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REVIEW

Current Practices in Carotid Surgery

Parsa Jamilian[1], Luiza-Diandra Bretfelean[1], Sriram Rajagopalan[2], Helen Suttenwood[3,*]

[1]School of Medicine, Keele University, Keele, UK
[2]Department of Vascular Surgery, University Hospitals North Midlands, Stoke, UK
[3]Department of Vascular Surgery, University Hospitals Birmingham, Birmingham, UK
*Correspondence: hsuttenwood@gmail.com (Helen Suttenwood)

Abstract

We outline the indications and contraindications of carotid endarterectomy (CEA) and appraise four key areas still debated to this day; shunting versus non-shunting, patch angioplasty (PA) versus primary closure (PC) and local anaesthesia (LA) versus general anaesthesia (GA). Importantly, we compare CEA with Best Medical Therapy (BMT), which is an area that is still largely debated, principally because many of the studies conducted to date do not reflect the era of modern BMT practices, and these outcomes are eagerly awaited. Literature searches were conducted using Pubmed with the keywords 'carotid', and 'endarterectomy', which provided a wide variety of journals and articles. We further stratified our data by using only randomised control trials (RCTs), meta-analyses, and systematic reviews, and then excluded studies with asymptomatic disease, diabetes, and plaque-imaging studies, including studies that did not fit our four desired topics for discussion. For each of the different domain's, results demonstrated similar peri-operative outcomes when comparing shunting vs. non-shunting and modality of anaesthesia and therefore practice still remains dependent on operator experience and preference. Patch-angioplasty reduces the risk of subsequent stroke, transient ischaemic attack (TIA), and re-stenosis compared to PC. In carotid stenosis >50% BMT offers limited benefits without accompanying surgical intervention and BMT alone tends to be advantageous primarily for patients with <50% carotid stenosis. Where CEA is appraised in terms of superiority of the procedural components; the literature does not support wildly contrasting outcomes to change majority practice. However, the area of considerable interest is superiority of BMT to surgical intervention in terms of both carotid artery stenting (CAS) and CEA and more studies need to be conducted in this area.

Key words: carotid; endarterectomy; shunting; patch; anaesthetic; BMT

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Introduction

Carotid endarterectomy (CEA) is the surgical resolution of stenosis in the common carotid and internal carotid arteries (ICA) due to the accumulation of atherosclerotic plaque. This procedure aims to reduce the future risk of atherosclerotic plaque-rupture leading to complications such as stroke or complete occlusion. The diseased carotid artery is controlled, opened and the plaque removed helping restore laminar blood-flow to the Circle of Willis (Rasheed et al, 2019).

Based on the North American Symptomatic Carotid Endarterectomy Trials (NASCET) (Barnett et al, 1998), the benefit of surgery was significant for those with severe carotid stenosis (DaCosta et al, 2023). Current guidelines recommend patients with carotid stenosis >50% and a history of ipsilateral stroke or transient

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ischaemic attack (TIA) to undergo CEA. Furthermore, in an asymptomatic group of patients with severe carotid stenosis, there was a significant 5-year risk-reduction of stroke (DaCosta et al, 2023).

Contraindications for CEA include patient fitness. In such circumstances stent insertion could be considered instead (Müller et al, 2020). Based on the Carotid Revascularisation Endarterectomy versus Stenting Trial (CREST) (Mantese et al, 2010), both CEA and stenting have similar rates of complications such as stroke, myocardial infarction (MI) and death (Müller et al, 2020). Symptomatic women have higher risk of complications after CEA, while asymptomatic patients have similar risks (Mayor et al, 2019).

Lifestyle adjustments and pharmacological interventions are of paramount importance in reducing risk of cerebrovascular events and important components of Best Medical Therapy (BMT) include blood pressure and diabetic control, lipid-lowering and anti-platelet therapies (Abbott et al, 2015). Nevertheless, limited randomised control trials (RCTs) data creates ambiguity about whether patients receiving both BMT and CEA benefit more than those receiving BMT alone.

Methodology

Literature searches were conducted using Pubmed with the keywords ‘carotid’, and ‘endarterectomy’, which provided a wide variety of journals and articles. We further stratified our data by using only RCTs, meta-analyses and systematic reviews and then excluded studies with asymptomatic disease, diabetes and plaque-imaging studies. Other studies were also excluded if they did not pertain to the four key areas of interest detailed in this review.

