

# Primary carotid artery stenting versus carotid artery stenting for postcarotid endarterectomy stenosis

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**Background:** Carotid artery stenting (CAS) has been advocated as an alternative to carotid endarterectomy (CEA) in high-risk surgical patients, including stenosis after CEA. This study compared early and midterm clinical outcomes for primary CAS vs CAS for post-CEA stenosis.

**Methods:** This study analyzed 180 high-risk surgical patients: 68 had primary CAS (group A), and 112 had CAS for post-CEA stenosis (group B). Patients were followed-up prospectively and had duplex ultrasound imaging at 1 month and every 6 months thereafter. All patients had cerebral protection devices. Kaplan-Meier life-table analysis was used to estimate rates of freedom from stroke, stroke-free survival,  $\geq 50\%$  in-stent stenosis,  $\geq 80\%$  in-stent stenosis, and target vessel reintervention (TVR).

**Results:** Patients had comparable demographic and clinical characteristics. Carotid stent locations were similar. Indications for CAS were transient ischemic attacks (TIA) or stroke in 50% for group A and 45% for group B. The mean follow-up was comparable, at 21 (range, 1-73) vs 25 (range, 1-78) months, respectively. The technical success rate was 100%. The perioperative stroke rates and combined stroke/death/myocardial infarction (MI) rates were 7.4% for group A vs 0.9% for group B ( $P = .0294$ ). No perioperative MIs occurred in either group. One death was secondary to stroke. The combined early and late stroke rates were 10.8% for group A and 1.8% for group B ( $P = .0275$ ). The stroke-free rates at 1, 2, 3, and 4 years for groups A and B were 89%, 89%, 89%, and 89%; and 98%, 98%, 98%, and 98%, respectively ( $P = .0105$ ). The rates of freedom from  $\geq 50\%$  carotid in-stent stenosis were 94%, 83%, 83%, and 66% for group A vs 96%, 91%, 83%, and 72% for group B ( $P = .4705$ ). Two patients (3%) in group A and seven patients (6.3%) in group B had  $\geq 80\%$  in-stent stenosis (all were asymptomatic except one). The freedom from  $\geq 80\%$  in-stent stenosis at 1, 2, 3, and 4 years for groups A and B were 100%, 98%, 98%, and 78% vs 99%, 96%, 92%, and 87%, respectively ( $P = .7005$ ). Freedom from TVR rates at 1, 2, 3, and 4 years for groups A and B were 100%, 100%, 100%, and 100% vs 99%, 97%, 97%, and 92%, respectively ( $P = .261$ ).

**Conclusions:** CAS for post-CEA stenosis carried a lower risk of early postprocedural neurologic events than primary CAS, with a trend toward a higher restenosis rate during follow-up. (*J Vasc Surg* 2009;50:1031-9.)

Carotid endarterectomy (CEA) is the accepted treatment modality for certain patients with significant symptomatic and asymptomatic carotid artery stenosis. Meanwhile, carotid artery stenting (CAS) has established a limited role in the treatment of significant carotid artery stenosis in patients who are at high risk for traditional CEA. This subset of patients includes previous CEA, neck radiation, high or low cervical lesions, and those with significant cardiopulmonary disease.<sup>1-3</sup>

The accepted stroke rate for CEA is  $<5\%$  for symptomatic patients, and  $<3\%$  for asymptomatic patients.<sup>4</sup> The stroke rates for CAS have varied from 5% to 12% in various

clinical trials.<sup>1-3,5-14</sup> The subset of patients who undergo CAS may determine the outcomes, such as stent revascularization for native atherosclerotic carotid artery lesions versus post-CEA stenosis.

Carotid artery disease is primarily due to atherosclerosis, and stenting of such arteries carries complications such as distal embolization resulting in stroke, hypotension, and bradycardia due to disruption of baroreceptors.

This present study compares the early and midterm clinical outcome of primary CAS (group A), where no previous carotid interventions (CEA or CAS) were done, versus CAS for post-CEA stenosis (group B).

## METHODS

**Patients.** This study included 180 patients considered high risk for CEA who underwent CAS during a 7-year period (June 2001 to June 2008) at our institution. This study was approved by our Institutional Review Board, and written informed consent was obtained from all patients. All patients were part of several carotid clinical trials (Table I), including:

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Competition of interest: none.

