

Pro-CAS

A Prospective Registry of Carotid Angioplasty and Stenting

Wolfram Theiss, MD; Peter Hermanek, MD; Klaus Mathias, MD; Ramazanali Ahmadi, MD; Lothar Heuser, MD; Franz-Josef Hoffmann, MD; Rüdiger Kerner, MD; Franz Leisch, MD; Horst Sievert, MD; Stefan von Sömmogy, MD; for the German Societies of Angiology and Radiology

Background and Purpose—The German Societies of Angiology and Radiology have instituted a prospective registry of carotid angioplasty and stenting (CAS) to limit uncontrolled use of CAS and to collect data about technique and results of CAS outside clinical trials.

Methods—A total of 38 centers register their patients prospectively before CAS is performed. At discharge, technical details, periprocedural medication, and the clinical course are reported on a standardized form.

Results—During the first 48 months, 3853 planned interventions were recorded, and CAS was actually attempted on 3267 patients of whom 1827 (56%) were symptomatic and 1433 (44%) were asymptomatic. In 3127 (98%) cases, stents were used, of which 2784 (89%) were of the self-expanding type. Other technical aspects such as the use of guiding catheters and protection devices varied widely among the centers. Periprocedural medication rather uniformly included aspirin and clopidogrel before and after CAS and high-dose heparin and atropin during CAS. CAS was successful in 3207 (98%) cases. There was a 0.6% (n=18) mortality rate, a 1.2% (n=38) major stroke rate, and a 1.3% (n=41) minor stroke rate. The combined stroke and death rate was 2.8% (n=90).

Conclusions—These prospective multicenter data are likely to give a realistic picture of the possibilities and limitations of CAS in the general community. They suggest that CAS may be performed with similar results in the general community as they have been reported by highly specialized centers and in clinical studies. (*Stroke*. 2004;35:2134-2139.)

Key Words: angioplasty ■ carotid stenosis ■ primary prevention ■ secondary prevention ■ stents ■ stroke

A growing number of reports about single-center experiences with carotid angioplasty and stenting (CAS) suggest good immediate and intermediate results and a low rate of complications,¹⁻⁵ but the lack of a control group precludes direct comparison with carotid endarterectomy, the standard treatment of carotid artery stenosis. Some small randomized trials comparing CAS with carotid endarterectomy have yielded controversial results.⁶⁻⁸ This uncertainty about the value of CAS compared with carotid endarterectomy has resulted rightly in the initiation of large randomized studies in the United States (Carotid Revascularization with Endarterectomy vs Stenting Trial [CREST]), Europe (International Carotid Stenting Study [ICSS]), France (Endartérectomie Versus Angioplastie chez les patients ayant une Sténose carotide Symptomatique Serrée [EVA-3S]), and Germany and Austria (Stent-protected Percutaneous Angioplasty of the Carotid vs Endarterectomy [SPACE]).

However, final data of these studies will not be available for several years.

Although it has been claimed that during this period, patients should only be treated within trials,⁹ the promising results reported by the majority of authors involved in CAS are leading to its increased use in everyday practice in many parts of the world. In view of this situation, the German Society of Angiology and the German Society of Radiology decided to install a registry of CAS as a measure of quality assurance and control against unrestricted use of the method. In addition, the registry offers an opportunity to document results as they are obtained in a relatively unselected patient population and with methods and materials as they are used under routine conditions without restrictions of a trial protocol. This article reports the short-term results of 3267 interventions that were entered into the registry during its first 4 years.

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From the Medizinische Klinik der Technischen Universität (W.T.), Munich, Germany; the Bayerische Arbeitsgemeinschaft für Qualitätssicherung in der Stationären Versorgung (P.H.), Munich, Germany; the Institut für Strahlendiagnostik der Städtischen Kliniken (K.M.), Dortmund, Germany; the Abteilung Angiologie der Universität (R.A.), Vienna, Austria; the Institut für Radiologie des Knappschaftskrankenhaus (L.H.), Bochum, Germany; the Abteilung für Interventionelle Radiologie des Krankenhaus Neunkirchen (F.-J.H.), Neunkirchen, Germany; the Abteilung Innere Medizin und Interventionelle Angiologie des Marienhospital (R.K.), Kvelaer, Germany; the Medizinische Abteilung des AÖ Krankenhaus (F.L.), Linz, Austria; the Cardiovascular Center (H.S.), Frankfurt, Germany; and the Klinik für Operative und Interventionelle Gefäßchirurgie (S.v.S.), Behandlungszentrum Vogtareuth, Germany.

Correspondence to Prof Dr Wolfram Theiss, 1 Medizinische Klinik der TUM, Ismaninger Str 22, D-81675 München, Germany. E-mail theiss@med1.med.tu-muenchen.de

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Patients and Methods

The registry has been approved by the review committees of the 2 participating societies, and the data are collected and evaluated in anonymized form by the Bavarian Permanent Working Party for Quality Assurance (Bayerische Arbeitsgemeinschaft für Qualitätssicherung, Munich, Germany), a nongovernmental, nonprofit agency that has been set up by the Bavarian Medical Society, the Bavarian Hospital Society, and the Bavarian Health Care Assurances for the sake of external quality assessment in medicine. Participants are supplied with their individual evaluations and cumulative results of the entire registry for benchmarking every 6 months.

The registry is open to any investigator in Germany, Austria, and Switzerland who is active in CAS. The first centers started entering their patients in July 1999, and by July 2003, 38 centers participated in the registry. Participating centers are listed in the Appendix. Interventional angiologists (n=19), cardiologists (n=19), and radiologists (n=26) are represented with similar frequency (multiple nominations per center allowed).

