HEALTH SCIENCES QUARTERLY

Volume: 3
Issue: 4
2023

E-ISSN: 2791-6022
https://journals.gen.tr/jsp

Received: 2023-04-25
Accepted: 2023-06-15

ORIGINAL ARTICLE

The comparison of the postoperative complications, mortality, and morbidity of the eversion technique and the classical technique in carotid endarterectomy

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Abstract

In the present study, the purpose was to compare the postoperative early and mid-term results of Eversion Carotid Endarterectomy (ECEA) and Classical Carotid Endarterectomy (CCEA) techniques used in the surgical treatment of carotid artery disease. A total of 269 patients who underwent carotid endarterectomy (105 ECEA and 164 CCEA) were included in the study. The 1st, 6th, and 12th-month follow-ups of 266 patients were performed because three patients died in the early postoperative period. All patients were started on acetylsalicylic acid, clopidogrel, and statin treatment in the postoperative period. When the postoperative results were evaluated, it was found that the cross-clamp and operation times of the surgeries performed with the ECEA technique were shorter than the CCEA at statistically significant levels (p=0.0002). Although there statistically significant differences were detected in terms of bleeding/drainage, need for reoperation because of bleeding, and restenosis, ECEA had more positive results than CCEA, and there were no statistically and proportionally significant differences between the two methods in terms of postoperative stroke and mortality. Considering the experience of the surgical team, the use of the ECEA technique has more positive results in terms of operation time and cross-clamp time compared to CCEA. We think that extending the follow-up periods of patients in the postoperative period and conducting multicenter studies with more patients would be more accurate in comparing these two methods.

Keywords: Carotid endarterectomy, eversion, stroke

Citation: Kocaoğlu AS, Ovalı C. The comparison of the postoperative complications, mortality, and morbidity of the eversion technique and the classical technique in carotid endarterectomy. Health Sci Q. 2023;3(4):195-203. https://doi.org/10.26900/hsq.2066

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Introduction

Carotid artery stenosis because of atherosclerosis of the carotid arteries is the main cause of ischemic stroke, and carotid artery disease has high morbidity and mortality rates. Stroke is still the third most common cause of mortality in Western societies following heart diseases and cancer [1]. The most important cause of extracranial ischemic cerebrovascular event (CVE) is atherosclerosis which affects the carotid bifurcation [2]. Although the symptoms vary according to the affected area of the brain, symptoms such as weakness, paralysis, numbness, and tingling can be seen in the contralateral extremity. Aphasia can also be seen in cases if dominant hemisphere is affected. Depending on the occlusion of the carotid plate in the ipsilateral retinal artery, temporary or permanent, total or partial vision loss (Amarosis fugax) may also be seen [2]. It may progress asymptomatically when there is severe stenosis in the carotid arteries or symptoms as a result of embolism may also be seen in the ulcerated lesions without severe stenosis [3].

Combined with optimal medical management, surgical intervention in the form of Carotid Endarterectomy (CEA) plays important roles in preventing subsequent strokes in properly selected patients. In the 2021 Guideline of the Society of Vascular Surgery (SVS), CEA was found to be superior to Carotid Artery Stenting (CAS) in symptomatic carotid artery disease in 50% or more patients with low surgical risk, CEA is recommended compared to medical treatment in asymptomatic stenosis between 70-99% in low-risk surgical patients [4]. However, routine CEA is not recommended for asymptomatic patients [5]. Considering the additional characteristics of patients, asymptomatic patients with 60% or more stenosis should be evaluated for surgery.

There are Classical Carotid Endarterectomy (CCEA) (Figure 1) and Eversion Carotid Endarterectomy (ECEA) among the surgical techniques (Figure 2). In previous studies, no significant differences were reported in terms of factors such as stroke, death, local findings, restenosis rates, *etc.* between ECEA and CCEA, but differences were detected in conditions such as long plaque, tortuous Internal Carotid Artery (ICA), difficulty in access, and bleeding risk [6].

In the present study, among the patients operated on for carotid artery disease, the postoperative early and mid-term results of those who underwent ECEA and those who underwent CCEA were evaluated and compared in terms of infection, cerebrovascular event, permanent sequelae, death, bleeding, restenosis rates at one, six and twelve months, and preoperative risk factors.

