Carotid artery stenting in high-risk patients: immediate and short-term results

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Received: 13 November 2019
Accepted: 9 December 2019
Published: 27 April 2020

The Egyptian Journal of Surgery 2020, 39:305–312

Aim
To review the immediate and short-term results of carotid artery stenting (CAS) in high-risk patients for surgery.
Patients and methods
This prospective study was carried out on 36 patients experiencing significant CAS. Patients were scheduled for CAS during the period between December 2015 and June 2018 and followed up for 1 year. All procedures were done in 6 October Insurance Hospital and Mahmoud Mosque Specialized Hospital. Most carotid lesions were internal carotid artery [33 (91.7%) patients], and only three (8.3%) patients had common carotid artery lesions. Overall, 31/36 patients had symptomatic carotid stenosis, whereas 5/36 patients were asymptomatic. The commonest presentation was stroke (58.3%) and transient ischemic attack (27.8%).
Results
Technical success was achieved in all patients. Embolic protection devices were used in all cases. Three (8.3%) patients developed stroke; two patients had intraoperative stroke after stent deployment and the other occurred during the 12-month follow-up. One (2.8%) patient developed cerebral hemorrhage. Six (16.7%) cases developed transient ischemic attack. Acute myocardial infarction occurred in three (8.3%) patients.
Conclusion
Management of CAS is challenging in high-risk patients. Stroke prevention is the main goal of successful treatment. Risk–benefit assessment should be based on patient status and procedural risk, rather than on the controversy between carotid endarterectomy and CAS.

Keywords:
carotid stenting, high-risk patients, immediate results

Egyptian J Surgery 39:305–312

1110-1121

Introduction

Cerebrovascular disease is one of the commonest causes of mortality and a major source of permanent neurological and physical deficit in adults. In United States, cerebrovascular disease is considered the fifth most common cause of death with ~795 000 stokes annually. Stroke is the most prevalent, as ~15–20% of these ischemic strokes occurred owing to significant stenosis caused by carotid atherosclerosis [1]. Because of this fact, carotid artery stenosis (CAS) should be suspected in any patient with cerebral stroke or transient ischemic attack (TIA), and it can be assessed easily by duplex ultrasound (US) imaging [2].

Symptomatic CAS is defined as stenosis in internal carotid artery (ICA) with cerebral manifestations associated with ipsilateral carotid lesions [3].

Carotid endarterectomy (CE) remains the golden standard treatment of CAS. CAS is another option for carotid revascularization, which has developed rapidly over the past 30 years because of less invasiveness, less morbidity, and faster convalescence. Restenosis is fortunately rare after CAS (3–5%), and the long-term results are encouraging [4].

In comparison with other endovascular peripheral arterial interventions, CAS is a more challenging procedure requiring complex catheter-based skills and continuing learning curve [5].

CAS may be a substitute for surgery especially in high-risk patients. However, embolic stroke, even with a meticulous technique and experienced operators, represents the major drawback of the procedure. Most neurological complications are due to intracerebral embolism of plaque fragments or thrombosis during procedural steps [6]. Careful selection of patients, improvements in endovascular

 DOI: 10.4103/ejs.ejs_203_19

tools, and proper medication may reduce the embolic risks. Embolic protection devices (EPD) retain fragments and debris generated during the procedure aiming to decrease the incidence of neurological complications [7]. Several studies suggest that CAS even without cerebral protection can be performed with an acceptable perioperative stroke and death rate of 2.9–8.2% [8].

Patients and methods

This prospective study was carried out in Vascular Surgery Department at 6 October Insurance Hospital and Mahmoud Mosque Specialized Hospital on 36 patients experiencing significant CAS. CAS was done during the period between December 2015 and June 2018. Overall, 31/36 patients had symptomatic carotid stenosis, whereas 5/36 patients were asymptomatic and referred from cardiac unit before coronary artery bypass grafting (CABG).

Inclusion criteria were symptomatic stenosis more than 55% associated with one or more of the high surgical risks, congestive heart failure (class III/IV) and/or ejection fraction less than 30%, unstable angina (CCS class III/IV), recent myocardial infarction (MI) (within 30 days), and stenosis was more than 70% in asymptomatic carotid lesions requiring CABG. Exclusion criteria were acute ischemic neurologic event within the past 48 h or total occlusion of carotid artery.

After discussing the procedure, its possible complications, benefits, risks, and other alternative interventions with patients, an informed written consent was obtained. This study was approved by hospital ethics committee.

