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Research Article

Eversion and Conventional Carotid Endarterectomy Techniques in Terms of a Comparison of Hypertension

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Abstract

Background: The operative procedures for carotid stenosis differ in that the eversion technique requires an oblique circumferential incision of the internal carotid artery (ICA) at the carotid bulb and transection of the carotid sinus nerve fibers. In this study, the incidence of postoperative hypertension (HTN) after eversion carotid endarterectomy (E-CEA) was compared with conventional carotid endarterectomy (C-CEA) in the short- and mid-term follow-up periods.

Methods: Baseline blood pressures were recorded in all patients during presurgery testing 1 to 2 weeks before the CEA. Systolic blood pressure value was ≤ 140 mmHg and the value of those under 90 mm Hg diastolic blood pressure was evaluated to have normal blood pressure. Postoperative follow-up of patients with hypertension in the first, sixth, and twelfth months were recorded by outpatient visits, phone calls, and home visits. A total of 164 patients were included in the study without hypertension in the preoperative period (E-CEA=76, C-CEA=88).

Results: In the postoperative period at one month, patients in the E-CEA group had significantly ($P < .005$) higher mean peak systolic, diastolic, and mean blood pressures when compared to the C-CEA group. In the sixth and twelfth month follow-up, there was no significant difference between the two groups in terms of hypertension ($P \geq .078$). In the E-CEA group, antihypertensive agents continued to be administered to 4 (5.2%) patients and 3(3.4%) in the C-CEA group. Normalization of arterial blood pressure was achieved in the other patients. No significant postoperative neurological, surgical, or cardiac complications developed in any patient in either group.

Conclusion: As a result, no significant difference between the two groups in terms of postoperative hypertension.

INTRODUCTION

The value of carotid endarterectomy (CEA) in patients with symptomatic and asymptomatic carotid artery stenosis has been well established [1]. The efficacy of carotid endarterectomy is significant in the prevention of stroke. The optimal CEA technique to reduce complications and restenosis rates has not yet been established. Currently, two techniques for CEA are used. CEA is most often performed with the conventional technique. Eversion CEA is commonly employed as an alternative approach to C-CEA. Thus, the ideal surgical technique for CEA has yet to be defined and the operating surgeons experience and preference determines the surgical option. Conventional carotid endarterectomy (C-CEA) is performed through a longitudinal arteriotomy of the internal carotid artery (ICA). The eversion carotid endarterectomy (E-CEA) technique requires an oblique circumferential transaction of the ICA at the carotid bulb and distal eversion of the ICA on itself for removal of plaque, which has a potential advantage that no patch plasty is necessary [1,2]. The operative procedures for carotid stenosis differ in that the eversion technique requires an oblique circumferential incision of the ICA at the carotid bulb and transection of the carotid sinus nerve fibers. With C-CEA, the longitudinal arteriotomy is generally on the anterior surface of the common carotid artery (CCA) and the ICA, thus limiting the dissection and disruption of the carotid sinus nerve fibers. Previous studies have investigated early hypertension. Higher E-CEA revealed early hypertension in this study. There are no studies related to mid- and long-term hypertension [2,3]. In this study, the incidence of postoperative HTN after E-CEA was compared with that after short- and mid-term follow-up period of C-CEA.

PATIENTS AND METHODS

Between March 2003 and May 2016, primary CEA was performed on 380 consecutive patients in the different surgical groups. The C-CEA was performed on 202 patients, and E-CEA was performed on 178 patients. All operative procedures were most often performed under general anesthesia with cerebral monitoring. The method of cerebral monitoring for the detection of clamping ischemia was used in the transcranial cerebral oximetry (near infrared spectroscopy- NIRS). These patients were evaluated retrospectively. Patients' demographics, indications for surgery, severity of disease and clinical outcomes for the two groups were similar, as shown in Table (1), Table (2). All 202 E-CEAs and 178 C-CEAs were performed with patients under general endotracheal anesthesia; 156 patients were symptomatic and 224 asymptomatic patients had high-grade (80%) carotid artery stenosis. Of these patients, 164 patients with non-hypertension were enrolled. Baseline blood pressures were recorded in all patients during presurgery testing 1 to 2 weeks before the CEA. Systolic blood pressure value was ≤ 140 mmHg, and the value of those under 90 mm Hg diastolic blood pressure were evaluated as normal blood pressure. The patients with a history of hypertension, on antihypertensive medication, uncontrolled hypertension in the preoperative period, severe bilateral atherosclerotic lesions, a history of previous CEA, and developing mortality and morbidity during the follow-up period were excluded from the study. Postoperative follow-up of patients with hypertension in the first, sixth, and twelfth months were recorded by outpatient visits, phone calls and home visits. A total of 164 patients were studied without hypertension (E-CEA=76, C-CEA=88). All of these patients gave their appropriate informed consent and were studied under the approval of the institutional review boards.

