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ORIGINAL RESEARCH

Factors That Influence the Occurrence of Acute Postoperative Complications after Carotid Endarterectomy

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ABSTRACT

Background: This study aimed to identify early postoperative complications after carotid endarterectomy and the factors that may influence their occurrence. **Methods:** This was an observational, analytical, prospective study conducted over a period of 3 years in 2 university hospitals in Târgu Mureș, Romania. One hundred nineteen patients who underwent carotid endarterectomy for severe carotid stenosis were included. Statistical analysis was used to identify the independent factors with a direct influence on the acute complications in the first 48 h after carotid endarterectomy. **Results:** We followed up on the acute postoperative complications occurring in the first 2 days after surgery. These were represented by a limited number of neurological complications and major neck hematomas. Among all comorbidities and risk factors, only advanced coronary artery disease ($p = 0.05$) and smoking ($p = 0.03$) were independent factors that directly influenced the occurrence of major neck hematomas. Operative time exceeding the median time of 90 minutes increased the risk of neurological complications ($p = 0.02$). The risk of major neck hematomas was also increased by preoperative treatment with anticoagulants ($p = 0.01$) and anticoagulants associated with antiplatelet therapy ($p = 0.009$). **Conclusions:** This study has identified factors such as advanced coronary artery disease, smoking, operative time, and anticoagulant therapy that may be indepen-

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dently associated with an increased risk of acute postoperative complications after carotid endarterectomy.

Keywords: carotid endarterectomy, operative time, neurological complications, major neck hematomas, emergencies

INTRODUCTION

Carotid atherosclerosis is a disease specific to people over the age of 50 years, especially those at high cardiovascular risk, with a long asymptomatic course.[1,2] Also, elderly patients with multiple vascular diseases (peripheral arterial disease, coronary artery disease) often present atherosclerotic carotid stenosis, which needs to be diagnosed early.[3]

When the stenosis of the common or internal carotid artery due to an atherosclerotic plaque exceeds 50%, hemodynamic changes begin to occur in the artery, and the first cerebrovascular symptoms may appear.[1] These symptoms are sometimes neglected. Often, the first manifestation of carotid atherosclerosis is stroke, which is one of the leading causes of death and disability worldwide. Strokes can occur because of high-grade carotid stenosis or carotid atheroma plaque instability.[4] A report of the American Heart Association on patients who have had a stroke revealed that approximately 75% of these patients will remain with dysfunctions, and between 15% and 30% will remain severely disabled.[5]

According to the latest statistics from the World Health Organization, stroke is the second leading cause of death in Romania, with an incidence of 104.36 deaths per 100,000 inhabitants. This positions the country in 65th place in the world, with twice as many strokes as its neighbors Hungary and Croatia, and five times as many as Central European countries like Austria, Germany, Luxembourg, and France.[2,6–8]

According to the clinical guideline published in 2023 by the European Society of Vascular Surgery for the management of atherosclerotic carotid disease, carotid endarterectomy (CEA) is the optimal therapeutic solution for symptomatic patients with high-grade carotid stenosis. With a reduced number of postoperative emergencies, this type of surgery, together with appropriate drug treatment, can significantly reduce the occurrence of stroke or transient ischemic attacks in patients with high-grade carotid stenosis.[9–13]

This study aimed to identify the acute postoperative complications after CEA and the factors that may influence their occurrence.

MATERIAL AND METHOD

This was a prospective clinical study conducted in the 2020–2022 period at the Clinic of Vascular Surgery of the County Emergency Clinical Hospital of Târgu Mureș, Romania, and the Clinic of Cardiovascular Surgery of the Emergency Institute for Cardiovascular Diseases and Transplantation, Târgu Mureș, Romania. The study included all patients admitted to the hospital with carotid artery stenosis of more than 70% who underwent carotid revascularization. Patients with near occlusion of the carotid, meaning severe stenosis with distal vessel collapse, patients with a second stenotic lesion in the intracranial part of the internal carotid artery, patients with restenosis on the same side after CEA, and patients with hematological disorders were excluded from the study.

COLLECTION OF PATIENT DATA

Patient data were obtained from the patients' clinical charts and medical records regarding age, sex, symptoms, comorbidities – hypertension, ischemic heart disease (IHD), advanced coronary artery disease (ACAD), diabetes, chronic kidney disease (CKD), peripheral arterial disease (PAD), dyslipidemia, smoking, previous stroke, location and degree of carotid stenosis, preoperative medications, blood tests, type of surgery, type of anesthesia, operative time, and carotid clamping time. Patients with ACAD were considered those who underwent a coronary endovascular procedure or aortocoronary bypass for moderate-severe heart ischemia. The patients were followed for the first 2 days postoperatively to observe acute postoperative complications such as stroke, transient ischemic attack, or major neck hematomas (MNHs), and whether any patient underwent reoperation in emergency conditions.

