Outcome of carotid endarterectomy in patients with symptomatic carotid near occlusion with partial collapse

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Received: 30 September 2023
Revised: 11 October 2023
Accepted: 16 October 2023
Published: 31 January 2024

The Egyptian Journal of Surgery 2024, 43:9–15

Background
Symptomatic carotid near occlusion with partial collapse (CNOPC) of the distal internal carotid artery (ICA) is an uncommon condition. Guidelines for its treatment have recommended conservative management, although surgery may be indicated for many patients. In this work, our goal was to examine the postoperative outcomes of CNOPC patients who had undergone carotid endarterectomy (CEA) for symptomatic disease.
Methods
Symptomatic CNOPC patients were identified in this single-center retrospective study from January 2019 to February 2022. Patients' demographics, comorbidities, and CEA indications were gathered. At 30 days and 1 year after surgery, postoperative complications including stroke and death, hospital stay, and operational details were evaluated.
Results
In the 3-year study period, 128 CEAs were done, and 21 (16.4%) patients had CNOPC. Males were 15 (71.4%) with no sex difference in comorbidities except a significantly higher IHD in men, *P* less than 0.01. The mean ipsilateral to contralateral distal ICA luminal narrowing ratio was 34.1%. All patients had carotid patches. General anesthesia was associated with more shunt usage, *P* less than 0.05. High carotid bifurcation lengthened CEA time ($P<0.05$), but neither anesthetic type, nor the use of a shunt or patch did. At 30-day post CEA, there was only 1 (4.7%) recorded cerebrovascular event (CVA), no mortality, and no carotid restenosis or occlusion was found. At 1-year, no new CVA were reported but 1 (4.7%) fatality was recorded.
Conclusion
Carotid endarterectomy for patients with carotid near occlusion and partial distal collapse is safe and may be considered despite marginally higher procedural risks than patients with low-to-moderate risk anatomy.

Keywords:
carotid, endarterectomy, partial collapse outcomes

Egyptian J Surgery 43:9–15

1110-1121

Introduction

Carotid endarterectomy (CEA) benefit in symptomatic high-grade internal carotid artery (ICA) stenosis is very well proven by landmark trials [1,2]. However, in patients with carotid near occlusion (CNO) and distal collapse, CEA was not recommended based on post hoc re-analysis of pooled data [3] from NASCET [1] and European Carotid Surgery Trial (ECST) [2] despite the fact that both trials were not designed to assess this subgroup of patients [3].

This was reflected as level III and class C evidence in the latest 2023 European Society for Vascular Surgery (ESVS) carotid guidelines [4] which concluded that CNOs with distal ICA collapse should only be offered best medical treatment (BMT) because there was no obvious benefit from CEA unless recurrent symptoms developed while on BMT when carotid revascularization (CEA or carotid stenting (CS)) would be considered after the multidisciplinary team (MDT) review or as part of a randomized controlled trial. However, this recommendation does not take into consideration the degree of distal ICA collapse.

CNO is abroad term and includes ICA full collapse, a thread like distal lumen, also known as string sign, slim sign, or sub occlusion (CNOFC) and CNO with partial vessel collapse (CNOPC) with a less pronounced distal collapse with a more normal-appearing distal artery but will be significantly narrower compared with contralateral ICA [5]. It not a very rare finding and has a prevalence of just less than 10% in patients with significant carotid disease [6].

Johansson E. *et al.* [7], studied this patient subgroup and reported a very high risk of stroke recurrence. A recent meta-analysis concluded that BMT was not superior to CEA or CS either at 30-day or 1-year stroke or mortality prevention in patients with CNO. These patients were not shown to constitute a high-risk group for carotid revascularization, and it was recommended to include them in future studies [8].

Furthermore, as the two subgroups of CNO were not considered in the ESVS guidelines and are treated as one group, it is hypothesized that the risk of CEA may not be particularly higher in CNOPC.

The aim of this study is to assess postoperative stroke, morbidity, and mortality at 30-day and up to 1 year post-CEA in patients with CNOPC.

