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Outcomes Following Carotid Endarterectomy with Patch Plasty Versus Eversion Technique: A Comparative Study of 5 Years of Experience

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ABSTRACT

Background: Prompt carotid endarterectomy (CEA) for stroke prevention is still a cornerstone in the treatment of symptomatic carotid stenosis. CEA with patch plasty (CEPP) and eversion CEA (ECE) are two distinct surgical techniques widely used for the above. In this study, we have evaluated and compared the early outcomes of both techniques.

Methods: Between January 2018 and August 2023, a retrospective study was conducted. All patients who underwent surgical treatment for confirmed carotid artery stenosis were included. In our center, both ECE and CEPP techniques are performed. Early outcomes (≤ 30 days) were examined for the frequency of complications, such as cerebral hyperperfusion syndrome, cranial nerve injury, stroke, myocardial infraction, re-exploration, and death.

Results: A total of sixty patients were divided into two groups: those in which ECE was performed (ECE group, n = 44) and those in which CEPP was performed (CEPP, n = 16). There were no statistical differences in perioperative and 30-day outcomes between the CEPP and ECE groups. A significant difference was found in hospital stay (8.1 ± 1.7 vs. 10.1 ± 1.9 days) and clamping time of the carotid artery (7.1 ± 0.5 vs. 13.4 ± 1.2 min) between the ECE and CEPP, respectively.

Conclusion: Our experience showed that the early outcomes of both techniques were comparable. Even though ECE decreases hospital stay and clamping time of the carotid artery, it does not offer any additional advantages of decreasing the early outcomes compared to CEPP. Surgeon experience plays a crucial role in determining the most suitable surgical approach.

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Introduction

Stroke, also known as cerebrovascular accident (CVA), is the leading cause of mortality and disability worldwide [1]. In low-income countries like Yemen, stroke is a devastating problem [2]. Among all causes of death, stroke ranks third in the world, with 13,570, or 8.72%, of total deaths in Yemen [2-4]. The internal carotid artery (ICA) is confirmed to be the origin of 8% of strokes, or 13.4 strokes per 100,000 people annually [5].

Surgical intervention in the form of CEA is crucial in preventing subsequent large and devastating strokes in individuals who were not properly selected, especially when combined with the best medical therapy [6]. According to the most recent guidelines from the European Society for Vascular Surgery for the management of extracranial carotid disease, all surgically fit patients with symptoms of extracranial carotid disease who have stenosis of 70 to 99% and stroke/death rates less than 6% should get a CEA right away. Additionally, it ought to be considered for symptomatic patients with 50–69% stenosis, particularly those who are older than 70. Asymptomatic patients should not all frequently be offered CEA; those for whom benefit can be sought are increasingly specific [7]. This procedure is associated with a significant stroke risk, the rate of which is dependent on several factors, both intrinsic and extrinsic to the patient. According to the original European Carotid Surgery Trial, the overall risk of a severe stroke or death after surgery was 7% [6]. Later randomized controlled trials (RCTs) and meta-analyses mostly agree that CEA is still helpful for some groups of asymptomatic people and for a small number of carefully selected symptomatic patients as long as it is given within two weeks [8].

Atherosclerosis is the primary cause of carotid artery stenosis (CAS). Fisher first described CAS as a pathologic substrate for ischemia-related diseases of the ipsilateral brain and eye in 1951 [9]. Preventive management of asymptomatic CAS involves a combination of lifestyle changes (such as regular exercise and smoking cessation), medication (including antihypertensives, statins, and antiplatelets), and regular monitoring (such as diabetic control) [10-12]. For patients with symptomatic ICA stenosis, CEA is one of the recommended treatment options, primarily based on the North American Symptomatic Carotid Endarterectomy Trial and the European Carotid Surgery Trial [13-15].

In carotid surgery, two distinct surgical techniques are in widespread use: ECE and CEPP. Debakey first described the ECE in the 1950s. It involves transectioning the common carotid artery (CCA) immediately below the bifurcation, eversion of the ICA and external carotid arteries (ECA), and end-to-end reanastomosis of the CCA [16]. At our center, we use a different version of this process where the origin of the ICA is excised obliquely off the carotid bifurcation, and is inverted on its own. This is in contrast to the CEPP, which involves accessing the plaque with a longitudinal arteriotomy along the ICA/carotid bulb over the affected area. Patch angioplasty may or may not be necessary after this [17].