Literature Review

Shunting vs. Non-Shunting

During CEA, a temporary reduction in the cerebral blood perfusion ensues as the internal carotid artery is clamped proximally and distally to the endarterectomy site. This interruption in cerebral perfusion could increase the risk of stroke and post-operative neurological deficits, therefore, the rationale for using a shunt is to maintain cerebral perfusion preventing brain hypoxia and ischaemia. Shunting could pose additional risks, including air-embolism, carotid dissection, plaque-embolisation, also increased risks of infection, neck haematoma and cranial nerve injuries (Naylor et al, 2018).

“Routine shunters” refers to surgeons who routinely use shunting during CEA; while “selective shunters” are those who decide whether to shunt or not on a case-by-case basis. A systematic review of 5683 CEAs performed within two weeks of an acute event demonstrates no difference in postoperative stroke risk whether the operator has planned to shunt or not (Levin et al, 2020). In cases with unplanned shunting, stroke amongst other post-operative complications were observed (Levin et al, 2020). Surgeons should plan the surgical method before the operation but also be familiar with and ready for emergency shunting if the circumstances arise

(Levin et al, 2020). A study (Boontje, 1994) which forms part of a large review, report excellent results of CEA without shunt placement.

The risk of peri-operative stroke or death in CEA performed with shunts compared to non-shunt operations yields similar outcomes. A recent systematic review included six RCTs of 1270 patients and found the available data were too limited to support routine or selective shunting (Chuatrakoon et al, 2022). However, larger double-blinded RCTs are needed to draw more accurate conclusions. The current European Society for Vascular Surgery (ESVS) guidelines (Naylor et al, 2023) recommends that surgeons can decide whether shunting is considered for their patients undergoing CEA, further supporting the paucity of convincing data in this area to warrant a change in practice.

Patch-Angioplasty vs. Primary Closure

Another intra-procedural technique widely debated is patch angioplasty (PA) versus primary closure (PC). Current surgical guidelines recommend PA over PC, favouring this technique based on lower post-operative stroke and re-stenosis risk (Bonati et al, 2021). Nevertheless, extensive debate throughout the literature regarding better perioperative outcomes in terms of infection, lifetime risk of further ischaemic or embolic events, re-stenosis and long-standing morbidity still exists.

A literature review of post-operative outcomes from 11 trials (Orrapin et al, 2022) of patients undergoing CEA (n = 2100) comparing PA with PC found no differences in peri-operative stroke risk between the two methods ($p = 0.06$). However, PA significantly reduced peri-operative arterial occlusion ($p < 0.01$). Additionally, at long-term follow-up (5 years) PA was found to significantly reduce the risk of stroke ($p = 0.02$), death ($p = 0.03$), re-stenosis ($p < 0.01$).

One possible explanation for the advantages seen with PA could be attributed to superior haemodynamic flow of blood by increasing carotid artery diameter (Maertens et al, 2016). Nevertheless, this should be cautiously interpreted due to the non-heterogeneity of data.

Similar results from a prospective RCT of 399 CEA patients (mean follow-up 30 months) randomised into 4 groups; PC, saphenous vein patch, jugular vein patch, and polytetrafluoroethylene patch (AbuRahma et al, 1999). They found the incidence of ipsilateral stroke post-CEA to be 5% for PC, 1% for polytetrafluoroethylene and 0% for saphenous and jugular vein patch. At 48 months, stroke-free survival rate was highest for vein patch (88%), followed by polytetrafluoroethylene (84%), with the PC having the lowest rate (82%).

At follow-up, 96%, 84% and 47% of patients did not experience re-stenosis in the polytetrafluoroethylene, vein, and PC CEA groups, respectively. Conversely, the PC group was significantly less susceptive to long-term carotid artery dilatation compared to those with vein patch (AbuRahma et al, 1999). Despite these results indicating that PA might be superior to PC in the various post-operative outcomes, there still is large debate as to which type of patch poses most benefits and whether the use of patch at all increases the risk of late carotid dilatation in susceptible patients.

Compelling evidence suggests that PC might in fact be non-inferior to PA. A meta-analysis (Marsman et al, 2021) (n = 2187) found no conclusive evidence in terms of stroke risk, all-cause mortality or serious adverse events between the two and similar results are reported elsewhere.

