diurnal Holter recording of BP and HR in the early postoperative period (median 41.15 in ARBCCA group, median 50.40 in the "classic" CEA group, $P = .04$; Tables 5 and 6), but after Bonferroni correction there were no statistically significant differences.

To assess the effects of the surgical treatment on the basis of changes in parameters of BP and HR, we conducted an intragroup analysis of dependent variables in patients in each group. While analyzing, we took into consideration the following parameters: HR max, HR min, HR mean, SBP min, SBP max, DBP min, DBP max, SBP mean, DBP mean, AHTI SBP, and AHTI DBP. The analysis showed that not all parameters are changed statistically significantly. Parameters of HR mean (95% CI, 78.26-82.79, $P = .001$), SBP mean (95% CI, 129.00-134.81, $P = .006$), AHTI SBP (95% CI, 37.21-49.16, $P = .02$), AHTI DBP (95% CI, 9.14-17.92, $P = .01$) increased statistically significantly in ARBCCA group after surgery. The same parameters increased statistically significantly in "classic" CEA group after surgery (HR mean [95% CI, 76.24-81.33, $P = .001$], SBP mean

Table 1A. Type of antihypertensive therapy before and after the operation in both groups

Type of AHT	Group 1 (ARBCCA) n = 93 before/after operation	Group 2 ("classic" CEA) n = 90 before/after operation	P value
Angiotensin-converting enzyme inhibitor	38/38	36/36	.9
Angiotensin II receptor blockers + diuretic	27/27	25/25	.85
Calcium channel blocker + beta-blocker	15/15	19/19	.39
Angiotensin-converting enzyme inhibitor + calcium channel blocker	13/13	10/10	.56

Abbreviations: AHT, arterial hypertension; ARBCCA, autoarterial remodeling of bifurcation of the common carotid artery; CEA, carotid endarterectomy.

Table 2. Characterization of carotid arteries atherosclerotic lesion in patients of both groups

Characteristics	Group 1 (ARBCCA), n = 100	Group 2 ("classic" CEA), n = 100	P value
ICA stenosis (%)	76 (70; 82)	74 (70; 80)	.15
ICA diameter, mm	3.80 (3.05; 4.30)	3.60 (2.75; 4.25)	.31
CCA diameter, mm	6.85 (6.00; 7.80)	7.30 (6.65; 7.95)	.056
ICA flow velocity, m/s	2.36 (1.74; 3.15)	2.60 (1.70; 3.60)	.19
CCA flow velocity, m/s	.65 (.53; .74)	.69 (.56; .83)	.07
ECA patency, n (%)	94 (94)	92 (92)	.78
Contralateral ICA stenosis (%)	47 (30; 59)	26.67 (20.5; 32.83)	.00005
ICA plaque length, mm	26 (21;30)	29 (23; 36)	.74
Heterogeneous plaque structure, n (%)	52 (52)	42 (42)	.20
Hypochoic plaque structure, n (%)	25 (25)	28 (28)	.75
Hyperechoic plaque structure, n (%)	23 (23)	29 (29)	.42
Plaque surface with thrombus, n (%)	10 (10)	6 (6)	.44
Calcified plaque surface, n (%)	4 (4)	6 (6)	.75
Closed circle of Willis, n (%)	43 (43)	40 (40)	.77

Abbreviations: ARBCCA, autoarterial remodeling of bifurcation of the common carotid artery; CCA, common carotid artery; CEA, carotid endarterectomy; ECA, external carotid artery; ICA, internal carotid artery.