The study was conducted under the principles of the Declaration of Helsinki and was approved by the ethics committees of the "George Emil Palade" University of Medicine, Pharmacy, Science and Technology of Târgu Mureș (no. 906/2020), County Emergency Clinical Hospital of Târgu Mureș (no. 29496/2019), and the Emergency Institute for Cardiovascular Diseases and Transplantation of Târgu Mureș (no. 1680/2020).

TYPE OF ANESTHESIA AND SURGICAL TECHNIQUE

Study patients underwent general anesthesia with orotracheal intubation or cervical plexus block as indicated by the anesthesiologist, according to the patients' comorbidities. Throughout the operation, cerebral oxygenation in each hemisphere was monitored using the INVOSTM 5100 cerebral oximeter (Medtronic, USA), which was connected to the patient via 2 sensors placed in the frontal region.

The surgical procedure consisted of a longitudinal incision in the anterior cervical region (ACR) parallel to the anterior border of the sternocleidomastoid muscle, followed by the dissection of the anatomical planes and the identification of the common, internal, and external carotid arteries. These arteries were isolated on vascular loops. The carotid arteries were clamped, and if cerebral oxygenation decreased by 20% compared to baseline in the first 2 minutes or if regional cerebral oxygen saturation fell below 40%, a shunt was placed to avoid cerebral hypoxia. All patients received systemic heparin 2,500 IU, followed by the clamping of the carotid arteries, longitudinal arteriotomy at the level of the common and internal carotid arteries, and endarterectomy with or without placement of a shunt (Flexcel™ Carotid Shunt, LeMaitre®, USA). A monofilament wire was used to suture the artery, juxta-arterial drainage was placed for monitorization of bleeding and to prevent postoperative hematoma, and the skin was sutured intradermally.

STUDY OUTCOMES

The primary outcomes of the study were the occurrence of early postoperative complications such as stroke, transient ischemic attack, cranial nerve palsy, and MNH (a possibly life-threatening complication that requires an emergency complex multidisciplinary therapeutic approach) occurring within the first 2 days after surgery. Secondary endpoints included the identification of correlations between these complications and the patients' comorbidities, type of surgery and anesthesia, operateive time, and carotid clamping time.

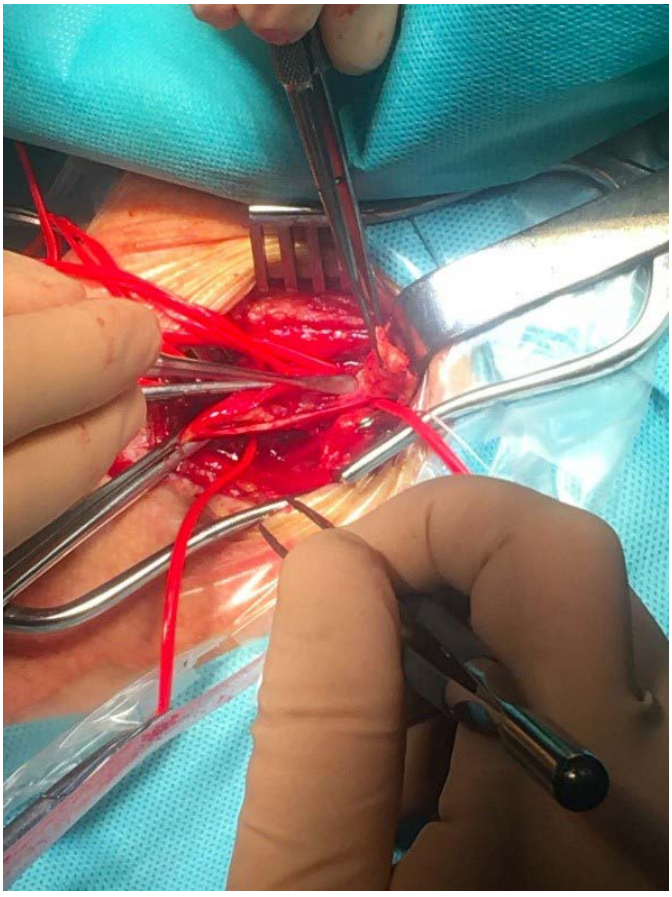

FIGURE 1. Removing the carotid plaque during CEA

STATISTICAL ANALYSIS

The database containing all information on patients who underwent CEA was created using Microsoft Excel (Mi-