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**Table I.** Carotid stent trials

Carotid trial	Group A no. (%)	Group B no. (%)	Total no.
CAPTURE	43 (63.2)	66 (58.9)	109
EXACT	11 (16.4)	10 (8.9)	21
MAVERIC 1	2 (3)	9 (8)	11
MAVERIC 2	7 (10.5)	15 (13.4)	22
MAVERIC 3	2 (3)	2 (1.8)	4
Parodi	1 (1.5)	1 (0.9)	2
SHELTER	2 (3)	8 (7.1)	10
VIVA	0	1 (0.9)	1
Total	68	112	180

*CAPTURE*, Carotid Rx Acculink/Rx Accunet Post-approval Trial to Uncover Unanticipated or Rare Events; *EXACT*, rapid exchange carotid stent system Xact with Emboshield protection system by Abbott Medical; *Group A*, primary carotid artery stenting; *Group B*, carotid artery stenting for stenosis after carotid endarterectomy; *MAVERIC 1, 2, and 3*, evaluation of the Medtronic AVE Self-Expanding Carotid Stent System with Distal Protection in the Treatment of Carotid Stenosis; *Parodi*, Parodi Anti-Emboli System as an adjuvant cerebral protection device during carotid stent-supported angioplasty with the Boston Scientific Carotid Wallstent Monorail Endoprosthesis; *SHELTER*, Stenting of High Risk Patients: Extracranial Lesion Trial with Emboli Removal; *VIVA*, ViVEXX Carotid Revascularization Trial.

- MAVERIC 1, 2, and 3 (Evaluation of the Medtronic AVE Self-Expanding Carotid Stent System with Distal Protection in the Treatment of Carotid Stenosis started in July, 2002),
- SHELTER (Stenting of High Risk Patients: Extracranial Lesion Trial with Emboli Removal, October, 2001),
- Parodi (Parodi Anti-Emboli System as an adjuvant cerebral protection device during carotid stent-supported angioplasty with the Boston Scientific Carotid Wallstent Monorail Endoprosthesis, October, 2001),
- CAPTURE (Carotid Rx Acculink/Rx Accunet Post-approval Trial to Uncover Unanticipated or Rare Events, July, 2004),
- EXACT (rapid exchange carotid stent system Xact with Emboshield protection system by Abbott Medical, August, 2007), and
- VIVA (ViVEXX Carotid Revascularization Trial, November, 2005).

The inclusion and exclusion criteria were outlined by each clinical trial, and patients were selected according to the specific protocol of each trial. This study included high-risk patients as defined by the protocol of these trials and confirmed by their respective vascular surgeons. These high-risk categories generally included anatomic high risk, defined as post-CEA stenosis, high cervical lesion (>C2), neck irradiation, radical neck dissection, contralateral laryngeal nerve injury, and tracheostomy. They also included cardiac comorbidities, defined as New York Heart Association (NYHA) functional class III/IV heart failure or left ventricular ejection fraction  $\leq 35\%$ , recent myocardial infarction (MI)  $\leq 6$  weeks, unstable angina, or severe coronary artery disease. Other medical comorbidities included

chronic obstructive pulmonary disease with forced expiratory volume in 1 second  $< 30\%$ , dialysis-dependent renal failure, and liver failure. The indications for CAS included symptomatic  $\geq 50\%$  carotid artery stenosis and asymptomatic  $\geq 80\%$  carotid artery stenosis.

The demographic/clinical characteristics were collected by medical record review, and the intraoperative data were obtained from the records of the Circulatory Dynamic Laboratory (CDL) where the procedures were done. The CDL is an independent invasive vascular laboratory with an advanced imaging system (General Electric System), located outside the cardiac catheterization laboratories and operating rooms.

Statin use could not be analyzed in all patients. Before CAS, all patients underwent baseline preoperative carotid color duplex ultrasound (DU) imaging (done at a vascular laboratory accredited by the Intersocietal Commission for Accreditation of Vascular Laboratories), with or without computed tomography angiography (CTA) or magnetic resonance angiography (MRA), followed by carotid arteriograms.

We used our previously published criteria for optimal carotid DU velocity for defining severity of carotid artery stenosis.<sup>15</sup> Specifically, carotid stenosis of  $\geq 50\%$  was defined by a peak systolic velocity of  $> 140$  cm/s on DU examination with spectral broadening through systole, and  $\geq 80\%$  stenosis was defined by a peak systolic velocity of  $> 140$  cm/s and an end diastolic velocity of  $> 140$  cm/s. All stenoses before CAS were confirmed by a conventional carotid arteriogram and underwent independent preoperative and postprocedural neurologic evaluations. Postprocedural cerebral CT/MRI scans were only performed on patients with documented neurologic transient ischemic attacks (TIA) or strokes.

All patients were prescribed a regimen of 325 mg of aspirin and 75 mg of clopidogrel (Plavix; Bristol-Myers Squibb/Sanofi Pharmaceutical Partnership, Bridgewater, NJ) daily for 3 to 5 days before the CAS, which was followed by a regimen of 75 mg of clopidogrel and 325 mg aspirin daily after the procedure. Clopidogrel was continued for 6 weeks, and aspirin was continued indefinitely.

