Risk-adjusted 30-day outcomes of carotid stenting and endarterectomy: Results from the SVS Vascular Registry

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Objective: **As the first operational societal registry of carotid procedures, the Outcomes Committee of the Society for Vascular Surgery (SVS) developed the Vascular Registry (VR) in response to the Centers for Medicare and Medicaid Services' (CMS) National Coverage Decision on carotid artery stenting (CAS). Although CMS requires data submission only on CAS, the VR collects similar data on carotid endarterectomy (CEA) to allow comparison of outcomes, as well as potential for expansion to other procedures.**

Methods: **SVS-VR on-line provider-reported data include baseline through follow-up visits to better understand long-term risks and benefits associated with CAS and CEA. The primary outcomes are combined death, stroke, and myocardial infarction (MI). An independent data coordinating center maintains the database, which is Health Insurance Portability and Accountability Act (HIPAA)-compliant and auditable.**

Results: **As of December 26, 2007, 6403 procedures with discharge data were entered by 287 providers at 56 centers on 2763 CAS patients (1450 with 30-day outcomes, 52.5%) and 3259 CEA patients (1368 with 30-day outcomes, 42%). Of the total cohort, 98% of CEA and 70.7% of CAS ($P < .001$) were performed for atherosclerotic disease. Restenosis accounted for 22.3% and post-radiation induced stenosis in 4.5% of CAS patients. Preprocedure lateralizing neurologic symptoms were present in a greater proportion of CAS patients (49.2%) than CEA patients (42.4%, $P < .001$). CAS patients also had higher preprocedure prevalence of coronary artery disease (CAD), MI, congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), and cardiac arrhythmia. For CAS, death/stroke/MI at 30 days was 7.13% for symptomatic patients and 4.60% for asymptomatic patients ($P = .04$). For CEA, death/stroke/MI at 30 days was 3.75% in symptomatic patients and 1.97% in asymptomatic patients ($P = .05$). After risk-adjustment for age, history of stroke, diabetes, and American Society of Anesthesiologists (ASA) grade (ie, factors found to be significant confounders in outcomes using backwards elimination), logistic regression analysis suggested better outcomes following CEA. There were no statistically significant differences when examining CAS outcomes based on center volume. CAS in atherosclerotic disease had significantly worse outcomes than in nonatherosclerotic stenosis. When CAS and CEA were compared in the treatment of atherosclerotic disease only, the difference in outcomes between the two procedures was more pronounced, with death/stroke/MI 6.42% after CAS vs 2.62% following CEA, $P < .0001$.**

Conclusion: **Following best possible risk adjustment of these unmatched groups, symptomatic and asymptomatic CAS patients had significantly higher 30-day postprocedure incidence of death/stroke/MI when compared with CEA patients. The initial 1.5 years of data collection provide proof of concept that a specialty society based VR can succeed in meeting regulatory and scientific goals. With continued enrollment and follow-up, analysis of SVS-VR will supplement randomized trials by providing real-world comparisons of CAS and CEA with sufficient numbers to serve as an outcome assessment tool of important patient subsets and across the spectrum of peripheral vascular procedures. (J Vasc Surg 2009;49:71-9.)**

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The Society for Vascular Surgery (SVS) Outcomes Committee developed the Vascular Registry (VR) for Carotid Procedures in response to the 2004 Centers for Medicare and Medicaid Services (CMS) National Coverage Decision (NCD) on carotid artery stenting (CAS)[1] for symptomatic high-risk patients with >70% stenosis, and other patients enrolled in IDE trials, which was based upon the Acculink for Revascularization of Carotids in High-Risk (ARCHeR)[2] (Guidant Corporation, Santa Clara, Calif) and Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy (SAPPHiRE)[3] (Cordis Corporation, Warren, NJ) clinical trials approved by the FDA. Although CMS requires data submission for facility certification/recertification only on CAS, SVS designed VR to collect similar data on carotid endarterectomy (CEA) to allow comparison of outcomes, with potential for expansion to procedures involving other vascular beds.

As the first societal registry to enroll CAS and CEA patients, the SVS-VR is available to all clinical facilities and individual providers in the United States wishing to participate. The VR does not have inclusion or exclusion criteria for patient eligibility and is reliant on site entry of patients in whom CAS or CEA is performed. Since the VR is designed to capture real-world practices, it does not have predefined visit intervals and relies upon each facility's standards of care practice. However, for purposes of reporting, data are allocated to 30-day, 6-month, 1-year, and annual subsequent time points. The VR Audit Program has two purposes: (1) to ensure all cases of CAS/CEA are being reported; and, (2) to verify data accuracy and completeness.

The VR allows each facility real-time access to downloadable datasets of all carotid procedures entered in the registry for that facility with the ability to assess correlations among practitioners, procedures, comorbidities, and outcomes within the facility. In addition, although CMS only requires in-hospital data for certification, longer follow-up data were included in the VR since perioperative mortality and complications may take place after discharge, and longer follow-up would provide information on recurrent disease. Furthermore, the VR provides reports that allow comparison of outcomes among various facilities in an anonymous manner.

The purpose of this publication is to report the feasibility of the VR and to provide the baseline demographics and risk-adjusted 30-day outcomes of CAS and CEA.

METHODS

VR data are reported by providers through web-based electronic data capture. The measurement schedule includes baseline (preoperative) demographics, medical history, carotid symptom status, and preprocedural diagnostic imaging and laboratory; procedural (CAS or CEA) information including clinical utility, and intraoperative and predischarge complications; and follow-up information such as postoperative mortality, stroke, myocardial infarction and other morbidity. All data entered into the VR are fully compliant with the Health Insurance Portability and Accountability Act (HIPAA) regulations and are auditable. All data reports and analyses performed include only de-identified and aggregated data.

The New England Research Institutes, Inc (NERI, Watertown, Mass) maintains the on-line database. Funding for the administration and database management of the VR has been provided by the Society for VR.