Patients and methods

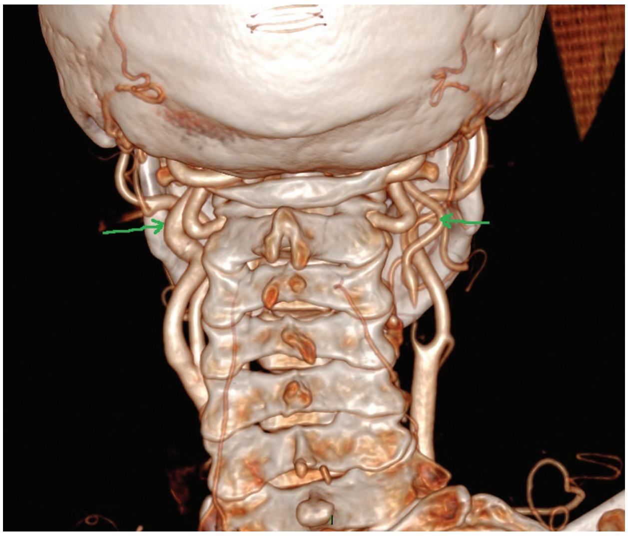
A prospectively maintained electronic theatre database was used to find consecutive patients who underwent CEA at a single center (The Lister Hospital, Stevenage, UK) between January 2019 and February 2022. Our hospital serves as a tertiary referral center for stroke care for a population of around 800 000. Only patients who had CEA with CNOPC (<50%) were included in the study who were identified by reviewing all CEAs cross-sectional imaging. Exclusion criteria were patients who had carotid artery total occlusion or CNOFC or whose treatment was capped at BMT level only because of being unfit or declining surgery, and patients who had CS or CEA with normal size distal ICA.

Retrospective review of the patient's medical records, electronic hospital database, and hospital radiology system. Age, sex, ischemic heart disease (IHD), hypertension (HTN), diabetes, smoking, chronic kidney disease (CKD) with eGFR less than 60, peripheral arterial disease (PAD), and respiratory disease were recorded. Demographics and related risk factors are shown in Table 1.

On presentation to hospital, either brain magnetic resonance imaging (MR) or computerized tomography (CT) brain and carotid duplex ultrasound (CDU) were performed in all patients. When CDU showed greater than 50% stenosis, additional cross-sectional carotid imaging was done (either CT angiogram (CTA), Figs. 1 and 2, or MR angiogram (MRA), Fig. 3). All imaging data were collected from hospital radiology system. Surgical indication and time from cerebrovascular accident (CVA) event to CEA were noted.

All patients' history and imaging were discussed at the vascular MDT if time allowed. However, surgery was

Figure 1



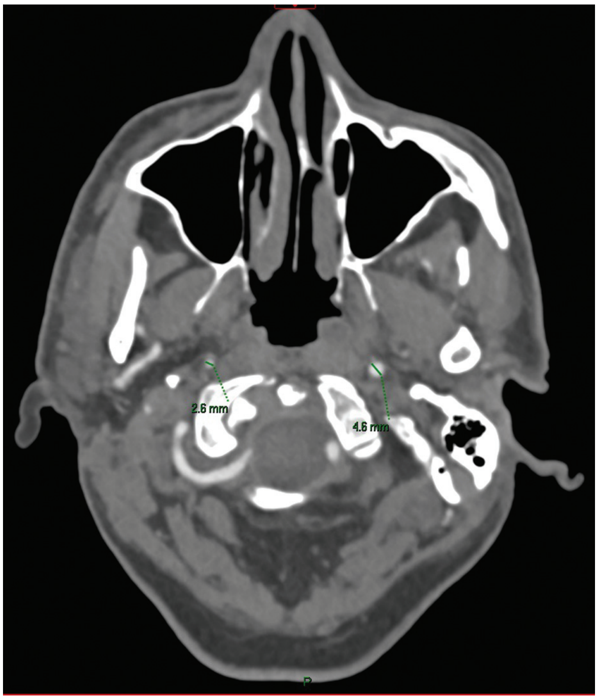
Carotid computerized tomography angiogram three dimensional reconstruction of a patient with right carotid near occlusion with partial collapse (posterior view).