**CAS protocol.** Our technique for CAS has been described and published previously.<sup>1</sup> All procedures were done using distal cerebral protection devices, according to various carotid protocols. Predilatation was done in most patients with severe or tight stenosis before filter insertion using 3- or 4-mm balloons. Postdilatation using 5-mm balloons was also performed after stent deployment to achieve optimal stent strut position.

**Post-CAS surveillance and long-term follow-up.** All patients had immediate postprocedural carotid DU imaging, which was repeated at 30 days and every 6 months, or according to their protocol. Three patients were lost to follow-up beyond the immediate perioperative period; one in group A and two in group B.

The long-term follow-up data were assessed by patient examination in the Vascular Center of Excellence at our institution. For practical purposes and to comply with the

standard classification of carotid stenosis, we used a cutoff of <30% stenosis to indicate normal to minimal disease. Carotid stenoses were, therefore, classified into 30% to 49%, 50% to 79%, and 80% to 99% stenoses. Angiographic measurement of the stenoses were calculated according to the North American Symptomatic Carotid Endarterectomy Trial, basically by comparing the narrowest segment of the carotid stent with the diameter of the distal normal internal carotid artery (ICA) where the walls become parallel.<sup>16</sup>

We used our previously published criteria for optimal carotid DU velocity for defining severity of carotid in-stent stenosis.<sup>17</sup> Specifically, an ICA peak systolic velocity (PSV) of  $\geq 154$  cm/s was optimal for the diagnosis of  $\geq 30\%$  carotid in-stent stenosis, an ICA PSV of  $\geq 224$  cm/s was optimal for the diagnosis of  $\geq 50\%$  carotid in-stent stenosis, and an ICA PSV of  $\geq 325$  cm/s was optimal for the diagnosis of  $\geq 80\%$  carotid in-stent stenosis. All patients with  $\geq 80\%$  in-stent stenosis, as defined by DU imaging, underwent further imaging, including carotid arteriography or CTA, or both, for confirmation of the diagnosis or further intervention.

**Definitions and end points.** The clinical end points included TIAs (resolving  $\leq 24$  hours), a minor stroke (defined as a neurologic deficit persisting  $>24$  hours, resulting in grade I or II Rankin scale), or a major stroke (grades III-V Rankin scale). A stroke was referred to as an ipsilateral stroke if it affected the same cerebral hemisphere of the carotid stenting or a contralateral stroke if it affected the contralateral cerebral hemisphere of the stented carotid artery.

MI was defined as a Q-wave MI as noted in two or more leads, or non-Q-wave MI as noted by elevation of creatine kinase (CK) levels to greater than three times the upper limit of normal in the presence of elevated CK-MB (greater than upper limit of normal) and in absence of new Q-wave in two or more leads.

**Statistical methods.** The statistical comparison of continuous data was examined with the unpaired *t* test, and the discrete variables were compared with the  $\chi^2$  or Fisher exact test. The time to occurrence of events (time to  $\geq 50\%$  in-stent stenosis,  $\geq 80\%$  in-stent stenosis, or stroke or death) was calculated using the Kaplan-Meier method. Statistical comparisons were made with the Wilcoxon rank sum test.

## RESULTS

This study included 180 patients who underwent CAS during a 7-year period, with a mean follow-up of 21 months and a median of 19.0 months (range, 1-73 months) for group A and a mean of 25 months and a median of 22.6 months (range, 1-78 months) for group B. Table I summarizes the various CAS trials that were used in this series. Most patients were part of the CAPTURE trial.

Table II summarizes the demographic and clinical characteristics of this series. Procedures were for high-risk indications in 68 patients in group A in contrast to 112 patients in group B. Group B included 69 patients with stenosis that occurred at  $\geq 24$  months after primary CEA and

**Table II.** Demographics and clinical characteristics

Characteristic	Group A	Group B	P
Total patients	68	112	
Age, mean (range), y	70.3 (46-85)	69.7 (40-88)	.6781
Gender, %			
Male	62	54	.2822
Female	38	46	
Hypertension, %	78	84	.3142
Diabetes mellitus, %	47	43	.5823
Coronary artery disease, %	74	77	.6221
Congestive heart failure, %	26	13	.0175
Hypercholesterolemia, %	60	58	.7653
Renal failure w/dialysis, %	0	3	.2909
Renal failure w/o dialysis, %	19	21	.8176
Smoking, %	54	59	.1178
Pulmonary comorbidity, %	12	8	.4069
Follow-up, mean mon	21.23 (1-73)	25.30 (1-78)	.1243
Carotid stent location, %			
CCA/ICA	76	83	.2806
ICA only	24	17	
Indications			
Symptomatic $\geq 50\%$			
Amaurosis fugax	38	38	.9214
TIA/stroke	12	7	.2968
Asymptomatic $\geq 80\%$ stenosis	50	55	.7523

CCA, Common carotid artery; Group A, primary carotid artery stenting; Group B, carotid artery stenting for stenosis after carotid endarterectomy; ICA, internal carotid artery.