Outcomes. In order to provide information required by the CMS NCD, the primary outcome measure is combined death, stroke, and myocardial infarction (MI). Analysis of 30-day outcomes was based on only those patients who had at least a 30-day postprocedure visit (window 15 to 59 days) or who experienced an endpoint (death, stroke, or MI) within 30 days of treatment. Stroke is defined as any nonconvulsive, focal neurological deficit of abrupt onset persisting more than 24 hours. The ischemic event must correspond to a vascular territory. An MI is classified as either Q wave MI in which one of the following criteria is required: (1) chest pain or other acute symptoms consistent with myocardial ischemia and new pathological Q waves in two or more contiguous ECG leads; or (2) new pathologic Q waves in two or more contiguous ECG leads and elevation of cardiac enzymes; or (3) non-Q wave MI, defined as CK ratio >2, and CK-MB >1 in the absence of new, pathological Q waves.

Procedural success data were also collected. A procedure, either CAS or CEA, is deemed successful when all of its components are completed without the need of conversion (CAS to CEA or vice versa) or its abandonment prior to completion.

Statistical methods. Tests of statistical significance were conducted with χ^2 or Fisher's exact tests for categorical variables and analysis of variance (ANOVA) for continuous variables. Descriptive statistics are listed as mean ± standard deviation for continuous variables and percent (frequency) for categorical variables. Subset analyses were performed using the two-tailed t test for continuous variables and the χ^2 or Fisher exact, as necessary, for discrete/categorical data. Unadjusted and adjusted odds ratios were used to compare the primary outcomes across treatment groups. Odds ratios were adjusted for age and any significant baseline factors that were kept after using backwards elimination methods. Differences were considered significant if $P < .05$. All statistical analyses were performed by NERI using SAS Statistical Software (Cary, NC).

RESULTS

For the purpose of this study, data collected in the VR from beginning of electronic data entry on July 11, 2005 to December 26, 2007 were analyzed for death/stroke/MI and compared between CAS and CEA at 30 days postprocedure. Since CMS requires in-hospital peri-CAS results for recertification, a subgroup analysis was performed to analyze intraoperative and predischarge data. A total of 6403 procedures with discharge data were entered by 287 providers from six specialties at 56 centers on 2763 CAS patients (1450 with 30-day outcomes, 52.5%) and 3259 CEA patients (1368 with 30-day outcomes, 42%). The

Table I. Baseline demographics and past medical history for all patients (entire cohort) by treatment arm

	CAS *n = 2763*	*CEA* *n = 3259*	P *value*[a]
Age (y, mean)	70.74 ± 9.86 (range 36-96)	71.06 ± 9.52 (range 24-99)	.208
Gender (male, %)	59.8% (1651/2763)	58.5% (1907/3259)	.330
White (%)	92.7% (2560/2763)	93.2% (3036/3259)	.447
Hispanic	4.2% (115/2763)	2.3% (76/3259)	< .001
Etiology			
Atherosclerosis	70.7% (1954/2763)	98.0% (3193/3259)	< .001
Dissection	0.9% (25/2763)	0.1% (4/3259)	
Fibromuscular dysplasia	0.1% (4/2763)	0.1% (4/3259)	
Radiation	4.5% (123/2763)	0.2% (5/3259)	
Trauma	0.3% (7/2763)	0.1% (2/3259)	
Restenosis	22.3% (615/2763)	1.2% (38/3259)	
Other	1.3% (35/2763)	0.4% (13/3259)	
Symptomatology (% symptomatic)	49.2% (1359/2763)	42.4% (1382/3259)	< .001
Coronary artery disease	60.8% (1679/2763)	48.1% (1569/3259)	< .001
Myocardial infarction	22.1% (610/2763)	16.5% (537/3259)	< .001
Valvular heart disease	7.3% (203/2763)	7.3% (238/3259)	.948
Cardiac arrhythmia	13.2% (365/2763)	12.3% (402/3259)	.310
Congestive heart failure	13.5% (373/2763)	6.9% (226/3259)	< .001
Hypertension	80.2% (2215/2763)	80.9% (2637/3259)	.465
Diabetes	33.0% (912/2763)	28.8% (940/3259)	< .001
Stroke (CVA)	25.4% (702/2763)	19.2% (626/3259)	< .001
Transient ischemic attack	21.2% (587/2763)	18.8% (612/3259)	.017
TMB/amaurosis fugax	7.1% (196/2763)	6.5% (213/3259)	.391
COPD	17.9% (494/2763)	15.8% (516/3259)	.034
Renal failure (Cr ≥ 3 mg/dL)	3.3% (91/2763)	3.1% (100/3259)	.619
Peripheral vascular disease	37.4% (1033/2763)	34.8% (1133/3259)	.035
GI ulcer/bleeding	3.5% (97/2763)	2.5% (82/3259)	.024
Current or past smoker	58.2% (1609/2763)	55.8% (1819/3259)	.059
Cancer	16.8% (465/2763)	11.5% (376/3259)	< .001
Coagulopathy	1.0% (27/2763)	1.3% (43/3259)	.217
ASA grade			
≤3	91.5% (2529/2763)	92.9% (3029/3259)	.041
>3	8.5% (234/2763)	7.1% (230/3259)	
NYHA scale			
≤2	87.4% (2415/2763)	93.2% (3038/3259)	< .001
>2	12.6% (348/2763)	6.8% (221/3259)	

CAS, Carotid artery stenting; *CEA,* carotid endarterectomy; *CVA,* cerebrovascular accident; *TMB,* transient monocular blindness; *COPD,* chronic obstructive pulmonary disease; *GI,* gastrointestinal; *ASA,* American Society of Anesthesiologists; *NYHA,* New York Heart Association.
[a]*P* values are all found using χ^2 tests.

specialties represented in the VR are vascular surgery, interventional cardiology, interventional radiology, neurosurgery, neuroradiology, and cardiothoracic surgery. Baseline demographics for the entire cohort by treatment arm are presented in Table I. The average age was 71 years, approximately 59% were male, and 93% were white for both treatment arms.

