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# The Impact of Unilateral and Bilateral Eversion Carotid Endarterectomy on Postoperative Hemodynamic Parameters

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## ABSTRACT

**Background:** Carotid endarterectomy (CEA) is an effective and safe treatment of stenosed carotid arteries, and is a preventive operation with well-defined indications. It is associated with a loss of the baroreceptor reflex and postoperatively increased hemodynamic parameters. **Objective:** The aim of the study was to confirm the sensitivity of baroreceptors and the impact on arterial pressure and heart rate in unilateral and bilateral eversion carotid endarterectomies. **Methods:** A retrospective study was conducted with 30 patients treated with E-CEA in local anesthesia at the Clinic for cardiovascular surgery from December 2019 to May 2021, due to stenosis of the carotid arteries. Patients were divided into two groups: 15 patients in group A (patients with unilateral E-CEA; 15 patients in group B: patients with bilateral E-CEA). **Results:** Out of the total of 30 patients included in the research, 15 patients in groups A and B respectively, there were no statistically significant differences in regards to gender ( $p=0,245$ ) and preoperative risk factors: smoking ( $p=0,449$ ); hypertension ( $p=0,388$ ); diabetes ( $p=0,714$ ); hyperlipidemia ( $p=0,388$ ), coronary disease ( $p=0,461$ ) and symptomatic stenosis of the carotid arteries ( $p=0,449$ ). Noted were the statistically significant differences in values of systolic and diastolic pressure on the 3rd postoperative days in patients with bilateral E-CEA ( $p=0,001$ ;  $p=0,001$ ), a statistically significant difference in the heart rate was not found in the analyzed groups in the postoperative period ( $p=0,225$ ;  $p=0,994$ ). **Conclusion:** This study identified statistically significant differences in values of systolic and diastolic pressure in the early postoperative period. In his period, early detection and correction of these hemodynamic disorders are needed.

**Keywords:** baroreceptor sensitivity, eversion carotid endarterectomy, post-endarterectomy hypertension.

## 1. BACKGROUND

Hemodynamic instability following carotid endarterectomy (CEA) is a well-recognized phenomenon (1). Both hypotension and hypertension may appear, which may result in prolonged hospitalization or, even more seriously, may be associated with neurologic complications (2).

Carotid Endarterectomy (CEA) is an effective and safe treatment of stenosed carotid arteries and is a preventive operation with well-defined indications which are founded on the results of extensive randomized prospective studies (3-6). However, they are often associated with post-operative changes in blood pressure (7-10).

Carotid surgery is unique given that the main components of physiologic mechanisms of arterial pressure control, baroreceptors in the carotid sinus, are involved in the very disease process itself, and may be impacted by surgical intervention. Although certain studies showed a relationship between preoperative and postoperative hypertension (11) and between perioperative hypertension and poor neurologic outcome and death (12), other large studies did not identify such relationships amongst CEA (13).

These hemodynamic changes can be associated with changes in baroreceptor sensitivity of the carotid sinus (14). Baroreceptors, reacting to changes in pressure and sending signals to the brain regarding current changes in arterial blood pressure, are found in key locations within the cardiovascular system. They control numerous reflex responses which lead to autonomic and endocrine corrections, and thus lead to maintaining cardiovascular homeo-

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stasis (15). In this way, baroreflexes take part in short-term and long-term control of blood pressure (16).

The widening of vascular structures due to increased blood pressure jumpstarts the sending of impulses from the baroreceptor, and the frequency of impulses is directly proportional to the mean arterial pressure and speed of changes in pressure change (17). Impulses are spread through glossopharyngeal and vagal nerves, to the nucleus tractus solitarius medulla, and lead to the activation of parasympathetic and inhibition of sympathetic nuclei (18). Rising blood pressure, causing activation of baroreceptors leads to a reduction in the impact of the sympathetic nervous system on the heart, kidneys, and peripheral blood vessels, as well as an increased parasympathetic tone on the heart. All of this results in a fall in peripheral vascular resistance, heart rate, minute volume and blood pressure.

The most utilized carotid endarterectomy technique is the conventional carotid endarterectomy (C-CEA), which is performed with a longitudinal arteriotomy of the internal carotid artery. Its alternative is the eversion carotid endarterectomy (E-CEA), which was described by DeBakey, and later popularised by Etheredge (19, 20). In contrast to C-CEA, in which patch angioplasty is sometimes needed, in E-CEA it is not, which represents a potential advantage. This technique requires cross-sectioning the longitudinal nerve fibers of the carotid sinus nerve and potential loss of baroreceptor sensitivity, which represents a potential adverse outcome (21).