Materials and Methods

The approval of Eskişehir Osmangazi University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee was obtained for the study (E-25403353-050.99-146237). The files and hospital admission records of 403 CEA patients operated on for carotid artery disease in our hospital between January 2016 and December 2019 were reviewed retrospectively. It was found that 127 of the operations did not come to the clinic follow-ups in the postoperative period, 276 patients regularly came to the clinical follow-ups. Seven of the patients were excluded from the study because there would be differences in their medical treatments because of atrial fibrillation in the postoperative period, and a total of 269 patients were included in the study. All cases were done by the same surgical team. All patients were scheduled to have surgery after the examination and decision of the Neurology Stroke Clinic together with the results of Dupplex Ultrasonography (USG) and Computed Tomographic Angiography (CT Angiography). Sixteen of the patients had bilateral carotid artery stenosis and the side where the stenosis was more critical was operated on first. Among the patients who were included in the study, 105 (39%) had ECEA, and 164 (61%) patients underwent CCEA. The Cerebral Oximetry Device was used in all patients during the operations. A shunt was used in patients who had a decrease of more than 20% in cerebral oximetry after clamping the carotid artery or who had weak retrograde flow from the ICA.

In the Eversion CEE Method, the ICA was separated from the bifurcation area by cutting a full thickness, and the plaque was removed from the wall with the help of an elevator, the ICA was everted distally and the plaque was then removed. The inside of the ICA was washed, anastomosis was made with a continuous suture to the bifurcation area, the air was removed, and the surgery was completed in this way. In the Classical CEA Method, following a longitudinal incision from the Common Carotid Artery (CCA) to the ICA, the plate was removed with the help of an elevator and then the incision on the artery was closed. Since three patients died in the early postoperative period, they were not included in the data analysis. All the remaining patients were those who received a postoperative 24-hour intravenous (IV) Heparin infusion followed by twelve months of Acetylsalicylic Acid (ASA), Clopidogrel, and statin therapy. All patients who underwent Classical CEA were those who underwent primary closure. From patient files and clinical follow-ups, the demographic characteristics, preoperative and postoperative neurological status, amount of postoperative drainage, bleeding complications, reoperation requirements, sequelae and infection status, death status, and restenosis status were evaluated by looking at the Carotid Doppler USG and ICA/PSV ratios and were transferred to the data table. Carotid Doppler USG follow-ups and measurements were made by the same team with the Samsung Sonoace X7 ultrasound device. The patients were divided into two groups as those who underwent CCEA and ECEA during the analysis.

Statistical Analysis

The Statistical Package for Social Sciences (SPSS) software, version 21 was used for statistical analysis and a $p<0.05$ value was taken as statistical significance. Continuous variables such as age