There was a statistically significant difference in symptomatology, with 49.2% of CAS and 42.4% of CEA being performed in patients presenting with lateralizing neurologic symptoms ($P < .001$). CAS patients had higher prevalence of preprocedure stroke (25% vs 19% CEA, $P < .001$), transient ischemic attack (TIA) (21% vs 19% CEA, $P = .02$), CAD (61% vs 48% CEA, $P < .001$), MI (22% vs 17% CEA, $P < .001$), CHF (13% vs 7% CEA, $P < .001$), chronic obstructive pulmonary disease (COPD) (18% vs 16% CEA, $P = .035$), peripheral vascular disease (37% vs 35% CEA, $P = .035$), and cancer (17% vs 12% CEA, $P < .001$). In addition, the CAS arm had a statistically significant higher incidence of American Society of Anesthesiologists (ASA) grade >3 (9% vs 7% CEA, $P = .04$) and New York Heart Association (NYHA) class for congestive heart failure >2 (13% vs 7% CEA, $P < .001$).

There was no significant difference in procedural success rates between CEA (99.9%) and CAS (99.1%). The CAS procedural failures include conversions to CEA. A total of 38 CAS patients (1.4%) had a second ipsilateral procedure also captured in the VR; while two had a third ipsilateral procedure. Of these secondary procedures, six were considered conversions to CEA (defined as a CEA performed on the same side within 30 days of the initial CAS procedure). Of the CEA patients, 14 (0.4%) had a second ipsilateral procedure and none had a third ipsilateral procedure.

In order to report on 30-day outcomes, an assessment of follow-up visits was made. At the time of the data freeze, there were a total of 56 sites participating in the VR. Of those, 37 sites had entered follow-up information on at

Table II. Baseline demographics and past medical history by treatment arm in 30-day follow-up cohort

	CAS *n = 1450*	*CEA* *n = 1368*	P *value*[a]
Age (y, mean)	70.78 ± 10.03 (range 37-94)	71.17 ± 9.39 (range 35-95)	.280
Gender (male, %)	59.5% (863/1450)	59.7% (817/1368)	.912
White (%)	93.6% (1357/1450)	94.9% (1298/1368)	.141
Hispanic	3.3% (48/1450)	1.4% (19/1368)	< .001
Etiology			
Atherosclerosis	67.7% (982/1450)	97.8% (1338/1368)	< .001*
Dissection	0.8% (12/1450)	0.3% (4/1368)	
Fibromuscular dysplasia	0.1% (2/1450)	0.2% (3/1368)	
Radiation	5.4% (79/1450)	0.3% (4/1368)	
Trauma	0.2% (3/1450)	0.1% (2/1368)	
Restenosis	24.3% (353/1450)	1.1% (15/1368)	
Other	1.3% (19/1450)	0.1% (2/1368)	
Carotid symptomatology (% symptomatic)	44.5% (645/1450)	37.0% (506/1368)	< .001
Coronary artery disease	61.4% (890/1450)	45.7% (625/1368)	< .001
Myocardial infarction	23.7% (343/1450)	15.6% (214/1368)	< .001
Valvular heart disease	7.7% (112/1450)	6.6% (90/1368)	.239
Cardiac arrhythmia	13.8% (200/1450)	11.1% (152/1368)	.031
Congestive heart failure	14.7% (213/1450)	6.9% (95/1368)	< .001
Hypertension	81.6% (1183/1450)	78.8% (1078/1368)	.064
Diabetes	33.0% (478/1450)	26.1% (357/1368)	< .001
Stroke (CVA)	25.1% (364/1450)	20.5% (281/1368)	.004
Transient ischemic attack	21.7% (314/1450)	18.9% (259/1368)	.073
TMB/amaurosis fugax	7.9% (114/1450)	5.0% (68/1368)	.002
COPD	18.1% (262/1450)	12.4% (170/1368)	< .001
Renal failure	2.9% (42/1450)	2.3% (31/1368)	.292
Peripheral vascular disease	38.3% (556/1450)	46.1% (631/1368)	< .001
GI ulcer/bleeding	4.0% (58/1450)	2.5% (34/1368)	.024
Current or past smoker	59.3% (860/1450)	55.6% (761/1368)	.048
Cancer	19.5% (283/1450)	9.8% (134/1368)	< .001
Coagulopathy	1.3% (19/1450)	1.5% (21/1368)	.614
ASA grade			
≤3	93.7% (1359/1450)	95.5% (1306/1368)	.041
>3	6.3% (91/1450)	4.5% (62/1368)	
NYHA scale			
≤2	86.8% (1258/1450)	90.2% (1234/1368)	.004
>2	13.2% (192/1450)	9.8% (134/1368)	

CAS, Carotid artery stenting; *CEA,* carotid endarterectomy; *CVA,* cardiovascular accident; *TMB,* transient monocular blindness; *COPD,* chronic obstructive pulmonary disease; *GI,* gastrointestinal; *ASA,* American Society of Anesthesiologists; *NYHA,* New York Heart Association.
[a]*P* values are all found using χ^2 tests except for etiology which uses Fisher exact test (denoted with an asterisk *).

least 20% of their enrolled patients. In order to capture all the visits, wide visit windows were used for each interval. For example, for 30-day complications, any complication that was reported to have happened within 30 days of the procedure and was reported by the patient during a visit that occurred 15 to 59 days postprocedure was considered for the 30-day interval. A sub-dataset of patients with any follow-up that accurately determine 30-day complication rates was created. Of the entire cohort (6022 patients), 2818 (44%) patients had a follow-up visit or died within 30 days (CAS = 1450, 52.2% of total CAS patients; CEA = 1368, 42% of total CEA patients).