Table 3. Characteristics of patients based on the results of diurnal Holter recording of BP and HR before the surgery

	Group 1 (ARBCCA), n = 100		Group 2 ("classic" CEA), n = 100		P value
	Median	95% CI	Median	95% CI	
HR max	97	[97.12; 03.67]	99.50	[97.69; 103.42]	.58
HR min	54	[52.95; 56.02]	52.50	[51.40; 54.75]	.15
HR mean	68	[66.48; 70.21]	68	[66.57; 70.48]	.84
SBP min	106	[102.36; 108.51]	102.5	[102.51; 108.26]	.87
SBP max	156.5	[155.28; 163.53]	150.00	[149.78; 157.55]	.056
DBP min	52.50	[50.68; 54.55]	52.50	[50.33; 54.14]	.70
DBP max	87	[84.91; 88.98]	83.00	[82.53; 87.80]	.055
SBP mean	125.95	[124.91; 131.57]	125.05	[125.70; 131.50]	.79
SBP mean	68.1	[66.23; 69.75]	67.00	[65.98; 69.52]	.82
AHTI SBP	34.8	[32.59; 43.63]	36.3	[32.44; 42.76]	.95
AHTI DBP	7.2	[4.17; 9.18]	7.1	[4.23; 9.37]	.76

Abbreviations: AHTI DBP, arterial hypertension time index by diastolic arterial blood pressure; AHTI SBP, arterial hypertension time index by systolic blood pressure; ARBCCA, autoarterial remodeling of bifurcation of the common carotid artery; CEA, carotid endarterectomy; CI, confidence interval; DBP, diastolic blood pressure; HR, heart rate; SBP, systolic blood pressure.

[95% CI, 132.58-139.27, $P = .001$], AHTI SBP [95% CI, 45.81-57.97, $P = .001$], AHTI DBP [95% CI, 7.31-15.08, $P = .02$].

In addition, in our study we did not use TS in both groups (indications for TS installation were not determined). A

significant difference in the length of the surgery between 2 groups was not revealed (102.6 ± 29.1 minutes [ARBCCA group] versus 114.1 ± 17.1 minutes ["classic" CEA], $P = .096$) but a significant difference was found in the time of the carotid arteries clamping (21.8 ± 2.81 minutes [ARBCCA

Table 4. Severe arterial hypertension and night variability of systolic BP and diastolic BP (night-peaker, nondipper) before the surgery in patients of both groups

	Group 1 (ARBCCA), n = 100		Group 2 ("classic" CEA), n = 100		P value
	Number	% of total	Number	% of total	
Severe AH	18	18	14	14	.28
Night-piker, nondipper (SBP)	51	51	66	66	.04
Night-piker, nondipper (DBP)	52	52	55	55	.77

Abbreviations: AH, arterial hypertension; ARBCCA, autoarterial remodeling of bifurcation of the common carotid artery; CEA, carotid endarterectomy; DBP, diastolic blood pressure; SBP, systolic blood pressure.

Table 5. Results of intergroup analysis of patients according to diurnal Holter recording of BP and HR in the early postoperative period

	Group 1 (ARBCCA), n = 100		Group 2 ("classic" CEA), n = 100		P value
	Median	95% CI	Median	95% CI	
HR max	111.50	[108.27; 115.62]	112.00	[108.54; 115.53]	.91
HR min	63.5	[61.16; 65.01]	61.00	[58.85; 63.36]	.16
HR mean	80.00	[78.26; 82.79]	78.00	[76.24; 81.33]	.48
SBP min	105.5	[102.81; 109.90]	109.00	[105.25; 112.02]	.63
SBP max	160.00	[157.13; 164.96]	165.00	[159.32; 167.97]	.21
DBP min	53.00	[50.56; 54.51]	52.00	[49.99; 54.26]	.56
DBP max	87.00	[84.78; 88.91]	87.00	[83.62; 88.89]	.28
SBP mean	131.70	[129.00; 134.81]	135.50	[132.58; 139.27]	.09
SBP mean	68.00	[66.71; 70.28]	70.00	[67.07; 70.62]	.88
AHTI SBP	41.15	[37.21; 49.16]	50.40	[45.81; 57.97]	.04
AHTI DBP	12.9	[9.14; 17.92]	11.25	[7.31; 15.08]	.23

Abbreviations: AHTI DBP, arterial hypertension time index by diastolic arterial blood pressure; AHTI SBP, arterial hypertension time index by systolic blood pressure; ARBCCA, autoarterial remodeling of bifurcation of the common carotid artery; CEA, carotid endarterectomy; CI, confidence interval; DBP, diastolic blood pressure; HR, heart rate; SBP, systolic blood pressure.

