Chapter 28
In Patients Undergoing Carotid Endarterectomy, Is the Eversion Technique Superior to a Patch Technique to Reduce Restenosis?

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Abstract Carotid endarterectomy (CEA) is the treatment of choice for symptomatic carotid stenosis and selected asymptomatic lesions. CEA is most often performed via a longitudinal anterior arteriotomy in the common carotid artery (CCA) extending through the carotid bulb and into the internal carotid artery (ICA). Many surgeons feel that this so-called "standard" technique (sCEA) allows for optimal visualization and excision of the plaque, and maximally facilitates arterial reconstruction. An alternative technique, known as "eversion endarterectomy" (eCEA) has also been popularized. eCEA is performed by transecting the carotid bulb just below the bifurcation and removing the plaque by everting the media/adventitia using the plaque as a mandrill over which to establish a cleavage plane. The purpose of this chapter is to describe, review and compare these methods of CEA, and make recommendations as to the optimal technique of the operation.

Keywords Carotid • Endarterectomy • Carotid endarterectomy • Eversion technique • Stroke

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Introduction

## *Standard Carotid Endarterectomy (sCEA)*

The hallmark of the standard technique of CEA (sCEA) is longitudinal carotid arteriotomy. It was originally performed by Michael DeBakey in 1953 in a patient with stroke and carotid occlusion [1], and first described by Felix Eastcott and Charles Rob in 1954 who explored and then resected the diseased carotid bifurcation of a woman who was found to have critical stenosis after sustaining 33 separate transient ischemic attacks [2].

In the modern era, sCEA is performed via a cervical skin incision parallel and anterior to the sternocleidomastoid muscle. Following incision, the platysma muscle is divided, the internal jugular vein retracted laterally and the facial vein ligated. The carotid sheath is incised and the common carotid (CCA), external carotid (ECA), internal carotid (ICA) and superior thyroid arteries identified and controlled. In order to expose the proximal ICA, the descending branch of the ansa cervicalis is divided facilitating superomedial retraction of the hypoglossal nerve. The patient is systemically anticoagulated and the internal, common and external carotid arteries sequentially clamped. A longitudinal arteriotomy is made in the CCA extending onto the ICA, and a cleavage plane developed within the arterial media to extract the plaque under direct vision (Fig. 28.1). The endarterectomy proceeds in the proximal-to-distal (caudal-to-cranial) direction. When the ECA is reached, it is endarterectomized via eversion by temporarily releasing its clamp. Finally, the distal portion of the plaque lining the proximal ICA is excised under direct vision, with care to make its endpoint smooth and free of residual stenosis.

The sCEA technique is ubiquitous, being utilized in the majority of the more than 100,000 CEA procedures performed annually [4]. It was the primary technique employed by investigators demonstrating the efficacy of the procedure in multi-center randomized trials [5, 6]. The contemporary clinical results of CEA are, perhaps, best illustrated by the *Carotid Revascularization Endarterectomy vs. Stenting Trial* (CREST) trial which randomized 2502 patients with carotid stenosis to undergo either CEA or carotid artery stenting in 117 North American centers [7]. Although the use of the sCEA wasn't mandatory, the fact that 62 % of patients underwent patch angioplasty suggests that it was the dominant technique. For the 1240 patients undergoing CEA in the trial, the overall risks of death, major ipsilateral stroke and any stroke were 0.3 %, 0.3 % and 2.3 %, respectively. It's instructive to note that the overall incidence of periprocedural stroke in patients undergoing primary CEA (2.3 %) was statistically significantly lower than in patients undergoing primary stenting (4.1 %; $p = 0.01$).