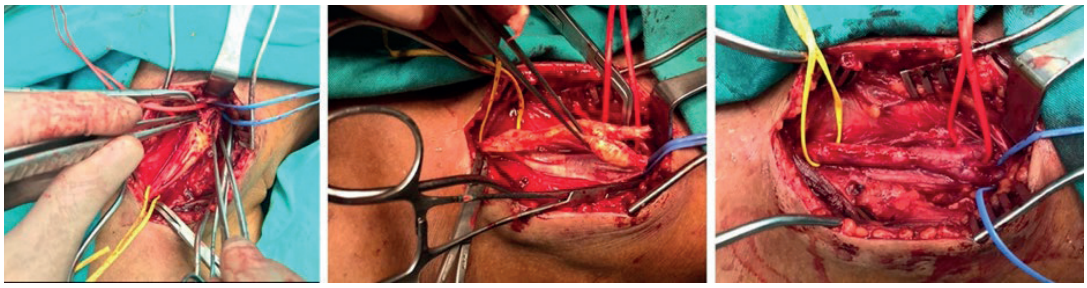

Figure 1. Classical carotid endarterectomy technique

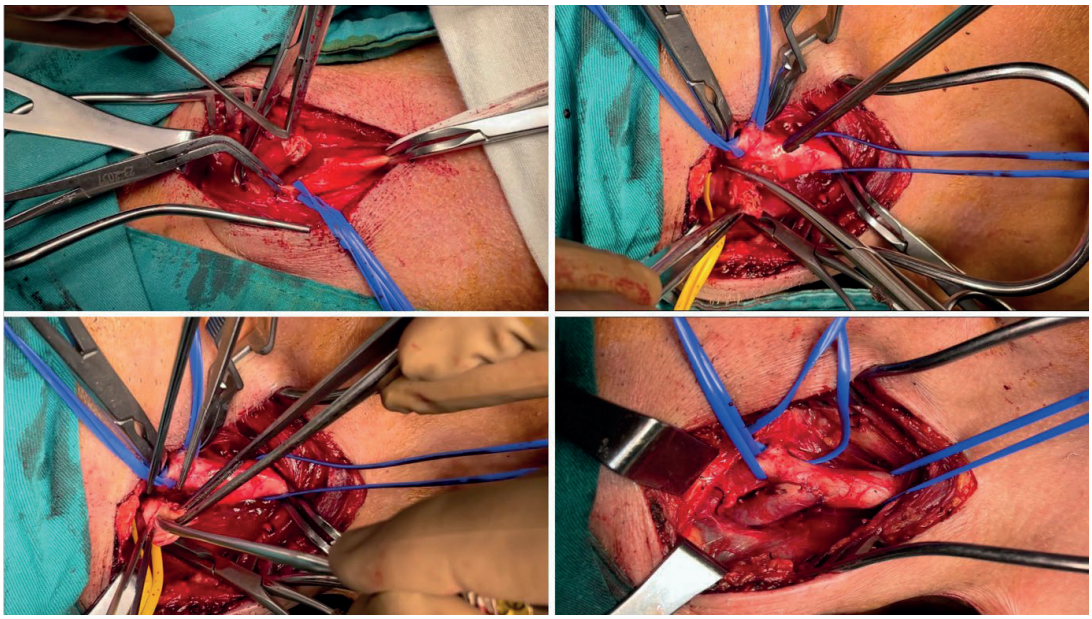

Figure 2. Eversion carotid endarterectomy technique

and the amount of postoperative drainage were evaluated in terms of the normal distribution with ICA, Peak Systolic Volume (PSV), and ICA/CCA PSV histogram, Q-Q graph, and *Shaphiro-Wilk* Test at postoperative first, sixth, and twelfth months. It was found that continuous variables did not have a normal distribution, and are given as median (minimum-maximum) values, and the Student's *t*-test was used to compare the continuous variables. The data of the categorized variables are given as frequency and percentage distribution. The *Fisher's* and/or *Pearson* Chi-Square Tests were used to compare the categorized variables.

Results

The median age of the study population, which consisted of a total of 269 patients, was found to be 69.3 years (41.8-89.6 years). A total of one hundred and ninety (70.6%) patients were male and 79 (29.4%) patients were female and 229 (85.1%) of them were symptomatic. Considering the degree of stenosis of all patients, it was determined that the majority of patients (n=110, 40.9%) had stenosis at a rate of 70-89%. The degree of carotid stenosis was between 50-69% in 11 (4.1%) patients, 90-99% in 97 (36.1%) patients, and near occlusion in 51 (19%) patients.

When all patients were evaluated, the eversion technique was applied to a total of 105 (39%) patients, and the primary closure technique was applied to 164 (61%) patients. Carotid artery diameter was greater than 6 mm in all patients who underwent the primary closure technique. Intravascular shunts were used for a total of 10 (3.7%) patients. Revisions were performed in 17 (6.2%) patients because of postoperative bleeding/hematoma and infection was detected in one (0.4%) patient. CVE developed in a total of 14 (5.2%) patients in the postoperative period and permanent sequelae developed in the same number of patients. Permanent sequelae were detected in the right hemiplegia in four patients (1.5%), monoparesis in the right upper extremity in four patients (1.5%), left hemiplegia in two patients (0.7%), monoplegia in the left upper extremity in two patients (0.7%), monoplegia in upper right extremity in one patient (0.4%), and hemiparesis in lower right extremity in one patient (%0.4).