TABLE 1. Comorbidities of the study population

Comorbidities	N (%)
Hypertension	110 (92.4%)
Ischemic heart disease	97 (81.5%)
Advanced coronary artery disease	19 (15.9%)
Diabetes	33 (27.7%)
Peripheral arterial disease	31 (26.1%)
Chronic kidney disease	14 (11.8%)
Dyslipidemia	115 (96.6%)
Stroke history	76 (63.9%)

TABLE 2. Type of surgery and anesthesia in carotid endarterectomy

Type of surgery	N (%)
CEA	110 (92.4%)
CEA + shunt	4 (3.4%)
CEA + vein patch	3 (2.5%)
CEA + vein patch + shunt	1 (0.8%)
CEA + prosthesis patch	1 (0.8%)
Type of anesthesia	
General anesthesia with orotracheal intubation	75 (63%)
Locoregional anesthesia - cervical plexus block	44 (37%)

CEA, carotid endarterectomy

TABLE 3. Modification of the variables for the patients with postoperative neurological complications

Variable	Patients with postoperative neurological complications (n = 8)	Patients without postoperative neurological complications (n = 111)	p value
Comorbidities			
Hypertension	7 (87.5%)	103 (92.79%)	0.5
Ischemic heart disease	6 (75%)	91 (81.98%)	0.6
Advanced coronary artery disease	2 (25%)	17 (15.31%)	0.4
Diabetes	1 (12.5%)	32 (28.82%)	0.3
Peripheral artery disease	1 (12.5%)	30 (27%)	0.3
Chronic kidney disease	1 (12.5%)	13 (11.7%)	0.9
Dyslipidemia	8 (100%)	107 (96.39%)	0.5
Stroke history	7 (87.5%)	69 (62.16%)	0.1
Risk factor			
Smoking	6 (75%)	52 (46.84%)	0.1
Carotid atherosclerotic plaque location			
Unilateral carotid plaque	5 (62.5%)	79 (71.17%)	0.6
Bilateral carotid plaque	3 (37.5%)	32 (28.82%)	
Type of anesthesia			
Cervical plex anesthesia	4 (50%)	40 (36%)	0.4
General anesthesia	4 (50%)	71 (63.9%)	
Surgery times			
Operative time <90 min	0 (0%)	46 (41.4%)	0.02
Operative time >90 min	8 (100%)	65 (58.5%)	
Carotid artery clamping time <17 min	2 (25%)	39 (35.13%)	0.5
Carotid artery clamping time > 17 min	6 (75%)	72 (64.86%)	
Preoperative medication			
Anticoagulant and antiplatelet	1 (12.5%)	25 (22.52%)	0.5
Anticoagulant	1 (12.5%)	28 (25.22%)	0.4
Antiplatelet	8 (100%)	103 (92.79%)	0.4

crosoft Office 365, Microsoft, Redmond, USA). Statistical analysis was performed using SPSS software (IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp). Data were expressed as the number of cases/patients, relative frequencies for qualitative variables (male or female sex, stenosis grade), and mean ± standard deviation for continuous variables. The chi-squared test and the Mann-Whitney U test were used to compare data of 2 types of variables. For all tests used, a p value <0.05 was considered statistically significant.

RESULTS

CHARACTERISTICS OF THE STUDY POPULATION

The study group consisted of 119 patients aged between 43 and 85 years, with a predominance of male gender (68.9%, n = 82). The degree of carotid stenosis varied from 70% to 95%, with a mean of 81.35%, and 34 of the patients also had atheromatous plaques in the contralateral carotid artery with a degree of stenosis greater than 30%. A number of 6 patients (5%) had high-grade bilateral carotid stenosis greater than 70% and underwent CEA on the opposite side at a 3-month interval. The most common comorbidities were hypertension (92.4%), ischemic heart disease (IHD) (81.5%), and dyslipidemia (96.6%). Of all the patients in the group, 76 (63.9%) had a previous stroke and 19 patients (15.9%) also had ACAD, which means the involvement of 2 vascular territories (Table 1).

