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Safe carotid endarterectomy: "one fits all strategy"

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Abstract

Introduction: Carotid artery stenosis of 50% or more in the extracranial internal carotid artery is responsible for 10–15% of all strokes. Interventional treatment options include carotid endarterectomy and carotid artery stenting, where endarterectomy is proven to be superior.

Aim: In this study, we report the carotid endarterectomy results of patients we operated on using the strategy we termed the "one fits all strategy".

Material and methods: Seventy-six patients undergoing carotid endarterectomy between July 2016 and April 2020 were retrospectively studied. Conventional endarterectomy under general anesthesia with primary closure of the arteriotomy was performed in all patients. We used a near infrared spectroscopy oximeter to measure regional cerebral oxygenation continuously throughout the surgery.

Results: The mean age of the patients was 70.96 8.15 years. There were 52 male and 24 female patients. The mean follow-up time was 20.6 ±13.6 months. Coronary artery disease was detected in 52 (73.6%) patients. Coronary artery bypass operation was indicated in 19 patients in whom a staged approach was performed in 13 and a reverse staged approach in 1. There were two perioperative strokes one of which recovered fully spontaneously and the other partially with physiotherapy. Eight cases were revised due to hematoma formation.

Conclusions: Carotid endarterectomy continues to prove its safety in carotid artery stenosis patients. Continuous cerebral oxygenation monitoring is indispensable for carotid surgery. Despite discrepancies in surgical techniques, we believe that "one fits all strategy: general anesthesia, conventional endarterectomy without patch plasty, never shunter and always NIRS monitorization" may be used safely in patients undergoing carotid endarterectomy.

Key words: carotid stenosis, endarterectomy, carotid, intraoperative complications, postoperative complications, spectroscopy, near infrared.

Streszczenie

Wprowadzenie: Zwężenie zewnątrzczaszkowej wewnętrznej tętnicy szyjnej o co najmniej 50% odpowiada za 10–15% wszystkich udarów. Leczenie interwencyjne obejmuje endarterektomię tętnicy szyjnej lub stentowanie tętnicy szyjnej, przy czym endarterektomia uznawana jest za metodę skuteczniejszą.

Cel pracy: W pracy przedstawiono wyniki endarterektomii tętnicy szyjnej przeprowadzonej u pacjentów przy zastosowaniu strategii, którą określamy jako „uniwersalna".

Materiał i metody: Retrospektywną analizą objęto 76 pacjentów poddanych endarterektomii tętnicy szyjnej od lipca 2016 do kwietnia 2020 r. U wszystkich pacjentów przeprowadzono konwencjonalną endarterektomię w znieczuleniu ogólnym z pierwotnym zamknięciem arteriotomii. Śródoperacyjnie prowadzono ciągły pomiar regionalnego utlenowania mózgu przy wykorzystaniu oksymetrii mózgowej, wykorzystując technologię spektroskopii bliskiej podczerwieni.

Wyniki: Średni wiek pacjentów wynosił 70,96 ±8,15 roku. Grupa obejmowała 52 mężczyzn i 24 kobiety. Średni czas obserwacji wyniósł 20,6 ±13,6 miesięca. Choroba wieńcowa występowała u 52 (73,6%) chorych. Operację pomostowania tętnic wieńcowych zlecono u 19 chorych – u 13 wykonano zabieg z dostępu stopniowanego, a u 1 z dostępu odwróconego. Okołooperacyjnie wystąpiły dwa udary. U jednego pacjenta objawy ustąpiły całkowicie samoistnie, a u drugiego częściowo po fizjoterapii. W 8 przypadkach wykonano rewizję ze względu na powstanie krwiaków.