The data used to compare the eversion technique with the classical technique as a surgical technique and the demographic characteristics of the patients are summarized in Table 1. No significant differences were detected between the groups in terms of side (p=0.575) and urgency (p=0.900). Also, shunt use (p=0.745) and symptomatic/asymptomatic patient distribution (p=0.829) did not differ at significant levels between the groups. No significant differences were detected in the rates of transient ischemic patients (p=0.983) or patients with permanent sequelae (p=0.586) in the preoperative period. Considering the duration of the surgery and the duration of the clamping of the carotid artery, ECEA had a statistically significantly shorter duration than the CCEA (p=0.0002). The use of shunt, which was determined by retrograde flow after carotid incision and/or more than 20% decrease in cerebral oximetry following the carotid clamping, was significantly higher in patients who were taken to emergency CEA when compared to those who were taken to elective surgery (11.4% vs 2.6%, p=0.029). Three patients (8.6%) who underwent emergency CEA had CVE in the postoperative period and eleven patients (4.7%) who underwent elective CEA had CVE in the postoperative period. Although the rate of incidence in patients who underwent emergency surgery in the development of postoperative CVE was approximately 2-fold higher, it was not found to be at a statistically significant level (p=0.404). When the mean amount of drainage between the eversion and the classical technique was examined, the amount of drainage was higher in the classical technique, but with no statistically significant differences (p=0.063). Although the rates of reoperation and postoperative hematoma because of bleeding in the early postoperative period were found to be higher in the classical endarterectomy group, the difference was not at a statistically significant level (p=0.088). Although CVE rates were higher in the classical endarterectomy group in the early postoperative period, it was not at a statistically significant level (p=0.576). The distribution of concomitant coronary artery disease in the groups was equal and coronary angiography was performed for 64 patients who did not have any history of intervention in the last one

year. No need for intervention was detected in 52 patients, coronary stenting was performed for seven patients, and coronary artery bypass surgery was performed simultaneously with CEA in five patients.

A total of 266 patients were followed up at the 1st, 6th, and 12th months because three of the patients included in the study died in the postoperative period. Therefore, the findings of the evaluations for the development of re-stenosis are given in Table 2.

In the first month follow-ups, 261 (98.1%) patients did not have recurrent carotid stenosis, but three (1.1%) patients had <49% and one patient (0.4%) had 50%, one patient 69%, and one patient 70%-98% stenosis. Although there was no recurrent carotid stenosis in 244 (91.7%) patients at 6-month follow-ups, stenosis was <49% in

Table 1. Comparison of the eversion and conventional carotid endarterectomy techniques and demographic characteristics of the study population.

	Surgical technique		
Variable	**Eversion (n= 105) n (%)**	**Classical (n= 164) n (%)**	***p* value**
Age, *year*	67.1 (42.3 – 86.2)	70.3 (49.1 – 89.6)	
Sex			
Female	32 (30.5)	47 (28.7)	
Male	73 (69.5)	117 (71.3)	
Side			
Right	45 (42.9)	76 (46.3)	0.575[a]
Left	60 (57.1)	88 (53.7)	
Urgency			
Urgent	14 (13.3)	21 (12.8)	0.900[a]
Elective	91 (86.7)	143 (87.2)	
Degree of stenosis			
%50 – 69	5 (4.8)	6 (3.7)	0.830[a]
%70 – 89	40 (38.1)	70 (42.7)	
%90 – 99	38 (36.2)	59 (36.6)	
Near occlusion	22 (21)	29 (17.7)	
Şhunt usage			
Yes	3 (2.9)	7 (4.3)	0.745[b]
No	102 (97.1)	157 (95.7)	
Clinical			
Symptomatic	90 (85.7)	139 (84.8)	0.829[a]
Asymptomatic	15 (14.3)	25 (15.2)	
Systemic diseases			
Hypertension	74 (70.5)	116 (70.7)	0.964[a]
Hyperlipidemia	46 (43.8)	55 (33.5)	0.090[a]
Diabetes mellitus	41 (39)	61 (37.2)	0.760[a]
Coronary artery disease	38 (36.2)	57 (34.8)	0.810[a]
Peripheral artery disease	12 (11.4)	15 (9.1)	0.543[a]
Chronic renal insufficiency	6 (5.7)	7 (4.3)	0.590[a]
Tobacco use	50 (47.6)	82 (50)	0.703[a]
Carotid cross clamp time, *min*	13.7 ± 4.5	21.5 ± 6.7	**0.002[c]**
Operation time, *min*	88 ± 22	107 ± 15	**0.002[c]**
Postoperative drainage, *ml*	13 (8 – 62)	29 (8 – 68)	0.063[c]
Reoperation for bleeding	5 (4.7)	12 (7.3)	0.088[a]
Postoperative hematoma	6 (5.7)	10 (6)	0.087[a]
Postoperative infection	1 (1)	0 (0)	0.391[b]
Postoperative cerebrovascular event	5 (4.8)	9 (5.5)	0.576[b]
Postoperative permanent sequel	5 (4.8)	9 (5.5)	0.794[a]
In-hospital mortality	1 (1)	2 (1.2)	1.0[b]

