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A Comparison of Clinical Outcomes with Eversion Versus Conventional Carotid Endarterectomy: A Single-Centre Experience

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Abstract **Original Research Article**

Background: Carotid endarterectomy has been successfully used to treat carotid artery stenosis, using different techniques (eversion and conventional). These techniques have been extensively studied, but the optimal endarterectomy technique for reducing perioperative complications, stroke rates, and recurrent carotid stenosis remains unclear. ***Objective:*** The clinical outcomes of carotid endarterectomy are generally evaluated by the preservation of neurological function and a low rate of restenosis. This study aims to compare the clinical outcomes of carotid endarterectomy performed using the eversion and conventional techniques. ***Methods:*** We conducted a retrospective study in the vascular surgery department at King Hussein Medical Centre, serving as a signal centre, from November 2017 to February 2025. Patients with extracranial carotid artery stenosis who underwent carotid endarterectomy were included. The choice of technique was determined by technical considerations and the surgeon's preference. A total of 322 CEAs were performed on 296 patients: 35 using the DeBakey eversion technique, 83 with the Kinney/Raithel technique, and 204 with conventional endarterectomy and patch angioplasty (97 autologous, 107 synthetic). Collected data included patient demographics, operative time, mortality, 30-day outcomes, overall complication rate, and comorbidities such as diabetes, coronary artery disease, congestive heart failure, and renal failure. Primary clinical endpoints were perioperative death, transient ischaemic attacks (TIAs), stroke, carotid restenosis or occlusion at the operative site and local complications. ***Results:*** The mean operative time was 31 minutes for eversion carotid endarterectomy, 39 minutes for carotid endarterectomy with autologous patch, and 46 minutes for carotid endarterectomy with synthetic patch ($P < .01$). The 30-day operative mortality rate was 0.8% for eversion CEA and 1.0% for each CEA with autologous and synthetic patch angioplasty (not significant). Serial postoperative carotid duplex examinations were performed in 291 surviving patients. No residual carotid plaque formation or restenosis at the CEA site was detected in any patient within 3 months postoperatively. Subsequent carotid restenosis >60% was observed in 2 (1.7%) eversion CEAs, 8 (9.3%) CEAs with autologous patch angioplasty, and 7 (6.5%) CEAs with synthetic patch angioplasty ($P < .05$), indicating a statistically significant lower restenosis rate in the eversion group. In terms of absolute risk reduction, eversion CEA offers reductions of up to 7.6% compared to autologous patch and 4.8% compared to synthetic patch, suggesting practical benefits in reducing restenosis. ***Conclusion:*** Despite extensive clinical studies of eversion and conventional techniques in carotid endarterectomy (CEA) for carotid artery stenosis, the optimal method for minimizing perioperative complications, reducing stroke rates, and preventing recurrent carotid stenosis remains unclear. There were no significant differences in perioperative mortality or stroke incidence during follow-up between eversion and conventional carotid endarterectomy techniques.

Keywords: Carotid artery stenosis (CAS), endarterectomy, eversion, conventional methods.

INTRODUCTION

Atherosclerotic carotid artery disease is a serious global health issue, particularly with advancing age. The prevalence of carotid plaque and stenosis rises significantly with age. It is a leading cause of stroke and other disabling neurological events. Globally, approximately 12.5% of men and 6.9% of women over 70 years have asymptomatic carotid artery disease [1].

The association between extracranial carotid artery disease and stroke was suspected as early as 1875, when Gowers described a patient with carotid artery occlusion, left-sided visual loss, and right hemiplegia. Later, in 1905, Chiari examined 400 consecutive autopsies and identified a thrombus on an atherosclerotic plaque in the carotid artery in seven patients, four of whom had embolic strokes. This significant observation is probably the first description linking carotid plaque atheroembolism to ischaemic stroke [1, 2, 3].

The greatest achievement in the study of cerebrovascular disease pathophysiology and a pivotal moment in medical history were Fisher's publications on the clinical and anatomical correlations of carotid artery occlusion in 1951 and 1954. Dr C. M. Fisher described the atherosclerotic plaque as the lesion responsible for carotid artery disease and, importantly, noted that the distal internal carotid artery (ICA) is usually free of disease, raising the possibility of surgical bypass to a healthy target vessel. He suggested that surgical treatment of the offending plaque, if feasible, could reduce the risk of stroke, sparking a collaborative effort that led to the development of carotid artery surgery. This era began in 1954 when Eastcott et al. published a case report documenting the first successful carotid artery reconstruction for symptomatic occlusive carotid artery disease in a woman with recurrent transient ischaemic attacks (TIAs). In this procedure, the carotid bifurcation was resected, and in-line flow was restored via a common carotid-to-internal carotid artery (ICA) anastomosis [2, 3].

The first carotid endarterectomy (CEA) was successfully performed by Michael De Bakey in 1953 and, in 1975, was documented with a 19-year symptom-free follow-up. De Bakey's method involved eversion of both the internal and external carotid arteries through a transverse arteriotomy at the level of the carotid bulb, just below the bifurcation. The plaque was removed from the distal bulb, proximal internal, and external carotid arteries by peeling away the adventitia and outer media of the arterial wall from the diseased intima and inner media (Fig. 1) [4, 5].

Then, in the 1960s, Samuel Etheredge pioneered this technique, reporting excellent results in more than 100 patients. He was also the first to recognize the benefit of this approach for tortuous, redundant distal vessels [5].

In the 1990s, several multicentre randomized clinical trials demonstrated the safety and efficacy of CEA, providing reassurance to the medical community about the procedure's reliability and its superiority over best medical management for symptomatic and asymptomatic carotid occlusive disease [2, 3].