## 2. OBJECTIVE

The aim of this study is to evaluate the impact of baroreceptor sensitivity on arterial pressure and heart rate in unilateral and bilateral eversion carotid endarterectomy. We presume that in bilateral E-CEA, there may be a significant difference in baroreceptor sensitivity which may result in a significant increase of hemodynamic parameters compared to unilateral E-CEA.

## 3. MATERIAL AND METHODS

This retrospective study included respondents with stenosis of the carotid arteries, on which E-CEA was conducted in local anesthesia, in the period from December 2019 to May 2021. Patients were divided into two groups: Group A patients who underwent unilateral E-CEA, and Group B—patients who underwent bilateral E-CEA (two separate CEA procedures conducted in a period of at least 3 months). For each patient the following variables were collected: age, gender, smoking status, history of hypertension (HTN), diabetes mellitus (DM), hyperlipidemia (HLP), history of coronary artery disease (CAD) which has not been surgically treated, and facts regarding the status of symptoms. The effect of unilateral and bilateral E-CEA (the previous CEA in the group of patients with bilateral CEA was conducted in the previous period) was analyzed according to postoperative values of blood pressure and heart rate (the first and third postoperative day).

The exclusion criteria for this study were: patients with restenosis of carotid arteries, stenosis of carotid arteries with concomitant stenosis of supra-aortic branches, dissection of carotid arteries, aneurysm of carotid arteries, significant neurologic deficits after stroke, simultaneous CEA operation and coronary artery bypass or peripheral revascularization.

CEA was performed via eversion technique (E-CEA) under local anesthesia. In E-CEA the carotid sinus nerve is cross-sectioned so that a complete mobilisation of the carotid bifurcation may be secured. Surgical treatment is indicated in asymptomatic patients with stenosis of 70 do 99%, and in symptomatic patients with stenosis > 60%. The degree of stenosis is determined by Color Doppler ultrasound and CT angiography or MRI angiography. The primary statistical source was a computerized database and standardized patient medical records while hospitalized (history of the disease, operative record, patient's medical/hospital list, letter of release from the hospital). Involved in the evaluation of patients' clinical status were neurologists, anesthesiologists, and vascular surgeons independent one of another. For this study, measuring (arterial blood pressure—systolic and diastolic, heart rate) were conducted on the day of admission and the first and third postoperative day. Prior to measurement, all patients were instructed to lie down for at least 10 minutes.

The E-CEA technique represents the transection at the level of the carotid bifurcation along with the removal of the atherosclerotic plaque by everting the artery, followed by plaque removal from the external carotid artery and common carotid artery, followed by the anatomic reimplantation of the internal carotid artery.

The first postoperative measurement was conducted 24 hours after the surgery, taking into account the potential effect of local anesthesia on baroreceptor sensitivity.

### *Statistical analysis*

In the statistical analysis of data, standard methods of descriptive statistics were utilized. The regularity of statistical distribution was determined by the Shapiro Wilks test. Depending on the results, non-parametric tests were used for further analysis.

Basic characteristics were collected and displayed as well as the number of cases and percentage of prevalence. Categorical variables were analyzed by the  $\chi^2$  test, Mann-Whitney U test, and Wilcoxon test was used in analyzing quantitative variables. Statistically hypotheses were tested at the level of  $\alpha=0.05$ , that is the difference between samples was considered significant if the  $p<0.05$ . In the statistical analysis, the SPSS version 21.0 program was used in statistical analysis.

## 4. RESULTS

The study included a total of 30 subjects divided into two groups. In the group of subjects with unilateral E-CEA (Group A) there were 8 (53.3%) males and 7 females (46.7%), and in the group with bilateral CEA (Group B) 12 males (80%) and 3 females (20%) ( $p=0.245$ ). The average age of respondents in group A was 66.8 years of

	Unilateral CEA (n = 15)	Bilateral CEA (n = 15)	P
Average age, years (SD)	66,8 (7,47)	69 (8,68)	0,633
Male (%)	8 (53,3%)	12 (80%)	
Female (%)	7 (46,7%)	3 (20%)	0,245
Smoker.no (%)	7 (46,7%)	4 (26,3%)	0,449
Hypertension. no. (%)	10 (66,7%)	13 (86,7%)	0,388
Diabetes. no. (%)	9 (60%)	7 (46,7%)	0,714
Hyperlipidemia. no.(%)	13 (86,7%)	10 (66,7%)	0,338
Coronary artery disease. no. (%)	5 (33,3%)	8 (53,3%)	0,461
Symptomatic Stenosis. no (%)	11 (73,3%)	8 (53,3%)	0,449

Table 1. Demographics and risk factors.