In order to ensure adequate comparison of baseline risk factors, Table II shows the baseline demographic and medical history of the subset of patient with follow-up information. Similar to the entire cohort, the subset of patients with follow-up demonstrated a statistically significant difference in symptomatology, with 45% of CAS and 37% of CEA being performed for symptomatic disease ($P < .001$). CAS patients had higher prevalence of preprocedure stroke (25% vs 21% CEA, $P = .004$), transient monocular blindness (TMB)/amaurosis fugax (8% vs 5% CEA, $P = .002$), CAD (61% vs 46% CEA, $P < .001$), MI (24% vs 16% CEA, $P < .001$), cardiac arrhythmia (14% vs 11% CEA, $P = .03$), CHF (15% vs 7% CEA, $P < .001$), diabetes (33% vs 26% CEA, $P < .001$), COPD (18% vs 12% CEA, $P < .001$), gastrointestinal (GI) ulcer/bleeding (4% vs 2% CEA, $P = .02$), smoking (59% vs 56% CEA, $P = .05$), and cancer (19% vs 10% CEA, $P < .001$). In patients with follow-up, there was a higher incidence of peripheral vascular disease in the CEA arm (46% vs 38% CAS, $P < .001$). In addition, the CAS arm had a statistically significant higher incidence of ASA grade >3 (6% vs 5% CEA, $P = .04$) and NYHA class >2 (13% vs 10% CEA, $P = .04$).

Procedurally, out of 1450 CAS patients, 1376 (94.9%) had embolic protection and 74 (5.1%) did not. Out of 1368 CEA patients, 952 (69.6%) had patch and 416 (30.4%) did not. For the subset of patients with 30-day follow-up, there

Table III. Outcomes at 30-days (includes intraop and predischarge) by treatment arm in 30-day follow-up cohort

Outcome	*CAS n = 1450 % (m)*	*CEA n = 1368 % (m)*	P *value*
Combined death/ stroke/MI	5.72% (83/1450)	2.63% (36/1368)	<.001
Death	2.07% (30/1450)	0.73% (10/1368)	.004
Stroke	3.52% (51/1450)	1.68% (23/1368)	.003
MI	1.17% (17/1450)	0.58% (8/1368)	.110
TIA	1.59% (23/1450)	0.80% (11/1368)	.060
TMB/amaurosis fugax	0.21% (3/1450)	0.00% (0/1368)	.250

CAS, Carotid artery stenting; *CEA,* carotid endarterectomy; *MI,* myocardial infarction; *TIA,* transient ischemic attack; *TMB,* transient monocular blindness.
Events were defined as any event occurring intraop, predischarge or after discharge up to 30 days. These events were found on procedure and follow-up forms.
The event rates in above table are per-patient.

Table IV. Unadjusted and adjusted odds ratios for CAS vs CEA in 30-day follow-up cohort

30-day outcomes	*CAS (vs CEA) - unadjusted*	P *value*	*CAS (vs CEA) - adjusted*[a]	P *value*
Death/stroke/MI	2.247	<.001	1.965	<.001
Death/stroke	2.331	<.001	2.016	.002
Death	2.865	.004	2.513	.013
Stroke	2.132	.003	1.812	.021
MI	2.016	.103	1.789	.181

CAS, Carotid artery stenting; *CEA,* carotid endarterectomy; *MI,* myocardial infarction; *ASA,* American Society of Anesthesiologists.
[a]Adjusted for age and any statistically significant baseline factors and then used backwards elimination to get a parsimonious model consisting of age, diabetes, stroke, and ASA grade (≤3, >3).

were unadjusted statistically significant differences among 30-day event rates between treatment arms, as seen in Table III. The CAS arm had higher 30-day event rates compared with CEA. This significant difference was maintained even after the data were risk-adjusted. Table IV provides the unadjusted and adjusted odds ratios for several pertinent outcomes using logistic regression. Age, race/ethnicity, symptomatology, history of atherosclerosis, CAD, MI, arrhythmia, CHF, diabetes, TIA, TMB/amaurosis fugax, stroke, COPD, peripheral vascular disease (PVD), GI bleed, cancer, ASA grade, and NYHA class were all considered as potential confounders on the outcomes of death, stroke, and MI. Mean-centered age, diabetes, stroke, and ASA grade (≤3, >3) were significantly different between the CAS and CEA arms at baseline and had a significant effect on the outcomes of death, stroke, and MI using backwards elimination techniques. Therefore, a parsimonious model of mean-centered age, diabetes, stroke, and ASA grade (≤3, >3) was used to adjust the estimates, which are presented in Table IV.

Table V. 30-day endpoints by site by CAS volume

30-day adverse event	*CAS patient volume* <25 patients 26 sites % (m)	25-50 patients 11 sites % (m)	>50 patients 13 sites % (m)	P *value*[a]
Mortality	1.67% (2)	2.79% (5)	2.00% (23)	.6602
Stroke	3.33% (4)	4.47% (8)	3.39% (39)	.7226
MI	0.83% (1)	1.12% (2)	1.22% (14)	1.0000
TIA	3.33% (4)	1.12% (2)	1.48% (17)	.2522
TMB/ amaurosis fugax	0.83% (1)	0.00% (0)	0.17% (2)	.2665
Death, Stroke, or MI	5.83% (7)	7.26% (13)	5.47% (63)	.5956

CAS, Carotid artery stenting; *MI,* myocardial infarction; *TIA,* transient ischemic attack; *TMB,* transient monocular blindness.
Events were defined as any event after discharge up to 30 days. These events were found on follow-up forms.
The event rates in above table are per-patient.
Columns represent patients treated at site with particular patient volume:
26 sites with <25 patients.
11 sites with 25-50 patients.
13 sites with >50 patients.
[a]*P* values were based on Fisher exact test.