Conventional carotid artery endarterectomy was the primary procedure for treating carotid stenosis for decades until the last decade of the 20th century, when Kieny and colleagues modified internal carotid artery (ICA) eversion endarterectomy in 1985. This technique was first described by Kasparzak and Raithel in 1989 and is based primarily on Kieny's modification [6].

The modern technique (Kinney/Kasprzak/ Raithel/Vanmale’s technique) of eversion endarterectomy, which is widely used, involves an oblique transection of the ICA at its origin from the carotid bulb and inversion of the ICA on itself. Endarterectomy is performed through an arteriotomy on the side of the carotid bifurcation. The ICA is then primarily re-anastomosed to the carotid bifurcation (Fig. 2) [6].

Conventional CEA with patch angioplasty (Fig. 3) remains the most widely used technique and serves as the standard for comparing the eversion carotid endarterectomy technique.

Despite extensive clinical experience, thorough research, and numerous studies over the past decade, including several prospective randomized trials comparing carotid endarterectomy (CEA) techniques, there remains insufficient statistical evidence regarding the optimal surgical approach to minimize complications and reduce stroke risk. Therefore, as authors and surgeons, we concur with the conclusion reached by Piergiorgio Cao in 2002 after his comprehensive review of carotid endarterectomy: "Until data are available, the choice of the surgical technique for CEA should depend on the experience and preference of the operating surgeon." [7].

METHODS:

Study design and patient selection

Over 8 years, from November 2017 to February 2025, 322 primary carotid endarterectomies were performed in 296 consecutive patients in the Vascular Surgery Department at King Hussein Medical Centre.

Carotid duplex ultrasonography was used to evaluate carotid artery disease preoperatively, and the severity of carotid stenosis was confirmed by either contrast angiography (CTA) or magnetic resonance angiography (MRA).

During the study period, no patients were withdrawn, excluded, or diverted to alternative techniques because of their clinical conditions, bilateral carotid artery stenosis, the surgeon's learning curve, or technical factors during the procedure.

The choice of carotid endarterectomy technique was based on the attending vascular surgeon's clinical judgment and discretion, taking into account technical considerations or the surgeon's preference.

Key technical considerations include the following: 1) Bilateral carotid disease, which may pose challenges for eversion carotid endarterectomies; 2) Anatomical factors, such as distal ICA stenosis, which may increase the likelihood of shunting; 3) Vessel tortuosity or coiling, which may favour the eversion technique. However, previous surgical experience and comfort with each technique are often decisive.

Three operative techniques are compared: 118 (37%) were eversion carotid endarterectomies using the 'DeBakey technique' and the "Raithel technique'; 97 (30%) carotid endarterectomies were closed with autologous patches (greater saphenous vein or basilic vein); and 107 (33%) carotid endarterectomies were closed with a synthetic or XenoSure Biologic Patch angioplasty.

Technical and demographic data were collected at the time of carotid endarterectomies. Vascular laboratory and postoperative clinical data were entered into a vascular database during follow-up. Primary clinical endpoints were perioperative death, transient ischaemic attacks (TIAs), stroke, and restenosis at the operative site. Secondary adverse clinical outcomes included complications such as myocardial infarction, cranial nerve injury, wound haematoma, or bleeding requiring return to the operating theatre.

Postoperatively, patients were followed up with serial clinical and vascular laboratory assessments. Carotid duplex ultrasonography was performed intraoperatively and, in all surviving patients, within one to three months after carotid endarterectomy to detect residual atherosclerotic disease in the carotid arteries.

Carotid duplex examinations were performed after 12 months and annually thereafter to monitor for recurrent carotid stenosis (defined as ≥ 50% of the lumen diameter detected by duplex scanning). Up to 10% to 20% of patients develop recurrent carotid stenosis within the first year. Once the first year passes without significant events, further restenosis is rare. Outpatient carotid duplex examinations were performed at the same institutions where the operations were performed, using standard ultrasonographic techniques and criteria.

Indications for Carotid Endarterectomy

We used the North American Symptomatic Carotid Endarterectomy Trial (NASCET) to assess the severity of carotid artery stenosis, a widely recognised and approved technique. In this approach, the numerator is the residual lumen diameter, and the denominator is the diameter of the healthy internal carotid artery (ICA) above the stenosis, where the vessel walls are parallel [8, 9, 10].

A duplex ultrasound scan is the first-choice imaging technique due to its accessibility, practicality, and affordability [11]. Table 1 outlines the duplex scan imaging criteria for determining stenosis thresholds based on peak systolic velocity (PSV), end-diastolic velocity (EDV), and their ratios in the internal carotid artery (ICA) and the common carotid artery (CCA) [9, 10, 11].

Operative Decision Making

Preoperative preparation is a multi-step process that includes a comprehensive medical history, physical examination, lifestyle adjustments (diet, smoking cessation, exercise), medication management, and duplex ultrasound imaging, to ensure safety, minimize risks, and optimize recovery [11, 12].