All patients were subjected to clinical assessment regarding identification of risk factors, for example, age, smoking, diabetes mellitus, hypertension, hyperlipidemia, and family history of related ischemic diseases. Neurological assessment was done by a neurologist with stress on the recent cerebral ischemia whether transient or persistent, weakness, tremors, sensory manifestations, numbness, cranial nerves affection, speech disturbances, visual symptoms, and cognitive function disturbances. All patients were evaluated by full laboratory investigations with concern on renal functions and coagulation profile. Carotid duplex was done for all cases to determine the degree of stenosis, plaque morphology, and systolic velocity of the ICA. Computed tomography (CT) angiography for aortic arch and carotid arteries and CT brain were performed to confirm infarction and exclude any hemorrhagic events.

Procedure

Preoperative medications with dual antiplatelet therapy in the form of loading dose of clopidogrel 300 mg and aspirin 150 mg were given the night before the procedure. The procedure was performed with local anesthesia by a retrograde transfemoral access. Overall, 5000 IU heparin was injected immediately after insertion of the sheath. Selective bilateral carotid angiography was performed to assess the lesion before intervention. A 0.035 stiff-angled guide wire is then advanced into one of the main branches of the external carotid artery. Replacement of this wire by a long stiff Amplatz wire was done and long sheath 6 Fr 90 cm length (Cook Medical Inc., Bloomington, Indiana, USA) was inserted and positioned at common carotid artery (CCA) below the target lesion.

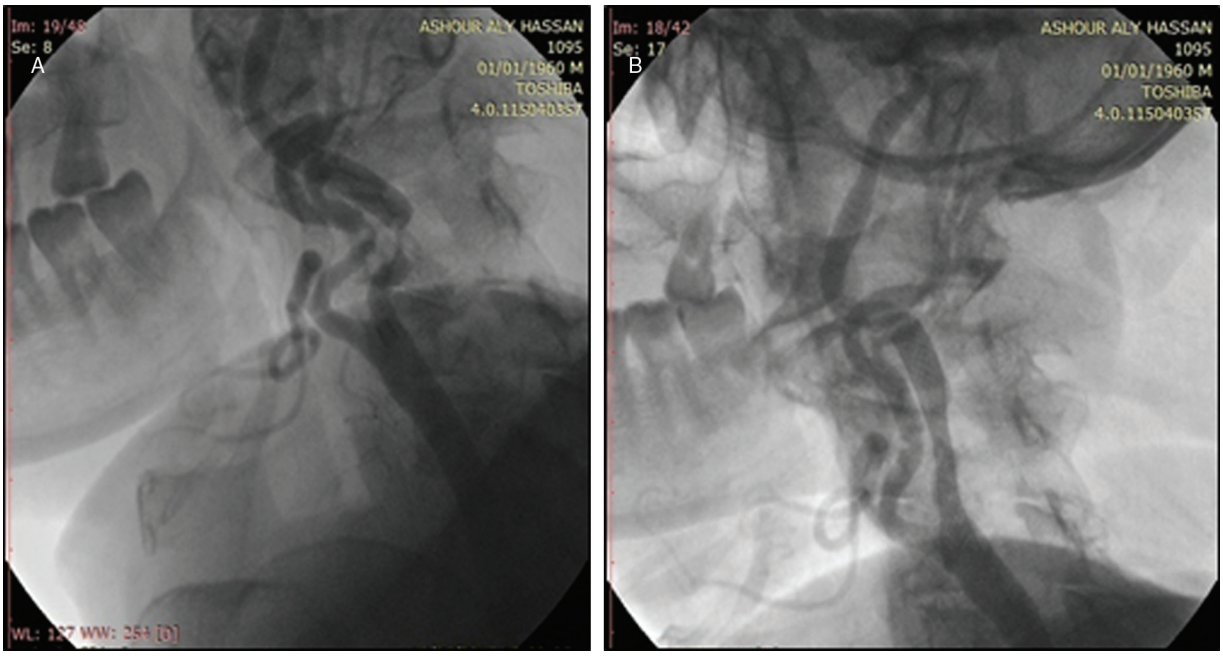
The filter (EPD) 0.014 guide wire (Filterwire Ez; Boston Scientific Corp., Massachusetts, USA) was slowly advanced across the stenosis till the petrous portion of ICA and then the filter basket was deployed in the straight portion of the cervical ICA.

Self-expandable stent (Wallstent; Boston Scientific Corp.) was deployed. The length of the stent was determined according to the lesion length (usually 20–40 mm) with avoidance of unnecessary excess lengths. Stent positioning should involve the distal CCA and proximal ICA. In such cases, the diameter of the stent should match the distal CCA (most commonly using an 8 mm diameter straight stent or 7–10 mm tapered stent). In case of tight or calcified lesions, balloon predilatation was performed using a 0.014 coronary balloon with a smaller diameter, for example, 1.5–2 mm, before stent deployment.