Recent years have witnessed growing interest in comparing the outcomes of these two techniques worldwide. However, to date, there has been no study published evaluating and comparing the outcomes of both techniques in Yemen. As a part of sharing our experience with CEA, we aim to provide a comprehensive comparison of these two techniques, considering their surgical outcomes and post-operative complications. By understanding the differences and similarities between these two techniques, healthcare providers can make informed decisions about the best course of treatment.

Methods

Study Design and Population

Between January 2018 and August 2023, a retrospective study was conducted at the vascular unit of surgical departments in the Al-Thawra Modern General Hospital (TMGH), Sana'a City, Yemen. All patients who underwent surgical treatment for confirmed CAS were included in this study. On the other hand, patients who were managed non-operatively, had severe organic diseases, and had missing hospital charts were excluded from the study's final analysis. Symptomatic carotid stenosis (SCS) is challenging to diagnose because it is uncommon and has few manifest symptoms. For the assessment of CAS, a duplex ultrasound study and occasionally computerized tomography angiography (CTA) were both used to measure the degree of stenosis. Symptomatic patients were defined as those who had experienced a transient ischemic attack (TIA) or a stroke in the territory of the ipsilateral carotid artery before entry. In our center, both conventional surgery and ECE are available. At the end of the study period, sixty patients were divided into two groups: those in which ECE was performed (ECE group, n = 44) and those in which ECPP was performed (ECPP, n = 16).

Surgical Procedure

At first, neurological function was assessed; if necessary, neurologists were consulted. Then, preoperative imaging studies such as a CTA, carotid doppler ultrasound, or magnetic resonance imaging (MRI) were performed to diagnose SCS as well as detect the degree of stenosis. At least three days before the procedure, the patients had received at least one antiplatelet agent (aspirin, 100 mg daily, and/or clopidogrel, 75 mg daily), as well as statins. All patients should be stabilized before the procedure in terms of blood pressure (BP), blood sugar, and hemodynamic stability. With intraoperative monitoring, the procedure was performed under general or local anesthesia. In ECE procedures with local anesthesia, all patients should respond to questions that evaluate cerebral function by pressing a toy in their hands, which produces sound. Intravenous heparin (5,000 units) was administered prior to the clamping of the carotid artery in order to avoid acute thrombosis. Options for procedures included both CEPP and ECE. The type of procedure is at the discretion of the surgeon. In the CEPP, we prepared a shunt preoperatively and inserted it after the arteriotomy. Intraoperative data, including the use of a shunt, clamping time, perioperative complications, and operation time, were examined.

Data Collection and Operational Definitions

We collected all related data retrospectively. We reviewed the statistical department, operating theater database, discharge registry, and patient clinical notes for information, and it was manually compiled and evaluated. We collected demographic and clinical data, such as age, gender, preoperative and radiological data (including side of stenosis, degree of ipsilateral CAS, and contralateral CAS), comorbidities, and presenting symptoms (including TIA and stroke). We also collected intraoperative data (including time of carotid clamp, ICA backflow, and shunting), and 30-day outcomes (including hematoma, uncontrolled BP, cerebral hyperperfusion syndrome (CHS), cranial nerve injury (CNI), stroke, myocardial infraction (MI), death, and re-exploration). Control duplex imaging was performed in all patients within 1 week after the procedure. We defined a history of smoking as being a smoker of any amount of any type (cigarette, water pipe, cigar, or pipe) before the procedure [18,19]. Hyperlipidemia is defined as non-high-density lipoprotein cholesterol (HDLc) $\geq$ 220 mg/dL ($\geq$ 5.7 mmol/L) + triglycerides $\geq$ 150 mg/dL ($\geq$ 1.7 mmol/L) [20,21]. The definition of diabetes mellitus (DM) is fasting blood glucose 7.0 mmol/L, self-report of a prior test with postprandial blood glucose 11.1 mmol/L or glycated hemoglobin (HbA1c) 7%, taking antidiabetic medications, or self-report of a physician's diagnosis [22]. Patients with systolic BP (SBP) $\geq$ 140 and/or diastolic BP (DBP) $\geq$ 90 mmHg are considered hypertensive patients [23]. Obesity was defined using a BMI of $\geq$ 30 (weight in kg divided by the square of height in m) [24].