Operative technique

Standard CEA: The C-CEA technique was previously described by Scher15. The CCA, ICA, and external carotid artery (ECA), were exposed through an oblique incision parallel to the anterior border of the sternocleidomastoid muscle. Manipulation of the carotid body at the carotid bifurcation was avoided. However, when bradycardia and hypotension occurred during the dissection, 1% lidocaine was injected locally within the adventitia of the carotid artery at the carotid bifurcation. After systemic heparinization, the CCA, ECA, and ICA were clamped. A longitudinal arteriotomy was made in the CCA and extended to the ICA, distal to the end of the atherosclerotic plaque. This was followed by a meticulous CCA, ECA, and ICA endarterectomy. Removal of the ICA intima, as well as the use of a patch for closure of the arteriotomy, was at the discretion of the surgeon. After obtaining complete hemostasis, the incision was closed.

Table 1: Patient demographics.

Patients	e- CEA	c- CEA	p value
	(n=76)	(n=88)	
Male	59(76.7%)	65 (71.5%)	0.08
Female	17 (22%)	23(25.3%)	0.081
Mean age	67.3 ± 13,4	64,8 ± 14,8	0.087
Side (left)	61(60.1%)	54 (59.4%)	0.065
CAD*	30(38, 8%)	36 (39.6%)	0.091
DM	30 (30.9%)	33 (36.3%)	0.087
HLP	65 (84.5%)	74 (81.4%)	0.799
PAD	9 (11,7%)	12 (15.6%)	0.061
Atrial fibrillation	4(5.2%)	10(10.1%)	0.093
Smoking	31 (40,3%)	35(38,5%)	0.084
Alcohol use	7 (7,6%)	8 (8,8%)	0.671
BMI	24,2	26,1	0.565
Renal failure	3(3.9%)	5(5,5%)	0.595

Table 2: Indication for surgery.

Surgical indication	Eversion CEA	Convensional CEA	p value
Patients	n=76	n=88	
Asymptomatic	43(61.2%)	48(56.7%)	0.072
Symptomatic patients	28(39.8%)	38(43.6%)	0.078
TIA	17(21.9%)	21(24.2%)	0.082
Stroke	8(11.7%)	11(13.3%)	0.065
Vertebrobasilar Symptoms	4(5.0%)	5(5.4%)	0.067
Preoperative ultrasound			
ICA velocity (cm/sec)	405 ± 120	410 ± 110	0.098

Abbreviations: TIA: Transient Ischemic Attacks; ICA: Internal Carotid Artery

Eversion CEA: The E-CEA technique was previously published [4-7]. It involves the oblique transection of the ICA from the common carotid artery at the bulb. After division, the ICA may appear redundant; a cephalad incision from the heel of the transected ICA may be used to shorten the artery. The ICA is everted over its athermanous core. It is important to remove the most external layers of the media when doing so to maintain eversion of the artery to the end of the atheroma. The endpoint is directly visualized and loose fragments are removed; 6-0 or 7-0 monofilament sutures can be placed distally, if necessary. Shunts were used only distal ICA systolic tension under 50mmhg pressured after cross clamping. After completion of the ICA endarterectomy, the arteriotomy can be extended in the common carotid artery to facilitate removal of the common carotid and external carotid artery plaque. The ICA can then be tailored and shortened if necessary for reanastomosis to the common carotid artery. After obtaining complete hemostasis, the incision was closed.