Poststent dilatation was performed by 5–6-mm-diameter, 20-mm-length balloon if significant residual stenosis was observed. Any residual stenosis less than 30% was an acceptable result. Poststent dilatation should be avoided in mild residual stenosis, especially in symptomatic patients, bulky atherosclerotic or noncalcified plaques to decrease the risk of distal embolization. Moreover, high-pressure inflation should be kept away to avoid the risk of carotid dissection, perforation, and distal embolization.

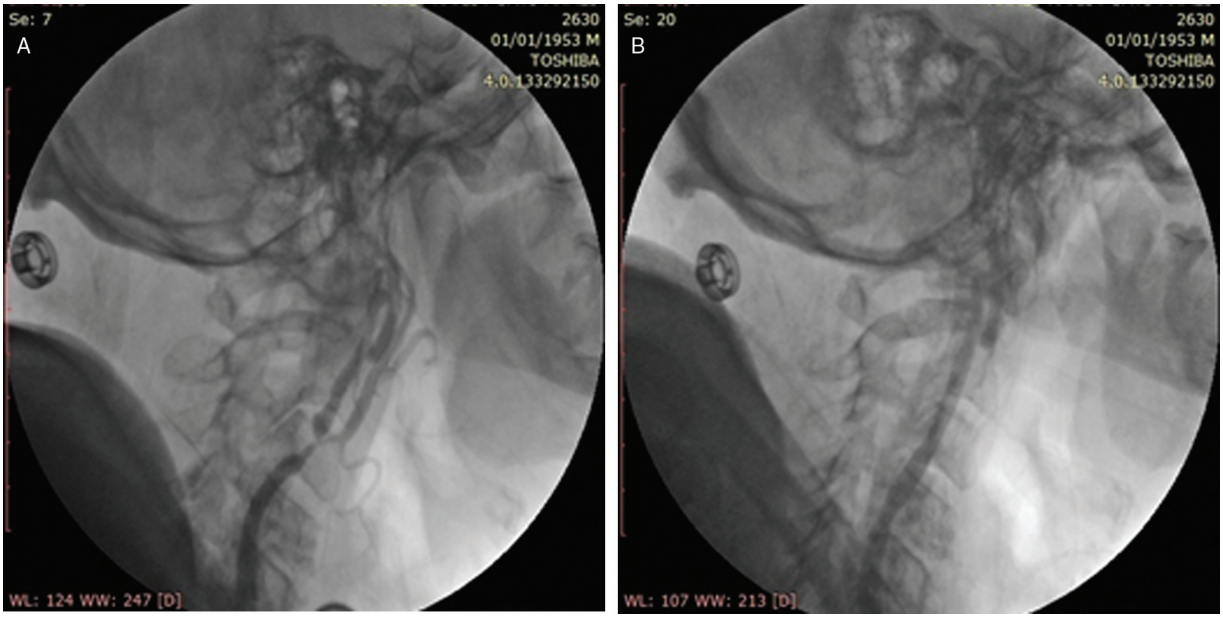
After retrieval of EPD, completion angiography of carotid bifurcation and intracranial circulation was performed to assess technical success, cerebral flow, and collateral circulation (Figs 1 and 2).

Figure 1



Left ICA stenosis (a): before treatment and (b) after stent deployment. ICA, internal carotid artery.

Figure 2



Right CCA and ICA stenosis: (a) before treatment and (b) after stent deployment. CCA, common carotid artery; ICA, internal carotid artery.

Postoperative management

Patients were closely monitored in ICUs for 24 h especially for blood pressure, heart rate, and neurological deficits. MRI or CT brain was performed if the neurological status changed. Postprocedure medications were prescribed for patients as enoxaparin every 12 h for 2 days, aspirin 150 mg daily for life, and clopidogrel 75 mg/day for at least 3 months.

After discharge, the patients were followed up at 1, 3, 6, 9, and 12 months in an outpatient clinic and assessed neurologically, especially for the cognitive functions and motor and sensory system affection. Duplex examination was performed routinely during the follow-up visits.

The study outcome included stroke, death, and MI if occurred immediately within first 30 days

postoperatively or throughout the 12-month follow-up.

Statistical analysis

All statistical analyses were performed using SPSS, statistical software. Descriptive statistics were done for parametric quantitative data by mean±SD.

Analysis was done by χ^2 test between different groups and McNemar test between different times.

Results

This study included 36 patients presented to the Vascular Surgery Department at 6 October Insurance Hospital and Mahmoud Mosque Specialized Hospital with significant CAS for whom CAS was done during the period between December 2015 and June 2018. Patient's criteria and demographic data are summarized in Table 1.

