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Abstract

Objectives: To evaluate the transition process from conventional carotid endarterectomy (cCEA) to eversion carotid endarterectomy (eCEA). **Methods:** Patients operated with carotid endarterectomy (CEA; 164 patients, 171 CEA) in 2002-2003 were retrospectively included. **Results:** In 2002, cCEA was applied in 64 (80%) and eCEA in 16 (20%) patients. There was an inversion on the preponderant surgical technique in 2003 (cCEA in 34 patients [37%] and eCEA in 57 patients [63%]). Perioperative stroke or death occurred in 3 patients (3.8%) in 2002 and 5 (5.5%) in 2003 ($P = .78$). Perioperative myocardial infarction occurred in 2 patients (2.5%) in 2002 and 2 in 2003 (2.2%, $P = 1.00$). Median follow-up was 83 (79-86) and 70 (67-74) months for the 2002 and 2003 cohorts, respectively, and there were no differences in survival or ipsilateral stroke between the groups. **Conclusions:** The transition from cCEA to eCEA is possible without significant changes in morbidity and mortality perioperatively and during follow-up.

Keywords

carotid endarterectomy, conventional, eversion, technique, transition

Introduction

Carotid endarterectomy (CEA) has been established in several large multicenter trials as the treatment for symptomatic and asymptomatic significant carotid stenosis.¹⁻⁶ Two main surgical techniques are in use.⁷⁻⁹ In conventional CEA (cCEA), the plaque is removed en bloc after a longitudinal incision. This has traditionally been the method of choice and still is the predominant technique at the majority of vascular centers. Eversion CEA (eCEA) allows the removal of the plaque after complete transection of the internal carotid artery. It has been proposed as a way of shortening operation time, avoiding synthetic graft material, and possibly decreasing the restenosis rate.^{6,7,10-12}

The introduction of a new technique may, however, be associated with a learning curve, which may condition the results and, therefore, decrease the benefit of the treatment during that period. A transition from cCEA to eCEA may be postponed or avoided in clinical practices due to the concern of problems arising during the transition process.^{10,13}

The aim of this study is to evaluate the short- and long-term results of transition from cCEA to eCEA at a single center.

Methods

Patient Population and Collection of Data

All patients undergoing CEA at our tertiary university referral center were identified in the hospital database registering all

surgical procedures and diagnosis on hospital discharge or death. Surgical procedures were classified according to the nationally revised version of the Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures.¹⁴ The search codes used were PAF20, PAF21, PAK21, PAN20, and PAN21. These codes correspond to thrombendarterectomy of the common or internal carotid arteries, reimplantation of the internal carotid arteries, and arterioplasty of the common or internal carotid arteries, respectively. The diagnosis at the time of hospital discharge or death was registered following the 10th revised version of the *International Classification of Diseases, (ICD-10)*. The search codes used were I65.2 and I65.3, corresponding to occlusion or stenosis of the carotid arteries or multiple precerebral arteries. The findings were matched with the National Vascular Register (SwedVasc) in an attempt to identify any missing patients due to any possible erroneous coding.

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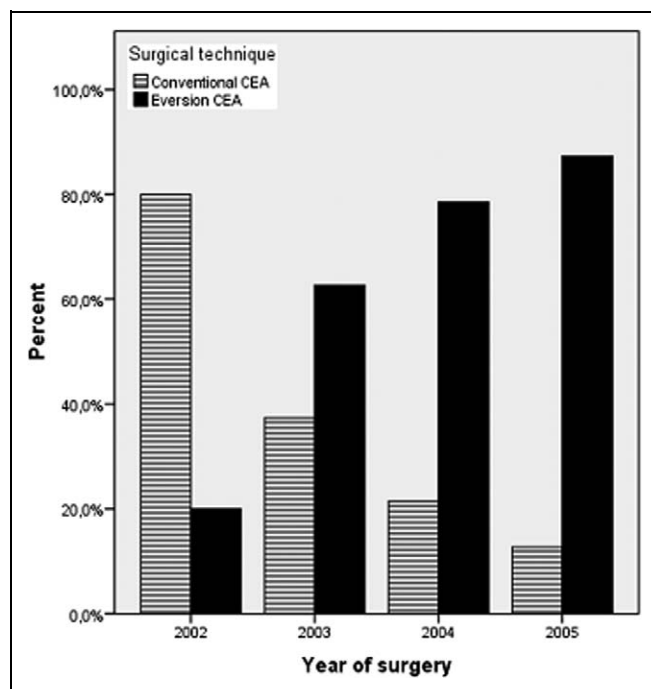