[a]Pearson chi square test, bFischer's exact test, cStudent's t test.

twelve (4.5%) patients, 50-69% in eight (3%) patients, and 70% - 98% in 2 (0.8%) patients. In the twelfth month follow-up, 237 (89.1%) patients did not have recurrent carotid stenosis, but twelve (4.5%) patients had <49%, eleven (4.1%) patients had 50-69%, and six (2.3%) patients had 70-98% stenosis. The results obtained when the rates of recurrent stenosis in the first, sixth, and twelfth-month follow-ups were compared according to the surgical techniques are given in Table 3. In this regard, when the distribution of recurrent stenosis degrees was examined in the postoperative first, sixth, and twelfth months, no statistically significant differences were detected between the two techniques in the postoperative first and sixth-month follow-ups. In the 12th month follow-up, although the rate of 50% or more restenosis was higher in the classical endarterectomy technique, no statistically significant differences were detected because of the surgical technique (p>0.05). None of the four patients who underwent surgical treatment with the Eversion CEA technique and had more than 50% restenosis required re-surgical intervention. In the 1-year follow-up of the patients, restenosis rates were found to be between 50-60%, and no symptoms were detected. As a result of the evaluations made by the neurology stroke clinic after symptom development, carotid artery stenting was used for three patients with 50% or more restenosis among those who were treated with the Classical CEA technique.

Discussion

Stroke is an important cause of mortality and morbidity worldwide and can be detected because of parenchymal hemorrhages or disruption of blood flow in the vessels going to the brain because of atherosclerosis and embolism. As a result of the disruption of the flow in the stenosis area because of the carotid artery stenosis, thrombus formation and deterioration of cerebral flow may cause neurological symptoms and ischemic strokes might occur when the pieces of plaque in the carotid artery go directly to the cerebral arteries. Although the risk of stroke is 1% in patients with 60% or less stenosis, this risk increases 3-5-fold in 80% or more stenosis [7,8].

In a study conducted by Cao et al., (1997) comparing 240 patients who underwent CCEA and 274 patients who underwent ECEA, the carotid clamp time was found to be 28.3 ± 10.1 minutes in the CCEA group and 25.5 ± 7.4 minutes in the ECEA group, and this difference was at a statistically significant level (p=0.0001)

Table 2. Distribution of the degree of stenosis in the 1st, 6th, and 12th month follow-up.

	Follow-up visits		
Degree of stenosis	**1st month**	**6th month**	**12th month**
No stenosis	261 (98.1)	244 (91.7)	237 (89.1)
<%49	3 (1.1)	12 (4.5)	12 (4.5)
%50 - 69	1 (0.4)	8 (3)	11 (4.1)
%70 - 98	1 (0.4)	2 (0.8)	6 (2.3)

Table 3. Comparison of the surgical techniques regarding restenosis in the 1st, 6th, and 12th month follow-up

Variables	Degree of stenosis	Eversion (n= 104)	Classical (n= 162)	*p* value
Postoperative 1th month	<%50	103 (99)	161 (99.4)	1.0[b]
	≥%50	1 (1)	1 (0.6)	
Postoperative 6th month	<%50	100 (96.2)	156 (96.3)	1.0[b]
	≥%50	4 (3.8)	6 (3.7)	
Postoperative 12th month	<%50	100 (96.2)	149 (92)	0.770[b]
	≥%50	4 (3.8)	13 (8)	

[b]Fischer's exact test.

[9]. Similar to the results of other studies in the literature, when Schneider et al. (2015) compared the operation times, the mean operation time was found to be 121 ± 50 minutes in the CCEA group and 115 ± 57 minutes in the ECEA group, and the difference was at a statistically significant level (p<0.001) [10]. In the present study, similar to the results of the studies in the literature, the mean operation time in patients who underwent CCEA was found to be 107 ± 15 minutes, and the mean operation time in patients who underwent ECEA was 88 ± 22 minutes (p=0.0002). Similarly, the mean cross-clamp time in the patients who underwent ECEA was 13.7 ± 4.5 minutes (p=0.0002) and the mean cross-clamp time was 21.5 ± 6.7 minutes in the patients who underwent CCEA. The results were found to be statistically significant showing that the ECEA operation has a shorter cross-clamp and operation time.