Statistical analysis

Data were collected retrospectively in an electronic database (Microsoft Excel, Redmond). The StatDirect statistical software version 2.7.3(The StatDirect Ltd, Cheshire, United Kingdom) was used for analysis. Cohort comparisons of demographic data were assessed using two-tailed *t*-tests for continuous variables, χ^2, and Fischer's exact *t*-tests for categorical data. Two-sided P values were always computed and differences were considered statistically significant at p ≤0.05.

RESULTS

Patient demographics, indications for surgery, and shunting data are listed in Tables (1,2).

The mean age was 67.3 ± 13.4 (SD 11.8, range 54–84) years in the e-CEA group and 64.8 ± 14.8 (SD 12.3, range 52–82) years in the C-CEA group. Carotid shunts were used in (74%) of the C-CEA group, but were required in 5% of the E-CEA group (p≤0.05). The mean clamping time for E-CEA and C-CEA were found to be 7.54 ± 4.6 minutes and 9.62 ± 3.7 minutes (p=0.236), respectively. All 88 patients in the C-CEA group (100%) and 76 patients in the E-CEA group (100%) had a history of normal tension. The gender distribution was similar in both groups (E-CEA: men 78 %, C-CEA: men: 74%). In the C-CEA group, there was a significantly higher symptomatic stenosis as well as shunting rate (E-CEA: 19% and 5%; C-CEA: 48% and 74%, p ≤.005) (Table 3). In the postoperative period, patients in the E-CEA group had significantly (*p*< 0.05) higher mean peak systolic, diastolic, and mean blood pressures when compared to the C- CEA group (Figure 1). The dosage of existing antihypertensive medications in the postoperative first month (especially the first week) was increased. Annti hypertensive medication was prescribed for 15 patients (20.5%) after E-CEA and for 14 patients (10.7%) after C-CEA (p≤0.05). The additional prescription was significantly relevant for beta-blockers, angiotens in-converting enzyme inhibitors, and calcium channel blockers. No correlation could be demonstrated with the incidence of coronary artery disease, diabetes, dyslipoproteinemia, peripheral artery disease, arrhythmia, alcohol or nicotine use, and grade of carotid artery stenosis. In the sixth and twelfth month follow-ups, there was no significant difference between the two groups in terms of hypertension (p≥.078) (Table 4). In the E-CEA group, 4 (5.5%) patients were kept on antihypertensive agents, and 3(3.4%) patients were kept on antihypertensive agents in the C-CEA group. Normalization of arterial blood pressure was achieved in the other patients. No significant postoperative neurological, surgical, or cardiac complications developed in any patients in either group.

DISCUSSION

The safety, feasibility, and durability of CEA have been validated in many trials. The ideal surgical technique to optimize early outcome and long term durability of CEA has yet to be determined [2]. As first described by De Bakey et al. [4], in 1959, the E-CEA technique has not been widely used because of its reputed difficulty and poor visualization of the distal ICA plaque end point. Since the development of the modified E-CEA procedure currently in use, a number of recent studies have demonstrated the feasibility of E-CEA and reported clinical results comparable to the more widely used C-CEA techniques [5,6]. Several advantages have been cited in favor of the eversion technique [1-13]. Eversion CEA avoids the use of prosthetic

Table 3: Surgical results.

	Eversion CEA	Convensional CEA value	P Value
Patients	76	88	
Primary endpoint (Ipsilateral stroke or death within 30 days after operation)			
Death	none	1(1.13%) 0.762	
Major Stroke	1(1.31%)	1(1.13%) 0.762	
Peroperative secondary endpoints at 30 days			
Dysaesthesia wound areas	2 (2,62%)	3 (3,39%)	0,532
Hematoma	1(1,31%)	1(1,13%)	0.932
MI(fatal)	1(1,31%)	0(0%)	0.876
TIA	2(2, 62%)	1(1,13%)	0.674
Revision	0(0%	0(0%)	
Postoperative HTN	28(38.1%)	5(5.65%)	0.044
Restenosis	1(1,31%)	2(2.26%)	0.634
Shunting	2(2.62%)	10(11, 3%)	0.017
2-year secondary endpoints including periprocedural events			
Major stroke	0(0%)	2(2.26%)	0,045
Any stroke	1(1,13%)	2 (2,26%)	0,832
Death	1(1,31%)	1(1,13%)	0,832

Abbreviations: MI: Myocardial Infarction; CN: Cranial Nerve; TIA: Transient Ischemic Attacks; HTN: Hypertension; NS: Not Significant; Fisher exact t test shown.