Figure 1. cCEA and eCEA performed between 2002 and 2005. cCEA indicates conventional carotid endarterectomy; eCEA, eversion carotid endarterectomy.

Inclusion for the study was limited to patients operated for atherosclerotic lesions in the biennium 2002-2003 when the major transition between cCEA and eCEA occurred (Figure 1). A total of 164 patients (106 men, median age 72) underwent 171 CEAs between January 2002 and December 2003 and were included.

All data were retrospectively obtained and registered in a computer-based database. Information concerning preoperative clinical data, examinations, and surgical procedures was obtained from medical charts. Information on postoperative neurological events was taken from the clinical charts at the time of contact with the hospital. This information was also completed through telephone interviews with surviving patients. Patients were followed until death or June 30, 2009. Dates and causes of death were obtained through the National Population Register.

Pre- and Postoperative Evaluation and Surgical Procedures

All patients were evaluated preoperatively by an independent neurologist. The decision for surgical treatment was taken at a weekly multidisciplinary conference involving neurologists, angiologists, and vascular surgeons. Indication for surgery was based on the presence of a carotid stenosis >70% on duplex evaluation and ipsilateral symptoms. Asymptomatic patients were considered when they had a stenosis >80% on duplex and/or had a history of contralateral symptomatic carotid stenosis. All patients underwent a repeated duplex scan the day before

surgery to exclude occlusion of the carotid. Brain-computed tomography was done for symptomatic patients.

Surgery was performed according to the standard procedures for cCEA and eCEA, preferably under locoregional anesthesia. The carotid was exposed through an ante- or retro-jugular approach, followed by either cCEA or eCEA. The use of patch while performing the cCEA was left to the surgeon's consideration and whenever used ($n = 65$, 66%), a sealed macroporous knitted fluoropolymer patch was preferred (Fluoropassiv thin wall carotid patch, Vascutek Ltd, Scotland, UK). The use of shunt was decided intraoperatively based on the conscience level and the development of focal symptoms. By the end of each surgery, the surgeons assessed the difficulty of the procedure using a scale from 1 to 6, where 1 signified the easiest and 6 the most difficult. Dextran 70 (Macrodex 60 mg/mL, Meda AB, Stockholm, Sweden) was used intraoperatively as a single dose (500 mL) and once a day during the first 2 postoperative days. Intravenous heparin (5000 IU) was used intraoperatively whenever there was a contraindication for dextran or on the placement of a shunt.

Follow-up included a duplex ultrasound as well as an additional clinical examination by a neurologist 1 month postoperatively. A telephone interview was also performed by the surgeon 1 year after the operation. All duplex ultrasound examinations were independently performed at the Clinical Physiology Department. Stenosis grade was assessed based on the flow velocities which had been previously validated comparing to the common carotid artery diameter.¹⁵ Surviving patients underwent a repeated telephone interview at the time their medical chart was reviewed. This interview followed a preestablished protocol focusing on new cardio- or cerebrovascular events and/or interventions. Clinical charts from contacts with the hospitals in the region were reviewed to assess any new cardio- or cerebrovascular events and/or interventions after the CEA.

End Points and Statistical Analysis

End points of the study were perioperative stroke or death and ipsilateral stroke or death during follow-up. Perioperative stroke or death was defined as stroke or death appearing within 30 days following surgery. Stroke was defined as any persistent neurological deficit.