Table 1 Demographics and comorbidities

		Sex			
	Total (*n*=21)	Males (*n*=15)	Females (*n*=6)	Test	*P*
Age, Mean±SD	67.68 (±SD 9.1)	67.6 (±SD 10.2)	67.8 (±SD8.6)	*t*=0.309	0.740
DM	7 (33.3%)	4 (26.6%)	3 (50%)	χ^2=3.527	^{FE}p=0.068
HTN	13 (61.9%)	9 (60%)	4 (66.6%)	χ^2=0.054	^{FE}p=0.789
Renal disease (eGFR <60)	2 (9.5%)	1 (6.6%)	1 (16.6%)	χ^2=0.405	^{FE}p=0.738
IHD	6 (28.5%)	6 (40%)	0	χ^2=9.488*	^{MC}p=0.008*
Smoker	12 (57.1%)	9 (60%)	3 (50%)	χ^2=0.014	^{FE}p=0.906
PVD Hx	3 (14.2%)	2 (13.3%)	1 (16.6%)	χ^2=0.405	^{FE}p=0.738
Respiratory Hx COPD/Asthma	3 (14.3%)	3 (20%)	0	χ^2=3.585	^{FE}p=0.098

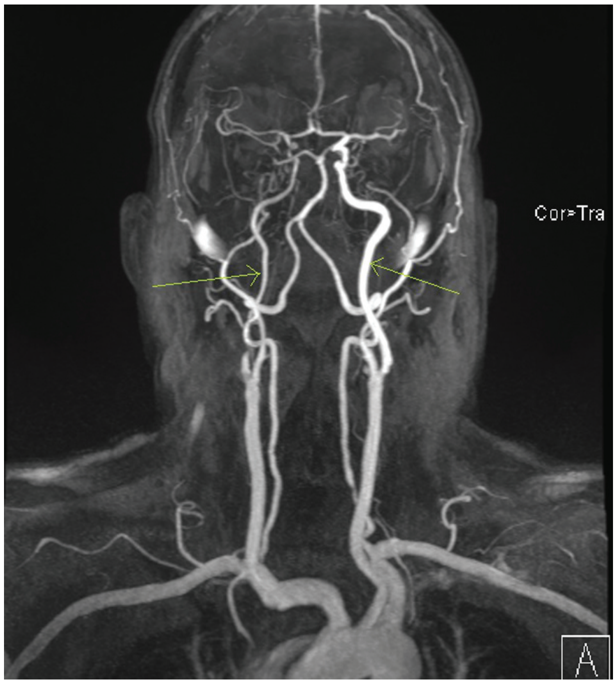
χ^2, Chi square test; FE, Fisher Exact; Hx, History; MC, Monte Carlo. *P**: *P* value statistically significant at *P* less than or equal to 0.05.

Figure 2



Carotid computerized tomography angiogram transverse cut at distal internal carotid artery level (right carotid near occlusion with partial collapse).

Figure 3



Carotid magnetic resonance angiogram, right carotid near occlusion with partial collapse.

performed if waiting for the MDT would cause CEA to be delayed by more than 14 days from CVA event after consulting stroke and radiology consultants to decide that it was a proper decision. When surgery was advised, informed consent was obtained from the patient and their family (if the patient so desired) before the procedure. Each patient was seen by a consultant anesthetist, who may have recommended more tests for preoperative evaluation to optimize patients for surgery.

Patients were informed of and given options for both general (GA) and local (LA) anesthetic procedures. Patients with CNOPC were informed about the controversy about carotid near occlusion (CNO), risks, benefits, and alternatives. If a patient declines surgery or is considered unfit, management was kept at the BMT level (and was excluded from the study), which was defined as the management of hypertension, other risk factors, such as diabetic mellitus (DM) control, and antiplatelet and lipid-lowering medications. Patients with recurrent symptoms who were at very high operative risk were referred to another tertiary center if suitable for carotid stenting (CS).

The stroke team took care of all patients before surgery and started them on BMT. Patients were first given 300 mg of Aspirin, which was later changed to 75 mg of Clopidogrel postoperatively.

Shunts were routinely taken into consideration in all CEA under GA and some LA cases if the patients' cerebral function declined during surgery. All patients received a minimum of 5000 I.U. of heparin intraoperatively. Information about the procedure, such as the type of anesthesia used, the use and type of shunt or patch, and any unexpected findings (such as nerve injury, significant bleeding, or CVA0 were gathered from the patients' surgical records. Postoperatively, all patients were transferred to the high dependency unit (HDU) to be monitored for at least 24 h. Following local trust protocol, Metaraminol and Labetalol infusions were used to maintain blood pressure (BP) in the desired postoperative range (100-160 mmHg systolic BP). Medical records, discharge letters, and outpatient letters were examined for any postoperative mortality or morbidity, including CVA. Patients were stepped down to a ward bed when deemed safe before being discharged when deemed medically fit.