PERIOPERATIVE MANAGEMENT

Because of the increased risk of cerebral thromboembolic complications in patients with high-grade carotid stenosis, preoperative anticoagulant (ACT) and/or antiplatelet (APT) therapy was administered, as indicated by the neurologist, adjusted to the patients' comorbidities. The preoperative treatment was oral ACT in 24.4% of cases, APT

TABLE 4. Modification of the variables for the patients with major postoperative hematoma of the cervical region

Variable	Patients with postoperative major neck hematoma (n = 4)	Patients without postoperative major neck hematoma (n = 115)	p value
Comorbidities			
Hypertension	3 (75%)	107 (93%)	0.1
Ischemic heart disease	2 (50%)	95 (82%)	0.09
Advanced coronary artery disease	2 (50%)	17 (14.78%)	0.05
Diabetes	1 (25%)	32 (27%)	0.9
Peripheral artery disease	1 (25%)	30 (26%)	0.9
Chronic kidney disease	0 (0%)	14 (12%)	0.4
Dyslipidemia	4 (100%)	111 (96%)	0.7
Stroke history	1 (25%)	75 (65%)	0.1
Risk factor			
Smoking	4 (100%)	54 (46%)	0.03
Carotid atheroma plaque location			
Unilateral carotid plaque	3 (75%)	81 (70%)	0.8
Bilateral carotid plaque	1 (25%)	34 (29%)	
Type of anesthesia			
Cervical plex anesthesia	2 (50%)	42 (36%)	0.5
General anesthesia	2 (50%)	73 (63%)	
Surgery times			
Operative time <90 min	1 (25%)	47 (40%)	0.5
Operative time >90 min	3 (75%)	68 (59%)	
Carotid artery clamping time <17 min	1 (25%)	60 (52%)	0.2
Carotid artery clamping time > 17 min	3 (75%)	55 (47%)	
Preoperative medication			
Anticoagulant and antiplatelet	3 (75%)	23 (20%)	0.009
Anticoagulant	3 (75%)	26 (22%)	0.01
Antiplatelet	4 (100%)	107 (93%)	0.5

in 93.3% of cases, and both in 21.8% of cases. Oral ACT treatment was stopped 2 days before surgery, and APT treatment was stopped on the day of surgery and postoperatively on the first day. After surgery, all patients were treated with ACT, including unfractionated heparin and various low-molecular-weight heparins, until discharge.

We also tracked the type of procedure, which was distributed as follows: CEA in 92.4% of patients (Figure 1), CEA + shunt in 3.4%, CEA + vein patch in 2.5%, CEA + vein patch + shunt in 0.8%, and CEA + prosthesis patch in 0.8% of patients.

Operative time ranged from 65 to 130 minutes with a mean of 90 minutes, and the carotid clamping time ranged from 14 to 26 minutes with a mean of 17 minutes (Table 2). Due to the multiple comorbidities of the patients, the type of anesthesia was chosen to minimize the anesthetic risk. Thus, 75 patients underwent surgery under general anesthesia with orotracheal intubation and 44 patients under loco-regional anesthesia – cervical plexus block.

EARLY POSTOPERATIVE COMPLICATIONS

All patients were monitored for biological parameters and clinical status during the first 2 postoperative days. Acute postoperative complications such as neurological disorders (stroke, transient ischemic attack) and medium-large hematomas of the cervical region requiring additional care or reoperation were monitored. We identified 12 patients with complications after CEA and no deaths. Eight patients were identified with neurological complications (3 with stroke, 5 with transient ischemic attack), and 2 patients with stroke were major emergencies needing multidisciplinary therapy including intensive care monitoring. Medium and large hematomas at the level of the anterior cervical region were found in 4 patients, but they did not have a compressive effect. The hematoma did not have a compressive effect, and only 1 of the 4 patients required reintervention in emergency conditions because of bleeding that was externalized

at the level of the cervical wound. Three of the patients with postoperative neck hematoma received an incisional neck drain tube.

There were no significant differences between patients with and without postoperative MNH regarding hypertension, ischemic heart disease, diabetes, chronic renal disease, dyslipidemia, or stroke, but smokers (100% versus 46%, p = 0.03) and subjects with ACAD (p = 0.05) were more likely to present this complication. We found no statistical significance between the occurrence of postoperative neurological complications and comorbidities, as shown in Table 3.

We also analyzed whether the unilateral or bilateral carotid location of the atherosclerotic plaque, type of anesthesia, operative time above/below median time (90 minutes), carotid clamping time above/below median time (17 minutes), and preoperative ACT and/or APT treatment influenced the postoperative occurrence of neurological complications and MNH. The results were statistically significant only for the increased risk of developing MNH after CEA in patients with preoperative oral ACT (p = 0.01) and oral ACT combined with APT treatment (p = 0.009), even when oral ACT was not administered one day before surgery and the international normalized ratio (INR) value was within normal limits on the day of surgery (Table 4).

In addition, a longer surgery time (over 90 minutes) was found to increase the risk of neurological complications (p = 0.02). The mean carotid clamping time was 17 minutes, but there were no significant differences between patients with a clamping time above or below this timeframe (Tables 3 and 4).