Wnioski: Wyniki potwierdzają bezpieczeństwo endarterektomii wykonywanej u pacjentów ze zwężeniem tętnicy szyjnej. Ciągłe monitorowanie utlenowania mózgu jest niezbędne podczas zabiegów obejmujących tętnice szyjne. Niezależnie od rozbieżności pod względem techniki chirurgicznej, uważamy, że „uniwersalna strategia: znieczulenie ogólne, konwencjonalna endarterektomia bez plastyki łatą, bez przetoki i z monitorowaniem metodą NIRS" może być bezpiecznie stosowana u pacjentów poddawanych endarterektomii tętnicy szyjnej.

Słowa kluczowe: zwężenie tętnicy szyjnej, endarterektomia, tętnice szyjne, powikłania śródoperacyjne, powikłania pooperacyjne, spektroskopia, bliska podczerwień.

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Introduction

Carotid artery stenosis (CAS) is defined as having 50% or more stenosis in the extracranial internal carotid artery (ICA). It is responsible for 10–15% of all strokes. To name it symptomatically, it must be related to the symptoms in the preceding 6 months [1]. The symptom spectrum can range from numbness and weakness in the face, arms and legs, to transient ischemic attacks (TIA) and stroke. In TIA/stroke patients, immediate visualization of the brain and supra aortic vessels is required by imaging techniques [2]. For therapeutic and prophylactic reasons, carotid endarterectomy (CEA) is the most popular treatment option in CAS. With the technological advances and experience in endovascular intervention techniques, carotid artery stenting has gained popularity in CAS as in other peripheral arterial diseases in recent years. However, when 30-day mortality and stroke rates are compared, CEA was proven to be superior [3].

Aim

In this study, we hypothesized that simplification and standardization of the surgical strategy may improve perioperative outcomes. Therefore, we defined our strategy of general anesthesia, conventional endarterectomy with primary closure, never shunter and always cerebral monitorization as the “one fits all strategy”. We aimed to document our surgical strategy and its outcomes. We believe it is very simple and applicable

Material and methods

Seventy-six patients with CAS undergoing CEA between July 2016 and April 2020 were included in the study and retrospectively studied. The study was approved by the institutional ethical committee waiving informed consent based on retrospective nature and complies with the Declaration of Helsinki. Follow-up data were based on clinical follow-up visits of the patients. For ones who did not show up, a telephone questionnaire was used to determine patients’ clinical status by a medical secretary. The patient was questioned about any kind of neurological symptom either transient or permanent, any kind of neurological consultation or any kind of further carotid intervention.

Anesthesia and surgical technique “one fits all strategy”

All patients were premedicated with 10 mg of oral diazepam on the night prior to surgery and general anesthesia was induced with thiopental sodium 4 mg/kg (Pental Sodyum, İ.E.ULAGAY, İstanbul, Turkey), fentanyl citrate 1 mg/kg (Talinat, VEM, Tekirdağ, Turkey), rocuronium 0.6 mg/kg (Esmeron, MSD, Germany), lidocaine 1 mg/kg (Jetmonal, ADEKA, İstanbul, Turkey) and continued with sevoflurane (Sevorane liquid 100%, Abbvie, England) 1 MAC with 50% oxygen and 50% air.

We monitored all patients using electrocardiography, radial artery catheterization, central venous pressure measurement via an internal jugular vein catheter and pulse oximeter. The internal jugular vein catheter was inserted on contralateral side if there was no contralateral stenosis. If so, a contralateral subclavian vein catheter was inserted. Near infrared spectroscopy (NIRS) INVOS oximeter (Somanetics Corporation, Troy, Michigan, USA) was used to measure regional cerebral oxygenation (rSO_2) in all cases. Two sensors were placed on the forehead before induction of anesthesia on awake status and rSO_2 was followed continuously during the surgery.

All patients were transferred to the intensive care unit and extubated thereafter. All patients were monitored in intensive care for one night.