Table 4: Preoperatif and postoperatif sistolic, diastolic and mean arterial pressure value.

	e-CEA	c-CEA
preop	postop1.month *significiances pre-post	preop postop1.month * significiances pre-post
	[median (IQR)] [median (IQR)]	median (IQR)] [median (IQR)]
	ABP(mmhg)	
SP	120.25 130.48 ≤ 0.0001	SP 122.46 128.74 NS
	(108.24-140.68) (136.18-160.78)	(108.24-140.44) (110.18-142.32)
DP	78.16 86.65 ≤ 0.0001	DP 78.16 76.65 NS
	(54.56-89.17) (60.08-96.78)	(56.56-85.12) (60.08-86.54)
MAP	84.03 98.08 ≤ 0.0001	MAP 84.07 88.04 NS
	76.09-82.08) (78.09-100.76)	(75.06-80.08) (70.09-82.98)

Abbreviations: E-CEA: Eversion Carotid Endarterectomy; C-CEA, Conventional Carotid Endarterectomy; ABP: Arterial Blood Pressure; SP, Systolic Pressure; DP: Diastolic Pressure; MAP: Mean Arterial Pressure
*Comparison Of Non-Normally Distributed Values With Wilcoxon's Signed Rank Test.

material and is particularly useful in situations in which the internal carotid artery is coiled or kinked [10]. Concerns about carotid eversion include difficulty in visualization of the endarterectomy end-point, increased technical demand, difficulty when the use of a shunt is required, and the possibility that a distal flap may remain if the endarterectomy endpoint is not properly performed [14,15]. Shunting has a remarkable embolism risk, can prolong clamp times, and makes the endarterectomy technically difficult. Using shunts and patchplasty techniques prolong the clamp time and the researchers believe that these two methods should be used in selected patients (small diameter of the carotid artery, inactive anterior communicating artery, and poor cerebral collateral blood flow) [16] This stance was supported by a case series involving 25 patients in whom carotid endarterectomy was successfully performed without the aid of a shunt, in spite of complete occlusion of the contralateral carotid artery [17]. In the current study, shunts were used only in distal ICA systolic tension under 50 mmhg pressure after cross clamping. However, hypertension after E-CEA seems to be a major problem in many studies [2,3]. Hypertension after CEA is an important cause of morbidity and a significant risk for myocardial infarction, hyper perfusion syndrome, cerebral hemorrhage, stroke, and death. Patients with preoperative HTN are at an increased risk for developing postoperative HTN [18,19]. On the other hand, there are no clear reports for patients without preoperative HTN [6]. Towne and Bernhard[6] reported that the incidence of preoperative hypertension in patients who developed postoperative hypertension was 79.6%, compared with 57.4% in patients who did not develop this complication. Moreover, they found a significantly increased incidence of neurological deficits and operative mortality rate in the group that developed postoperative hypertension. Bove et al. [26], reported a 19% incidence of postoperative hypertension after carotid endarterectomy and noted a 10% incidence of fixed neurological deficits in these patients. The persistence of hypertension after CEA is quite rare. Approximately 21% of normotensive patients may have increased blood pressure after carotid endarterectomy [6,26]. The particular peak of risk is highest in the first 48 hours after surgery. The pathophysiology of typically episodic hypertension might be related to surgically induced abnormalities of carotid baroreceptor sensitivity. Particular attention is required during dissection of the common carotid artery to avoid damaging the vagus nerve and the carotid sinus, and to prevent carotid baroreceptor dysfunction. Unstable blood pressure occurs in 73.5% of patients during the first 24 hours after carotid endarterectomy [27]. Ahn et al. 16 concluded that post carotid endarterectomy HTN is associated with elevated cranial norepinephrine levels, suggestive of a central nervous system sympathomimetic mechanism as a result of reflex inhibition of the vasomotor center, which is likely linked to a baroreceptor-reflex breakdown. Baro receptor insensitivity has been found in hypertensive patients. Baroreflex failure syndrome might be a potential complication in hypertensive patients with severe bilateral atherosclerotic lesions, even after unilateral carotid endarterectomy [28]. HTN after CEA may result in prolonged hospital admission or, more seriously, may be associated with neurological and cardiac complications [20,21]. The sustained increase in blood pressure in the immediate postoperative period after eversion, endarterectomy returned to preoperative levels by day 4 after surgery [2], Mehta et al. [3], theorized that in E-CEA, postoperative HTN after E-CEA may be attributable to the destruction of the baroreceptor apparatus. They retrospectively compared the incidence of postoperative HTN in E-CEA and C-CEA patients [3]. Their study showed that patients who underwent E-CEA had a significantly (p=0.044) increased postoperative blood pressure and required more frequent intravenous antihypertensive medication (24%), compared with patients receiving C-CEA (6%). In this study, in the first seven days in the first E-CEA group, systolic arterial blood pressure, diastolic, and mean arterial pressures were significantly higher. A retrospective study Demirel et al. [2], demonstrated that hypertension in the first four postoperative days was more frequent after E-CEA than after the conventional technique. However, there was no significant difference in hypertension at the end of the first month and in the following months (Figure 2,3). However, hypertensive episodes that is not statistically significant from time to time (Figure 3). The E-CEA results in the transection of the longitudinal nerve fibers of the carotid sinus nerve, and consequently, a loss of the baroreceptor reflex [2]. In C-CEA, the dissection and disruption of the carotid sinus nerve fibers are low risk due to the longitudinal arteriotomy, which commonly is performed on the anterior of the CCA and