The European Society for Vascular Surgery has established clear criteria for identifying patients who should undergo carotid endarterectomy. These criteria include the following:

1. For patients with an average surgical risk and asymptomatic carotid stenosis of 60-99%, carotid endarterectomy should be considered if one or more imaging / clinical criteria associated with a higher risk of late stroke are present (see Table 2), provided the 30-day stroke/death rate is ≤ 3% and the patient's life expectancy exceeds five years.
2. For patients reporting carotid territory symptoms (see Table 3) within the previous six months and with 70-99% carotid stenosis (per the North American Symptomatic Endarterectomy Trial criteria), carotid endarterectomy is recommended if the 30-day risk of death or stroke is less than 6%.
3. For patients presenting with carotid territory symptoms within the past six months and with 50-69% carotid stenosis, carotid endarterectomy should be considered, provided the documented 30-day risk of death or stroke is less than 6%.
4. For patients with chronic near-occlusion (CNO) who experience recurrent carotid territory symptoms despite best medical therapy, carotid endarterectomy may be considered only after review by a multidisciplinary team.

Chronic near occlusion (CNO), characterised by complete vessel collapse and a "threadlike" distal lumen (previously referred to as the string sign, slim sign, or subocclusion), and CNO with partial vessel collapse, have a prevalence of less than 10% in patients with significant carotid disease. Angiographic criteria for CNO include at least two of the following: (1) delayed contrast filling above the ipsilateral stenosis; (2) recruitment of the circle of Willis (CoW) or collaterals from the distal internal carotid artery (ICA); (3) distal ipsilateral ICA diameter less than that of the contralateral ICA; and (4) distal ICA diameter equal to or smaller than the ipsilateral external carotid artery (ECA). Because angiograms are not routinely performed, CTA criteria have been developed to distinguish CNO from a 90-95% stenosis without distal vessel collapse, and include: (1) residual lumen diameter of ≤1.3 mm; (2) ipsilateral distal ICA diameter of ≤3.5 mm; (3) the ratio of the ipsilateral distal ICA diameter to the contralateral ICA of ≤0.87; and (4) the ratio of the ipsilateral distal ICA diameter to the ipsilateral ECA diameter of ≤1.27. It has also been suggested that combining a distal ICA diameter ≤2 mm with an ICA diameter ratio ≤0.42 provides better prognostic information [11, 12].

Preoperative Medical Management

Medical management of carotid artery disease has advanced considerably over the past decade. Risk stratification is essential for determining the most appropriate preoperative cardiac assessment and perioperative management for patients with vascular conditions, including those undergoing carotid endarterectomy (CEA). The American Heart Association (AHA) perioperative guidelines classify CEA as an intermediate-risk procedure [11, 12].

Preoperative cardiac assessment for patients undergoing intermediate-risk procedures generally includes a 12-lead electrocardiogram (ECG). Additional tests, such as stress tests, may be performed if the patient has three or more clinical risk factors, including ischaemic heart disease, a history of heart failure (previous or compensated), diabetes, or renal failure. The medical management of patients undergoing carotid endarterectomy should include blood pressure control, along with beta-blocker, statin, and antiplatelet therapy [11, 12].

Operative Technique

Anesthesia

Carotid endarterectomy performed under regional anaesthesia enhances patient comfort in the operating theatre, reduces anxiety, and may increase procedural success rates. The use of urinary catheters, central and arterial lines, and sequential compression devices is generally avoided unless clinically indicated [13, 14].

Regional anaesthesia is performed with a superficial cervical block using 0.5% lidocaine. The maximum dose, approximately 4.5 mg/kg, should be calculated to prevent systemic toxicity. To achieve an effective block, a generous volume is injected along one-third to two-thirds of the posterior aspect of the sternocleidomastoid muscle, extending both superiorly and inferiorly [14].

Ultrasound can be used to visualize the cervical plexus, though it is not always readily visible, and it is not necessary in most cases. Increasing the overall volume of lidocaine appears more important than its concentration. Therefore, we dilute our 0.5% lidocaine 1:1 with normal saline to make a 0.25% solution [14].

Statistical analysis

Statistical analysis was conducted using chi-square tests for independence and analysis of variance (ANOVA). Differences between groups or variables were considered statistically significant when the P value was below 0.05.

RESULTS

The patient demographics, indications, and patient selection criteria for carotid endarterectomy were similar in the three groups, as shown in Tables 4 and 5.

The mean operative times are 31 minutes for eversion carotid endarterectomy, 39 minutes for carotid endarterectomy with an autologous patch, and 46 minutes for carotid endarterectomy with a synthetic patch.

Perioperative strokes occurred in one patient who underwent eversion carotid endarterectomy (0.8%) and in only one patient who underwent carotid endarterectomy with autologous patch angioplasty (1%), but in three patients who underwent carotid endarterectomy with synthetic patch angioplasty (2.8%), highlighting potential risks and complications.

However, these differences were not statistically significant. The comparable operative mortality rates of 0.8%, 1.0%, and 2.8% should reassure patients about the safety and durability of these techniques.

The combined stroke and death rate, reflecting overall significant morbidity, was 0.8% for eversion CEAs (1 stroke-death), 1% for CEAs with autologous patch angioplasty (1 stroke-death), and 2.8% for CEAs with synthetic patch angioplasty (1 stroke-death and two non-fatal strokes). Future studies are planned to assess long-term outcomes and the durability of each technique.

Postoperative TIAs occurred in three of the eversion CEAs (2.5%), five of CEAs with autologous patch angioplasty (5.2%), and three of CEAs closed with synthetic patch angioplasty (2.8%). All patients fully recovered, and none have progressed to a permanent neurological deficit. Secondary adverse clinical outcomes were also similar across all three groups (Table 6).

No patients were lost to follow-up, and there were no late deaths or strokes during the study period. The mean clinical follow-up was 22 months (range, 6-41 months) across all groups. Serial postoperative carotid duplex examinations were performed in 291 surviving patients. No residual carotid plaque or restenosis at the carotid endarterectomy site was observed in any patient within three months of surgery.