A longitudinal anterior sternomastoid incision was used to achieve carotid bifurcation. Before clamping the carotid artery, we administered intravenously 5000 IU heparin and used activated clotting time to determine the effectiveness of heparin dose (maintained > 200 s). Surgery was performed via conventional endarterectomy technique (vertical carotid incision initiated 1 cm proximal to the bulbus, continued till 1 cm distal to atherosclerotic plaque). The media just distal to the endarterectomy plane was sutured to adventitia by 8/0 prolene at two sides in order to prevent arterial dissection. Primary closure of the arteriotomy line was performed in all patients. We did not use any kind of patch in any patient. We did not use a carotid shunt in any patient. We define the “One fits all strategy” as general anesthesia, always NIRS monitorization, never shunter, conventional CEA, primary closure and no patch.

In all patients a mini hemovac surgical drain was inserted in order to prevent hematoma or wound revision.

Dual antiplatelet therapy with clopidogrel 75 mg and acetylsalicylic acid 100 mg, po, was initiated in every patient the day before surgery and maintained for one year followed by sole acetylsalicylic acid. Statin therapy with either pravastatin 40 mg (Pravachol, Deva İlaç, İstanbul, Turkey) or pitavastatin 4 mg (Pratin, Nobel İlaç Sanayi, İstanbul, Turkey) was initiated the day before surgery if the patient was not on statin therapy and maintained postoperatively lifelong.

For patients with preoperative stroke, surgery was performed within 14 days of onset of symptoms in order to facilitate faster and full recovery [3].

Statistical analysis

The data were analyzed using the software SPSS version 17 (SPSS Inc, Chicago, IL, USA). Continuous variables were presented as mean± SD, median (min., max.) and categorical variables were presented as numbers and percentages.

Results

There were 52 (68.5%) males and 24 (31.5%) females in the study (male/female: 2.16). The mean age of the patients was 70.96 ±8.15 (min.: 47, max.: 90). Diabetes mellitus was present in 24 (31.5%) patients, hypertension in 66 (86.8%) patients and hyperlipidemia in 55 (72.3%) patients. While 22 (28.9%) patients had a history of TIA, 16 (21%)

patients had a neurological sequela due to stroke preoperatively. Coronary artery disease was detected in 56 (73.6%) patients. Thirty-seven (48.6%) patients were treated medically. For patients in whom coronary artery bypass surgery was indicated (*n* = 19), a staged approach was used in 13 (17.1%), a reversed staged approach in 1 (1.3%). In the staged approach, CEA was performed 3 to 5 days prior to CABG. In the reverse-staged approach, CABG was performed first and CEA 1 month following coronary surgery. The indication for a reversed approach was a severe left main stenosis with unstable angina. Five (6.57%) patients refused operative therapy. The patients who refused CABG were treated by guideline-directed medical therapy.

The preoperative characteristics of the patients are summarized in Table I.

We performed left sided CEA in 25 (32.8%) cases and right sided CEA in 40 (52.6%) cases. Bilateral CEA was performed in 11 (14.4%) patients, each at 3-day intervals. The mean carotid artery clamp time was 12.75 ±3.99 (min.: 6, max.: 26) min. All operations were performed by a single surgeon. Table II shows the intraoperative features of the patients.

When NIRS values are explored, pre-clamp values are 66.60 ±9.73 (min.: 40, max.: 80), values during clamping are 56.70 ±8.56 (min.: 33, max.: 75) and flowing are 69.68 ±8.36 (min.: 50, max.: 84). When pre-clamp and during clamp values are compared, there is a statistically significant difference ($p < 0.001$; 14.15% decrease). When during clamp and after clamp values are compared, there is a statistically significant difference ($p = 0.001$).

All 16 patients with preoperative stroke were operated on within 14 days of onset of symptoms. All recovered fully in the early postoperative period. Postoperative complications occurred in 10 (11.4%) cases. Revision due to hematoma was performed in 8 (10.5%) patients. One (1.3%) patient experienced a transient ischemic attack that recovered spontaneously and one patient experienced stroke. Both incidents occurred de novo. Those patients did not have any neurologic event prior to CEA. In the patient with stroke it was a case of contralateral hemiplegia that turned out to become 3/5 motor functioned hemiparesis after 6 months with physiotherapy. No kind of thrombosis was observed in that case perioperatively.