	Unilateral E-CEA (n=15)		P	Bilateral E-CEA (n=15)		P
	Preop. [median (IQR)]	Postop. 24h [median (IQR)]		Preop. [median (IQR)]	Postop. 24h [median (IQR)]	
Arterial blood pressure (mm HG)						
SP	120,00 (115,00-120,00)	125,00 (120,00-129,00)	<b>0,001</b>	121,00 (115,00-125,00)	127,00 (120,00-130,00)	<b>0,001</b>
DP	74,00 (70,00-76,00)	78,00 (75,00-80,00)	<b>0,003</b>	70,00 (70,00-79,00)	76,0 (74,00-81,00)	<b>0,003</b>
HR	81,00 (75,00-84,00)	79,00 (76,00-83,00)	<b>0,203</b>	80,00 (70,00-82,00)	78,00 (72,00-82,00)	<b>0,977</b>

Table 2 Hemodynamic parameters averaged over the 10-minute recording (preoperative versus postoperative 24 h) E-CEA-eversion carotid endarterectomy; SP, systolic pressure; DP, diastolic pressure; HR, heart rate.

	Unilateral E-CEA (n=15)		P	Bilateral E-CEA (n=15)		P
	Preop. [median (IQR)]	Postop. 72h [median (IQR)]		Preop. [median (IQR)]	Postop. 72h [median (IQR)]	
Arterial blood pressure (mm HG)						
SP	120,00 (115,00-120,00)	121,00 (120,00-128,00)	<b>0,003</b>	121,00 (115,00-125,00)	126,00 (120,00-129,00)	<b>0,001</b>
DP	74,00 (70,00-76,00)	79,00 (75,00-81,00)	<b>0,007</b>	70,00 (70,00-79,00)	79,00 (74,00-81,00)	<b>0,001</b>
HR(beats/min)	81,00 (75,00-84,00)	80,00 (75,00-85,00)	<b>0,225</b>	80,00 (70,00-82,00)	79,00 (75, -81,00)	<b>0,994</b>

Table 3 Hemodynamic parameters averaged over the 10-minute recording (preoperative versus postoperative 72 h). E-CEA-eversion carotid endarterectomy; SP, systolic pressure; DP, diastolic pressure; HR,heart rate.

age (SD 7.47, in the range from 55 years to 81 years), and in group B was 69 years of age (SD 8.68, in the range from 57 years to 85 years) (p=0.633). The prevalence of preoperative risk factors did not point to statistical significance between the two compared groups: smoking 7 (46.7%) compared to 44 (26.3 %), p= 0.449; HTN 10 (66.7%) compared to 13 (86.7%), p=0.388; DM 9 (60%) compared to 7 (46.7%), p= 0.714; HLP 13 (86.7%) compared to 10 (66.7%), 0.338 ; CAD 5 (33.3%) compared to 8 (53.3%), p=0.461, and symptomatic stenosis 11(73.3%) compared to 8 (53.3%), p=0.449 (Table 1).

According to the analysis of preoperative and postoperative hemodynamic parameters (24 hours after the surgical procedure) a statistically significant difference in values of systolic pressure in unilateral E-CEA (p=0,001), as well as in bilateral E-CEA (p=0,001) was established. A statistically significant difference was,

additionally, identified in the values of diastolic pressure, unilateral E-CEA (p=0,003) and in bilateral E-CEA (p=0,003), however, upon analysis of the heart rate values, no statistically significant difference among the analysed groups was identified: in unilateral E-CEA (p=0.203), and in bilateral E-CEA (p=0,977) (Table 2).

Statistically significant difference in values of systolic pressure was even found after 72 hours: in the group of patients with unilateral E-CEA (p=0.003) as well as in the bilateral E-CEA (p=0.001). Also confirmed was a statistically significant difference in values of diastolic pressure: in the group with unilateral E-CEA (p=0.007), and in the group of patients with bilateral E-CEA (p=0.001). Statistically significant differences were not determined upon analysis of heart rate, as unilateral E-CEA (p=0.225), and the group with bilateral E-CEA (p=0.994) (Table 3).

## 5. DISCUSSION

Baroreceptors are found in the adventitia and media of the carotid sinus. They are the final part of the afferent fibers which through the Herring nerve traverse into the glossopharyngeal nerve. An increase in blood pressure (BP) leads to stretching of the walls of the blood vessel and a reaction from the receptors. With variations in blood pressure (BP) signals are sent to active the responsible centers in the brain which regulate the sympathetic and parasympathetic nervous system. If the influence of the sympathetic system is decreased, heart rate is slow down and the diameter of blood vessels increases, which results in a fall of BP in the arterial system. The role of the baroreceptor system in the regulation of blood pressure (BP) was first described by Cooper (22). Hering and Korner experimented on animals and showed that cross-sectioning the nerves of the carotid sinus leads to systemic hypertension (23, 24). All this information exemplifies the primary function of the baroreceptor system—to stabilize values of blood pressure and to prevent large short-term fluctuations.