Statistical Analysis

We analyzed data with the Statistical Package for Social Science Analysis (SPSS, Inc., Chicago, Illinois, USA) version 28.0 for Windows throughout. We presented continuous variables as the mean ± standard deviation (SD) and cohort characteristics as absolute numbers with percentages in parentheses. We stratified patients into two analytic cohorts based on the type of procedure: CEPP and ECE. We analyzed the differences between two groups of continuous variables by a t-test or the Mann-Whitney U test according to their distributions. We compared the dichotomous outcomes and clinical variables between both groups by Fisher's exact test or the chi-square test. All comparisons were two-sided, with statistical significance defined as a value of $P \leq 0.05$.

Results

No patients met our exclusion criteria; all were included in this retrospective study. Sixteen (26.6%) patients underwent CEPP, while 44 (73.4%) patients underwent ECE. All patients who underwent CEPP had SCS, whereas in the ECE group, 36 (81.8%) patients had SCS. A total of 8 cases were asymptomatic, of which 4 cases were synchronous CEA and coronary artery bypass grafts (CABG), and the remaining 4 were staged CEA and CABG.

Table 1 demonstrates the preoperative characteristics of CAS, patients' demographics, and comorbidities. The overall mean degree of stenosis was 85.4 ± 4.5. All patients were classified as having a severe degree of stenosis (the minimum degree of stenosis recorded in our study was 78.0). The left side was the most common side of stenosis, with a distribution of 45 (75.0%). The overall mean age was 65.8 ± 3.3 years, with mostly male patients (n = 50, 83.3%). The most common comorbidities were hypertension (HTN) and hyperlipidemia, followed by DM, smoking, obesity, coronary artery disease (CAD), and heart failure (HF).

In Table 1, we can see how preoperative features of CAS, demographics, and comorbidities were different from the CEPP group to the ECE group. There were no statistical differences in preoperative features of CAS and patients' demographics in either group ($P > 0.05$). The prevalence of obesity was statistically significantly higher in the CEPP group as compared to the ECE group (56.3% vs. 18.2%, respectively, $P = 0.004$). In contrast, the prevalence of CAD was statistically significantly higher in the ECE group than the CEPP group (36.4% vs. 0.0%, $P = 0.003$). Although the prevalence of HF was higher in the ECE group, this difference did not achieve statistical significance ($P = 0.142$). The prevalence of HTN, hyperlipidemia, DM, and smoking was statistically similar in both groups ($P > 0.05$).

Table 1: Preoperative Characteristics of Carotid Artery Stenosis, Patients' Demographics, and Comorbidities

Characteristics	Total (n = 60)	CEPP (n = 16)	ECE (n = 44)	P-value
Degree of ipsilateral CAS, mean (SD)	85.4 (4.5)	85.3 (3.4)	85.5 (4.9)	0.980
Contralateral CAS, n (%)	5 (8.3)	1 (6.3)	4 (9.1)	0.597
Stenosis side, n (%)				
Left	45 (75.0)	12 (75.0)	33 (75.0)	0.622
Right	15 (25.0)	4 (25.0)	11 (25.0)	
Age, mean (SD)	65.8 (3.3)	65.5 (2.7)	66.0 (3.5)	0.801
Gender, n (%)				
Male	50 (83.3)	12 (75.0)	38 (86.4)	0.250
Female	10 (16.7)	4 (25.0)	6 (13.6)	
Comorbidities, n (%)				
HTN	48 (80.0)	15 (93.8)	33 (75.0)	0.103
DM	43 (71.7)	10 (62.5)	33 (75.0)	0.342
Smoking	35 (58.3)	10 (62.5)	25 (56.8)	0.693
Obesity	17 (28.3)	9 (56.3)	8 (18.2)	0.004*
Hyperlipidemia	44 (73.3)	14 (87.5)	30 (68.2)	0.120
HF	6 (10.0)	0 (0.0)	6 (13.6)	0.142
CAD	16 (26.7)	0 (0.0)	16 (36.4)	0.003*

*Significant difference (p-value < 0.05). CAD, Coronary Artery Disease; CAS, Carotid Artery Stenosis; CEPP, Carotid Endarterectomy with Patch Plasty; DM, Diabetes Mellitus; ECE, Eversion Carotid Endarterectomy; HF, Heart Failure; HTN, Hypertension; n, Number; SD, Standard Deviation.