Proponents of the sCEA technique point to its proven clinical utility and the fundamental surgical advantage of direct visualization of the distal extent of the plaque. Other potential benefits include the relative ease of intraluminal shunt insertion, the option to provide enhanced luminal size through the use of patch angioplasty, the avoidance of circumferential dissection with minimal disturbance of the

Fig. 28.1 Standard
carotid endarterectomy
(Adapted from Zarins and
Gewertz [3]. With
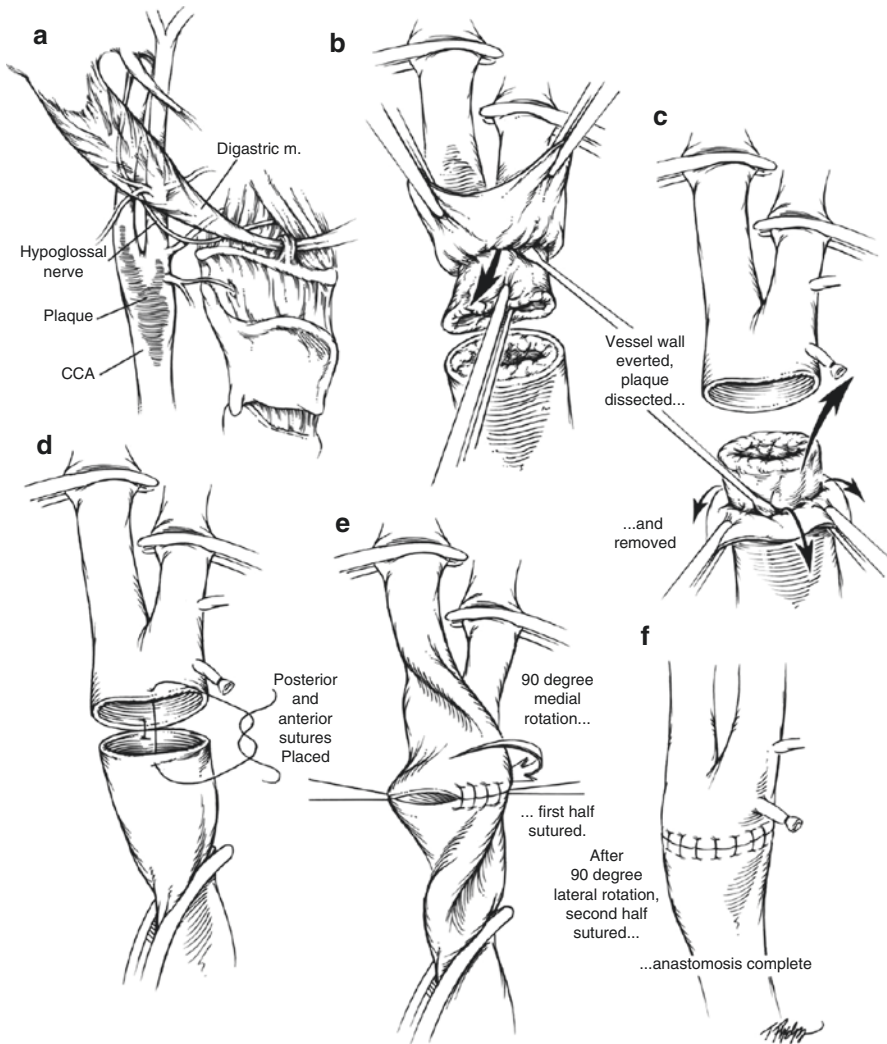permission from Elsevier)
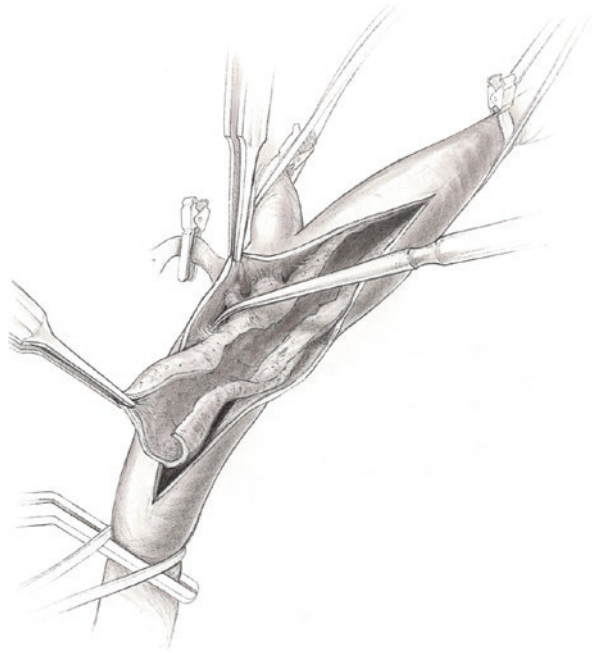
carotid baroreceptors, and the efficiency with which the procedure can be taught to surgical trainees.