ICA. Injury of the carotid sinus nerve fibers is caused by the baroreceptor-reflex breakdown, which may lead to postoperative hypertension. The results of the current study support the hypothesis that unilateral carotid sinus nerve denervation is sufficient to generate significant physiological changes, parallel with the clinical findings of a previous study that demonstrated a rise in systolic blood pressure until the fourth day following E-CEA$_2$. The current results show that with the eversion technique, the baroreceptor sensitivity (BRS) dropped significantly on postoperative day 1 and remained markedly reduced on postoperative day 3, but showed a trend towards BRS recovery.$_2$ Speculatively, the explanation for the transience of this phenomenon may be related to the recovery of BRS through the baroreflex apparatus located on the contralateral side and the aortic arch, which are compensatory mechanisms that may require several days to adapt [2]. Scher et al. [22], demonstrated a rise in mean blood pressure lasting for 1 week in a large animal model of bilateral carotid sinus nerve denervation. As noted by Demirel et al. [23], after one week, it was thought that baroreceptor sensitivity was regenerated and ensured tension arterial regulation in this way. However, the researchers of the current study believe that this situation must be investigated and needs to be shown as histopathological. At our institution, all CEAs were mostly performed under general anesthesia, depending on the experiences and preferences of the anesthetist and surgeon, and patient co-morbidities and preferences. Murphy et al. [24], reported their experience with the use of general anesthetics during CEAs; they suggest that the resulting vasodilatation causes a loss of cerebral auto regulation and, therefore, an increased dependency of cerebral blood flow on elevated systemic pressures. The main factors in producing good results for CEA are preoperative evaluation, case selection and optimization, and the experience expertise and close attention of the anesthetic, surgical, and perioperative care team. The conduct of perioperative care is more important than the type of anesthesia used [25]. Eversion endarterectomy has some advantages like total removal of plaque, no enosis in ICA, no need for patchplasty, and short cross clamp time. Additionally, elongated or kinked ICA can be corrected by this technique. E-CEA should be very well assisted when performed, and shunt usage is more complicated compared to C-CEA. However, patients who have extended plaque to CCA, E-CCA has some disadvantages such as prolonged cross clamp time and failure of the total removal of plaque. As a result, no significant difference between the two groups in terms of postoperative hypertension.

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