DISCUSSION

CEA is a procedure that removes the atherosclerotic plaque from the carotid artery to ensure adequate postoperative blood flow to the brain. CEA is strongly recommended by the guidelines of the European Stroke Organisation and the European Society for Vascular Surgery for patients with carotid artery stenosis greater than 70%,[9,10] because it is a surgery with few complications, it improves the quality of life, and significantly reduces the risk of stroke.[1,13,14]

Similar results to the present study were also reported by Cruz Silva *et al.*,[15] regarding mean age, male predominance, type of comorbidities, and preoperative stroke, in their study group of 304 patients. In this study, preoperative treatment with ACT and double APT medication did not prevent the occurrence of postoperative neurological complications. Also, Krafcik *et al.*,[16] in a study published in 2018 on a group of 15,341 patients, demonstrated that APT and statin treatment did not affect the immediate postoperative outcome in patients with CEA. In particular, they demonstrated that the use of preoperative APT drugs did not independently influence the postoperative occurrence of myocardial infarction, stroke, and major cardiac complications.[16]

Rerkasem *et al.* conducted a study using the results of 13 clinical trials involving 4,839 patients with severe carotid stenosis who underwent CEA under cervical plexus block or general anesthesia. They compared complications occurring in the first 30 days after these 2 types of anesthesia and found no significant differences in stroke (3.2% vs. 3.5%), death (0.9% vs. 1.4%), myocardial infarction (0.6% vs. 0.4%), local bleeding (7.7% vs. 7.8%), and shunt use.[14] Similarly, in our study, the type of anesthesia had no influence on the incidence of immediate postoperative complications or the average length of hospital stay.

Regarding acute complications after CEA, Huibers *et al.*[17] studied the characteristics of postoperative stroke and found 8 possible mechanisms in their study. Out of 3,120 patients, no predominant mechanism of stroke was found, and stroke occurred in only 53 (2.7%) patients, most of them on the day of surgery, with a predominance of ischemic strokes (81%), which was similar to the results of our study.

Rivolta *et al.*[18] conducted a systematic review and meta-analysis to determine the safety and efficacy of routine incisional neck drain placement after CEA to prevent neck hematoma. In their study, patients in whom postoperatively a drain tube has been placed near the carotid artery had a significantly higher re-exploration rate after CEA compared to those who did not receive drainage with no heterogeneity in their group. They concluded that routine drain placement did not provide complete protection against the development of cervical hematoma and may provide the surgeon a false sense of security in wound drainage. We used incisional neck drain placement after CEA only in specific cases, and most of our patients who had a MNH received a juxta-arterial drain tube.

Comorbidities may influence the postoperative outcome in patients with severe carotid stenosis, as Cruz Silva *et al.*[15] showed that the presence of coronary artery disease in patients undergoing CEA increased the risk of postoperative important cervical hematoma (p = 0.03), which was similar to our findings. Other comorbidities, including previous stroke, did not influence postoperative complications. We also found that smoking significantly increased the risk of MNH. Cruz Silva *et al.* also found that patients who received ACT or double APT therapy in the perioperative period had an increased risk of developing MNHs.

Doig *et al.*[19] demonstrated that the risk of developing a MNH after CEA was influenced by the preoperative use of medications, increased by ACT ($p = 0.04$) and decreased by APT drugs ($p = 0.03$). We found that the risk of postoperative MNH was highest when ACT and APT drugs were used together.

As we analyzed in our group, prolonged operative time increased the risk of postoperative complications if it exceeded the average of 90 minutes. We obtained statistically significant data regarding the occurrence of neurological complications in prolonged CEA, which was also demonstrated in the study published by Aziz and Reed in 2015.[20]

LIMITATIONS OF THE STUDY

This study has some limitations, such as the relatively low number of patients, which may limit the ability to observe certain immediate postoperative complications. This is attributable to the fact that some types of patients, with certain comorbidities, may manifest other complications, which are not included in the study. Further studies on larger patient populations are required in order to establish the risk factors for developing postoperative complications in subjects undergoing CEA.

CONCLUSIONS

Carotid endarterectomy is a surgical procedure performed in patients with severe carotid artery stenosis, usually in the elderly, to prevent the occurrence or recurrence of stroke and to improve postoperative quality of life. In this study, the occurrence of immediate postoperative complications was not influenced by the type of anesthesia, but the presence of advanced coronary artery disease, smoking, prolonged operative time, and preoperative use of ACT or ACT with APT increased the risk for early postoperative complications such as cervical hematoma and neurological events. These complications can sometimes represent major life-threatening emergencies that require multidisciplinary treatment.

CONFLICT OF INTEREST

Nothing to declare.

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