Table 6. Results of intergroup analysis of severe arterial hypertension and night variability of systolic BP and diastolic BP (night-peaker, nondipper) in patients of both groups in the early postoperative period

	Group 1 (ARBCCA), n = 100		Group 2 ("classic" CEA), n = 100		P value
	Number	% of total	Number	% of total	
Severe AH	15	15	20	20	.23
Nigh-piker, nondipper (SBP)	62	62	63	63	.88
Nigh-piker, nondipper (DBP)	63	63	68	68	.55

Abbreviations: AH, arterial hypertension; ARBCCA, autoarterial remodeling of bifurcation of the common carotid artery; CEA, carotid endarterectomy; DBP, diastolic blood pressure; SBP, systolic blood pressure.

group] versus 24.7 ± 4.4 minutes ["classic" CEA], $P = .02$), and after Bonferroni correction there were statistically significant differences.

There were no cases of perioperative myocardial infarctions, strokes, and mortality within 30 days of CEA in both groups (asymptomatic and symptomatic patients). Transient ischemic attacks (TIA) were diagnosed in both groups (1 [4%] in the first group [symptomatic patient subgroup], 1 [3.7%] in the second group [symptomatic patient subgroup]). The plaque structure was of embolic character with hemorrhage and calcified in both cases (Table 7).

There were no cases of mortality within 24-month follow-up period in both groups. At the end of the 24-month follow-up period, carotid restenosis greater than 50% was detected in 4 (4%) cases (ARBCCA group) and 12 (12%) cases ("classic" CEA), respectively, $P = .037$ and after Bonferroni correction there were statistically significant differences.

Two cases (2.7%) of myocardial infarctions were diagnosed in "classic" CEA group (asymptomatic subgroup, $P = .25$). One (1.3%) case of TIA in ARBCCA group and 2 (2.7%) cases of TIA in "classic group" were determined

Table 7. Complications during a 30-day post procedural period in both groups

	Group 1 (ARBCCA), n = 100		Group 2 ("classic" CEA), n = 100		P value
	Symptomatic patients (N = 25)	Asymptomatic patients (N = 75)	Symptomatic patients (N = 27)	Asymptomatic patients (N = 73)	
Stroke	0	0	0	0	NA
TIA	1 (4%)	0	1 (3.7%)	0	.5
Myocardial infarctions	0	0	0	0	NA
Mortality	0	0	0	0	NA

Abbreviations: ARBCCA, autoarterial remodeling of bifurcation of the common carotid artery; CEA, carotid endarterectomy; TIA, transient ischemic attacks.

Table 8. Complications within 24-month follow-up period in both groups

	Group 1 (ARBCCA), n = 100		Group 2 ("classic" CEA), n = 100		P value
	Symptomatic patients (N = 25)	Asymptomatic patients (N = 75)	Symptomatic patients (N = 27)	Asymptomatic patients (N = 73)	
TIA	1 (4%)	0	2 (7.4)	0	.6
Stroke	0	0	0	0	NA
Myocardial infarctions	0	0	0	2 (2.7%)	.25
Mortality	0	0	0	0	NA

Abbreviations: ARBCCA, autoarterial remodeling of bifurcation of the common carotid artery; CEA, carotid endarterectomy; TIA, transient ischemic attacks.

during the 24-month follow-up period ($P = .55$). All TIA cases were diagnosed in symptomatic patients. Stroke was not diagnosed within 24-month follow-up period in both groups (Table 8).