The mean intubation time was 3.86 ±0.73 hours (min.: 3, max.: 5) and the mean length of hospital stay was 4.93 ±3.09 days (min.: 3, max.: 19). In-hospital mortality was not observed. Mean follow-up time was 20.6 ±13.6 months (min.: 1, max.: 45). There were no postoperative neurologic events or mortality throughout the follow-up period. The postoperative characteristics of the patients are given in Table III.

Table I. Preoperative characteristics of patients

Parameter	Results
Age, mean ± SD [years]	70.96 ±8.15
BMI, mean ± SD [kg/m^2]	25.4 ±2.2
Sex, *n* (%):	
Male	52 (68.5)
Female	24 (31.5)
Diabetes mellitus, *n* (%)	24 (31.5)
Hypertension, *n* (%)	66 (86.8)
Hyperlipidemia, *n* (%)	55 (72.3)
Transient ischemic attack, *n* (%)	22 (28.9)
Preoperative stroke, *n* (%)	16 (21)
Coronary artery disease, *n* (%):	56 (73.6)
Staged CEA	1 (1.3)
Reverse staged CEA	13 (17.1)
Refused CABG	5 (6.5)
Medical treatment	37 (48.6)

BMI – body mass index, CEA – carotid endarterectomy, CABG – coronary artery bypass grafting. Staged approach – CEA was performed 3 to 5 days prior to CABG. Reverse stage approach – CABG was performed first and CEA 1 month following coronary surgery.

Table II. Intraoperative characteristics of patients

Parameter	Results
Left sided CEA, *n* (%)	25 (32.89)
Right sided CEA, *n* (%)	40 (52.64)
Bilateral CEA, *n* (%)	11 (14.47)
Cross-clamp time, mean ± SD [min]*	12.75 ±3.99
Pre-clamp NIRS value, mean ± SD	66.04 ±9.73
During clamp NIRS value, mean ± SD	56.70 ±8.56
Following clamp NIRS value, mean ± SD	69.68 ±8.36

**N* = 76 patients (totally 87 CEA including bilateral cases). CEA – carotid endarterectomy.

Table III. Postoperative characteristics of patients

Parameter	Results
Hematoma, *n* (%)	8 (9.1)
Stroke, *n* (%)	2 (2.3)
Intubation time, mean ± SD [hours]*	3.86 ±0.73
Hospital stay, mean ± SD [days]	4.93 ±3.09
Follow-up, mean ± SD [months]	20.6 ±13.6

**N* = 87 CEA (including bilateral cases/totally 76 patients). SD – standard deviation.

Discussion

Carotid artery stenosis is a peripheral vascular disease that can cause serious neurological consequences from the moment it begins to be symptomatic. In asymptomatic cases with diagnosis of CAS, there stands the same risk. Therefore, from the moment it is detected, it should be treated either medically or interventionally within the indications outlined in the guidelines [3]. In patients who are symptomatic or asymptomatic and detected during routine examinations, detailed history, identification of risk factors and physical examination are indispensable for carotid artery stenosis [4, 5]. Routine screening for asymptomatic cases with duplex ultrasound (DUS) is not recommended due to cost-effectiveness issues [6]. Screening should be considered in asymptomatic patients who have a history of severe peripheral artery disease regardless of age or have atherosclerotic risk factors over 65 years of age [3].

The first imaging method to be used in extracranial ICA stenosis is DUS. Computed tomography angiography (CTA) and magnetic resonance angiography (MRA) allow simultaneous evaluation of the aortic arch and brain parenchyma with the carotid arteries. Digital subtraction angiography (DSA) is preferred as a guideline for carotid artery stenting procedures or if there are inconsistencies in the results of non-invasive imaging techniques [2].