According to the National Institutes of Health Stroke Scale, the most common presenting symptoms were minor stroke, 31 (51.7%) cases, followed by TIA, 18 (30.0%) cases, and major stroke, 3 (5.0%) cases. In comparison, there were no statistical differences in patients' symptoms (TIA, minor stroke, and major stroke) between the CEPP and ECE groups (Table 2).

Table 2: Presenting Symptoms

Presenting symptoms	Total (n = 60)	CEPP (n = 16)	ECE (n = 44)	P-value
TIA, n (%)	18 (30.0)	7 (43.8)	11 (25.0)	0.161
Minor stroke, n (%)	31 (51.7)	8 (50.0)	23 (52.3)	0.876
Major stroke, n (%)	3 (5.0)	1 (6.3)	2 (4.5)	0.613

CEPP, Carotid Endarterectomy with Patch Plasty; ECE, Eversion Carotid Endarterectomy; n, Number; SD, Standard Deviation, TIA, Transient Ischemic Attack.

Table 3 represents the mean and proportion of patients undergoing CEA within ≤ 2, 3-7, 8-14, and ≥ 15 days after the onset of symptoms caused by carotid stenosis. The overall mean time interval between symptom onset and CEA was 16.1 ± 6.5 days, with no statistical differences between both groups (P = 0.462). No patient underwent CEA within ≤ 2 days after SCS. The majority of patients underwent CEA within 8-14 days, 23 (44.2%), and ≥ 15 days, 23 (44.2%), after SCS.

Table 3: Mean and Proportion of Symptomatic Patients Undergoing Actual CEA within ≤ 2, 3-7, 8-14, and more than 15 Days after Onset of Symptoms Caused by Symptomatic Carotid Stenosis

Variables	Total (n = 52)	CEPP (n = 16)	ECE (n = 36)	P-value
Time from symptom onset to intervention, mean (SD)	16.1 (6.5)	15.4 (6.8)	16.5 (6.5)	0.462
Proportion of symptomatic patients undergoing CEA, n (%)				
≤ 2 days	0 (0.0)	0 (0.0)	0 (0.0)	-
3-7 days	6 (11.5)	2 (12.5)	4 (11.1)	
8-14 days	23 (44.2)	9 (56.3)	14 (38.9)	
≥ 15 days	23 (44.2)	5 (31.3)	18 (50.0)	

CEA, Carotid Endarterectomy; CEPP, Carotid Endarterectomy with Patch Plasty; ECE, Eversion Carotid Endarterectomy; n, Number; SD, Standard Deviation.

The intraoperative data are presented in Table 4. The overall incidence of reduced backflow of ICA was 6.7% (4 cases). Although there was no statistical significance (P = 0.287), the incidence of reduced backflow of ICA was higher in the CEPP group than the ECE group (12.5% vs. 4.5%, respectively). Carotid shunting was used in 16 (26.7%) patients for the prevention of ischemic events. All these 16 patients underwent only CEPP. The mean time of carotid artery cross-clamping for CEPP was significantly higher than for ECE (13.4 vs. 7.1 min, respectively, P < 0.001).

Table 4: Intraoperative Data

Intraoperative data	Total (n = 60)	CEPP (n = 16)	ECE (n = 44)	P-value
Reduced backflow of ICA, n (%)	4 (6.7)	2 (12.5)	2 (4.5)	0.287
Shunt, n (%)	16 (26.7)	16 (100)	0 (0.0)	< 0.001*
Time of carotid clamp (min), mean (SD)	8.8 (2.8)	13.4 (1.2)	7.1 (0.5)	< 0.001*

*Significant difference (p-value < 0.05), CEPP, Carotid Endarterectomy with Patch Plasty; ECE, Eversion Carotid Endarterectomy; ICA, Internal Carotid Artery; min, Minutes; n, Number; SD, Standard Deviation.