A retrospective analysis (Avgerinos et al, 2016) compared closure technique outcomes in 1737 patients using multivariate-regression models. The authors reported similar stroke and mortality rates between PA (2.2%) and PC (2.7%) in the perioperative period, suggesting that the type of closure has no predictive value on these outcomes. Instead, variables such as statin use ($p < 0.01$), renal insufficiency ($p = 0.03$), baseline presence of symptoms ($p < 0.01$) and heart failure ($p = 0.03$) were more closely linked with stroke and mortality compared with closure technique (Avgerinos et al, 2016).

The similar rates of post-operative complications could be attributed to PC reducing clamp time and eliminating graft complications compared to PA and thus benefit-risk ratios of the two might overlap. Despite these findings, the retrospective nature of the study limits the generalisability with high susceptibility to selection bias of participants.

Although data suggests conflicting evidence as to whether PA is superior to PC in unilateral carotid stenosis important findings were reported (AbuRahma et al, 1999). This study compared the effectiveness of PC versus PA in patients (n = 74) who underwent bilateral CEAs. PA was performed on one artery and PC on the other artery in the same patient. The study reported strong evidence in favour of PA versus PC at a mean follow-up of 29 months. Re-stenosis was more common in PC (22%) versus PA (1%) as well as total occlusion of the ICA (8% vs. 0%). Re-stenosis that required additional CEA was also higher in PC (14%) versus PA (1%).

Neurological complications such as ipsilateral stroke and TIAs were more prevalent for PC versus PA (12% vs. 1%) and more patients in the PA group (98%) were stenosis free at 24 months compared to PC (75%) (AbuRahma et al, 1999). The small sample limits the validity of these data and larger studies are needed for more definitive conclusions. Additionally, patients undergoing bilateral CEA in this study had different grades of stenosis and almost double receiving PA were asymptomatic and this further limits the generalisability of these results to patient that we tend to treat in the UK.

Current clinical guidelines favour PA over PC (Paraskevas et al, 2018). Compelling evidence indicates that PA offers increased protection for patients in terms of risk of subsequent vascular events such as stroke, TIA and re-stenosis. This empirical evidence highlights that despite disadvantages such as increased operative and clamping time, heightened risk of infection and bleeding, PA might be superior to PC in reducing morbidity and mortality.

BMT vs. CEA

The current treatment options vary depending on the degree of stenosis, the symptom profile and patient fitness (Lanzino et al, 2009). For minor stenosis, BMT alone and management of co-morbidities is recommended (Bonati et al, 2021).

Pharmacological interventions such as anti-platelets, lipid-lowering drugs and anti-hypertensives are commonly prescribed as prevention for disease progression (Abbott et al, 2015). A RCT compared BMT alone to CEA and BMT in 659 patients with a carotid stenosis of 70–99%. BMT consisted of aspirin 1300 mg per/day and as indicated, other pharmacological interventions. At two years, the cumulative-risk of ipsilateral stroke was 26% in patients assigned to BMT alone compared to 9% in those assigned to CEA. BMT was not clearly defined in the study and statins were not used routinely, so different results may be seen in the modern era of BMT. CEA was found to be beneficial when the analysis included all strokes and deaths (32.3% for BMT vs. 15.8% for CEA) (North American Symptomatic Carotid Endarterectomy Trial Collaborators, 1991).

A similar RCT (NASCET) (Barnett et al, 1998) compared BMT alone (n = 1118) versus CEA and best available BMT (n = 1108) in patients with varying degrees of carotid stenosis with the primary outcome being any fatal or non-fatal stroke on index symptomatic carotid artery. At 5-year follow-up, surgically treated patients with 50–69% stenosis had lower rates of ipsilateral stroke than those treated medically (15.7% vs. 22.2%). However, no significant differences were found in patients with <50% stenosis (14.9% for CEA vs. 18.7% for BMT). Best available BMT was anti-platelet therapy at the discretion of the medical-team based on blood results. Statins were not routinely prescribed and importantly the majority of patients did not have hyperlipidaemia, indicating that statin therapy might not have been initiated, questioning whether the results for BMT only group are underestimated. Other limitations affecting generalisability are that the patient populations appeared younger than who we treat today with the majority being employed or unemployed and only a third retired. We need to remember, this RCT was born out of necessity as CEA did not appear to be safe or efficacious due to high complications rates almost reaching 10%, which is incomparable by today's standards.