The main presentations were stroke [21/36 (58.3%)], TIA [10/36 (27.8%)], and asymptomatic patients [5/36 (13.9%)]. All asymptomatic patients were referred from cardiac surgery unit who were prepared for CABG and discovered accidentally by routine preoperative carotid duplex. All patients were investigated by duplex study and CT angiography of the aortic arch and its branches including carotid arteries. Most carotid lesions were ICA in 33 (91.7%) patients, and only three (8.3%) patients had CCA lesions. A total of 31 (86.1%) patients were symptomatic (16 patients of them with stenosis 55–70% and the other 15 patients with stenosis >70%). The remaining five (13.9%) patients were asymptomatic and had stenosis more than 70% (Table 2).

Balloon predilatation was done in four cases owing to very tight lesions using coronary balloons 2 mm in diameter. EPD was deployed in all cases. Poststent balloon dilatation was done in six cases owing to significant residual stenosis.

Immediate (within 30 days) complication were as follows: stroke occurred in 5.6% (two patients) and TIA in 8.3% (three patients), with no deaths or MI. Both stoke and TIA incidences were observed in patients with carotid stenosis more than or equal to 70%, whereas no complications occurred in patients with carotid stenosis less than this percentage (Fig. 3).

Regarding the complications during 1 year, three (8.3%) patients developed stroke, where two cases had intraoperative stroke after stent deployment in spite of using the filter, and the other one occurred during the 12-month follow-up. CT brain showed patent stent. One (2.8%) patient developed cerebral hemorrhage at 6-month follow-up owing to uncontrolled hypertension. Six (16.7%) cases developed TIA; their carotid duplex showed patent stent, and CT brain showed no recent infarction. Acute MI occurred in three patients: one was admitted to coronary care unit and underwent coronary angiography, whereas the other two cases died because of massive MI. Five cases had intraoperative bradycardia either during stent deployment or balloon predilatation and were relieved by immediate administration of atropine. Two patients died postoperatively after CABG (Table 3).

Discussion

CE has been established in late 20th century as the preferred method for prevention of stroke for symptomatic patients experiencing carotid stenosis more than 55% and asymptomatic patients with more than 60% carotid stenosis compared with medical therapy [9]. Moreover, broad-based guidelines support CAS for treatment of carotid

Table 1 Patient criteria and risk factors

	N=36 [*n* (%)]
Age	62 (52–68)
Male/female	26/10 (72.2%/27.8%)
Risk factors	
DM	28 (77.8)
Hypertension	36 (100)
Smoking	20 (55.6)
Hyperlipidemia	36 (100)
Renal impairment	6 (16.7)
Cardiovascular disease	24 (66.7)

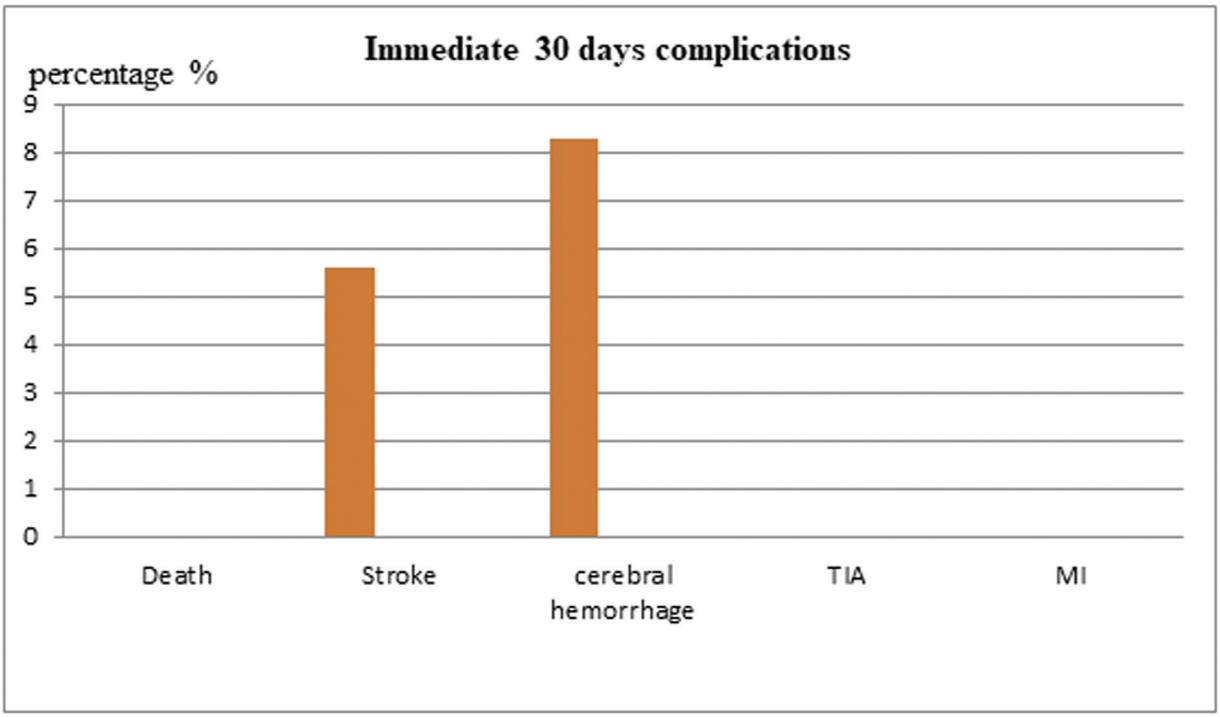
DM, diabetes mellitus.