Subsequent carotid restenosis exceeding 60% was detected in 2 eversion CEAs (1.7%), 8 CEAs with autologous patch angioplasty (9.3%), and 7 CEAs with prosthetic carotid patch angioplasty (6.5%). Of the 17 patients with carotid restenosis, none required reoperation for recurrent symptoms. However, 4 patients underwent redo carotid endarterectomy because of critical (>90%) asymptomatic carotid restenosis confirmed by 4-vessel angiography: 1 in the eversion carotid endarterectomy group, 2 in the carotid endarterectomy with autologous patch angioplasty group, and 1 in the carotid endarterectomy with synthetic patch angioplasty group.

Table 1 presents details of duplex ultrasound criteria for defining stenosis thresholds using peak systolic velocity (PSV), end-diastolic velocity (EDV), and their ratios in the ICA and common carotid artery (CCA), based on the NASCET measurement method.

Diagnostic velocity criteria for NASCET-based carotid stenosis measurement.			
% stenosis NASCET	**PSV ICA cm/sec**	**PSV ICA/ PSVCCA ratio**	**EDV ICA cm/sec**
<50%	<125	<2	<40
50-69%	≥125	2.0-4	≥40
60-69%			
70-79%	≥230	≥4	40-100
80-89%			
>90% but not near occlusion	≥400	≥5	≥100
Near-occlusion	High, low - string flow	Variable	Variable
Occlusion	No flow	Not applicable	Not applicable

Table 2 summarises these criteria. Criteria include silent infarction on CT/MRI, ≥ 20% stenosis progression, large plaque area or large juxtaluminal black area (JBA) on computerized ultrasound plaque analysis (defined as an area of pixels with a greyscale value < 25 adjacent to the lumen without a visible echogenic cap after image normalization), plaque echolucency, IPH on MRI, impaired CVR, and at least one spontaneous MES during ≥ 1 hour of transcranial Doppler (TCD) monitoring.

Clinical and imaging features associated with an increased risk of late stroke in patients with asymptomatic 50-99% carotid stenosis treated medically	
Imaging / clinical parameter	**Annual rate of ipsilateral stroke**
Silent ipsilateral infarction on CT	Yes: 3.6% No: 1.0%
Stenosis progression ≥ 20%	Regression: 0.0% Unchanged: 1.1% Progression: 2.0%
Plaque area on computerized ultrasound plaque analysis	<40 mm^2: 1.0% 40-80 mm^2: 1.4% >80 mm^2: 4.6%
Juxtaluminal black area (JBA) on computerized ultrasound plaque analysis	<4 mm^2: 0.4% 4-8 mm^2: 1.4% 8-10 mm^2: 3.2% >10 mm^2: 5.0%
Intraplaque haemorrhage on MRI	Yes: 3.6% No: 1.0%
Impaired cerebral vascular reserve (CVR)	Yes: 6.1% No: 1.2%
Plaque lucency on DUS	Predominantly echolucent: 4.2% Predominantly echogenic: 1.6%
≥ 1 spontaneous micro-embolisation (MES) during≥ 1 hour monitoring of transcranial Doppler (TCD)	Yes: 7.4% No: 0.9%
Spontaneous embolisation plus uniformly or predominantly echolucent plaque	Yes: 8.9% No: 0.8%
Contralateral TIA/stroke	Yes: 3.4% No: 1.2%

Table 3 shows the symptoms associated with the carotid territory.

Carotid territory symptoms
Higher cortical dysfunctions Aphasia: the loss of the ability to understand or express speech. Dysgraphia: difficulty in writing coherently. Apraxia: inability to perform particular purposive actions, Visuospatial problems and visual field deficits
Amaurosis fugax / transient monocular blindness blurring
Chronic ocular ischaemia syndrome
Weakness and/or sensory impairment of face/arm/leg (one or all areas may be affected)
Upper/lower limb clumsiness (the quality of being awkward or careless in one's movements).
"Limb-shaking TIAs": Haemodynamic events in patients with severe symptomatic carotid stenosis (SCS) and exhausted CVR

Table 4. Patient demographics

Demographic characteristics	**Eversion CEA**	**CEA with autologous patch angioplasty**	**CEA with synthetic patch angioplasty**	**P value**
No. of patients	112	91	93	
Mean age (y)	69	70	67	NS
Male sex	109 (92%)	91 (94%)	97 (91%)	NS
Smoking	99 (84%)	84 (87%)	89 (83%)	NS
Hypertension	82 (73%)	67 (74%)	70 (75%)	NS
CAD	38 (34%)	29 (32%)	31 (33%)	NS
Diabetes	24 (20%)	16 (16%)	21 (20%)	NS
High cholesterol	17 (14%)	14 (14%)	16 (15%)	NS
Renal Impairment	17 (14%)	16 (16%)	16 (15%)	NS
Bilateral CEAs	6	6	14	NS

Table 5. Indications for surgery

Surgical indication	**Eversion CEA**	**CEA with autologous patch angioplasty**	**CEA with synthetic patch angioplasty**	**P value**
No. of CEAs	118	97	107	
Asymptomatic CAS 60-99% *	71 (60%)	62 (64%)	60 (56%)	NS
Transient Ischemic Attack (TIA)	23 (19%)	17 (18%)	22 (23%	NS
Amaurosis fugax / transient monocular blindness blurring	14 (12%)	8 (8%)	10 (9%)	NS
(TMB)	10 (9%)	10 (10%)	15 (14%)	NS

* If one or more imaging or clinical features linked to a higher risk of late stroke are present