Although preoperative stroke was included in the risk adjustment model, TIA and TMB/amaurosis fugax were not because they were not statistically significant factors on backward elimination.

In order to analyze CAS outcomes based on the experience of the medical center performing this procedure, centers were divided into those performing less than 25 procedures, 25 to 50 procedures, and over 50 procedures (Table V). The data show no statistically significant difference in outcomes based on the number of CAS procedures performed.

There was a statistically significant difference in carotid artery disease etiology, with 98% of CEA compared with 70.7% of CAS ($P < .001$) being performed for atherosclerotic disease. In the CAS arm, 22.3% and 4.5% were performed for recurrent stenosis and radiation-induced stenosis, respectively. Within the CAS arm, when we compared the results based on the etiology of the stenotic lesion, there was a statistically significant higher incidence of 30-day postprocedural stroke ($P = .049$) when the atherosclerosis group (41/982, 4.1%) was compared with the nonatherosclerosis group (10/468, 2.1%), Table VI. When CAS and CEA were compared in the treatment of atherosclerotic disease only, the difference in outcomes between the two procedures was more pronounced, with CAS faring worse in death/stroke/MI (6.42% vs 2.62% CEA, $P < .0001$, respectively), death (2.04% vs 0.75% CEA, $P = .0085$, respectively), and stroke (4.18% vs 1.64% CEA, $P = .0003$; Table VII).

In addition to examining the adjusted odds ratios in Table IV, a subset analysis of symptomatic vs asymptomatic patients was performed. Table VIII demonstrates that symptomatic patients fared worse than asymptomatic pa-

Table VI. Outcomes at 30-days (includes intra-op and predischarge) in CAS based on the etiology of carotid disease

	CAS		
30-day adverse event	*Atherosclerotic n = 982 % (m/n)*	*Nonatherosclerotic n = 468 % (m/n)*	P *value*[a]
Death, stroke, or MI	6.42% (63/982)	4.27% (20/468)	.1159
Mortality	2.04% (20/982)	2.14% (10/468)	1.0000
Stroke	4.18% (41/982)	2.14% (10/468)	.0486
MI	1.43% (14/982)	0.64% (3/468)	.2962
TIA	1.73% (17/982)	1.28% (6/468)	.6552
TMB/amaurosis fugax	0.10% (1/982)	0.43% (2/468)	.2451

CAS, Carotid artery stenting; *MI*, myocardial infarction; *TIA*, transient ischemic attack; *TMB*, transient monocular blindness.
Events were defined as any event after discharge up to 30 days. These events were found on follow-up forms.
The event rates in above table are per-patient.
[a]*P* values were based on Fisher exact test.

Table VII. Outcomes at 30 days (includes intra-op and predischarge) by treatment arm in atherosclerotic disease only

30-day adverse event	*CAS atherosclerotic n = 982 % (m/n)*	*CEA atherosclerotic n = 1338 % (m/n)*	P *value*[a]
Death, stroke, or MI	6.42% (63/982)	2.62% (35/1338)	<.0001
Mortality	2.04% (20/982)	0.75% (10/1338)	.0085
Stroke	4.18% (41/982)	1.64% (22/1338)	.0003
MI	1.43% (14/982)	0.60% (8/1338)	.0509
TIA	1.73% (17/982)	0.82% (11/1338)	.0548
TMB/amaurosis fugax	0.10% (1/982)	0.00% (0/1338)	.4233

CAS, Carotid artery stenting; *CEA*, carotid endarterectomy; *MI*, myocardial infarction; *TIA*, transient ischemic attack; *TMB*, transient monocular blindness.
Events were defined as any event after discharge up to 30 days. These events were found on follow-up forms.
The event rates in above table are per-patient.
[a]*P* values were based on Fisher exact test.

tients. The CAS arm had significantly more symptomatic patients 44.5% vs 37.0% in the CEA arm. The *P* values in Table VIII indicate that although symptomatology may confound the relationship between procedure type and key outcomes, it does not modify the relationship (ie, symptomatic patients are more likely to have adverse events, regardless of the procedure type).

For CAS, combined death/stroke/MI at 30 days was 7.13% for symptomatic patients and 4.60% for asymptomatic patients. For CEA, death/stroke/MI at 30 days was 3.75% in symptomatic patients and 1.97% in asymptomatic patients. After risk-adjustment for age, history of stroke, diabetes, and ASA grade (ie, factors found to be significant confounders in outcomes using backwards elimination); logistic regression analysis demonstrated better outcomes following CEA.

There were no statistically significant differences in either the CAS or CEA arm in 30-day outcomes when performing gender analysis, as seen in Table IX. In the CAS arm, there was a higher rate of death/stroke/MI in females (7.0%) compared with males (4.9%), $P = .106$. In the CEA arm, males had a higher death/stroke/MI rate (3.2%) compared with females (1.8%), $P = 0.167$.

Since CMS requires only in-hospital, predischarge results to be reported for CAS facility recertification, we performed a subgroup analysis for intraprocedure and predischarge data (Table X). CAS data indicated that an additional 1.79% of combined death/stroke/MI take place after hospital discharge but within 30 days of procedure (Fig) compared with only 0.58% for CEA.