**Table III.** Perioperative complications at 30 days

Complication	Group A no. (%)	Group B no. (%)	Total no. (%)	P
Total patients	68	112	180	
Stroke	5 (7.4)	1 (0.9)	6 (3.3)	.0294
Death	1 (1.5)	0	1 (0.6)	
Combined stroke and/or death	5 (7.4)	1 (0.9)	6 (3.3)	.0294
Transient ischemic attack	3 (4)	0	3 (1.7)	
Amaurosis fugax	1 (1)	0	1 (0.6)	
Combined neurologic events	9 (13)	1 (0.9)	10 (5.6)	.0008

Group A, Primary carotid artery stenting; Group B, carotid artery stenting for stenosis after carotid endarterectomy.

43 patients with stenosis of  $<24$  months after primary CEA. The high-risk criteria were similar for all clinical trials used. The comorbidities in each individual trial were comparable for both groups. As noted in Table II, the demographic and clinical characteristics were comparable for both groups, except for congestive heart failure.

The immediate technical success was 100%; that is, there was no immediate technical failure in this series. The residual stenosis was 0% to 10%, except in five patients where it was between 10% and 30%.

**Early (30-day) perioperative outcome.** Table III summarizes the rate of perioperative stroke, death, and other complications. The perioperative rates of stroke or stroke, death, and MI, or both were statistically signifi-

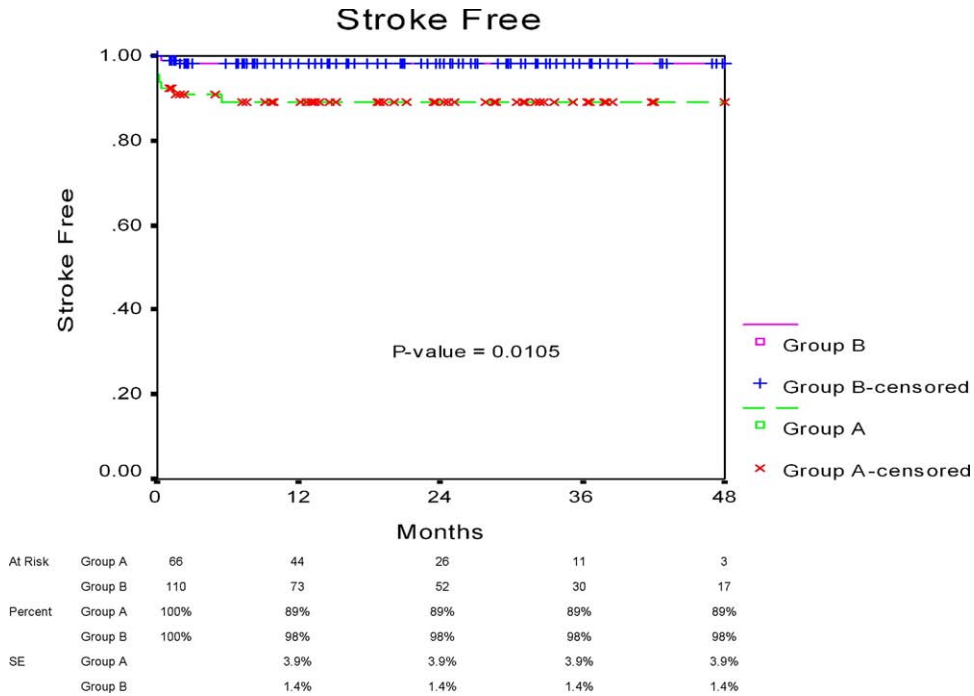


Fig 1. The rates of freedom from stroke at 1, 2, 3, and 4 years. Group A, Primary carotid artery stenting; Group B, carotid artery stenting for stenosis after carotid endarterectomy.

cantly worse for group A versus group B ( $P = .0294$ ). All early perioperative strokes were noted in the symptomatic patients of both groups, that is, five of 32 (16%) for group A and one of 50 (2%) for group B ( $P = .0313$ ). All of the perioperative strokes were determined to be embolic, except for a stroke secondary to cerebral hemorrhage in one patient in group A. All strokes were ipsilateral to the stented carotid artery, except for one in group A that affected the contralateral hemisphere.

Three of the five strokes in group A were noted immediately upon completion of the procedure, one was noted several hours after stenting, and one was noted  $\leq 24$  hours of stenting. Meanwhile, the stroke in group B was noted immediately after the procedure. This patient's stenosis was noted over 36 months after the primary CEA. Similarly, the causes of TIAs were thought to be embolic.

Overall, there were six perioperative strokes: five in the CAPTURE trial, using the ACCULINK (Abbott Vascular, Abbott Park, Ill)/ACCUNET (Abbott Vascular) system, and one in the EXACT trial using the XACT stent system (Abbott Vascular). No strokes occurred in the remaining carotid trials; however, the number of patients included from these trials was very limited.