Table 6. Postoperative surgical results and follow-up evaluation

Surgical results	**Eversion CEA**	**CEA with autologous patch angioplasty**	**CEA with synthetic patch angioplasty**	**P value**
No. of CEAs	118	97	107	
Operative mortality	1 (0.8%)	1 (1%)	3 (2.8%)	NS
Strokes	1 (0.8%)	1 (1%)	3 (2.8%)	NS
Stroke/deaths	1 (0.8%)	1 (1%)	3 (2.8%)	NS
TIA	3 (2.5%)	5 (5.2%)	5 (5%)	NS
Nonfatal Myocardial Infarction	0	1 (1%)	0	NS
Nerve injury	3 (2.5%)	3 (3%)	2 (2%)	NS
Postoperative bleeding	3 (2.5%)	1 (1%)	3 (2.8%)	NS
Mean follow-up (mo)	23.1	23.8	23.4	NS
>60% restenosis	2 (1.7%)	9 (9.3%)	7 (6.5%)	<.05
Repeat CEA	1 (0.8%)	1 (1%)	2 (2%)	NS

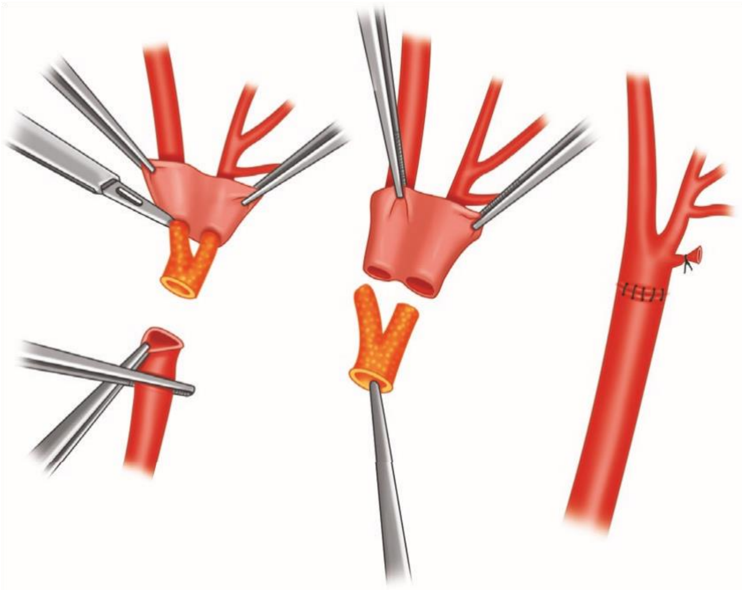

Fig. 1: Eversion carotid endarterectomy using the "DeBakey technique".

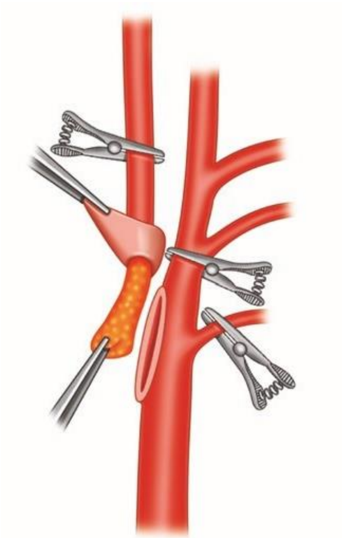

Fig. 2 The modern technique of Eversion carotid endarterectomy using the Kinney/Kasprzak/Raithel/Vanmale's technique.

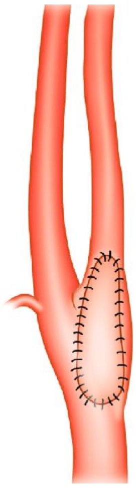

Fig. 3 Conventional carotid endarterectomy with patch angioplasty

DISCUSSION

In 1914, Ramsey Hunt identified the relationship between carotid artery disease (CAD) and its potential complications, notably contralateral hemiplegia and ipsilateral amaurosis fugax, which are critical signs of carotid involvement and assist early diagnosis and management [4].

There is debate about whether to classify TIA/stroke as time-based or tissue-based; this article follows the time-based definitions set by the European Society for Vascular Surgery (ESVS), which significantly influence current clinical practice [12].

The term 'cerebrovascular accident' has been replaced by the more accurate terms 'TIA' and 'stroke'. A Transient Ischemic Attack (TIA) is an episode of focal brain, retinal, or spinal cord dysfunction of non-traumatic, vascular origin lasting less than 24 hours, serving as a critical diagnostic threshold. A stroke, also known as a cerebral infarction, is a sudden onset of focal (not global) neurological deficit of non-traumatic, vascular origin lasting more than 24 hours or causing death within 24 hours [12].

Cerebrovascular disease is the second leading cause of death worldwide, accounting for approximately 9.5% of all deaths. Around 15% of strokes are fatal, 15% to 20% are severely disabling, and another 15% to 20% of stroke survivors experience a subsequent disabling stroke. About 80% of these strokes are ischaemic, with extracranial carotid artery disease (CAD) responsible for at least 40% of ischaemic strokes [15, 16].

Strokes secondary to carotid artery stenosis result from atheroembolization or thromboembolism to the intracranial vessels, usually affecting the middle cerebral artery (MCA) in the anterior circulation. These strokes may also result from lesions in the common carotid artery or in the distal or intracranial segment of the internal carotid artery. Additionally, strokes can occur secondary to a low-flow state through the carotid artery [11].