DISCUSSION

The SVS has developed vascular registry expertise over the last decade with the initial emphasis being on compiling the data from US FDA approved clinical trials of abdominal aortic endografts compared with control surgical procedures. This registry has provided valuable data regarding the efficacy of endovascular repair of AAA, particularly in high-risk patients,[4] and has produced a surgical control data analysis that will be available for comparison for future endograft trials.[5] This registry's experience and the recent CMS NCD decision that called for outcomes reporting as a condition for CAS facility recertification stimulated the SVS and its Outcomes Committee to create an on-line registry that prospectively collects data on carotid artery procedures. Although the NCD required data only on CAS, SVS decided to include data collection on CEA as well to allow for further comparisons between the two procedures. This is particularly important for not only determining the natural history of CAS compared with CEA but also for providing broad-based clinical outcomes and practice pattern data that will provide quality assessment measurements and standards developed using contemporary data. In addition, while the CMS NCD requires only in-hospital predischarge data on CAS procedures, the SVS-VR collects long-term data well beyond the immediate postprocedure period to allow for better understanding of the long-term impact of CAS and comparison between CAS and CEA. The Audit Program, which began in September 2006 when the first site was audited, was designed to (1) verify that the data entered into the VR were accurate and complete, and (2) ensure all cases of CAS and/or CEA are entered into the VR. For the purpose of this review, we analyzed data collected during the initial 18 months of registry activity to provide and compare 30-day outcomes of CAS to those of CEA. Of 6022 patients who were entered in the VR, 2818 patients (1450 CAS patients and 1368 CEA patients) have had 30-day outcomes entered; therefore, this study was based on data derived from this sub-group. As the VR matures, and if CMS mandates longer term outcomes assessment, the percentage of patients with extended fol-

Table VIII. Outcomes at 30-days (including intraop and pre-discharge) by treatment arm by symptomatology in 30-day follow-up cohort

	CAS			*CEA*		
30-day outcomes	*SYMPT n = 645 % (m)*	*ASYMPT n = 805 % (m)*	P *value (CAS)*[a]	*SYMPT n = 506 % (m)*	*ASYMPT n = 862 % (m)*	P *value (CEA)*[a]
Combined Death/stroke/MI	7.13% (46/645)	4.60% (37/805)	.0410	3.75% (19/506)	1.97% (17/862)	.0544
Death	2.17% (14/645)	1.99% (16/805)	.8539	0.79% (4/506)	0.70% (6/862)	1.0000
Stroke	5.27% (34/645)	2.11% (17/805)	.0014	2.37% (12/506)	1.28% (11/862)	.1333
MI	0.93% (6/645)	1.37% (11/805)	.4747	0.59% (3/506)	0.58% (5/862)	1.0000
TIA	2.02% (13/645)	1.24% (10/805)	.2918	1.38% (7/506)	0.46% (4/862)	.1119
TMB/amaurosis fugax	0.16% (1/645)	0.25% (2/805)	1.0000	0.00% (0/506)	0.00% (0/862)	N/A

CAS, Carotid artery stenting; *CEA,* carotid endarterectomy; *MI,* myocardial infarction; *TIA,* transient ischemic attack; *TMB,* transient monocular blindness.
Events were defined as any event occurring intraop, predischarge, or after discharge up to 30 days. The event rates in above table are per-patient.
[a]*P* values were based on Fisher exact test.

Table IX, A. Adverse events through 30-days in CAS arm by gender

	CAS		
Adverse event	*Male n = 863 % (m/n)*	*Female n = 587 % (m/n)*	P *value*
Combined death/ stroke/MI	4.87% (42/863)	6.98% (41/587)	.106
Death	1.85% (16/863)	2.39% (14/587)	.574
Stroke	2.78% (24/863)	4.60% (27/587)	.081
MI	0.93% (8/863)	1.53% (9/587)	.326
TIA	1.74% (15/863)	1.36% (8/587)	.671
TMB/amaurosis fugax	0.35% (3/863)	0.00% (0/587)	.277

CAS, Carotid artery stenting; *MI,* myocardial infarction; *TIA,* transient ischemic attack; *TMB,* transient monocular blindness.
Events were defined as any event occurring intraop, predischarge, or after discharge up to 30 days.
The event rates in above table are per-patient.

Table IX, B. Adverse events through 30-days in CEA arm by gender

	CEA		
Adverse event	*Male n = 817 % (m/n)*	*Female n = 551 % (m/n)*	P *value*
Combined death/ stroke/MI	3.18% (26/817)	1.81% (10/551)	.167
Death	1.10% (9/817)	0.18% (1/551)	.057
Stroke	1.96% (16/817)	1.27% (7/551)	.396
MI	0.61% (5/817)	0.54% (3/551)	1.000
TIA	0.86% (7/817)	0.73% (4/551)	1.000
TMB/amaurosis fugax	0.00% (0/817)	0.00% (0/551)	N/A

CEA, Carotid endarterectomy; *MI,* myocardial infarction; *TIA,* transient ischemic attack; *TMB,* transient monocular blindness.
Events were defined as any event occurring intraop, predischarge, or after discharge up to 30 days.
The event rates in above table are per-patient.

low-up should improve. In addition, since the CMS NCD regarding CAS calls for reporting only on in-hospital data, we analyzed and compared intraprocedure and predischarge data for CAS and CEA to 30-day outcomes to find out whether complications of these procedures do occur and are reported beyond the in-hospital, predischarge period. We focused our outcome comparisons on the combined death/ stroke/MI since many other reported series used this end-point and that the CAS NCD was based on this composite endpoint.

In comparison to other reported studies, the overall 30-day outcome of death/stroke/MI in the CAS arm (5.7%) is consistent with the outcomes observed in Boston Scientific EPI-A Carotid Stenting Trial for High Risk Surgical Patients (BEACH)[6] (5.8%) and Medtronic AVE Self-Expanding Carotid Stent System with distal protection in the treatment of Carotid stenosis (MAVErIC)[7] (5.9%), but higher than Carotid Revascularization using Endarterectomy or Stenting Systems (CaRESS)[8] (2.1%), Carotid Artery Revascularization Using The Boston Scientific FilterWire EX/EZ and the EndoTex NexStent (CABernNET)[9] (3.9%), Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy (SAPPHIRE)[3] (4.8%), and Carotid Artery Stenting with Emboli protection Surveillance study (CASES-PMS)[10] (5.0%). The 30-day event rate observed in the VR in the CAS arm was lower than CREATE[11] (6.2%), ARCHeR[2] (8.3%), SECuRITY[12] (8.5%), and CAPTURE[13] (6.3%). However, a 5.7% composite outcome for CAS in our study was significantly higher than that for CEA (2.63%, $P < .001$). When these outcomes were risk-adjusted for age, diabetes, stroke, and ASA grade, CAS continued to have a significantly higher composite outcome than CEA with adjusted odds ratio (AOR) of 1.96, $P < .001$. In addition, except for MI, each of the components of combined outcome has shown a significantly higher AOR for CAS compared with CEA (Table IV). Although the AOR for MI did not reach statistical significance, the AOR for MI in CAS was 1.78 compared with CEA. Results of the symptomatic VR subset may also be compared with those of the recently published EVA-