Discussion

As it is known, the indicator of the hypertension time index determines the percentage of time during which BP values exceed the critical ("safe") level. It shows that BP is higher (lower) than baseline of the time from the total duration of monitoring (or in what percentage of measurements). The conditional limit of the norm for daytime is 140/90, and for the nighttime it is 125-130/80 mm Hg.²³

Therefore, the fact of surgical treatment of this pathology leads to an increase of HR, AHTI SBP, and AHTI DBP in both groups. This can be explained by the operating injury and the damage of the carotid sinus. The damage increases sympathetic innervation and causes dysregulation of the baroreceptor mechanism.^{24,25}

In a retrospective study by Demirel et al²⁶ 100 eversion CAEs were compared with 101 "classic" CEA. BP was significantly higher in the eversion group during the first 4 postoperative days, although it did not cross the threshold of 140 mm Hg (134 mm Hg versus 126 mm Hg, $P < .001$). Postoperative usage of intravenous or oral vasodilators was significantly higher in the eversion CEA group.

In a prospective study by Ballota et al,²⁷ there were no significant differences in postoperative arterial hypertension between 2 groups of 86 patients with eversion CEA and "classic" CEA (13% in the eversion group versus 6% in the "classic" CEA group, $P = .18$). The authors determined arterial hypertension as BP above 180 mm Hg or as an increase of mean systolic BP more than 30% of baseline BP. The level of systolic BP was higher on admission to the operating room than during an anesthesiologist's examination in the ward in both groups. This can be explained by the stress factor associated with surgery and the cancellation of antihypertensive therapy before the surgery.

Mehta et al²⁸ concluded that eversion CEA increases the risk of postoperative arterial hypertension in the first 24 hours. In their retrospective study, 137 "classic" CEA and 82 eversion CEA were compared. Postoperative arterial

hypertension was defined as systolic BP above 200 mm Hg or more than 40% relative to baseline systolic BP. Patients in the eversion CEA group had higher mean systolic BP than the "classic" CEA group in the first 24 hours ($P < .005$).

Postoperative hypertension is a complication after CEA. Nevertheless, the pathophysiological mechanism of postoperative hypertension is not well known. There are several hypotheses. Some authors^{9,29} suggested that postoperative hypertension is associated with transient dysfunction of the baroreceptor reflex. Ahn et al³⁰ believe that postoperative hypertension is associated with an increase in the level of intracerebral norepinephrine. Smith et al³¹ suggested that postoperative hypertension is associated with an increase of intracerebral renin's synthesis.

It is known that the autonomic nervous system controls constantly BP using the principle of negative feedback. One of the main mechanisms of controlling the level of BP is the baroreceptor reflex.³²

Baroreceptors are nerve endings located in the wall of the arteries. They are responsible for the dilatation of the artery wall. Carotid baroreceptors which are located in the adventitial layer of the medial part of the proximal ICA play one of the main roles in BP buffering. Carotid baroreceptors signals are conducted along Hering's nerves to the glossopharyngeal nerve, and then along a bundle of a single path into the medullary part of the brainstem.³³

The increase of sympathetic activity is the central pathogenetic mechanism of AH development. Progression of hypertension as a rule leads to a violation of the baroreflex control of the sympathetic tone. Reduction of the function of the baroreceptor mechanism depends on various reasons. But the main reason for this is the inhibition of the baroreceptor reflex of central genesis.³²

CEA is related with hemodynamic changes and it is always noted as its major disadvantage. Morbidity and mortality after CEA can be directly or indirectly influenced with hemodynamic instability, especially postoperative hypertension.²⁸ This can be explained by the fact that the carotid sinus may be damaged during the procedure and it influences BP. The hemodynamic instability caused by CEA has a close relationship with the baroreceptor function.³⁴ Attempts to solve this problem and to reduce the operation trauma led to the emergence of less

invasive technique – CAS. CAS was suggested as a less invasive alternative interventional procedure for severe carotid stenosis, especially for patients at a high surgical risk. However, hemodynamic depression including arterial hypotension and bradycardia is diagnosed during and after CAS.³⁵ And such cases are not rare. Many researchers report that the frequency of hemodynamic depression is between 13% and 75.9%.³⁶⁻³⁸ It can be explained by baroreceptor dysfunction appeared because of the carotid sinus baroreceptors stimulation by the angioplasty balloon and stent.³⁹