Symptomatic carotid artery stenosis is a common finding in the practice of vascular surgeons. Understanding that it affects a large part of the population and can lead to high mortality and morbidity can help healthcare professionals appreciate the importance of their role in prevention and management. It initially affects 20% to 30% of patients and increases to about 50% within five years. Carotid artery stenosis (CAS) is thought to be responsible for around 20% to 30% of strokes, while only about 15% of strokes are preceded by a warning transient ischaemic attack. Atherosclerosis is the most common pathology found in extracranial CAS [11].

As plaque burden increases at the origin of the internal carotid artery due to low wall shear stress, flow separation, and loss of unidirectional flow, plasma exposure to the vessel wall is prolonged. This process can result in intraplaque haemorrhage, potentially leading to rupture, ulceration, and platelet accumulation [17].

Platelets may embolize into branches of the middle cerebral artery (MCA), and less commonly, the anterior cerebral artery (ACA) and branches of the central retinal artery. Early detection and management of these changes are essential for stroke prevention [17].

Duplex ultrasound (DUS) is currently the most practical and accessible diagnostic tool for extracranial carotid artery stenosis. It is used as a primary imaging test and provides a cost-effective means of assessing carotid artery stenosis, supporting effective assessment of plaque morphology and flow characteristics [18, 19].

When significant stenosis is detected, further evaluation with modalities such as computed tomography angiography (CTA) or magnetic resonance angiography (MRA) may be necessary, supporting a comprehensive approach to patient care [18, 19].

Using duplex ultrasound, the prevalence of asymptomatic carotid artery disease with moderate (>50%) and severe (>70%) stenosis in a population was 2.0% and 0.5%, respectively. No evidence screening individuals reduces stroke, and no randomized controlled trials have assessed the benefits of screening compared to no screening for asymptomatic carotid stenosis (ACS) [19, 20, 21, 22].

In asymptomatic patients, the presence of "significant" carotid stenosis should prompt Best Medical Therapy (BMT), patient education on stroke signs and symptoms—an essential step in empowering patients and enhancing their participation in care—and consideration of carotid intervention [11].

The management of CAS has experienced notable changes over the past 30 years. A medical-surgical team approach to carotid diseases is currently improving as we seek the most effective ways to prevent strokes caused by extracranial cerebrovascular disease. Carotid endarterectomy (CEA) remains the gold standard treatment for symptomatic patients with carotid artery disease unless they have severe comorbidities such as congestive heart failure, recent myocardial infarction, or uncontrolled hypertension [16].

Deciding the optimal timing for surgery after a stroke or transient ischaemic attack (TIA) involves weighing the risks and complications of the procedure against the benefits of preventing another stroke. Carotid endarterectomy is usually recommended within two weeks of symptom onset for patients with mild to moderate strokes or transient ischaemic attacks, provided their neurological status is stable, they have carotid artery stenosis of more than 50% according to NASCET criteria, and the risks of surgery are acceptable. Prompt intervention helps prevent future strokes. Research indicates that the benefits are greatest when surgery is performed within two weeks, especially for those with mild to moderate symptoms. The risk of another stroke is highest in the first 7 to 14 days after the initial event, and medical management becomes less effective over the following year. Most patients with mild-to-moderate symptoms benefit from carotid endarterectomy, but there is insufficient evidence to show the same benefit for those with severe deficits [11, 12].

Operative Technique

Anesthesia

The selection of an appropriate anaesthetic technique is a critical consideration in carotid endarterectomy (CEA) procedure and is influenced by patient-specific and surgical factors. CEA can be performed under general anaesthesia (GA), regional anaesthesia (RA) with either deep or superficial cervical block, or local anaesthesia (LA). Although early studies suggested that RA was associated with shorter hospital stays, recent evidence indicates that hospital stays are now comparable between patients receiving RA and those receiving GA [13, 14].

Most studies comparing these two techniques have shown better cardiac stability during the perioperative period with regional anaesthesia (RA), but this does not necessarily lead to a lower incidence of myocardial infarction (MI). Recognizing the trade-offs, such as patient discomfort or anxiety, helps clinicians make informed choices. Disadvantages of regional anaesthesia include patient discomfort or anxiety, the risk of seizures or allergic reactions, surgeons' anxiety about performance, and compromising the technique in a teaching environment [13, 14].

Conventional Endarterectomy

The conventional technique for CEA involves vertical arteriotomy and closure with patch angioplasty. In this case, a vertical arteriotomy begins on the CCA and continues through the carotid bifurcation into the ICA [11, 12].

The endarterectomy begins in the CCA within the plane between the media and the adventitia. The proximal endpoint in the distal CCA is identified, and the plaque is carefully trimmed in that area with a beveled approach. The procedure continues into the ECA, first using a Freer elevator, then a fine clamp inserted along the plane of the endarterectomy. The clamp is spread apart to further free the plaque from the adventitia at the 6-, 9-, and 12 o'clock positions; passing the clamp at the 3 o'clock position near the flow divider is usually tricky. The vessel loop on the ECA is temporarily released while the plaque is everted within the vessel. The endpoint of the plaque is examined; an ideal endpoint tapers gradually and appears feathered. Careful plaque removal reassures the audience that the procedure is safe and thorough [11, 12].

Achieving a satisfactory endpoint in the internal carotid artery (ICA) is generally feasible, in our practice. However, special manoeuvres may be necessary to expose the distal ICA and to perform an extended arteriotomy to facilitate the extraction of a long endarterectomy specimen. Tacking sutures at the distal endpoint should be avoided unless necessary; such sutures can be problematic and are associated with an increased perioperative stroke risk. The endarterectomy should end in the normal ICA with a gradual, tapered transition to normal intima; this is best achieved by pulling the plaque transversely away from the artery with lateral traction. Avoid pulling the plaque out or down, as this is more likely to cause a step-off that can be difficult to correct without traumatizing the artery. Emphasizing the avoidance of tacking sutures reassures the audience about safety and adherence to best practices [11, 12].