We examined the early complications within 30 days after CEA. Table 5 shows 30-day outcomes following CEA. The overall mean hospital stay was 8.6 ± 2.0 days. The mean hospital stay for the CEPP group was 10.1 ± 1.9 days, while it was 8.1 ± 1.7 days in the ECE group, which was statistically significant (p < 0.0001). There was no statistical difference in 30-day outcomes between the CEPP and ECE groups. The overall incidence of hematoma was 3.3%, which developed in two cases, both of whom underwent ECE procedures. There were 6 (10.0%) and 3 (5.0%) cases of postoperative uncontrolled BP and CHS, all of whom underwent ECE procedures, and there were no significant differences between both groups (P = 0.141 and 0.387, respectively). Only one case (1.7%) with a CNI developed in the ECE group. Both the overall rate of stroke after the procedure and the rate of mortality were 5.0%. These complications happened in 3 patients who all had ECE procedures, which were not statistically different from CEPP procedures (P = 0.387). There was no MI in either group. Two (3.3%) cases underwent re-exploration, both of whom underwent ECE procedures.

Table 5: Association between the type of CEA Procedure and 30-day Outcomes

30-day outcomes	Total (n = 60)	CEPP (n = 16)	ECE (n = 44)	P-value
Hospital stays (Days), mean (SD)	8.6 (2.0)	10.1 (1.9)	8.1 (1.7)	< 0.001*
Hematoma, n (%)	2 (3.3)	0 (0.0)	2 (4.5)	0.534
Uncontrolled BP, n (%)	6 (10.0)	0 (0.0)	6 (13.6)	0.141
CHS, n (%)	3 (5.0)	0 (0.0)	3 (6.8)	0.387
CNI, n (%)	1 (1.7)	0 (0.0)	1 (2.3)	0.733
Stroke, n (%)	3 (5.0)	0 (0.0)	3 (6.8)	0.387
MI, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	-
Mortality, n (%)	3 (5.0)	0 (0.0)	3 (6.8)	0.387
Re-exploration, n (%)	2 (3.3)	0 (0.0)	2 (4.5)	0.534

*Significant difference (p-value < 0.05), BP, Blood Pressure; CEPP, Carotid Endarterectomy with Patch Plasty; CHS, Cerebral Hyperperfusion Syndrome; CNI, Cranial Nerve Injury; ECE, Eversion Carotid Endarterectomy; MI, Myocardial Infarction; n, Number; SD, Standard Deviation.

We also examined the associations between the type of anesthesia and 30-day outcomes. There was no statistical association between type of anesthesia and 30-day outcomes, with the exception of more days of hospital stay in cases who underwent general anesthesia (P < 0.001) (Table 6).

Table 6: Association between type of Anesthesia and 30-day Outcomes

30-day outcomes	Total (n = 60)	General Anesthesia (n = 43)	Local Anesthesia (n = 17)	P-value
Hospital stays (Days), mean (SD)	8.6 (2.0)	9.4 (1.7)	6.5 (0.7)	< 0.001*
Hematoma, n (%)	2 (3.3)	2 (4.7)	0 (0.0)	0.510
Uncontrolled BP, n (%)	6 (10.0)	5 (11.6)	1 (5.9)	0.449
CHS, n (%)	3 (5.0)	3 (7.0)	0 (0.0)	0.361
CIN, n (%)	1 (1.7)	1 (2.3)	0 (0.0)	0.717
Stroke, n (%)	3 (5.0)	3 (7.0)	0 (0.0)	0.361
MI, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	-
Mortality, n (%)	3 (5.0)	3 (7.0)	0 (0.0)	0.361
Re-exploration, n (%)	2 (3.3)	2 (4.7)	0 (0.0)	0.510

*Significant difference (p-value < 0.05), BP, Blood Pressure; CHS, Cerebral Hyperperfusion Syndrome; CNI, Cranial Nerve Injury; MI, Myocardial Infarction; n, Number; SD, Standard Deviation.

Discussion

The use of ECE shows promise as a potential alternative to CEPP. Clinical outcomes from ECE have been demonstrated to be comparable to those from CEPP, including the outcomes presented in our study. Nonetheless, CEPP is still regarded as the gold standard surgical technique worldwide [3,25].

With the entire CEPP group and the majority of the ECE group being SCS, our two study groups were reasonably matched. This is likely due to similarities in procedure goals. Both ECE and CEPP aim to remove plaque buildup (endarterectomy) from the carotid artery to improve blood flow and reduce the risk of stroke in patients with SCS. Both techniques address the underlying cause of stroke risk in symptomatic patients.