The technical success of sCEA technique depends, in some measure, upon successful eversion endarterectomy of the ECA. Indeed, the ease of ECA eversion was likely the stimulus for the rise in popularity of the alternative technique: eversion CEA (eCEA).

Eversion Carotid Endarterectomy (eCEA)

ECEA was originally described by Michael DeBakey in his classic clinical review of extracardiac vascular surgery published in 1959 [8–10]. It is performed via a similar incision as sCEA, although some would argue that eCEA requires only a limited operative field and can be performed through a smaller incision. Surgical exposure of the carotid bifurcation proceeds identically to sCEA, except that the arteries should be freed from the surrounding tissues circumferentially, and division of the superior thyroid artery should be performed as a matter of routine.

Once the arteries have been exposed and clamped, the CCA is transected just proximal to the bifurcation. Figure 28.2 depicts a CCA that is transected transversely, although many authors recommend oblique transection as a means to facilitate visualization and closure. Following division of the CCA, endarterectomy of the ICA and ECA is performed by developing a cleavage plane within the arterial

Fig. 28.2 Eversion carotid endarterectomy (Adapted from Black et al. [11]. With permission from Elsevier)

media and everting it over the plaque (Fig. 28.2b). The plaque acts as a natural mandrill over which to fold the artery; it is gently retracted caudad to facilitate the dissection. Eversion CEA of the ECA is performed in an identical fashion as in sCEA. Because primary carotid plaques are localized to the bulb and proximal ICA, downward retraction and careful blunt withdrawal of the plaque will cause it to "pop" out of the ICA once it reaches its natural endpoint. The result is complete excision of the plaque from the both the ECA and ICA with achievement of a smooth residual lumens that contain no suture lines (Fig. 28.2c).

Attention is then turned toward the CCA which is everted in a similar fashion through, theoretically, the same cleavage plane. There's rarely a natural proximal endpoint of the plaque within the CCA so it's transected sharply after a distance of approximately 2 cm. If the ICA is redundant, a rim of CCA can be resected to accomplish its straightening. End-to-end anastomosis of the two ends of the transected CCA is facilitated by rotating the "freely floating" artery within the field (Fig. 28.2e). The completed reconstruction bears no suture line within the ICA (Fig. 28.2f). In the 1990s, several surgeons described modifications to the above technique, most notably Vanmaele et al. who proposed transection, eversion and reimplantation of the ICA at its origin [12], and Reigner et al. who described oblique transaction of the ICA distal to the lesion followed by eCEA through longitudinal incision of the CCA and ECA [13].

Proponents of the eCEA technique point to the more limited dissection it requires, the rapidity in which it can be performed, the ease to which arterial redundancy can be addressed, the advantages of placing sutures in the widest part of the bifurcation, the avoidance of patches leading to better fluid dynamics [14], the fact that the reconstruction is accomplished without tacking stitches or suture lines in the ICA [15, 16] and, potentially, reduced restenosis [17]. Some even advocate the procedure for recurrent stenoses [18, 19].