In our study group, all patients were diagnosed with DUS followed by CTA imaging for further evaluation of whole cerebral circulation and determination of diagnosis. Surgical indication was always based on CTA imaging. We did not prefer MRA, which may also be used for guiding in determination of vascular anatomy, plaque morphology at the level of stenosis, and visualization of bleeding or infarct areas in the brain parenchyma. When both techniques are compared for lesions > 70% stenosis CTA has a sensitivity of 85–95% and specificity of 93–98% [7].

For determining surgical indications, besides the symptoms and comorbidities of the patient, the severity of stenosis, anatomical features and plaque structure are also taken into consideration. Surgery is recommended primarily in symptomatic cases of 50% or more CAS and 70% or more CAS regardless of symptoms. Compared to medical treatment, CEA provides long-term reduction in ipsilateral stroke and death rates. CEA is not recommended for patients with stenosis below 50% [3]. In our study, we operated on patients with over 70% CAS presenting with symptoms or patients undergoing coronary bypass surgery and detected incidentally during preoperative examinations.

In CAS, the existence or severity of symptoms has different effects on outcomes of CEA; therefore each should be handled separately when deciding on the timing of the operation. Preoperative stroke caused a higher incidence of postoperative stroke compared to preoperative TIA and/or amaurosis fugax [8]. The risk of postoperative stroke is 7.4% in CEA, which is performed within the first 48 hours, especially in patients presenting with stroke decreasing to 4.5% within the first 15 days. It was also stated that the width of the infarct area may be a criterion when deciding to postpone the operation [9]. As widely accepted worldwide and according to current guideline recommendations, patients with newly developing symptoms experience maximum benefit from carotid interventions within the first 14 days [3]. In our study, in order to obtain optimal postoperative results, we considered the first 14 days criterion in surgical planning of patients presenting with CAS symptoms. All sixteen patients with preoperative stroke recovered fully postoperatively.

Approximately 28% of patients undergoing CEA have severe coronary artery disease. The severity of CAS is an important risk factor for the development of stroke after coronary bypass surgery. Therefore, a staged or concomitant approach is required, but the strategy to be implemented must be adapted based on the clinical severity of each disease. In presence of severe carotid artery stenosis with severe coronary artery disease, it is known that a staged approach has a lower 30-day mortality rate with a decrease in postoperative stroke [10, 11]. In our study, we have taken into consideration the severity of both diseases in determining the intervention strategy in the light of current literature and guideline information. We performed a staged approach in 13 and a reversed stage approach in 1 case. We did not perform any concomitant CEA and coronary bypass surgery.

Both general and locoregional anesthesia can be considered for CEA. Although they have their own advantages, there is no significant difference between them in terms of perioperative death, stroke and MI. Therefore, the type of anesthesia to be used during CEA is based on surgeon's preference [12, 13]. All patients in our study group were suitable for general anesthesia without any contraindication and we preferred it to increase surgical comfort.

One of the main causes of perioperative stroke is intraoperative cerebral hypoperfusion. Noninvasive methods including EEG, transcranial DUS and NIRS are used for the rapid detection of brain ischemia during CEA. Cerebral oxygenation defects can easily be detected by NIRS. Twenty percent or more reduction in rSO_2 during ICA clamping is associated with a 10-fold increase in ischemic stroke [14]. The values measured with NIRS are consistent with transcranial doppler and a 12.3% reduction from baseline in rSO_2 can be used as a reliable threshold for intraoperative cerebral perfusion [15]. Moreover, it aids in avoiding carotid artery manipulation by reducing unnecessary use of shunts which may result in dissection or embolism [16]. We think that CEA without any cerebral monitorization method (NIRS particularly) is like using an aircraft without navigation. In our study, we preferred NIRS for brain perfusion monitoring because it is non-invasive, cheap and easy to apply. Of interest, the cost is 500 Turkish Liras (65 Euros) for 1 patient (two disposable probes are utilized). But, here we have to mention that local anesthesia in an awake patient is always cheaper than general anesthesia and NIRS.