According to previous studies, there were no statistical differences in demographics, comorbidities, or symptoms between both groups [3, 26-29]. With the exception of a significantly higher prevalence of obesity in our CEPP group, our findings are consistent with those of the above. Obese patients often have unique anatomical challenges due to increased neck adiposity and thicker carotid arteries. CEPP may be preferred in obese patients due to several factors. Firstly, the patch provides better adaptation to the thicker arterial wall, reducing the risk of leakage or dissection. Secondly, reduced technical difficulty in CEPP. In obese patients, direct suturing (as in ECE) can be technically challenging due to limited exposure and handling difficulties. Lastly, CEPP may reduce the risk of restenosis (re-narrowing) in obese patients [30]. In summary, while both techniques have their merits, CEPP may be favored in obese patients due to its technical advantages and potential benefits in preventing restenosis. However, individual patient factors and surgeon expertise play a crucial role in selecting the most appropriate techniques [30,31].

Even though CEPP had a much longer clamping time on the carotid artery than ECE, there were no statistically significant differences in the number of cases presenting with symptoms such as major strokes, minor strokes, or TIAs between the two techniques in our study. Likewise, there were no significant differences in 30-day hematoma, uncontrolled BP, CHS, stroke, MI, mortality rate, or re-exploration. Our findings were similar to those from several previous studies from different geographical regions of the world [3, 27-29]. However, Kumar et al, revealed that the ECE group had a significantly higher rate of CNI than the CEPP group (19.4% vs. 3.2%, respectively, P = 0.045). This is different from what we found, as we discovered that the rate of CNI was the same in both techniques [26]. Kumar et al, argued that they found “a marginal mandibular nerve, followed by hypoglossal, and a recurrent laryngeal branch of vagus” to be the most common CNI, while the majority of research reported vagus and hypoglossal nerves. Because of this, the high rate of marginal mandibular nerve dysfunction in their study could be because the transverse incision in ECE was pulled too far up toward the mandible, which is where the nerve normally runs [26].

Chen et al, showed that the expected operation time and carotid clamping time were crucial factors that affect the use of shunts. It is evident that CEPP requires a longer operation time and carotid clamping time than ECE, which may be the primary cause of the significantly higher shunt use in CEPP patients [29]. These findings are supported by the Everest trial, in which the clamp time during CEPP was significantly higher than during ECE (34.5 ± 14.4 vs. 31.7 ± 15.9 min, respectively), which is also in line with our study [32]. On the contrary, Kumar et al, revealed that the time of carotid clamp during CEPP was significantly shorter (13.8 ± 6.3 vs. 20.7 ± 8.5 min). Again, the researchers argued about how to explain their opposite finding and interpreted that all of their CEPP were performed with a shunt, but in the Everest trial, the shunt was only used in 16% of CEPP patients and 11% of ECE patients [26,32].

The stroke-related mortality rate following CEA depends on several factors, including patient characteristics and the specific procedure. Our study showed that the overall perioperative stroke and mortality rate was 5%, a figure that is considerably higher in comparison with others’ findings of 0.0% as showcased in 0.27% as showcased in and 0.9% as showcased in [3, 26-29]. The European Society for Vascular Surgery (ESVS), in its latest version, recommends CEA for patients with severe (70%–99%) carotid stenosis, provided the anticipated rates of perioperative stroke and mortality are < 6% [7]. Although our finding is within this range, it remains quite alarming. There are a few possible explanations for our findings. One possibility is that patients in low-income countries, like Yemen, may present later in the course of their disease, often with more advanced and complicated atherosclerosis, making surgery riskier and outcomes poorer. The average time between symptom onset and CEA in our study was 16 days, which is longer than the recommended 14 days, supporting this interpretation [33]. Actually, the timing of CEA relative to symptom onset is a critical factor in the incidence rate of complications following CEA. While delayed intervention may increase the risk of complications due to ongoing plaque instability, embolization, or hemodynamic changes, early intervention may reduce the risk of recurrent strokes [34,35]. Adding insult to injury, we found the minimum degree of stenosis was 78, which makes all of our cases have severe degrees of stenosis. Severe stenosis increases the risk of stroke-related mortality after CEA [36]. Another possibility relates to less access to advanced technology in low-income countries. The lack of advanced medical technology, such as high-resolution imaging equipment and intraoperative monitoring tools, can lead to increased perioperative risks. Moreover, the quality of postoperative care, including intensive care facilities and the ability to manage complications, can be lower in low-income countries, which could lead to higher mortality rates. It should be noted that, although not statistically proven, all three dead cases in our study underwent general anesthesia. The choice of general or local anesthesia can influence the risk of complications, although this is a complex topic with ongoing research. Optimal management during and after CEA that includes an experienced surgical team, a balance of anesthetic options, neuromonitoring, and individualized care can improve the outcomes of CEA.