Table X. Intraoperative and predischarge events by treatment arm in 30-day follow-up cohort

Outcome	*CAS* *n = 1450*	*CEA* *n = 1368*	P *value*[a]
Intraoperative only			
Stroke	0.897% (13/1450)	0.219% (3/1368)	.022
TIA	0.552% (8/1450)	0.073% (1/1368)	.039
TMB/amaurosis fugax	0.069% (1/1450)	N/A	N/A
Predischarge only			
Combined death/stroke/MI	3.379% (49/1450)	1.827% (25/1368)	.013
Death	1.448% (21/1450)	0.512% (7/1368)	.013
Stroke	2.000% (29/1450)	1.170% (16/1368)	.098
MI	0.828% (12/1450)	0.512% (7/1368)	.362
TIA	0.552% (8/1450)	0.219% (3/1368)	.228
TMB/amaurosis fugax	0.138% (2/1450)	0.000% (0/1368)	.500
Combined intraop and predischarge			
Combined death/stroke/MI	3.931% (57/1450)	2.047% (28/1368)	.004
Death	1.448% (21/1450)	0.512% (7/1368)	.013
Stroke	2.690% (39/1450)	1.389% (19/1368)	.017
MI	0.828% (12/1450)	0.512% (7/1368)	.362
TIA	1.034% (15/1450)	0.292% (4/1368)	.020
TMB/amaurosis fugax	0.207% (3/1450)	0.000% (0/1368)	.250

CAS, Carotid artery stenting; *CEA,* carotid endarterectomy; *MI,* myocardial infarction; *TIA,* transient ischemic attack; *TMB,* transient monocular blindness. Intraop and predischarge events were found on procedure forms.
[a]*P* values found using Fisher exact test.

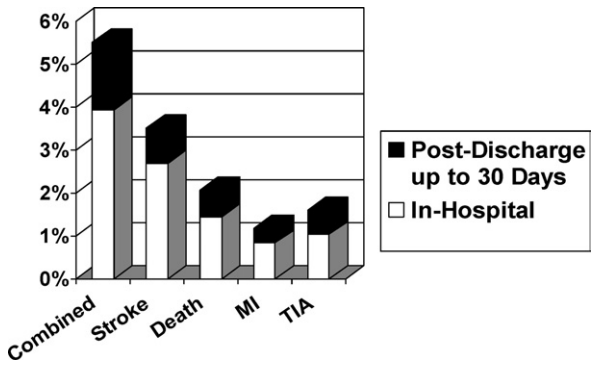

Fig. 30-day outcomes of CAS during in-hospital stay and post-discharge up to 30 days.

3S[14] randomized controlled trial of CAS vs CEA in 527 symptomatic patients. The 30-day stroke or death rate following CEA was 3.9% in EVA-3S, while the combined end point of stroke, death, or MI was slightly less (3.75%) in symptomatic VR patients. Likewise, the 30-day stroke or death rate following CAS in EVA-3S was 9.6% compared with 7.13% for the combined death/stroke/MI end point in symptomatic VR patients. While the reported event rates in both studies favor CEA in symptomatic patients, the VR CAS results were less morbid than those of EVA-3S.

In this series, patients in the CAS group had significantly higher proportion of preprocedure lateralizing symptoms (49.2% vs 42.4% for CEA, $P < .001$). This is expected since the NCD coverage is limited to high surgical risk symptomatic patients with greater than 70% carotid artery stenosis, and asymptomatic patients may be covered by Medicare only when enrolled in IDE trials. In both CAS and CEA patients, asymptomatic patients fared better on the composite outcome than those with symptoms; however, the results reached statistical significance in the CAS group only (Table VIII).

It is of interest to note that the etiology of the carotid stenosis in the CAS and CEA groups was significantly different. Although over 97% of CEA procedures were performed for stenoses caused by atherosclerotic disease, only 67.7% of CAS procedures were performed for this etiology. About one third of CAS procedures in our study were performed for stenoses caused by etiology other than atherosclerosis the most common of which were recurrent stenosis and history of prior neck irradiation. When outcomes in CAS group were analyzed based on etiology, only postoperative stroke rate was found to be significantly higher when CAS was performed for stenoses caused by atherosclerotic lesions (4.1% vs 2.1% for nonatherosclerotic etiology, $P = .049$). This confirms other reported series that suggested that CAS performed for recurrent carotid artery stenosis has more favorable results.[15]

It is important to note that this study's results suggest that in-hospital outcomes are not adequate to capture the full spectrum of carotid procedures impact especially in CAS. We performed a subgroup analysis for intraprocedure and predischarge data and compared them with outcome data from full 30-day follow-up, which was documented in almost half of the patients in this study for both CAS and CEA (Table X). The results indicated that 31% of 30-day combined complications appear after hospital discharge in CAS patients (Fig); therefore, reporting in-hospital data only as required for CAS facility recertification do not reflect the full picture of CAS outcomes.