Surgical options vary for CEA and still a debate is going on [3]. Conventional endarterectomy with standard longitudinal arteriotomy and closing primarily or with patches, and eversion endarterectomy with oblique transection and eversion of ICA are defined techniques [17]. It was documented that eversion technique improves perioperative stroke and death rates compared with the conventional method and less restenosis is achieved in the late period. However, it is also stated that similar results were obtained with the conventional method modified using a patch [18, 19]. Routine shunt use during surgery does not provide superiority in terms of stroke and mortality compared to not using it at all. The decision on this matter is left to the preference of the surgeon [20, 21]. We believe that the shunt and patch technique, which prolongs the carotid clamp time, should be used in selected patients. For this reason, we used conventional endarterectomy without patch plasty as a surgical technique based on the surgeon's experience and for the purpose of reducing clamp time. We did not use any shunt at all in 76 patients.

Postoperative stroke is defined as the development of a new focal neurological deficit or worsening of the existing deficit after CEA. Although the causes are often ICA thrombosis and embolism from the endarterectomy region, hyperperfusion syndrome and intracranial bleeding may also be present. In these patients, regulation of treatment by eliminating ICA thrombosis is essential. Initiation of dual antiplatelet therapy before intervention can prevent early postoperative thromboembolic stroke. We have employed this regimen in all our patients [21]. Hemorrhagic cerebral infarction and ICA thrombosis were eliminated by MRI in 2 patients in whom we detected new focal neurologic deficit following full recovery from anesthesia. Patients were heparinized and consulted with neurology and physical therapy departments. A physical therapy and rehabilitation program and strict medical treatment were applied for neurological recovery. One patient recovered spontaneously while the other was 3/5 motor functioned with hemiparesis at the 6^{th} postoperative month.

Hematoma requiring exploration after CEA occurs in 3.4% of patients and the vast majority overlap with the uncontrollable hypertension period in the first 6 hours [22, 23]. Despite discrepancies on use of protamine, it was shown to significantly reduce hematoma formation [24]. We did not routinely administer protamine in order to avoid early postoperative ICA thrombosis risk, provided that there was no significant finding in favor of bleeding in the surgical field after CEA. We however used a mini surgical hemovac drain in order to prevent hematoma formation or wound revision.

The rate of development of cranial nerve damage in patients undergoing CEA is 5% and it is reversible in the vast majority. The most frequently affected nerves include the hypoglossal nerve, facial nerve, vagus nerve, recurrent laryngeal nerve and glossopharyngeal nerve. Good anatomical information and careful dissection are required to reduce the risk of nerve damage [3]. In our study, cranial nerve damage was not observed in any of our patients.

Restenosis can develop due to neointimal hyperplasia or recurrent atherosclerosis after surgery. The rate of restenosis is 6.3% at 2-year follow-up after CEA [3]. Restenosis-related factors include female gender, smoking, diabetes mellitus, hypertension, small carotid artery diameter, residual stenosis, and primary closure after endarterectomy [25]. Surveillance for restenosis after endarterectomy is made by DUS practically. Peak systolic volume measurements can provide information about the stenosis that may develop. We have followed the DUS criteria for restenosis after CEA described in the 2017 European Society for Vascular Surgery Clinical Practice Guidelines for Management of Atherosclerotic Carotid and Vertebral Artery Disease [3]. We have a mean follow-up time of 20.6 ± 13.6 months and no hemodynamically significant restenosis was detected in any of our patients.

Conclusions

Today, CEA is an intervention technique that continues to prove its safety in CAS patients. Continuous cerebral oxygenation monitoring is indispensable for carotid surgery. In selecting the surgical technique to be used during CEA, the main target should be to reduce clamp times. To achieve this, we used traditional CEA in our clinic, with primary arteriotomy closure and without use of a shunt. We believe that the "one fits all strategy" we define here is easy to follow and applicable.

Disclosure

The authors report no conflict of interest.

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