Table 2 Patient presentation and lesion criteria

Patients presentations [*n* (%)]	
Symptomatic	
Previous stroke	21 (58.3)
TIA	10 (27.8)
Asymptomatic	5 (13.9)
Lesion criteria [*n* (%)]	
Site of lesion	
ICA	33 (91.7)
CCA	3 (8.3)
Severity of lesion [*n* (%)]	
55–70%	16 (44.4)
>70%	20 (55.6)

CCA, common carotid artery; ICA, internal carotid artery; TIA, transient ischemic attack.

Figure 3



Immediate 30-day complications.

Table 3 Procedure-related complications

	Immediately (30 days) [*n* (%)]	3 months [*n* (%)]	6 months [*n* (%)]	12 months [*n* (%)]	Total [*n* (%)]
Death	0	1 (2.8)	2 (5.6)	1 (2.8)	4 (11.1)
Ischemic stroke	2 (5.6)	0	0	1 (2.8)	3 (8.3)
TIA	3 (8.3)	1 (2.8)	2 (5.6)	0	6 (16.7)
Cerebral hemorrhage	0	0	1 (2.8)	0	1 (2.8)
MI	0	2 (5.6)	1 (2.8)	0	3 (8.3)

MI, myocardial infarction; TIA, transient ischemic attack.

artery disease in symptomatic and asymptomatic patients with high or average surgical risk features [10]. Moreover, recent evidence from randomized controlled trials and meta-analyses appreciated CAS with EPD for management of CAS, as it offers better periprocedural outcomes comparable to CE, especially in patients with high risk for surgical approach [11].

Patients included in this series had either symptomatic stenosis more than 55% or asymptomatic stenosis more than 70%, and both had high surgical risks. They were diagnosed by duplex US and CT angiography. Brott *et al.* [12] had recorded that the eligibility for CAS was extended to include asymptomatic patients with stenosis more than or equal to 60% by angiography or more than or equal to 70% by duplex US.

Regarding risk factors in this study, incidence of hypertension and hyperlipidemia was 100%, followed by diabetes mellitus (77.8%). International Carotid Stenting Study (ICSS) trial had noticed similar incidences apart from decreased incidence of hyperlipidemia (61%) [13].

Male to female ratio in CAS is now widely accepted and can be attributed to the effect of female sex hormones that seem to play a protective role on vascular endothelial function, lipid homeostasis, and cardiovascular risk factors [14]. Moreover, Mathur *et al.* [15] suggested that estrogens had a plaque-stabilization effect, besides its role in inflammatory status. De Weerd *et al.* [16] found that the prevalence of moderate stenosis increases with age in either men or women, but men at all ages have higher prevalence estimates. In this study, male to female ratio was 2.60 : 1 (72.2 vs. 27.8%). Nearly similar results were obtained by the sapphire study [17] in which the incidence of males was 66.9% and females was 33.1%.

Duplex US is an acceptable and sensitive diagnostic tool in evaluating the hemodynamics of carotid vessels as well as its effectiveness in decision making. Significant CAS is considered when peak systolic

velocity is greater than 250 cm/s or if the end diastolic velocity is greater than 120 cm/s [18]. Other methods of assessment incorporate CT angiography and MRI. Both CT angiography and MRI are useful in evaluation of the anatomical variation of aortic arch [19]. In this series, all cases were diagnosed first by duplex US followed by CT angiography.