It does not detract from surgical treatments being beneficial in patients with moderate to severe carotid stenosis (>50%) and maximally beneficial in patients with severe stenosis (70–99%), (McKinsey, 2008). An important limitation of previous trials comparing CEA with BMT is that they do not reflect common practice. The BMT doses used in trials such as NASCET are different from doses used in UK practice and further trials are needed to address this discrepancy. Additionally, a RCT is required to investigate whether BMT compared to CEA is still less superior in patients with higher degree of stenoses, as BMT has markedly improved since the publication of these studies, so we await a study comparing carotid intervention with BMT.

GA vs. LA

Since peri-operative stroke is an important complication, it was predicted that stroke would be more avoidable in local anaesthesia (LA) compared to general anaesthesia (GA). This was perceived to be the case because the surgeon would pause the procedure exactly at the point the patient demonstrated signs of hypoperfusion or neurological focal deficit and do something different. However, there

have been several RCTs that compared the risk of perioperative stroke and death in both methods and the difference was not significant.

General Anaesthesia versus Local Anaesthesia for carotid surgery (GALA) (GALA Trial Collaborative Group et al, 2008) still remains the largest RCT conducted in this space. A 4.0% risk of stroke is demonstrated in the GA group compared to 3.7% in LA group. Furthermore, the overall risk of stroke or death is 4.6% (GA) compared to 4.2% (LA) demonstrating a higher risk of complications in the GA cohort; without a statistically significant difference.

Similar findings were reported in a retrospective analysis (Dakour Aridi et al, 2018). A total of 75,319 cases were analysed to compare real-world outcomes of perioperative stroke, death and MI under GA versus LA. No significant differences were found between the two groups in terms of mortality (0.3% for GA vs. 0.2% for LA) ipsilateral stroke (0.9% for GA vs. 1% for LA), ipsilateral TIA (0.4% for GA vs. 0.3% for LA) or any neurological event (1.8% for GA vs. 1.7% for LA). The study reported that GA had twice the odds of postoperative MI compared to LA. The authors concluded this difference to be clinically irrelevant due to the low overall risk of post-CEA cardiac events and that the choice of anaesthesia should be made based on individual patient risk factors.

By contrast, a prospectively collected database of 371 patients (Mofidi et al, 2006) found that CEA under LA could be associated with a lower-risk of peri-operative stroke and shorter hospital stay. A total of 5.5% of patients developed stroke or TIA when CEA was performed under GA, as opposed to 1.6% under LA. No significant differences were found in peri-operative mortality between the two groups (1.7% after GA vs. 0.5% after LA). The duration of hospital stay was shorter with LA (median 3 days) compared to GA (median 4.5 days). The authors concluded that switching anaesthetic method does not compromise peri-operative patient outcomes and it might be associated with lower risk of peri-operative stroke and shorter hospital stay. Importantly, the length of stay does not reflect current UK practice since the majority of patients tend to be discharged home the day following the procedure.

Based on the results (GALA Trial Collaborative Group et al, 2008; Dakour Aridi et al, 2018) the risk of peri-operative complications, including stroke and death are not statistically significantly based on the modality of the anaesthesia. The decision on which method to choose lies with the care providers' preference.

Conclusion

A considerable number of studies included in this review were several decades old and the advancement of modern BMT could mean that superior outcomes could be achieved with manipulating the doses of anti-platelet and/or tailoring the anti-platelet dose to the patient depending on their individual drug metabolism potentially rendering CEA reserved for refractory carotid disease or re-stenosis. So, the ongoing debate for whether carotid stenting versus CEA; or whether patch-angioplasty or primary closure is superior, other focused studies need to be conducted to in the exciting area of tailored medical management which could change

the landscape with respect to all atherosclerotic disease. The other area that is gaining momentum is comparing different techniques for carotid disease such as trans-carotid arterial revascularisation (TCAR) versus CEA (Paraskevas et al, 2024) which could muddy the waters once more.

Key Points

- Our review concludes that there are no significant differences in peri-operative outcomes for shunting and non-shunting or between the types of anaesthesia.
- Patch angioplasty generally offers better long-term outcomes when compared to primary closure.
- Studies included within this review demonstrate that CEA combined with BMT shows greater results for patients with significant carotid stenosis compared to BMT alone.
- Further contemporary studies are needed alongside tailored medical management and other techniques on the horizon such as TCAR.

Availability of Data and Materials

All the data of this study are included in this article.

Author Contributions

PJ, LDB, SR, and HS made substantial contributions to conception and design, acquisition of data, analysis and interpretation of data. PJ and LDB wrote the manuscript. All authors contributed to important editorial changes of important content in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

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