One of the most important parameters in the follow-up after CEA is the development of restenosis in the surgical treatment of carotid artery diseases. The development of restenosis may occur because of the surgical method as well as additional risk factors that accelerate atherosclerosis such as diabetes mellitus (DM), hypertension (HT), hyperlipidemia, and smoking. The most commonly used examination in follow-up is Carotid Doppler USG because it is fast and cost-effective. In the meta-analysis conducted by Paraskevas et al. (2018), when ECEA and CCEA were compared in terms of restenosis rates, ECEA was found to be superior to CCEA in terms of stenosis of 50% or more (2.5% - 5.2%, p=0.00036), however, no statistically significant differences were detected between ECEA and CCEA in using a patch [11]. A total of 678 CCEA and 675 ECEA patients were included in the EVEREST Study, which is the most comprehensive of the randomized studies to compare CCEA and ECEA in carotid artery diseases and conducted in a multicenter. When the restenosis rates were evaluated in the 33-week mean follow-up results of this study, it was found that this rate was 2.8% in the ECEA group, 7.9% in the primary CCEA group, and 1.5% in the CCEA group with a patch [12,13]. Cao et al. (2002) conducted a study in which five studies were included and 2465 CEA patients were examined, stenoses above 50% were considered as restenosis. When the rates of restenosis were examined, restenosis was detected in 32 (2.5%) of the 1290 patients in the ECEA group and 66 (5.2%) of the 1267 patients in the CCEA group, this difference was found to be at a statistically significant level (p=0.0007) [14]. In the present study, Doppler USG follow-up was performed on the patients at the 1st, 6th, and 12th months in the postoperative period, and a stenosis of 50% or more was accepted as restenosis. According to the 1-year follow-up results, no statistically significant differences were detected between CCEA and ECEA in terms of restenosis rates (p=0.770), but it was found that there was 2-fold more restenosis in the CCEA group when compared to ECEA. We think that this difference occurred because patients who underwent ECEA were more suitable for the anatomical position after anastomosis, and that a statistically significant difference might occur between the two methods in terms of restenosis by increasing the number of patients and the follow-up times.

The most important consequences of carotid artery disease are stroke and death. When these two techniques were evaluated in this respect, in a single-center randomized controlled study conducted by Dakour-Aridi et al., no statistically significant differences were detected between the two techniques in terms of in-hospital and first 30-day stroke and mortality rates and 1-year stroke/mortality rates [15]. However, in the meta-analysis conducted by Paraskevas et al., it was reported that there were significant decreases in 30-day death, stroke, and mortality/stroke cases in favor of ECEA. In the Cochrane Library Review, which investigated the effectiveness of ECEA and CCEA techniques used in carotid artery stenosis, prospective randomized studies were evaluated and 2590 operations in 5 studies were included. No statistically significant differences were reported in stroke rates between the two methods [12,13]. Also, in the study conducted by Djedovic et al., both methods were compared and no statistically significant differences were reported between the two methods in terms of stroke and mortality [16]. In the present study, when the stroke rates of the patients were evaluated, stroke was detected in five patients

(4.8%) in the ECEA group and 9 patients (5.5%) in the CCEA group, and this difference was not at a statistically significant level (p>0.005). Similarly, no statistically significant differences were detected between ECEA and CCEA in terms of mortality rates (1-1.2%, respectively; p=1).

If the experience of the surgical team is adequate, we think that the eversion technique is more effective in terms of perioperative and postoperative stroke/death rates, as seen in the results of the present study, since this technique reduces the postoperative restenosis and the need for re-intervention, does not cause negativities such as aneurysm and infection because of patch use, provides a shorter operation and cross-clamping time, and is a more suitable method for natural anatomy. We also think that patients should be followed up for a longer period and future studies should be conducted with the participation of more patients.

Conclusion

In conclusion, the experience of the surgical team in choosing the method is very effective on the perioperative and postoperative morbidity and mortality rates. ECEA technique has shorter cross-clamp and operation time than CCEA technique. This means that less anesthetic effect and more brain perfusion in ECEA technique compared to CCEA.The treatment of carotid artery disease requires a multidisciplinary study in which neurology, anesthesia, and cardiovascular surgery work in agreement and support each other.

Acknowledgement

This study was produced from the thesis of Alper Selim Kocaoğlu **#757009** https://tez.yok.gov.tr/UlusalTezMerkezi/giris.jsp

Funding

The authors received no financial support for the research and/or authorship of this article.

Conflict of interest

The authors do not have any conflict of interest in this study.

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