Routine use of EPD can achieve similar or even comparable results to surgery, particularly in high surgical risk group, so the indications of CAS could be extended, especially for lesions with high embolic risks [21]. On the contrary, Reimers *et al*. [20] had reported in their series that Pro-Case study; prospective comparative registry reported that 4709 patients were treated with EPDs and 3543 patients of this cohorts were performed without the use of EPDs, and concluded that there was no difference in stroke and death rates between the two groups. ICSS compared MRI data of patients before and after CAS and CE and also compared MRI results for patients treated with CAS either with or without EPD. They noticed that new ischemic lesions were found more in patients treated with CAS and cerebral protection devices than without. Moreover, the rate of stroke was higher in EPD group (5.1%) than the unprotected group (2.4%) [22]. Eller *et al*. [23] did not support the use of EPD and attributed their opinion to the following: delivery of EPDs may be difficult in tortuous vascular anatomy, balloon predeployment may be needed to cross the stenosis, and carotid lesion when crossed with the wire and filter, a step that is not protected may end by dissections and possible embolic complications. Moreover, filter devices do not have ideal wall apposition, allowing material to embolize around the filter. Thrombus may be formed inside the filter itself and then embolize around. Finally, EPDs add expense to the CAS procedure.

In this series, the type of stent was closed cell stent design: wall stent. Sahin *et al*. [24] reported in their study, which used two types of stents, that is, open cell stent and closed cell stent, randomly into two patient groups, that closed cell type are associated with low rate of ischemic stroke as a procedure-related complication.

In this study, five (13.9%) patients were asymptomatic and referred to CAS because of their high surgical risk and prepared for CABG. There are still questions about the management of asymptomatic CAS as those patients have low incidence of stroke per year. New era of best medical therapy, for example, antiplatelet agents, angiotensin-converting enzyme inhibitors, and statins, can stabilize the atheromatous plaque and decrease the incidence of stroke [25]. Gaba *et al*. [26] had reported that the guidelines 2018 of European Society of Vascular Surgery recommend that patients with asymptomatic CAS of 60–99% and average surgical risk should be considered for CE only, as there is increased risk of late ipsilateral stroke. Aboyans *et al*. [19] had reported that in symptomatic patients more than 60% carotid stenosis, the incidence of cerebral stroke is more than 10% yearly and thus intervention is mandatory and becomes more beneficial when performed within 14 days, whereas in asymptomatic stenosis, the need for reperfusion is limited because the stroke incidence is ~2% and concluded that, it is preferable to limit the carotid revascularization in asymptomatic patients to the following indications: presence of occluded contralateral carotid artery, quick progress of carotid stenosis, silent brain infarction in CT brain, and vulnerable plaque found on duplex US.

In this study, patients were discharged on drug regimen as enoxaparin every 12 h for 2 days, aspirin 150 mg/day for life, clopidogrel 75 mg/day for at least 3 months, and atorvastatin according to the presence or absence of dyslipidemia. This drug regimen was recorded in ICSS trial [13] but with little difference in clopidogrel duration, which was continued for 4–6 weeks only in asymptomatic patients and for 3 months in symptomatic patients.

Regarding immediate (within 30 days) complications, stroke occurred in 5.6% (two patients) and TIA in 8.3% (three patients), with no deaths or MI. Both stoke and TIA incidences were observed in patients with carotid stenosis more than or equal to 70%, whereas no complications have been occurred in patients with carotid stenosis less than this percentage. These results were consistent with Mathur *et al*. [15] who found that CAS performed in lesions more than 90% stenosis were associated with higher 30-day stroke rate of 14.9% compared with 3.5% in patients with lesion less than 90% stenosis. Nearly similar results were obtained by CAVATAS study [27]and Angelini *et al*. [28]. Wall stent study [29] reported 12.1% stroke in symptomatic carotid stenosis (60–99%). They attributed this high incidence as they did not use EPD during CAS, and thus, the neurological complications were owing to embolization of atheromatous materials.

In this study, stent patency rate was 100% during the whole 12-month follow-up period. In CAVATAS study, 1-year patency rate was 86% [27].Stroke occurred in three (8.3%) cases; two of them occurred intraoperative mostly owing to embolization in spite of

using EPD, and the other occurred at the 12th month postoperatively. One (2.8%) patient developed cerebral hemorrhage at 6-month follow-up period. Death occurred in four (11.1%) patients; two of them after extensive MI and the other two patients died after CABG by 3- and 6-month duration. In the CaRESS study [30], death and stroke rates were 10%, and the combined end point of death, stroke, or MI was 10.9%, and also in sapphire trial [17], it was 11.9%.

CAS is characterized by better quality of life especially during the early recovery period when compared with CE regarding physical limitations and pain. These differences diminished over time and were not evident after 1 year [31].

ICSS [32] investigators in 2010 compared CAS and CE in prevention of stroke, death, and procedure-related heart attacks in 1713 patients experiencing symptomatic carotid stenosis. Findings concluded that patients in CAS group had a significantly greater risk of stroke, death, or procedure-related heart attack.