Repairing the arteriotomy with a patch angioplasty represents the standard of care in contemporary practice. The patch is sewn in with running nonabsorbable suture. A variety of patch materials are available, including autologous veins, polytetrafluoroethylene (PTFE), woven polyester (Dacron), and bovine pericardium. Some studies have suggested that autologous veins may be superior to synthetic patches, but of the prosthetic patches, no material appears to be clearly superior to another [23].

Options for autologous vein include the external jugular and saphenous veins. The external jugular vein can be harvested through the same surgical incision and is generally used as a double-layer patch after the surgeon inverts an intact tubular vein segment without filleting it open. Careful handling to keep the inverted tube flattened as a rectangular patch is essential, as it reinforces the importance of precision and skill in achieving optimal results [23].

It is our practice to always start the suture line at the superior end of the ICA arteriotomy, which is typically the most critical and challenging part of an anastomosis. Gently stretching the artery while sewing ensures proper patch length [11, 12].

When the suture line is nearly complete, both clamps are briefly released to flush air or debris (or both) out of the arteries. The clamps should be placed proximally and distally to the patch or endarterectomized segment of the artery, as these surfaces can be thrombogenic. The carotid bifurcation is vigorously flushed with heparinized saline and re-inspected for debris or intimal flaps before the arteriotomy is finally closed. Once again, the clamp on the ICA is briefly released to fill the bifurcation with blood. It is then replaced while the clamps on the CCA and ECA are released, so that any remaining air or debris will be flushed up the ECA rather than the ICA. At this point, the ICA clamp is removed [11, 12].

Any bleeding from the suture line is currently being managed. However, an important technical point at this stage concerns the thrombogenicity of stagnant blood in contact with the patch material or the endarterectomized carotid bifurcation surface. Avoid reclamping unless necessary, as careful clamp and precise vascular control help prevent thrombus formation [11, 12].

Patch Closure

Patches used in vascular reconstructions are categorized as either autogenous or synthetic, highlighting their importance in surgical decision-making.

This risk has primarily been reported with the use of the greater saphenous vein segment during carotid endarterectomy. Another concern with using a segment of the greater saphenous vein as a patch is the fate of the remaining portion of the vein. Thrombosis of the vein could eliminate its potential future use as a bypass conduit for coronary or infrainguinal revascularization [23].

Saphenous Vein Patches

Before synthetic patches were introduced, surgeons mainly used the saphenous vein and the external jugular vein as patch materials, reflecting the longstanding clinical practice. Imparato routinely employed vein patching as early as 1965 [23].

Saphenous vein patching has been widely used with good outcomes. However, issues specific to saphenous vein patching include wound complications at the harvest site, potential compromise of a valuable conduit for future bypass procedures, and the serious complication of patch rupture, which has been reported in 0.5% to 4% of cases. As most of these ruptures occurred in the ankle veins, several investigators recommended harvesting the great saphenous vein (GSV) above the knee. Lord et al also observed that aneurysmal expansion of saphenous vein patches can develop in up to 17% of patients. Recognizing how harvest site choices impact future options can help surgeons feel more strategic and confident in their choices [23].

Archie et al investigated the relationship between GSV diameter and rupture pressure and found that GSVs with diameters less than 3.5 mm were more prone to rupture. Their team also observed that women were three times more likely to have GSVs measuring less than 3.5 mm. Applying this knowledge to their practice, Archie found that using a GSV with a distended vein diameter greater than 3.5 mm and maintaining a carotid bulb diameter less than 13 mm completely avoided patch rupture in a series of 534 patients over 8 years [24].

Synthetic Patches

With the availability of synthetic patch materials, these were incorporated into practice to avoid complications associated with saphenous vein patching. Commonly used synthetic patches for angioplasty post-carotid endarterectomy include polytetrafluoroethylene (PTFE), Dacron, and bovine pericardium (XenoSure Biologic patch) [25].

The main concerns with synthetic patches include bleeding from needle holes, handling characteristics, and the risk of infection. Especially, the infection rate for synthetic patches used during carotid endarterectomy is less than 1% [25].

In synthetic patches, Dacron patches appear to be associated with a higher rate of perioperative neurological events and a higher risk of recurrent stenosis than polytetrafluoroethylene (PTFE) patches. However, the clinical significance of these findings remains unclear, which highlights the need for continued research [25].

Bovine pericardium (XenoSure Biologic) patches are attracting interest because of their excellent early and long-term outcomes and good handling properties, which may encourage surgeons to consider them a suitable option [25].

Optimal Patch Material

The best patch material remains undetermined, which may encourage physicians to consider all options objectively and without bias [26].

Marien et al. highlighted important differences in bleeding outcomes between bovine pericardium and Dacron [27]. Goldman et al.'s findings of no significant differences in morbidity or risk of recurrent stenosis between vein and Dacron patches can reassure clinicians about the viability and durability of using different patch materials [28].

Finally, in a small RCT comparing Dacron with PTFE patching in carotid endarterectomy, AbuRahma et al observed a higher stroke rate with Dacron patch, mainly due to perioperative thrombosis. The trial led to reengineering the Dacron patch, and subsequent studies found no differences in outcomes between Dacron and PTFE patches. The initial difference was unclear, as early animal studies showed platelet accumulation was similar between gelatin-sealed Dacron and PTFE, but lower on vein patches [29].