**Midterm outcome.** Three patients in group A had late complications. Two of these were late TIAs, and neither of these patients was associated with significant ( $>50\%$ ) in-stent stenosis. One patient of the three with previous neck radiation in group A was found to have aneurysmal dilatation that was treated with a stent graft with an uneventful outcome. One patient in group B had a

Table IV. Incidence of restenosis

Restenosis	Group A no. (%)	Group B no. (%)	P
$<30\%$	39 (59)	64 (58)	.7605
30% to 49%	18 (27)	30 (27)	
50% to 79%	7 (11)	9 (8)	
$\geq 80\%$	2 (3)	7 (6)	$>.99$
Total <sup>a</sup>	66	110	
$<50\%$	57 (86)	94 (85)	.8672
$>50\%$	9 (14)	16 (15)	

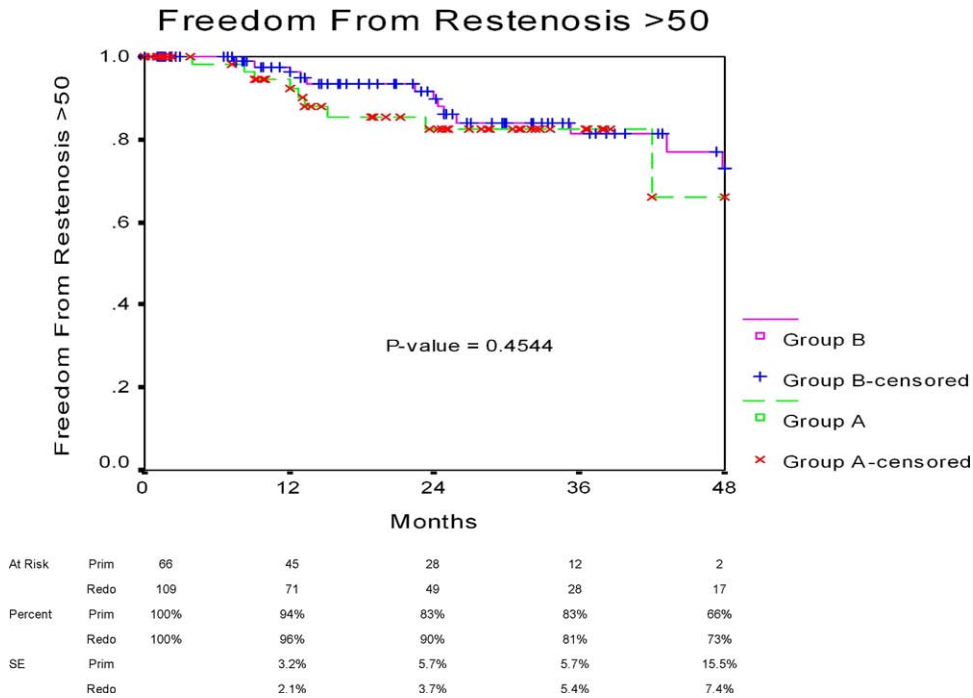
Group A, Primary carotid artery stenting; Group B, carotid artery stenting for stenosis after carotid endarterectomy.

<sup>a</sup>Four patients had no follow-up duplex ultrasound scans.

late TIA that was associated with 50% to 79% in-stent stenosis but refused further intervention.

Two late strokes occurred in group A versus one late stroke in group B, none of which were associated with significant  $\geq 50\%$  in-stent stenosis. The rates of freedom from stroke at 1, 2, 3, and 4 years were 89%, 89%, 89%, and 89% for group A versus 98%, 98%, 98%, and 98% for Group B ( $P = .0105$ ; Fig 1).

Table IV summarizes the incidence of restenosis for group A versus group B. Overall, 16 patients had 50% to 79% in-stent stenosis; seven in group A (10.6%) versus nine in group B (8.2%,  $P = .7605$ ). All were asymptomatic, except for a patient in group B who had a TIA and refused further intervention. The risk of  $\geq 80\%$  restenosis was twice as much in group B as in group A. Nine patients had  $\geq 80\%$



**Fig 2.** The rates of freedom from  $\geq 50\%$  carotid in-stent stenosis at 1, 2, 3, and 4 years. *Group A*, Primary carotid artery stenting; *Group B*, carotid artery stenting for stenosis after carotid endarterectomy.

in-stent stenosis: two in group A (3%) versus seven in group B (6.3%,  $P > .99$ ); none were associated with symptoms, except for a patient in group B who had a TIA that was treated with repeated stenting.

The rates of freedom from  $\geq 50\%$  carotid in-stent stenosis were 94%, 83%, 83%, and 66% for group A versus 96%, 91%, 83%, and 72% for group B ( $P = .4705$ ; Fig 2). The rates of freedom from  $>80\%$  carotid in-stent stenosis were 100%, 98%, 98%, and 78% for group A vs 99%, 96%, 92%, and 87% for group B ( $P = .7005$ ; Fig 3).