Facts mentioned above show that the problem of hemodynamic instability during severe carotid stenosis treatment is not still solved. Severe hypertension is diagnosed more often after CEA, while hemodynamic depression or bradycardia occurs more often after CAS. Moreover, there is no evident difference in short-term and long-term outcomes of CEA and CAS.^{40,23}

Any surgical technique of carotid stenosis treatment involves dissection of the bulb of the ICA. This is inevitably accompanied by partial (with longitudinal arteriotomy) or complete (with an eversion CEA) interruption of the baroreceptor reflex arc, which leads to a higher sympathetic activity.^{19,41}

Some authors suggested that the removal of atherosclerotic plaque causes a temporary interruption of the baroreflex. This leads to increase of BP and HR.⁴²

Perhaps the functions of the baroreceptors will change after infiltration of anesthetic into the periadventitial tissue around the carotid sinus. Prospective Rawi's study showed⁴³ that infiltration of the carotid artery led to a short-term repeal of the baroreceptor reflex and did not lead to changes in BP and HR. However, Fearn et al^{12,44} did not demonstrate the advantage of infiltration of carotid sinus by lidocaine before CEA. However, Gottlieb's study⁴⁵ showed that bupivacaine infiltration of the carotid artery significantly increased the risk of postoperative hypertension in patients undergoing CEA with patch plasty. Tang's meta-analysis,⁴⁶ including 4 prospective randomized studies, did not give an answer, if there was any benefit of carotid sinus infiltration in the form of stability in postoperative BP indicators. A recent macroscopic study of adjacent neuronal networks demonstrates that innervation of the sinus is variable and unpredictable.²⁴ Perhaps that is why the method of ARBCCA in comparison with the "classic" CEA showed no difference in running arterial hypertension in early postoperative period.

Besides, the time of carotid arteries clamping was significantly less in ARBCCA group than in the "classic" CEA group. This can be explained by the fact that a surgeon needs more time to cut out the patch in the "classic" CEA group.

At the end of the 24-month follow-up period, carotid restenosis greater than 50% in the "classic" CEA group was diagnosed significantly more often.

This was a prospective randomized study in a referral center where many patients are from different regions of Russia; thus, consistent follow-up is difficult. Nevertheless, all patients returned for follow-up in 2 years and were evaluated in subsequent years of follow-up, allowing assessment of medium-term results.

Unfortunately, our study has some limitations. The follow-up period is only 2 years. Longer follow-up is ideal and may reveal data that could alter our current conclusions.

ARBCCA is a new technique and we plan to analyze it in several stages. This article represents the results of the first stage: the comparison of ARBCCA and "classic" CEA. We started with this comparison as "classic" CEA is the most often used technique for severe carotid artery stenosis treatment. The second step of ARBCCA analysis is its comparison with the eversion CEA.

Conclusions

In our study, we did not reveal a significant difference in the incidence of postoperative hypertension and the dependence of HR on the choice of surgical technique. Thus, the proposed ARBCCA method does not lead to an increased risk of developing of pre-existing arterial hypertension.

A significant difference is found out on the parameter of the clamping time of carotid arteries in favor to ARBCCA group.

Another advantage of the suggested technique is the number of restenosis greater than 50% during the 2-year follow-up (4 [4%] cases [ARBCCA group] versus 12 [12%] cases ["classic" CEA], respectively, $P = .037$).

This single-center randomized study supports the safety and mid-term efficacy of ARBCCA method in a limited cohort of patients, thus emphasizing the need for larger scale clinical trials to evaluate this approach against "classic" CEA and eversion CEA.

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