Within four weeks, a discharge duplex ultrasound was scheduled to check for stenosis resolution, and carotid patency. Patients were seen in outpatient settings 6 weeks after CEA by the vascular and stroke teams. Through the electronic database system of the local

National Health Service trust, 1-Year late stroke and mortality data were gathered in May 2023.

Statistical analysis of the data

With the aid of the IBM SPSS software package version 20.0, data were fed into the computer and evaluated. (IBM Corp, Armonk, NY). Categorical data were shown as percentages and numbers. To compare two groups, the χ^2Chi-square test was used. Alternatively, when more than 20% of the cells had an expected count below 5, Fisher Exact or Monte Carlo correction test was used. Shapiro-Wilk tests were used to determine the normality of continuous data. Range (minimum and maximum), mean, standard deviation, and median were used to express quantitative data. For quantitative variables that were regularly distributed, the student *t*-test was employed to compare two groups. The Mann–Whitney test was employed to compare two groups for quantitative characteristics that were not regularly distributed. While the Kruskal-Wallis test was employed to compare various groups for quantitative variables that were not regularly distributed. At the 5% level, the significance of the results (*P* value) was determined.

Results

The study was conducted over a 3-year period. A total of 128 CEAs were done, of which, 21 (16.4%) symptomatic patients had CNOPC on the relevant side. This included 15 (71.4%) males and 6 (28.6%) females. The mean age was 67.76 (range: 51–83). All patients had CEA for symptomatic carotid disease. Fifteen (71.4%) patients had CEA within 2 weeks of the event as/ESVS guidelines [4]. Six (28.6%) patients were done 18–28 days postevent due to delayed referral (Table 2).

Table 2 Time from cerebrovascular event to carotid endarterectomy surgery

Event to surgery in days	Patient count	Percentage
1–7 days	10	47.6
8–14 days	5	23.8
15–21 days	4	19
21–28 days	2	9.6
Grand Total	21	100%

Preoperatively, all patients had carotids duplex ultrasound and 18 (85.7%) patients had CTA while 3 (14.3%) had MRA.

Cross-sectional imaging measurements showed an ipsilateral distal ICA lumen (above bulbus ICA level) mean diameter of 3.69 mm (range 2.5–5.4 mm) versus a contralateral distal ICA mean diameter of 5.59 mm (range 4.4–7.9 mm). The mean ipsilateral to contralateral distal ICA luminal narrowing ratio was 34.1% (range: 20–48.4%), Fig. 2. Mean ipsilateral carotid bulb diameter was 9.2 mm (range 7–11 mm). Ipsilateral ICA to its carotid bulb ratio was 59.9% (range 46.3–69.9%).

Twelve (57.1%) patients had CEA under GA, while 9 (42.9%) patients had LA. The use of LA significantly reduced the need for intraoperative shunting ($P<0.01$), while GA was associated with a significantly higher use of carotid shunting, *P* less than 0.05, (Table 3). Surgical time (skin to skin) average was 176 min (range: 112–245). Shunt was used in 10 (47.1%) patients (3 Javid, 7 Pruitt shunts), while in 11 (52.9%) patients, no shunt was used.

All patients had carotid patches. This included 13 (61.9%) bovine patches, 7 (33.4%) Dacron patches, and 1 (4.7%) vein patch. In 12 (57.1%) patients, difficult dissection or high bifurcation was reported in operative notes and was associated with a higher operative time greater than 200 min, *P* less than 0.05*. Neither anesthesia type, shunt or patch usage was found to affect operative time.

Postoperatively (Table 4), uneventful recovery was reported in 14 (66.6%) patients. There were 3 (14.3%) reported small hematomas (less than 2 cm in size). No large hematoma or return to theatre was reported. There was 1 (4.7%) recorded transient ischemic attack (TIA), which was diagnosed within 24 h post-CEA. CTA was done and did not show carotid thrombosis or evidence of emboli however, this patient had a low systolic BP (70 mmHg) at the time of the event, which was treated medically and recovered in 1 day with no permanent sequalae or drop in modified Rankin score (MRS). Another patient had hypotension postoperatively that needed metaraminol

Table 3 Type of anesthesia versus shunt usage

	No shunt used	shunt used	Total	
General anesthesia	3	9	**12**	$<$**0.05***
Local anesthesia	8	1	**9**	$<$**0.01***
Grand Total	**11**	**10**	**21**	