Search Strategy

A search of the University of Chicago *Articles Plus +* database was conducted for the years 1997–2015 to identify published data regarding open surgical approaches to treat carotid artery disease using the PICO outline (Table 28.1). The University of Chicago *Articles Plus +* is a database and search tool that allows simultaneous searching of a broad range of articles, books, and other collections. An *Articles Plus +* search includes hundreds of the Library's article databases, including MEDLINE, Science Direct and Academic Search Premier, over 40,000 journals and periodicals, the University of Chicago library catalog, and digitized collections of documents and images from a variety of organizations.

Eight comparative trials, and four single arm studies, were included in the analysis (see Tables 28.2 and 28.3).

Table 28.1 PICO table for technical approach to CEA

P (patients)	I (intervention)	C (comparator group)	O (outcomes measured)
Patients undergoing carotid endarterectomy	Standard carotid endarterectomy	Eversion carotid endarterectomy	Restenosis Stroke Death

Table 28.2 Large single-arm series of eCEA

Author and Reference	Year	n (CEAs)	Sympto-matic (%)	Shunt use (%)	Mean cross-clamp time (min)	Cranial/cervical nerve injury (%)	Reexploration for hemorrhage (%)	Peri-operative stroke/death (%)	Median follow-up (years)	Restenosis (%)	Late ipsilateral stroke (%)
Ballotta et al. [20]	2014	1773	72 %	16 %	NR	4.5 %	4.3 %	0.4 %	11.2	0.5 %	0.5 %
Ballotta and Giau [21]	2003	624	64 %	7 %	NR	0.5 %	0.0 %	0.6 %	4.3	0.0 %	0.0 %
Black et al. [11]	2011	534	44 %	0 %	18	0.9 %	0.6 %	3.8 %	8.9	4.1 %	NR
Radak et al. [22]	2012	9897	98 %	0 %	12	0.8 %	1.7 %	NR	NR	4.3 %	NR
Weighted Average			**90 %**	**2.6 %**		**1.3 %**	**1.9 %**	**1.1 %**		**3.6 %**	**0.3 %**

Table 28.3 Large comparative series of sCEA and eCEA

Author and reference	Year	n (CEAs)		Symptomatic (%)		Shunt use (%)		Mean cross-clamp time (min)		Cranial/cervical nerve injury (%)		Reexploration for hemorrhage (%)		Peri-operative stroke/death (%)		Median follow-up (years)	Restenosis (%)		Late ipsilateral stroke (%)	
		sCEA	eCEA	sCEA	eCEA	sCEA	eCEA	sCEA	eCEA	sCEA	eCEA	sCEA	eCEA	sCEA	eCEA		sCEA	eCEA	sCEA	eCEA
Brothers [23]	2005	100	100	40%	37%	59%	87%	NR	NR	NR	NR	NR	NR	3.0%	2.0%	2.4	38.0%	6.0%	NR	NR
Cao et al. [24]	1997	240	274	45%	51%	28%	2%	28	26	NR	NR	NR	NR	1.2%	0.7%	2.3	6.1%	1.9%	NR	NR
Cao et al. [25, 26]	1998	675	678	60%	57%	16%	11%	35	32	3.7%	3.8%	2.5%	3.5%	1.3%	1.3%	2.8	5.5%	2.8%	11.4%	9.4%
Crawford et al. [27]	2007	155	135	30%	31%	14%	0%	NR	NR	0.0%	0.8%	0.0%	0.0%	1.9%	0.0%	1.0	4.5%	5.2%	1.1%	0.0%
Demirel et al. [28]	2012	310	206	100%	100%	65%	17%	NR	NR	8.1%	8.2%	5.0%	8.0%	0.3%	4.0%	2.0	3.2%	2.4%	2.9%	0.0%
Green et al. [15]	2000	167	107	NR	NR	25%	8%	NR	NR	NR	NR	NR	NR	3.0%	0.9%	NR	4.7%	4.6%	NR	NR
Shah et al. [16]	1998	474	1934	44%	34%	6%	4%	NR	15	1.1%	0.3%	1.1%	1.2%	7.3%	3.1%	1.5	1.1%	0.3%	NR	NR
Yasa et al. [29]	2014	202	178	44%	40%	12%	3%	13	10	1.5%	1.1%	1.5%	1.1%	1.6%	1.6%	2.2	3.0%	2.2%	4.0%	0.6%
Weighted Average		2323	3612	55.9%	43.9%	23.7%	8.0%			3.2%	1.6%	2.4%	2.2%	2.6%	2.3%		5.4%	1.6%	7.1%	5.4%