The rates of freedom from target vessel reintervention at 1, 2, 3, and 4 years were 100%, 100%, 100%, and 100% for group A versus 99%, 97%, 97%, and 92% for group B, respectively ( $P = .261$ ; Fig 4). Overall, there were more interventions in group B than in group A: four patients had reintervention, all of whom were in group B (3.6%). Three of these had repeat stenting: two for asymptomatic  $\geq 80\%$  in-stent stenosis and one for TIA and  $\geq 80\%$  in-stent stenosis. The fourth patient underwent a percutaneous transluminal angioplasty (PTA) only for asymptomatic  $\geq 80\%$  in-stent stenosis. Five other patients with  $\geq 80\%$  in-stent stenosis refused or were too sick for further intervention.

The survival rates at 1, 2, 3, and 4 years were 91%, 86%, 80%, and 80% for group A versus 96%, 91%, 85%, and 80% for group B ( $P = .5099$ ; Fig 5). Overall, there were eight late deaths in group A (12.1%) versus 13 in group B (11.8%;  $P = .952$ ). No late deaths were stroke-related. Seven of the late deaths were secondary to late MI, two were secondary to cardiopulmonary causes and multiorgan system failure, one was secondary to chronic obstructive pulmonary dis-

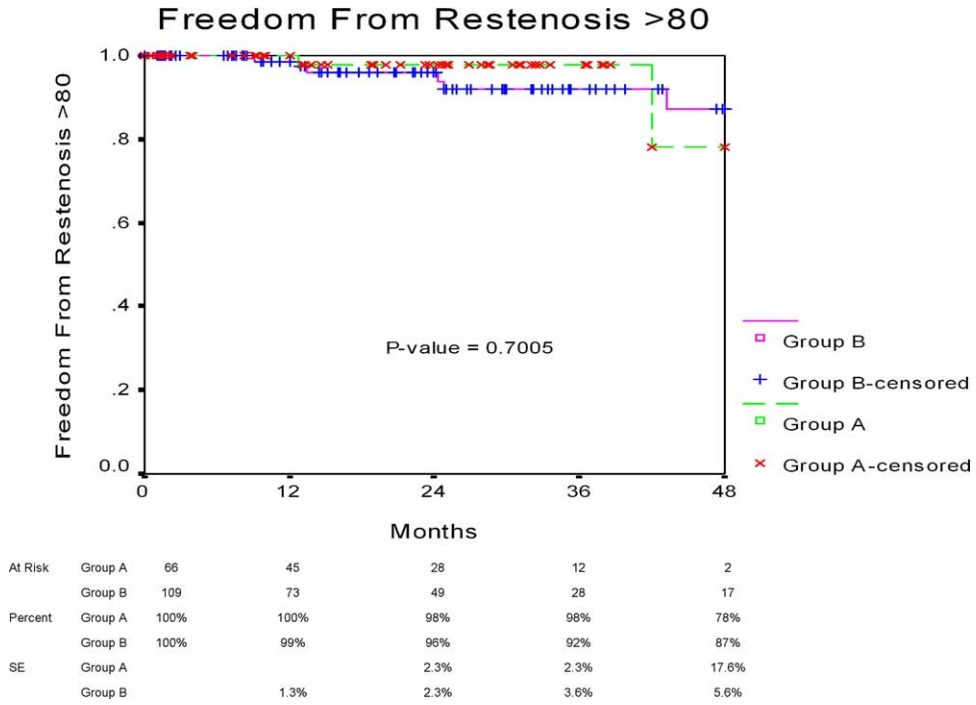
ease, one was secondary to lung cancer, one was secondary to gastrointestinal hemorrhage, and the remaining late deaths were of unknown causes.

A Cox regression analysis demonstrated that early stroke was significantly associated with group A versus group B, with an odds ratio of 8.9. No significant factors were associated with the incidence of in-stent stenosis of  $>50\%$  or  $>80\%$ .