Eversion Endartectomy

Eversion endarterectomy is an excellent alternative technique utilized in selected patients with suitable carotid pathology. Two different versions of eversion endarterectomy are performed, with indications tailored to patient anatomy and disease extent [4, 5].

Etheredge improved on DeBakey's technique by performing a complete transection of the bifurcation, allowing the origins of both the ICA and ECA to be everted over a longer distance. The endarterectomy is accomplished by mobilizing the entire circumference of the carotid adventitia off the plaque (described as a "circumcision" by Etheredge), then everting the adventitia and mobilizing it upward. This maneuver is performed distally into the orifices of the ICA and ECA and then proximally into the common carotid artery. Once the endarterectomy is complete, the divided bifurcation is reunited with a simple end-to-end anastomosis [4, 5].

Advantages of DeBakey's technique include rapid anastomosis and a lower rate of recurrent stenosis.

to restenosis; however, potential risks such as vessel retraction, difficulty in endpoint visualization, and challenges with shunting should be considered.

Disadvantages of DeBakey's technique include the need for more extensive dissection to mobilize the vessels during eversion. The procedure does not lend itself easily to shunting, though it is still possible with this method. Also, visualizing the endpoint in the ICA after plaque removal can be challenging, as the artery tends to retract once the plaque pulls away from the adventitia, making it difficult to expose and re-inspect that area. Therefore, a completion duplex scan should be performed [4, 5].

In 1985, Kieny and colleagues introduced a modification involving oblique transection of the ICA at its origin from the carotid bulb and inversion of the ICA on itself. Endarterectomy of the CCA and ECA is performed through an arteriotomy on the side of the carotid bifurcation. The ICA is then primarily re-anastomosed to the carotid bifurcation [6].

The modern technique (Kinney/Kasprzak/ Raithel/Vanmale's technique) of eversion endarterectomy, which is widely used, involves oblique transection of the ICA at its origin from the carotid bulb and inversion of the ICA on itself. Endarterectomy of the CCA and ECA is performed through an arteriotomy on the side of the carotid bifurcation. The ICA is then primarily re-anastomosed to the carotid bifurcation

The modern technique (Kinney/Kasprzak/ Raithel/Vanmale's technique) of eversion endarterectomy, offers several advantages, including facilitating independent manipulation of the internal carotid artery (ICA) and reducing the complexity of ICA eversion [6].

Typically, this technique is performed without a shunt, although it can be modified to include one if necessary. It also requires less dissection than transecting the bifurcation. However, the technique may limit exposure for complete endarterectomy of the common carotid artery (CCA) and external carotid artery (ECA), which should be considered during surgical planning [6].

Comparative Analyses

Strong evidence from randomized controlled clinical trials (RCTs) conducted by the British Intergroup for Vascular Research and comprehensive meta-analyses should reassure vascular surgeons and researchers about the strength of patch closure support for primary closure. These studies' comparison of vein patches with prosthetic patches, which shows no significant difference in primary endpoints. The review by Rockman et al. of outcomes following primary closure, patch angioplasty, or eversion carotid endarterectomy, using data from a New York State database, highlights the comprehensive nature of the analysis and provides evidence that perioperative stroke risk is comparable across techniques [30].

Finally, Kresowik et al. reported outcomes from more than 10,000 CEAs performed across several states. They found that the use of a prosthetic patch, was a statistically significant predictor of improved outcomes [30].

Comparison of Conventional Carotid Endarterectomy and Eversion Carotid Endarterectomy

Numerous studies have compared standard CEA with patching to eversion CEA. The EVEREST outcome trial, published in 1997, was a prospective, multicentre, randomised study conducted in Italy and highlighted the importance of robust evidence. Over 1400 patients were randomly assigned to either eversion or conventional carotid endartectomy. No statistically significant differences were observed in the results. However, a marginally higher rate of perioperative complications was noted with eversion carotid endarterectomy and a slightly higher rate of restenosis with conventional carotid endarterectomy [31].

In 2000, the publication of EVEREST outcome found no significant differences in clinical outcomes between conventional and eversion carotid endarterectomy, underscoring the importance of selecting evidence-based techniques. At 4-year follow-up, life-table estimates of restenosis risk were 3.5% for eversion CEA and 1.7% for CEA with patch. These results are consistent with another large institutional series from Massachusetts General Hospital involving 950 patients, which likewise found no significant difference in restenosis rates. Although some studies suggest better outcomes with eversion CEA, a large meta-analysis comparing eversion with conventional CEA found no significant differences in perioperative stroke or death (1.7% vs. 2.6%). However, it noted that eversion was associated with a lower restenosis rate (2.5% vs. 5.2%) [31].

Other studies have found no difference between the two techniques. Therefore, there is no definitively superior method. Surgeons should select the technique they are most experienced and comfortable with, as this can improve clinical outcomes. Eversion carotid endartectomy may be preferable in cases involving an elongated or kinked ICA, where its advantages may be more significant.

CONCLUSIONS

Carotid endarterectomy (CEA) remains one of the most effective procedures for lowering stroke risk in patients with carotid artery stenosis (CAS), nearly 70 years after its inception. There were no significant differences in perioperative mortality rates or stroke incidence during follow-up between eversion and conventional carotid endarterectomy techniques.

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Ethical approval

Ethical approval was obtained from the Ethical Committee at King Hussein Medical Center, Jordanian Royal Medical Services (JRMS), Amman, Jordan. The reference number is 16/2025–1, and the approval was granted on 26/1/2026.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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