Single-Arm Studies of eCEA

The clinical results of several large, single-arm series of eCEA are shown in Table 28.2; they demonstrate that excellent results have been achieved by surgeons devoted to this technique. Including over 12,000 eCEA procedures, the (weighted) averages of reported cranial/cervical nerve injury, reoperation for hemorrhage and peri-operative stroke/death were 1.3 %, 1.9 % and 1.1 %, respectively. After long-term follow-up (4–12 years), the risk of late ipsilateral stroke was only 0.3 %. The majority of patients in this analysis were culled from the experience of Radak, et al. whose series of 9,897 eCEAs in the Republic of Serbia represents the largest series reported to date [22].

Comparative Studies

The results of several prospective and retrospective studies directly comparing sCEA to eCEA are shown in Table 28.3. The studies encompass over 5,000 procedures in a variety of geographies and institutions. About half of all patients were symptomatic. The preference for performing eCEA without shunting is evident in the data as shunts were utilized in only 8 % of eCEA procedures compared to 24 % of sCEA procedures. Cross-clamp time was generally shorter for eCEA procedures, although only by a few minutes. Accepting that methods of reporting varied fairly widely among these studies, there appeared to be little discernable differences in short-term outcome measures including cranial/cervical nerve injury, the need to re-explore for hemorrhage and peri-operative stroke/death (weighted average 2.6 % for sCEA and 2.3 % for eCEA). Interestingly, some studies and meta-analyses conclude that peri-operative stroke/death is significantly lower after eCEA [16, 17], while others draw an opposite, but no less convincing, conclusion [28]. In the aggregate, these data appear to demonstrate clinical equipoise between sCEA and eCEA.

Long-term anatomic and clinical results are also shown in Table 28.3. After median follow-up intervals ranging from 1 to 2.8 years, the incidences of restenosis for sCEA and eCEA were 5.4 % and 1.6 %, respectively. However, one study reported the rate of >50 % restenosis of sCEA as 38 % which should probably be considered an outlier [23]. If this study is excluded from the analysis, the difference in the rates of restenosis is small, if present at all. Similarly, although not every study reported numeric rates for patients sustaining an ipsilateral stroke in the follow-up period; those that did generally found the risks to be comparable for the two procedures.

Interestingly, several authors have suggested that eCEA induces more post-operative hemodynamic liability than sCEA, the purported mechanism being that circumferential dissection of the blub denervates the terminal afferent fibers of the Nerve of Hering within the carotid sinus [28, 30–33]. Although some studies have shown that post-operative blood pressure control is more problematic after eCEA compared to sCEA, no differences in clinical outcome have been conclusively demonstrated to date.

> **Recommendation**
> Carotid endarterectomy can be safely and reliably performed using either standard or eversion techniques (**Quality of Evidence, strong; level of recommendation, strong**).

Personal View of the Data

Carotid endarterectomy (CEA) is the treatment of choice for symptomatic carotid stenosis and selected asymptomatic lesions. It can be safely and reliably performed using either standard or eversion techniques. Although the differences in these techniques have been exhaustively studied over the past decade, this author agrees with the overall conclusion reached by Piergiorgio Cao in 2002 after his comprehensive review of this same subject: "Until data are available, the choice of the surgical technique for CEA should depend on the experience and preference of the operating surgeon" [19].

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