## DISCUSSION

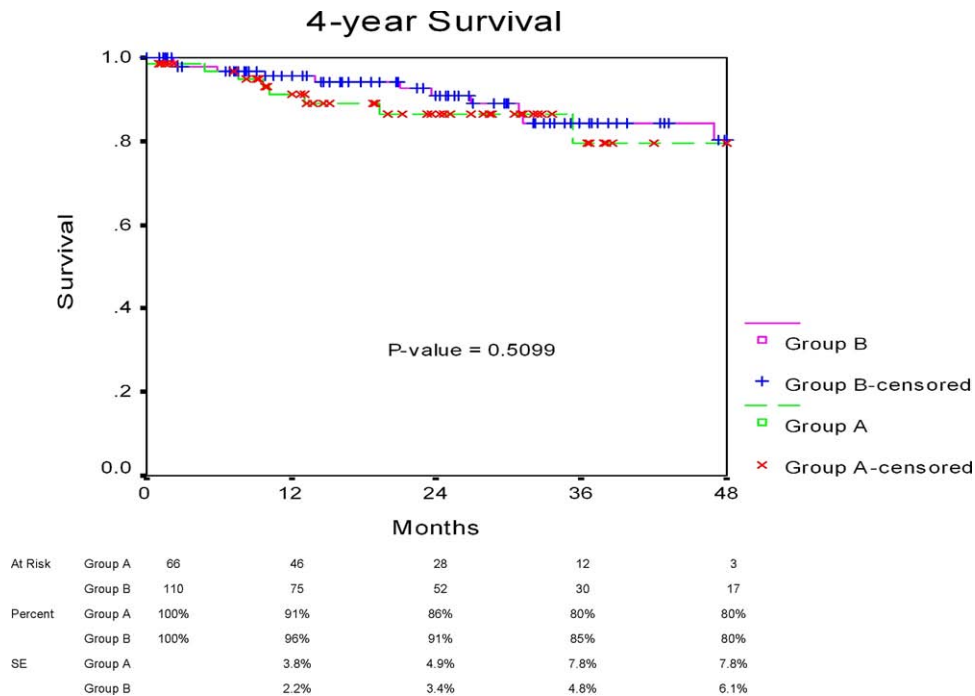
Atherosclerotic carotid artery disease has been implicated in 8% to 29% of all ischemic strokes.<sup>5</sup> Traditionally, CEA has been the procedure of choice for selected symptomatic and asymptomatic patients.<sup>16,18</sup> Carotid artery angioplasty was introduced in 1979,<sup>19</sup> and the first carotid stent in 1989.<sup>20</sup> As newer techniques in endovascular therapy evolve, such as the use of distal cerebral protection devices, and with more experience, CAS has been proposed as an alternative to CEA,<sup>2,3,21</sup> particularly in patients at high surgical risk. The data from the Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy (SAPPHIRE) trial<sup>2</sup> and the ACCULINK for Revascularization of Carotids in High-Risk Patients (ARCHeR) trial<sup>3</sup> demonstrated clinical outcomes that were not inferior to those reported for CEA in high-risk patients.

Despite the favorable clinical outcome for CAS in some of these studies,<sup>2,3,9,11</sup> its use has been questioned during the past 12 months since the Endarterectomy Versus Angioplasty in Patients With Symptomatic Severe Carotid



**Fig 3.** The rates of freedom from >80% carotid in-stent stenosis at 1, 2, 3, and 4 years. *Group A*, Primary carotid artery stenting; *Group B*, carotid artery stenting for stenosis after carotid endarterectomy.

**Fig 4.** The rates of freedom from target vessel reintervention at 1, 2, 3, and 4 years. *Group A*, Primary carotid artery stenting; *Group B*, carotid artery stenting for stenosis after carotid endarterectomy.



**Fig 5.** The survival rates at 1, 2, 3, and 4 years. *Group A*, Primary carotid artery stenting; *Group B*, carotid artery stenting for stenosis after carotid endarterectomy.

Stenosis (EVA-3S)<sup>12</sup> and Stent-Supported Percutaneous Angioplasty of the Carotid Artery versus Endarterectomy (SPACE) trial<sup>13</sup> were published.

The EVA-3S trial analyzed the results of a randomized, multicenter, noninferiority trial comparing CAS (265 patients) with 262 CEA (262 patients) in patients with symptomatic  $\geq 50\%$  carotid stenosis. The perioperative nonfatal stroke rate was 8.8% for CAS versus 2.7% for CEA ( $P = .004$ ), and the incidence of any stroke or death was 9.6% for CAS versus 3.9% for CEA ( $P = .01$ ).

The SPACE trial is a multicenter, randomized, noninferiority trial, comparing 1600 patients (CEA vs CAS) with symptomatic carotid stenosis. The ipsilateral stroke rate was 6.5% for CAS versus 5.1% for CEA. The combined stroke and death rate was 7.7% for CAS and 6.5% for CEA. The SPACE trial failed to prove the noninferiority of CAS compared with CEA for perioperative complication rates.

Most of the mentioned studies, however, compared CAS versus CEA for patients of different risk levels. CAS in these studies was done for both primary carotid atherosclerotic disease and stenosis after CEA.