Statistical analysis was performed using SPSS 17.0 (SPSS Inc, Chicago, Illinois). All variables were controlled for normality using the Shapiro Wilk W test. Normally distributed data are presented as mean $\pm$ standard deviation (SD), whereas nonnormally distributed data are presented as median and interquartile range (IQR) within parenthesis. For continuous variables, independent sample t test was used when data were normally distributed and Mann-Whitney U Test when data were nonnormally distributed. For categorical variables, chi-square or Fisher exact test was applied. Survival was analyzed according to Kaplan-Meier using log-rank test and with life table analysis. Survival estimates are presented as percentage $\pm$ standard error (SE). Results were considered significant when $P < .05$.

Table 1. Demographic and Clinical Features of Patients Operated During 2002-2003

	2002, n = 80	2003, n = 91	P Value
Age (years)			
Median (IQR)	71 (62-76)	73 (67-78)	.015
Gender male	48 (60%)	63 (69%)	.21
BMI	26 (23-28), n = 66	25 (24-28) (n = 73)	.53
Hypertension	54 (68%)	58 (64%)	.61
MI	19 (24%)	26 (29%)	.48
Diabetes mellitus	12 (15%)	18 (20%)	.41
PVD	14 (18%)	12 (13%)	.43
Smoking	36 (55%), n = 66	22 (36%), n = 61	.037
Lipid lowering drugs	57 (71%)	70 (77%)	.40
Anticoagulant drugs	79 (99%)	90 (99%)	.93
Preoperative creatinine ($\mu\text{mol/L}$)	86 (73-102), n = 78	90 (77-106), n = 87	.11

Abbreviations: IQR, interquartile range; BMI, body mass index; MI, history of myocardial infarction; PVD, peripheral vascular disease (defined as previous surgery or known diagnosis).

Table 2. Perioperative Data of Patients Operated During 2002-2003

	2002, n = 80	2003, n = 91	P Value
Operation technique			
Conventional CEA	64 (80%)	34 (37%)	<.0001
Eversion CEA	16 (20%)	57 (63%)	<.0001
Operated side (right)	39 (49%)	45 (50%)	.93
Symptomatic indication	71 (89%)	84 (92%)	.43
AF	12 (15%)	11 (12%)	.58
TIA	15 (19%)	39 (43%)	.001
Disabling stroke	44 (55%)	34 (37%)	.021
Degree of stenosis (%)			
Median (IQR)	95 (80-95)	90 (80-95)	.31
Contralateral stenosis (%)	45 (40-95), n = 75	40 (40-60), n = 84	.27
Perioperative stroke	2 (2.5%)	3 (3.3%)	1.00 ^a
Perioperative death	1 (1.3%)	3 (3.3%)	.62 ^a
Perioperative stroke or death	3 (3.8%)	5 (5.5%)	.73 ^a
Perioperative myocardial infarct	2 (2.5%)	2 (2.2%)	1.00 ^a
Reoperation	7 (8.8%)	9 (9.9%)	.80
Operation duration (minutes)	110 (95-129)	105 (90-130)	.39
Occlusion time (minutes)	40 (29-49)	30 (21-38)	<.0001
Shunt needed	13 (16%)	25 (27%)	.079
High assessed difficulty	28 (36%), n = 77	29 (34%), n = 86	.72
Days from symptom to operation	30 (14-48), n = 54	21 (10-50), n = 59	.23

Abbreviations: CEA, carotid endarterectomy; IQR, interquartile range; AF, amaurosis fugax; TIA, transient ischemic attack.

^a Fisher exact test.

Results

Patient's Characteristics

A total of 171 CEAs were performed on 164 patients during the study period. In 2002, operations were made by cCEA in 64 (80%) and eCEA in 16 (20%) patients. In 2003, there was an inversion on the preponderant surgical technique with cCEA being used in 34 patients (37%) and eCEA in 57 (63%; Table 1).