Certain studies showed that the presence of atheroma in the region of the carotid sinus may weaken the sensitivity of baroreceptors 25 and it seems that this damage may be larger in patients with a denser plaque. However, it is not clear if the lower sensitivity of these baroreceptors, after damage caused by surgical intervention, correlates with echogenicity of the removed carotid plaque on CEA. Research by Sigaudou-Roussel D, et al. showed that baroreceptor damage during CEA leads to post-operative hypertension (26). This finding is clearer in E-CEA, and despite this this technique is widely used due to its advantages. In the research of Cao, et al. A lower level of risk is described of arterial occlusion and re-stenosis E-CEA, however the authors concluded that until now there is not enough evidence which may point to the benefits or drawbacks of eversion CEA in regards to the outcome of stroke and death, restenosis/occlusion of the carotid artery and local complications (27). Because of this the ideal surgical technique for optimization of early outcome and longevity of CEA yet needs to be determined. Current evidence shows that

until further information is available, the choice of CE technique needs to be dependent upon the experience and inclination of the surgeon.

An increase in blood pressure (BP) following carotid endarterectomy is in correlation with increased nor-adrenaline in the brain due to sympathomimetic mechanisms of the Central nervous system caused by reflex inhibition of the vasomotor centers, likely associated with damage to the baroreceptor reflex (28).

Certain vascular surgeons advocate a blockade of the nerves of the carotid sinus with a local anesthetic, during CEA, to minimize fluctuations in blood pressure (BP), but the efficacy of prevention of postoperative hemodynamic instability via this procedure remains unclear. Research by Tang et al. (29) based on four randomized controlled studies, suggests that there is no conclusive evidence to support the routine use of local anesthetic for the blockade of the nerves of the carotid sinus to lower post-operative fluctuations in blood pressure (BP).

Our statistics show that an increase in blood pressure is present after E-CEA, in bilateral as well as in unilateral E-CEA. Thus, the theory that destroying the baroreceptor apparatus leads to postoperative increases in blood pressure, as described in certain studies (30), is supported in our results as well.

Well known is the explanation that following clamping of the common carotid artery, the carotid sinus is exposed to lower pressure which as a result decreases the stimulus of the baroreceptors which leads to decreases in the sending of impulses by the sinus nerves and glossopharyngeal nerves to the brain stem, which results in increased vasomotor tone. Because of this the carotid baroreceptors have an important role in maintaining normal arterial system pressure by buffering its short-term fluctuations.

In our retrospective study we showed that a significant increase in blood pressure in the immediate post-operative period (1st and 3rd day after carotid endarterectomy) following the use of the eversion technique. Compared to the eversion technique used in our study, in the research by Sigaudou-Roussel, et al. (26) the classic technique of CEA was used, and highlighted was the significant decreased in baroreceptor sensitivity on the 2nd day following the surgical procedure, which may be associated with a partial lesion of the nerves of the carotid body during classic CEA compared to a significant lesion which occurs during the eversion technique.

Preoperative neurologic deficits are independent predictors of hypertension following CEA. This phenomenon may be attributed to damage of the central components of the baroreflex (31). Thus, excluded from the study were patients which had previous severe strokes causing disability. The results of our study support the hypothesis that bilateral denervation of the carotid sinus nerve leads to an increase in systolic pressure, and that bilateral E-CEA, leads to an even more significant increase in systolic pressure which may be associated with bilateral denervation of the carotid sinus nerve, which supports the research by Mehta et al. (21) which highlights the relation between E-CEA and post-operative

hypertension. Our research did not show a statistically significant change in heart rate postoperatively, which is in unison with the research by Margulies, et al. (32).

To summarize, our research shows that a post-operative increase in blood pressure is present following E-CEA, whereby this increase is more pronounced in the 3rd postoperative day following bilateral E-CEA. Clinically this implies that patients with bilateral E-CEA are post-operatively more inclined to experience a significant increase in systolic and diastolic blood pressure than those who underwent unilateral E-CEA, and that thorough monitoring of blood pressure may be needed. The limitations of the study may be the relatively small number of patients, and additionally it would be beneficial via long-term study to confirm whether or not the change is examined values after the early postoperative period remains.

## 6. CONCLUSION

Early detection and correction of these hemodynamic disorders in the postoperative period is needed. For the early detection and correction of these hemodynamic disorders, intensive monitoring in the postoperative period are needed.

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