The main weakness of this study is its reliance on self-reporting with its biases inherent to any registry-based study. To minimize such bias, the Outcomes Committees

provided strict definitions of complications for conformity. In addition, the Committee put together an auditing process of the data. Furthermore, some facilities entered either CAS or CEA data; some institutions do not perform CAS and elected to participate in the VR and enter only CEA data. Others entered only CAS data. One criticism usually leveled against studies comparing CAS with CEA is that the centers performing CAS usually perform small numbers of this procedure; therefore, its outcomes are worse than CEA.[16] To test this argument, we analyzed our data based on the number of CAS procedures performed by various centers. We found no statistically significant difference in CAS outcomes among centers performing less than 25 procedures, 25 to 50 procedures, or over 50 CAS procedures (Table V). In addition, the majority of CAS procedures were performed in centers performing more than 25 procedures. Therefore, the reason why CAS outcomes do not match those of CEA in this report is not low CAS volume experience in participating centers.

The debate about the interpretation of the results of this study as well as results of other CAS studies will continue until randomized trials such as International Carotid Stenting Study (ICSS)[17] in Europe and CREST[15] in North America are reported. However, independent of the potential impact that randomized trials may have on defining the role of CAS and CEA, concurrent cohort entry of all patients treated for extracranial carotid disease in independent and verifiable registries will provide information about current practice patterns and efficacy and will provide an important component of quality assessment and establishment of practice standards.

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AUTHOR CONTRIBUTIONS

Conception and design: AS, RZ, RW, FS, MS, GS
Analysis and interpretation: AS, FS
Data collection: FS
Writing the article: AS, RZ, RW, FS, MS, GS
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Final approval of the article: AS, RZ, RW, FS, MS, GS
Statistical analysis: FS
Obtained funding: GA as Chair of the Outcomes Committee
Overall responsibility: AS, FS

REFERENCES

1. Centers for Medicare and Medicaid Services Decision Memorandum for Carotid Artery Stenting (CAG-00085R). http://www.cms.hhs.gov/mcd/viewdecisionmemo.asp?id=157. Last accessed 07/Apr/2008.
2. Gray WA, Hopkins LN, Yadav S, Davis T, Wholey M, Atkinson R, et al, for the ARCHeR Trial Collaborators. Protected carotid stenting in high-surgical-risk patients: the ARCHeR results. J Vasc Surg 2006;44:258-69.
3. Yadav JS, Wholey MH, Kuntz RE, Fayad P, Katzen BT, Mishkel GJ, et al. Protected carotid-artery stenting versus endarterectomy in high-risk patients. N Engl J Med 2004;351:1493-501.
4. Sicard GA, Zwolak RM, Sidawy AN, White RA, Siami FS, for the Society for Vascular Surgery Outcomes Committee. Endovascular abdominal aortic aneurysm repair: long-term outcome measures in patients at high-risk for open surgery. J Vasc Surg 2006;44:229-36.
5. Zwolak RM, Sidawy AN, Greenberg RK, Schermerhorn ML, Shackelton RJ, Siami FS, for the Society for Vascular Surgery Outcomes Committee. Lifeline registry of endovascular aneurysm repair: open repair surgical controls in clinical trials. J Vasc Surg 2008;48:511-8.
6. White CJ, Iyer SS, Hopkins LN, Katzen BT, Russell ME, BEACH Trial Investigators. Carotid stenting with distal protection in high surgical risk patients: the BEACH trial 30 day results. Cathet Cardiovasc Intervent 2006;67:503-12.
7. Hill MD, Morrish W, Soulez G, Nevelsteen A, Maleux G, Rogers C, et al. Multicenter evaluation of a self-expanding carotid stent system with distal protection in the treatment of carotid stenosis. Am J Neuroradiol 2006;27:759-65.
8. CaRESS Steering Committee. Carotid revascularization using endarterectomy or stenting systems CaRESS phase 1 clinical trial: 1-year results. J Vasc Surg 2005;42:213-9.
9. NexStent Carotid Stent and Delivery System. Summary of Safety and Effectiveness Data P050025. October 27, 2006.
10. Katzen BT, Criado FJ, Ramee SR, Massop DW, Hopkins LN, Donohoe D, et al. CASES-PMS Investigators. Carotid artery stenting with emboli protection surveillance study: 30-day results of the CASES-PMS study. Cathet Cardiovasc Intervent 2007;70:316-23.
11. Safian RD, Bresnahan JF, Jaff MR, Foster M, Bacharach JM, Maini B, et al. CREATE Pivotal Trial Investigators. Protected carotid stenting in high-risk patients with severe carotid artery stenosis. J Am Coll Cardiol 2006;47:2384-9.
12. Xact Carotid Stent System. Summary of Safety and Effectiveness Data P040038. September 6, 2005.
13. Gray WA, Yadav JS, Verta P, Scicli A, Fairman R, Wholey M, et al, CAPTURE Trial Collaborators. The CAPTURE Registry: results of carotid stenting with embolic protection in the post approval setting. Cathet Cardiovasc Intervent 2007;69:341-8.
14. Mas JL, Chatellier G, Beyssen B, Brancherau A, Moulin T, Becquemin JP, et al, EVA-3S Investigators. Endarterectomy versus stenting in patients with symptomatic severe carotid stenosis. N Engl J Med 2006;355:1660-71.
15. Chakhtoura EY, Hobson RW, Goldstein J, Simonian GT, Lal BK, Haser PB, et al. In-stent restenosis after carotid angioplasty-stenting: incidence and management. J Vasc Surg 2001;33:220-6.
16. Verzini F, Cao P, de Rango P, Parlani P, Maselli A, Romano L, et al. Appropriateness of learning curve for carotid artery stenting: analysis of periprocedural complications. J Vasc Surg 2006;44:1205-12.
17. Featherstone RL, Brown MM, Coward LJ. International carotid stenting study: protocol for a randomized clinical trial comparing carotid stenting with endarterectomy in symptomatic carotid artery stenosis. Cerebrovasc Dis 2004;18:69-74.

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