A recent and novel technique for management of CAS is transcarotid artery revascularization, which provides an alternative to CE and CAS for high-risk patients. This hybrid technology approached carotid arteries directly with cerebral blood flow reversal during stent deployment. It is characterized by minimal invasiveness and low risk of stroke [33]. This procedure reported less stroke rates in comparison with CE (1.8 vs. 2.4%) at 30 days and (1.8 vs. 3.6%) at 1 year. Regarding the complications, it was noted that cranial nerve injury and MI rates were similar, with a decreased rate of mortality at 30 days (P=0.026) [34].

Conclusion

Management of carotid stenosis is challenging in high-risk patients. Stroke prevention is the main goal of successful treatment. Risk–benefit assessment should be based on patient status and procedural risk, rather than on the controversy between CE and CAS.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Benjamin EJ, Blaha MJ, Chiuve SE, Cushman M, Das SR, Deo R, *et al.* Heart disease and stroke statistics-2017 update: a report from the American Heart Association. Circulation 2017; 135:e146–e603.

2 Wardlaw JM, Chappell FM, Stevenson M, De Nigris E, Thomas S, Gillard J, *et al.* Accurate, practical and cost-effective assessment of carotid stenosis in the UK. Health Technol Assess 2006; 10:iii–iv.

3 Park JH, Lee JH. Carotid artery stenting. Korean Circ J 2018; 48:97–113.

4 Brooks WH, Jones MR, Gisler P, McClure RR, Coleman TC, Breathitt L, Spear C. Carotid angioplasty and stenting versus carotid endarterectomy: randomized trial in a community hospital. JACC 2001; 38:1589.

5 Mas JL, Chatellier G, Beyssen B, Branchereau A, Moulin T, Becquemin JP, *et al.* Endarterectomy versus stenting in patients with symptomatic severe carotid stenosis. N Engl J Med 2006; 355:1660.

6 Cremonesi A, Castriota F, Manetti R, Balestra G, Liso A. Endovascular treatment of carotid atherosclerotic disease: early and late outcome in a non-selected population. Ital Heart J 2000; 1:801.

7 Theron J, Raymond J, Casasco A, Courtheoux F. Percutaneous angioplasty of atherosclerotic and post-surgical stenosis of carotid arteries. Am J Neuroradiol 1987; 8:495.

8 Gupta A, Bhatia A, Ahuja A, Shalev Y, Bajwa T. Carotid Stenting in patients older than 65 years with ingerable carotid artery disease: a single center experience. Catheter Cardiovasc Interv 2000; 50:1.

9 Halliday A, Mansfield A, Marro J, Peto C, Peto R, Potter J, Thomas D. Prevention of disabling and fatal strokes by successful carotid endarterectomy in patients without recent neurological symptoms: randomised controlled trial. Lancet 2004; 363:1491–1502.

10 Furie KL, Kasner SE, Adams RJ, Albers GW, Bush RL, Fagan SC, *et al.* Guidelines for the prevention of stroke in patientswith stroke or transient ischemic attack: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2011; 42:227–276.

11 Touzé E, Trinquart L, Felgueiras R, Rerkasem K, Bonati LH, Meliksetyan G, *et al.* A clinical rule (sex, contralateral occlusion, age, and restenosis) to select patients for stenting versus carotid endarterectomy: systematic review of observational studies with validation in randomized trials. Stroke 2013; 44:3394–3400.

12 Brott TG, Hobson RW II, Howard G, Roubin GS, Clark WM, Brooks W, *et al.* Stenting versus endarterectomy for treatment of carotid-artery stenosis. N Engl J Med 2010; 363:11–23.

13 International Carotid Stenting Study (ICSS). Carotid artery stenting compared with endarterectomy in patients with symptomatic carotid stenosis.an interim analysis of a randomised controlled trial. Lancet 2010; 375:985–997.

14 Iemolo F, Martiniuk A, Steinman DA, Spence JD. Sex differences in carotid plaque and stenosis. Stroke 2004; 35:477–481.

15 Mathur A, Roubin GS, Iyer SS, *et al.* Predictors of stroke complicating carotid artery stenting. Circulation 1998; 97:1239–1245.

16 de Weerd M, Greving JP, de Jong AW, Buskens E, Bots ML. Prevalence of asymptomatic carotid artery stenosis according to age and sex: systematic review and meta regression analysis. Stroke 2009; 40:1105–1113.

17 Yadav JS. Technical aspects of carotid stenting. 3rd ed. Paris: EuroPCR: 2003; 1–18.

18 Barnett HJ, Gunton RW, Eliasziw M, Fleming L, Sharpe B, Gates P, Meldrum H. Causes and severity of ischemic stroke in patients with internal carotid artery stenosis. JAMA 2000; 283:1429–1436.