An interesting finding in our study was that we found no patient underwent CEA within ≤ 2 days of SCS, and the average duration between symptom onset and the actual CEA intervention was 16 days, a figure that is higher than the recommended 14 days by the National Institute of Clinical Excellence [33]. Our finding is the highest compared to national registries in the Netherlands, Norway, and the UK; the average delay was 11 days compared with 9 days in Germany and 8 days in Sweden [37-41]. Our finding raises significant concerns and requires more context for proper interpretation in a low-income, developing country like Yemen. One interpretation may be due to the affordability of diagnostic tests, medications, and surgeries, which can be a significant hurdle in accessing timely and appropriate care. This could lead to a delayed diagnosis and intervention. Another possible explanation has to do with the fact that there are scarce healthcare resources in Yemen, which can lead to delays in diagnosis, inadequate monitoring, and suboptimal management of risk factors (such as HTN, DM, and hyperlipidemia). In addition, a lack of awareness about risk factors and preventive measures may result in delayed seeking of medical attention. Patients might not recognize symptoms or understand the importance of early intervention. Patients who lack awareness and face financial hardships may present for CEA late. Generally, the high average duration between symptom onset and the actual CEA intervention observed in our study may reflect a complex interplay of healthcare infrastructure, patient awareness, and socioeconomic factors. Efforts to enhance healthcare systems, raise awareness, and need urgent carotid duplex evaluation in a country like Yemen are crucial in the management of SCS. In addition, our finding fuels the need for multicenter RCTs with a large sample size. We are planning to further expand our study prospectively and carry out multicenter RCTs to achieve this endeavor.

Limitations

There were a number of limitations to our study. Firstly, it is a retrospective single-center experience, which is a main limitation of our study. Secondly, it is likely that there were several cases of data loss due to inadequate documentation and record-keeping. Thirdly, there was a lack of independent adjudication of 30-day outcomes because we relied on the recording of data from the statistical department, operating theater database, discharge registry, and/or patient clinical notes. It should be mentioned that we only included patients who presented to our hospital, and out-of-hospital mortalities were not available. Furthermore, a study with long-term follow-up to investigate the delayed complications of these two surgical techniques is still needed. However, with our strict selection criteria, we hope that this reflects the accurate 30-day outcomes of comparison between these two techniques in the TMGH setting.

Conclusion

Our experience showed that the early outcomes of both techniques were comparable. Even though ECE decreases hospital stay and clamping time of the carotid artery, it does not offer any additional advantages of decreasing the early outcomes compared to CEPP. The mean time interval between symptom onset and CEA was relatively high in our study. Surgeon experience and patient-specific factors play a crucial role in determining the most suitable surgical approach. Efforts to enhance healthcare systems, raise awareness, and need urgent carotid duplex evaluation in a country like Yemen are crucial in the management of SCS.

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Information Disclosure

A survey of records was conducted only after ethical approval of the study protocol by the administration of TMGH, and permission to access patient charts was also obtained from the hospital clinical service director and surgical department. Moreover, we conducted the study in accordance with the Declaration of Helsinki by including basic principles of ensuring the study subject's privacy, risk, and benefit, and even by having it conducted by trained professionals. The raw data were not made available to anyone and were not used as the determinant of the participant. The investigators were in charge of and oversaw all steps of data collection and compilation. Strict confidentiality was assured through the anonymous recording and coding of questionnaires, which were placed in a safe place.

Data Sharing Statement

All original data is available in the Department of General Surgery, TMGH, Sana'a City, Yemen. The data used to support the findings of our study are available from the corresponding author (Professor Nabeel Almadwahi) upon request.

Conflicts of Interest

The authors declare that there is no potential conflict of interest relevant to this study.

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