Patient characteristics in the 2002 cohort did not differ from the 2003 cohort, with the exception of age and prevalence of smokers (71 [62-76] years old and 55% smokers in 2002 vs

73 [67 to 78] years old and 36% smokers in 2003, $P = .015$ and $P = .037$, respectively; Table 1). The remaining patient characteristics and clinical parameters, including preoperative ipsilateral symptoms and degree of stenosis, did not differ between the 2002 and the 2003 cohorts (Tables 1 and 2). Although the relative numbers of symptomatic patients did not differ between the groups, there was a larger share of disabling strokes in 2002 compared to 2003 (55% and 37%, respectively, $P = .021$). Furthermore, there were fewer transitory ischemic insults (TIA) in 2002 compared to 2003 (19% and 43%, respectively, $P = .001$).

Table 3. Perioperative Data of Patients Operated During 2002-2003 According to the Technique

	Conventional CEA, n = 98	Eversion CEA, n = 73	P Value
Operated side (right)	50 (51%)	34 (47%)	.57
Symptomatic indication	89 (91%)	66 (90%)	.93
AF	13 (13%)	10 (14%)	.94
TIA	26 (27%)	28 (38%)	.10
Disabling stroke	50 (51%)	28 (38%)	.10
Degree of stenosis (%)			
Median (IQR)	90 (80-95)	90 (80-95)	.79
Contralateral stenosis (%)	50 (40-95), n = 91	40 (30-55), n = 68	.001
Perioperative stroke	5 (5.1%)	0 (0%)	.072 ^a
Perioperative death	3 (3.1%)	1 (1.4%)	.64 ^a
Perioperative stroke or death	7 (7.1%)	1 (1.4%)	.14 ^a
Perioperative myocardial infarct	1 (1.0%)	3 (4.1%)	.31 ^a
Reoperation	6 (6.1%)	10 (13.7%)	.092
Operation duration (minutes)	117 (97-140)	95 (89-120)	<.0001
Occlusion time (minutes)	37 (24-47)	32 (27-38)	.098
Shunt needed	29 (30%)	9 (12%)	.006
High assessed difficulty	38 (42%), n = 91	19 (26%), n = 72	.041
From symptom to operation (days)	23 (13-42), n = 70	30 (15-65), n = 43	.11

Abbreviations: CEA, carotid endarterectomy; IQR, interquartile range; AF, amaurosis fugax; TIA, transient ischemic attack.

^a Fisher's exact test.

Surgical Procedures

Surgery was performed in locoregional anesthesia in all except 7 patients (4.1%) for whom general anesthesia was used. The reasons for applying general anesthesia were insufficient understanding of the Swedish language ($n = 1$, 0.6%), severe intraoperative coughing ($n = 2$, 1.2%), intraoperative stroke ($n = 1$, 0.6%), and poor patient cooperation ($n = 3$, 1.8%). Shunt was used less often in 2002 ($n = 13$, 16%) than in 2003 ($n = 25$, 27%) but the difference did not reach statistical significance ($P = .079$). When comparing the techniques rather than the years (Table 3), a shunt was used more often in cCEA (30%) than in eCEA (12%, $P = .006$). Furthermore, eCEA (95 minutes [89-120]) required significantly less time than cCEA (117 minutes [97-140]; $P < .0001$).

The subjectively assessed difficulty of the operations did not differ between 2002 and 2003. When comparing the 2 techniques, however, a higher proportion of operations performed with cCEA was assessed as difficult (ranked 4-6, $P = .041$).