19 Aboyans V, Björck M, Brodmann M, Collet JP, Czerny M, De Carlo M, *et al.* Questions and answers on diagnosis and management of patients with peripheral arterial diseases: a companion document of the2017 ESC Guidelines for the Diagnosis and Treatment of Peripheral Arterial Diseases, in collaboration with the European Society for Vascular Surgery (ESVS). Eur J Vasc Endovasc Surg 2018; 55:457–464.

20 Reimers B, Sievert H, Schuler GC, Tübler T, Diederich K, Schmidt A, *et al.* Proximal endovascular flow blockage for cerebral protection during carotid artery stenting: results from a prospective multicenter registry. J Endovasc Ther 2005; 12:156.

21 Binning MJ, Maxwell CR, Stofko D, Zerr M, Maghazehe K, Liebman K, *et al.* Carotid artery angioplasty and stentingwithout distal embolic protection devices. Neurosurgery 2017; 80:60–64.

22 Bonati LH, Jongen LM, Haller S, Flach HZ, Dobson J, Nederkoorn PJ, ICSS-MRI Study Group. New ischaemic brain lesions on MRI after stenting orendarterectomy for symptomatic carotid stenosis: a substudy of the InternationalCarotid Stenting Study (ICSS). Lancet Neurol 2010; 9:353–362.

23 Eller JL, Dumont TM, Sorkin GC, Mokin M, Levy EI, Snyder KV, *et al.* Endovascular advances for extracranial carotid stenosis. Neurosurgery 2014; 74(Suppl 1):S92–S101.

24 Sahin M, Açar G, Özkan B, Alıcı G, Yazıcıoglu MV, Bulut M, *et al.* Comparison of short-term outcomes after carotid artery stenting

according to different stent designs. Postepy Kardiol Interwencyjnej 2013; 9:121–125.

25 Eckstein HH, Reiff T, Ringleb P, Jansen O, Mansmann U, Hacke W; SPACE 2 Investigators. SPACE-2: a missed opportunity to compare carotid endarterectomy, carotid stenting, and best medical treatment in patients with asymptomatic carotid stenoses. Eur J Vasc Endovasc Surg 2016; 51:761–765.

26 Gaba K, Ringleb PA, Halliday A. Asymptomatic carotid stenosis: intervention or best medical therapy?. Curr Neurol Neurosci Rep 2018; 18:80.

27 CAVATAS Investigators. Endovascular versus surgical treatment in patients with carotid stenosis in the Carotid and Vertebral Artery Transluminal Angioplasty Study (CAVATAS): a randomised trial. Lancet 2001; 357:1729–1737.

28 Angelini A, Reimers B, Della Barbera M, Saccà S, Pasquetto G, Cernetti C, *et al.* Cerebral protection during carotid artery stenting: collection and histopathologic analysis of embolizeddebris. Stroke 2002; 33:456–461.

29 Wiesmann M, Schöpf V, Jansen O, Brückmann H. Stent-protected angioplasty versus carotid endarterectomy in patients with carotid artery stenosis: meta-analysis of randomized trial data. Eur Radiol 2008; 18:2956–2966.

30 CaRESS Steering Committee. Carotid Revascularization using Endarterectomy or Stenting Systems (CaRESS): phase I clinical trial: 1-year results. J Vasc Surg 2005; 42:213–219.

31 Cohen DJ, Stolker JM, Wang K, Magnuson EA, Clark WM, Demaerschalk BM, *et al.* Health-related quality of life after carotid stenting versus carotid endarterectomy: results from CREST (Carotid Revascularization Endarterectomy Versus Stenting Trial). J Am CollCardiol 2011; 58:1557–1565.

32 International Carotid Stenting Study investigators,Ederle J, Dobson J, Featherstone RL, Bonati LH, van der Worp HB, *et al.* Carotid artery stenting compared with endarterectomy in patients with symptomatic carotid stenosis (International Carotid Stenting Study): an interim analysis of a randomized controlled trial. Lancet 2010; 375:985–997.

33 Wu WW, Liang P, O'Donnell TFX, Swerdlow NJ, Li C, Wyers MC, Schermerhorn ML. Anatomic eligibility for transcarotid artery revascularization and transfemoral carotid artery stenting. J Vasc Surg 2019; 69:1452–1460.

34 Kashyap VS, King AH, Foteh MI. A multi-institutional analysis of contemporary outcomes after transcarotid artery revascularization versus carotid endarterectomy. J Vasc Surg 2018; 67:1–26.