For years, redo CEA has been the standard treatment for post-CEA stenosis. This may carry a higher risk of complications, including perioperative stroke, TIAs, and cranial nerve injury. Redo is believed to be more difficult than primary CEA because of the dense scarring surrounding the carotid artery and the difficulty in obtaining tissue cleavage planes. Morbidity (including cranial nerve injury) and mortality rates of 8% to 20% after redo CEA have been

reported<sup>22-24</sup>; however, several other authorities have reported better results.<sup>25-30</sup>

Carotid percutaneous transluminal angioplasty and stenting is increasing in popularity and has been advocated by some investigators as an alternative to reoperation for post-CEA carotid stenosis.<sup>31-38</sup> In a multicenter study of 358 CAS procedures, New et al<sup>35</sup> reported a 30-day stroke and death rate of 3.7% with a 3-year rate of freedom from all strokes of 96% (SE, 1%). They concluded that CAS could be performed in patients with restenosis with 30-day perioperative complication rates comparable with most published series on reoperation.

In a study by Hobson et al,<sup>34</sup> CAS was successful in all 17 cases and produced no periprocedural neurologic deficits or deaths. Similar favorable results were reported by Yadav et al,<sup>33</sup> with only one minor stroke in 25 CAS procedures in 22 mainly symptomatic patients, and De Borst et al,<sup>38</sup> who reported 57 successful CAS procedures in 55 patients.

Cuadra et al<sup>39</sup> prospectively analyzed collected data on CAS procedures done during a 10-year period and compared between CAS performed for restenosis versus primary atherosclerosis. The 30-day stroke and stroke/death rates were not statistically significantly different between CAS for restenosis ( $n = 118$ , 2.5% and 5.1%) and CAS for primary atherosclerosis ( $n = 99$ , 3% and 3%). Within the CAS for restenosis group, these outcomes were also similar when 49 patients treated for late recurrence ( $>24$  months after CEA) were compared with 67 patients who were

treated for early recurrence. When stroke and TIAs were compared, however, patients with late recurrence had higher rates than early recurrence (10% vs 1.5%,  $P = .049$ ).

Our present study compares the early and midterm outcome of group A versus group B in 180 patients. The perioperative stroke rate was 7.4% for group A versus 0.9% for group B. The stroke-free rates at 1, 2, 3, and 4 years for group A were 89%, 89%, 89%, and 89% versus group B at 98%, 98%, 98%, and 98%, respectively ( $P = .0105$ ). This could be explained by the nature of primary disease, which involves plaque formation and possible ulceration and may carry a higher chance of embolization, compared with restenosis, where the pathology is mainly intimal hyperplasia in the first 2 to 3 years and may carry a lower chance of embolization. The five perioperative strokes in group A were in symptomatic patients and the perioperative stroke in group B was in a symptomatic patient who had CAS for post-CEA stenosis noted >36 months after the primary CEA. Our results differ from Cuadra et al,<sup>39</sup> because the treated lesions in the CEA stenosis group (group B) in our series might have been different from the treated lesions in their series.

Theiss et al<sup>14</sup> conducted a subgroup analysis of Pro-CAS, a prospective, multicenter registry of CAS. They performed a logistic regression analysis of possible predictive factors for stroke/death in 5341 interventions and found that primary interventions had a higher stroke/death rate of 3.8% versus 1.3% for intervention for restenosis.

Recently, the Society for Vascular Surgery (SVS) Vascular Registry also reported the early outcome for patients with CAS based on the etiology of carotid disease.<sup>40</sup> The perioperative stroke rate for patients with atherosclerotic lesions was 4.18% (41 of 982) versus 2.14% (18 of 468) for patients with nonatherosclerotic lesions ( $P = .0486$ ).

Our midterm follow-up showed that  $\geq 80\%$  in-stent stenosis is somewhat higher in group B patients compared with group A patients (6.4% vs 3%). Most of the patients with in-stent stenosis were asymptomatic, however, and did not require reintervention.

Recent studies suggest that previous CEA is a risk factor for restenosis. Zhou et al<sup>41</sup> reviewed 208 CAS procedures in 188 patients and found a 3.4% incidence of in-stent restenosis. Risk factor analysis identified patients with previous CEA to be at risk for in-stent restenosis.

Our study has limitations because it was a retrospective chart review; however, all of the patients were part of several prospective carotid stent trials. Also, the sample size in this study may not be large enough for strong conclusions. With more patients and a longer follow-up, our conclusions might have been different. However, until we have a randomized prospective study, the data from our present study can be useful.

## CONCLUSIONS

CAS for CEA stenosis carried a lower risk of early postprocedural neurologic events than primary CAS, with a trend toward a higher restenosis rate during follow-up. All

perioperative strokes were noted in the symptomatic patients of both groups.

## AUTHOR CONTRIBUTIONS

Conception and design: AA, SA, JB, AN, PS, LD, ME

Analysis and interpretation: AA, SA, PS, LD

Data collection: SA, JB, TK, MT, ZA

Writing the article: AA, SA, AN

Critical revision of the article: AA, SA, LD

Final approval of the article: AA, SA, JB, AN, PS, LD, TK, ME, MT, ZA

Statistical analysis: AA, LD

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