Table 4 Postoperative morbidities and mortality, high dependency unit, hospital stay

	Total (*n*=21)	Males (*n*=15)	Females (*n*=6)	*P* value
Stroke (<24 h)	1 (4.7%)	1 (6.6%)	0	^{FE}p=0.329
30-day Stroke	1 (4.7%)	1 (6.6%)	0	^{FE}p=0.329
Other complications 30 days				
Minor hematoma	3 (14.3%)	3 (20%)	0	^{FE}p=0.098
Int. Jugular vein thrombosis	1 (4.7%)	1 (6.6%)	0	^{FE}p=0.329
BP fluctuation	3 (14.3%)	2 (13.3%)	1 (16.6%)	^{FE}p=0.738
HDU (days) Mean±SD	1.23±0.7	1.15±0.75	1.33±0.6	0.481
Hospital LOS (days)±SD	2.76±1.9	2.73±1.7	2.83±2.1	0.625
Late Mortality	1 (4.7%)	1 (4.7%)	0	^{FE}p=0.329

FE, **Fisher Exact;** SD, **Standard deviation**. *Statistically significant at *P* less than or equal to 0.05.

infusion. One (4.7%) patient developed ipsilateral IJV thrombosis and was treated conservatively. Another patient (4.7%) developed hypotension, ectopic beats, confusion, and delirium which was diagnosed as acute ITU psychosis that recovered in 2 days. There was no recorded postoperative intracranial hemorrhage, seizures, or hyper-perfusion syndrome. There was no recorded immediate (<24 h) mortality.

Postoperatively, all patients were routinely admitted to HDU, with a mean stay of 1.23±0.5 days standard deviation. Afterwards, patients were stepped down to a regular ward bed before discharge when deemed fit (median stay: 2 days, Interquartile range: 1.4 days).

Three (14.3%) patients had delayed discharge 5, 9, and 13 days postoperatively. There was no more recorded 30-day Stroke. No 30-day mortality was recorded.

All other patients had a 4-week routine follow-up duplex ultrasound with no reported luminal restenosis. During 1-year follow-up, 1 (4.7%) patient was lost due to moving to another trust, but major adverse outcome data was looked for.

In April 2023, follow-up data review showed 1 (4.7%) mortality 8 months post-CEA due to myocardial infarction (MI). None of the patients had any late stroke at 1-year follow-up.

Discussion

The current study aimed to assess operative and postoperative complications up to 1 year in patients who had CEA with CNOPC for symptomatic carotid artery disease.

A CNO is characterized by a collapsed distal ICA beyond an extremely tight carotid stenosis. Due to the distal collapse in CNO, the residual patency is distinct from total distal occlusion or conventional carotid stenoses [5]. As carotid stenosis becomes more severe, the blood velocity progressively increases to maintain volume, flow, and pressure. There is a critical stenosis degree beyond which, further stenosis increase will not allow sufficient blood to pass, and distal ICA diameter progressively decreases, which may further progress to full occlusion [5].

In our study, all patients had CNOPC with a 34.1% mean (range: 20–48.4%) luminal reduction ratio of ipsilateral to contralateral ICA. Pokela M. *et al.* [9], studied CNOFC and CNOPC and reported a similar ICA diameter reduction ratio of 36% (±6–11%) in their CNOPC, whereas in their CNOFC, the ratio was 61% (±6–15%). This much narrower diameter in CNOFC would make shunting much more difficult, with a higher risk of trauma, dissection, or perforation of the distal ICA.

There is evidence that CNO (either with full or partial collapse) has a higher recurrent preoperative stroke risk. A Swedish study [7] reported a significantly higher 90-day risk of recurrent preoperative stroke rate in CNOFC (43%) versus CNOPC (0%) (95% C.I. 25–89%, *P*=0.035) after adjustment for age, gender, and presenting event. Gu T. *et al.* [10], found a similar 90-day recurrent preoperative stroke of 15% conventional greater than or equal to 50% stenosis, 22% among CNOPC, and 30% in CNOFC (log rank test *P*=0.01). All CEAs in the current study were done for symptomatic CNOPC, which was deemed indicated to avoid stroke recurrence.