Perioperative Results

The perioperative results did not differ between 2002 and 2003 (Table 2). Perioperative stroke occurred in 2 patients (2.5%) in 2002 and in 3 patients (3.3%) in 2003 ($P = 1.00$). Briefly, 1 patient (1.3%) died during the perioperative period in 2002, whereas in 2003 there were 3 fatalities (3.3%, $P = .62$). The combined perioperative stroke and death number was 3 (3.8%) in 2002 and 5 (5.5%) in 2003 ($P = .73$). Perioperative myocardial infarct occurred in 2 patients (2.5%) in 2002 and in 2 patients (2.2%) in 2003 ($P = 1.00$). Reoperation during the perioperative period due to hematoma was required in 7 patients (8.8%) in 2002 and in 9 patients (9.9%) in 2003 ($P = .80$).

Follow-Up

Median follow-up duration was 83 months (79-86) for the 2002 cohort and 70 months (67-74) for the 2003 cohort. Ipsilateral stroke and survival did not differ during the follow-up (Figures 2 and 3). In all, 21 patients from the 2002 cohort and 24 from the 2003 cohort died during the followup. The 5-year survival rate was $79\% \pm 5\%$ for the 2002 cohort and $80\% \pm 4\%$ for the 2003 cohort ($P = .30$). Ipsilateral stroke during follow-up occurred in 6 and 5 patients in the 2 cohorts, respectively. The 5-year ipsilateral stroke-free rate was $97\% \pm 2\%$ for the 2002 cohort and $95\% \pm 3\%$ for the 2003 cohort ($P = .61$).

Discussion

Eversion CEA has been introduced as a means to reduce operation time, avoid graft material, and possibly obtain a lower restenosis rate.^{6,9} Several studies have reported similar results with eCEA and cCEA regarding perioperative stroke and death as well as follow-up stroke-free time and survival.^{6,7} eCEA seems, therefore, to be at least noninferior to cCEA. Still, however, cCEA continues to be the dominant technique. One reason is that the specific transition process from cCEA to eCEA has been less well studied, making the actual decision to change operation technique a theoretically risky project, considering the possibility of a learning curve during the introduction of a new technique.¹³

In this study, no deleterious effect was found on any of the end points during the transition from cCEA to eCEA. The results indicate that a transition can be made without jeopardizing neither the perioperative results nor the long-term risk of ipsilateral stroke or death. These results were obtained through a progressive change because in 2003 there were still 37% of the operations performed by cCEA. Although a complete

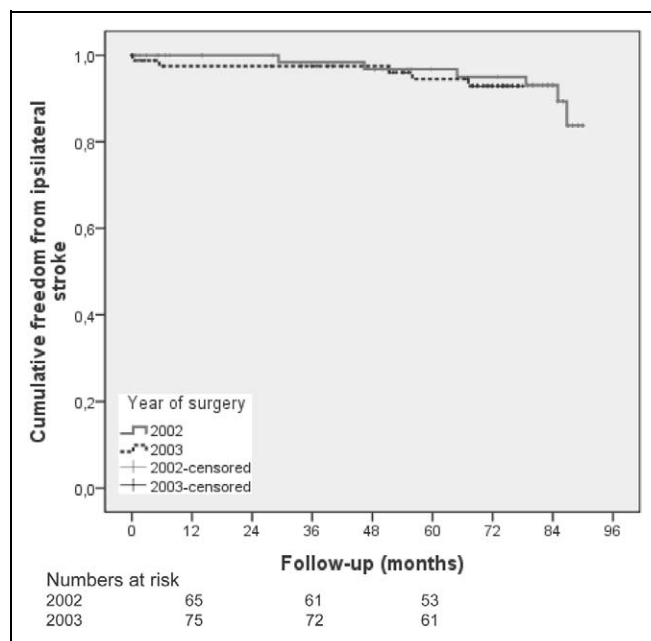


Figure 2. Kaplan-Meier analysis of freedom from ipsilateral stroke after CEA. Solid line, 2002 and dashed line, 2003; $P = .61$. CEA indicates carotid endarterectomy.