CVA was recorded in 1 (4.7%) patient in the form of a TIA with no drop in MRS. Despite this being marginally higher than ESVS guidelines [4] that the overall CEA stroke risk should be within 3%, it can be justified by the relatively small sample size in our cohort in addition to the fact that this particular subgroup of patients has a higher operative risk. Our 30-day major adverse outcome (combined CVA, MI, and death) rate (MAOR) was 4.7%. Pokela M. *et al.* [9], reported an overall 30-day MAOR of 3.7% in a series of patients with CNO with 1 stroke in their CNOFC (11%) and none in their CNOPC group. In the latter group, however, there were 3 (3.3%) recorded cases of postoperative intracranial hemorrhage, 2 of which developed hyperperfusion syndrome. In our cohort, no post-operative intracranial hemorrhage or hyperperfusion syndrome was recorded, which is possibly due to our hospital strict post-CEA BP management protocol.

A recent meta-analysis [11] was done on 26 studies for CNO and combined the 30-day MAOR to reduce statistical error because of the relatively small numbers in each subgroup of complications in all studies. This was reported as 4.82% for CEA and 5.39% for CS. Johansson E. *et al.* [12] reported a significantly higher 30-day MAOR between CNOFC (20%) and CNOPC (3%), P=0.03. Among which, 2 patients were diagnosed with post-operative intracerebral hemorrhages in the supply area of the operated carotid stenosis (one was fatal); both were in the CNOFC group.

Another recent meta-analysis study [8] on outcomes of CNO treatment reported a significantly higher combined 30-day stroke and death rate after BMT only (4.9%) than after carotid revascularization including CEA (1·8%) and CS (2.2%) (odds ratio 5·63, 95 per cent (C.I. 1·30 to 24·45); P =0·021). No difference was found between CEA and CS.

At 1 year, there was no recorded CVA however, there was 1 (4.7%) mortality 8 months postoperatively, which was the only MAOR. This is comparable to the study by Xue S. *et al.* [11], which reported a 1-year MAOR of 4.26% of carotid revascularization for CNO (combined CEA and CS) versus 13.3% for BMT only group (heterogeneity, I^2=88.3%, P<0.01). Similarly, Johansson E. *et al.* [8], reported a combined 1-year stroke- and mortality-free survival rate of 96·1% for CEA and 94·4% for CS, versus 81·2% for BMT only. This supports the argument that offering carotid revascularization may be beneficial for those patients.

All CEAs in this study were done by conventional carotid dissection with longitudinal arteriotomy, shunting, and patching considered. Radak D. *et al.* [13], reported on eversion carotid endarterectomy (all done under GA, without shunt or intraoperative cerebral functions monitoring) versus BMT alone for CNO. They reported only 1.5% of 30-day TIA in the CNO group. Their 1-year incidence of TIA, Stroke, and neurologic mortality was lower with eversion CEA than in BMT-only patients (5% vs. 24%, P<0.001; 1.5% vs. 14%, P<0.001; and 1.5% vs. 8%, P=0.034, respectively). They concluded that, at least in high-volume centers, CEA should be favored over BMT for the management of CNO. Despite the satisfactory safety evidence of eversion CEA [14], conventional CEA was adopted in the current study both for surgeons' preference and for the ability to use carotid shunting (especially when indicated if a patient develops cerebral perfusion deterioration while doing CEA under LA), which should be considered in such a high-risk group.

At 30-day postoperatively, follow-up duplex did not record any restenosis or total occlusion. Radak D. *et al.* [13] reported a 3% restenosis rate in their eversion CEA patients; however, in their BMT alone patient 37% progressed from CNO to total occlusion. This is a crucial point to be considered in preoperative consultation with those patients. Our low restenosis rate could be explained by the routine use of carotid patches.

Limitations of the study

The current study is a single-center, single-arm study without a control group (such as CEAs for conventional stenosis, CNOFC, or patients who had BMT only). Despite the authors' careful efforts to review all sources of data, it is prone to data collection bias due to its retrospective nature. The analysis may be prone to type II statistical error due to a relatively small sample size.

Conclusion

Carotid endarterectomy should be considered for symptomatic patients with carotid near occlusion and partial collapse despite the potential for higher postoperative stroke risk than in patients with carotid stenosis and normal distal lumen because it may outweigh the best medical therapy alone to reduce recurrent stroke risk. In this high-risk group, the use of local anesthesia lessens the need for carotid shunting and makes patching easier.

Acknowledgement

The authors would like to acknowledge and recognize the contributions of the vascular consultant body at Lister Hospital.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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