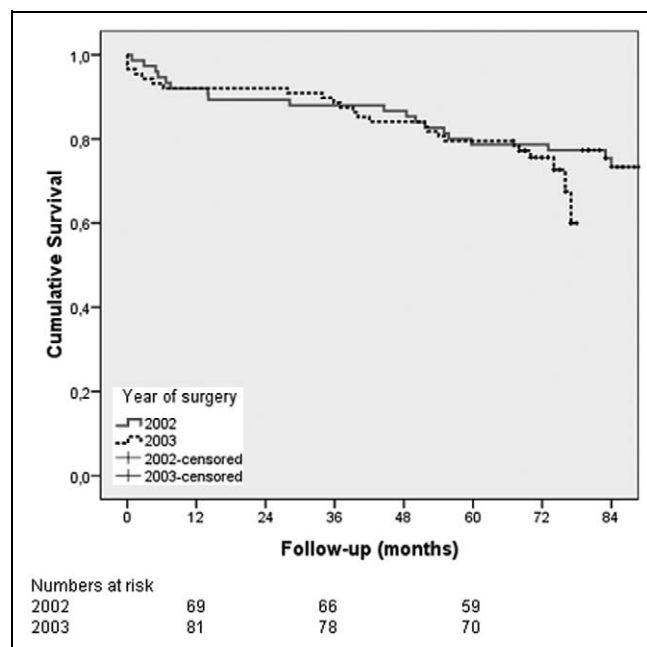


Figure 3. Kaplan-Meier analysis of survival after CEA. Solid line, 2002; dashed line, 2003; $P = .30$. CEA indicates carotid endarterectomy.

transition may have led to different results, this would not have reflected the clinical reality. An immediate complete transition would have been neither desirable nor defensible with respect to maintaining patient safety, because initially a less extensive experience with eCEA may make this technique less attractive when facing challenging anatomies. There is, thus, a possibility that in 2003 cCEA remained the method of choice primarily in technically more challenging patients such as those requiring shunt and having high-located lesions. The higher difficulty level of cCEA than of eCEA when subjectively estimated by the surgeons might be a reflection of this. Furthermore, this reinforces the importance of being able to offer both techniques as potential alternatives for each patient depending on the intraoperative findings, preference, and experience of the individual surgeon.⁷

There are some factors that may have influenced the results. Patients from the 2003 cohort were older than the 2002 cohort. Theoretically, this might disturb the analysis in disfavor of the transition because studies on CEA have reported a somewhat higher perioperative risk with increasing age.¹⁶ However, despite this theoretical disadvantage, the transition between the techniques occurred without significantly changing the results.

The distribution between TIA and disabling stroke as indication for surgery differed significantly between 2002 and 2003, whereas amaurosis fugax (AF) was similar in the 2 groups. However, this is unlikely to disturb the analysis, because preoperative TIA and disabling stroke have similar surgical risks, as opposed to AF, which is associated with substantially lower operative risk.¹⁷ The time interval in days from symptom to surgery was shorter in 2003 than in 2002, which had the potential of influencing the results of the transition.¹⁸ This could not be verified.

The difference in smoking prevalence between the 2 groups may be a reflection of the retrospective design of the study, because this factor is difficult to assess retrospectively.

It could be argued that the true learning curve had already taken place when eCEA was first introduced at our center, prior to 2002. However, when initiated eCEA was performed by a single surgeon only, and it was not until 2002 that eCEA started to be practiced more generally, making this year a natural starting point of this study because the aim of the study is to see the impact of the transition process in routine clinical practice. Our results support the idea of having an initial phase of a surgeon getting experienced with the technique and then generalizing its use to the rest of the practice.

In conclusion, this study shows that a gradual, but relatively fast transition from cCEA to eCEA seems to be possible without jeopardizing the results of the surgical intervention. Holding on exclusively to cCEA only by concern of a problematic transition process is therefore unjustified. However, both techniques should continue to be available while performing CEA to be able to offer the best-suited technique in challenging cases.

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Declaration of Conflicting Interests

The author(s) declared no conflicts of interest with respect to the authorship and/or publication of this article.

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