To avoid patient selection, participants are requested to report all their patients for whom CAS is planned without imposing any rules on indications or contraindications. Independent neurological evaluation, technical details of CAS, and periprocedural medication and monitoring are left entirely to the investigators' discretion, but they must be documented in detail for the registry. Patients must be registered prospectively before the procedure is started, and they must be followed until discharge or demise.

Diameter stenosis is determined according to North American Symptomatic Carotid Endarterectomy Trial Collaborators (NASCET) criteria¹⁰ and classified in steps of 0% to 19%, $\geq 20\%$, $\geq 50\%$, $\geq 70\%$, and $\geq 90\%$. A transient ischemic attack or transient monocular blindness is defined as a focal hemispheric or retinal event resolving completely within 24 hours; a prolonged reversible ischemic neurological deficit (PRIND) is defined as such an event resolving completely within 7 days. A minor respectively major stroke is defined as a neurological deficit that persists longer than 7 days and results in grades 1 or 2 respectively 3 to 5 on a modified Rankin scale.¹¹

Between July 1, 1999, and June 30, 2003, 3853 planned interventions were reported to the registry. Of these, the procedure was canceled by the patient or by his/her physician in 274 cases (7%). Documentation is still pending in 65 cases (1.7%), leaving 3514 fully documented cases that form the subject of this report.

Results

After angiography, it was decided to abandon CAS in 247 of the 3514 cases (7%), mostly because severity of the stenosis proved to have been overestimated by preceding examinations (163 cases) or because occlusions had been mistaken for high-grade stenosis (28 cases). In the remaining 56 cases, CAS was not attempted for a variety of reasons, mostly because the anatomical conditions appeared unfavorable (Table 1). During the initial angiography, a major stroke occurred in 2 patients and a retinal embolism in 1 patient, and the procedure was stopped in these patients without attempting CAS. These angiography-related complications are included in the morbidity/mortality statistics.

CAS was attempted in 3267 cases. The average age of these patients was 70 years (range 32 to 96 years); 9.9% were >80 years old; 70% were male; and 30% were female. A total of 56% had previous neurological (transient ischemic attack 27%, PRIND 5%, minor stroke 11%, major stroke 7%) or ocular (7%) symptoms; in 84% of these, the symptoms occurred ≤ 180 days before intervention. A total of 90% of the cases were seen by a board-certified neurologist for preprocedural examination and a second opinion, as well as 63% after the intervention. Before presentation, 48% did not

TABLE 1. Reasons for Not Attempting CAS

	No. of Cases
Degree of stenosis overestimated	163
Occlusion taken for high-degree stenosis	28
Difficulties of inguinal access	4
Unfavorable aortic arch	7
Kinking/elongation of internal carotid	6
Fresh thrombus	4
Excessive calcification	7
Extensive/long stenosis	4
Distal (petrous) localization	1
Aneurysm of the internal carotid artery	2
Major stroke during angiography	2
Retinal embolism	1
Miscellaneous	19
Total	248

have angiography; 33% had digital subtraction angiography; 15% had magnetic resonance angiography; and 3% had both. Lesion characteristics are given in Table 2.

Technical Intervention Details

The femoral artery was chosen as the access site in 3166 (99%) procedures; alternative access sites were the brachial artery in 15 cases and direct carotid puncture in 5 cases. A total of 627 (20%) interventions were performed over the wire; in 1607 (52%), a guiding catheter or shuttle sheath was used, and a combination of both methods was reported in 329 (11%) procedures. Use of protection devices was only monitored beginning in October 2000. They were used in 1609 (64%) interventions since that time. Distal balloon occlusive systems were used in 12% of these cases, proximal balloon occlusive systems in 9%, and nonocclusive, filter-based systems in 76%.

TABLE 2. Lesion Characteristics in 3267 Cases

Arteries Involved	
Internal carotid	3187 (98%)
Common carotid	195 (6%)
External carotid*	206 (6%)
Stenosis $>90\%$	
Stenosis 70% to 90%	1713 (52%)
Stenosis 70% to 90%	1329 (40%)
Contralateral carotid stenosis $>50\%$	1057 (32%)
Contralateral occlusion of internal carotid	287 (9%)
Contralateral occlusion of common carotid	24 (0.7%)
Restenosis after previous thrombendarterectomy	211 (7%)
Restenosis after previous carotid intervention	66 (2%)

*External carotid artery stenosis was treated only in conjunction with stenosis of either the common or the internal carotid artery in all but 4 cases. In 2 of the latter, the external carotid artery served as the essential collateral vessel for an occluded internal carotid artery; 1 patient had suffered an ipsilateral minor stroke with the common and internal carotid artery patent; in 1 patient, the intervention was performed to eliminate a loud murmur transmitted from the stenosis and found very bothersome by the patient.

TABLE 3. Neurological Complications in Asymptomatic and Symptomatic Patients

	Asymptomatic	Symptomatic*	Total*
No. of patients	1436 (100%)	1834 (100%)*	3270 (100%)*
Mortality	7 (0.5%)	11 (0.6%)	18 (0.6%)
Combined mortality and permanent neurological deficit	34 (2.4%)	56 (3.1%)*	90 (2.8%)*
Permanent deficit (total)	31 (2.1%)	52 (2.8%)*	83 (2.5%)*
Major stroke	19 (1.3%)	19 (1.0%)*	38 (1.2%)*
Minor stroke	11 (0.8%)	30 (1.6%)	41 (1.3%)
Visual defect	1 (0.1%)	3 (0.2%)	4 (0.1%)
Transient symptoms (total)	84 (5.8%)	147 (8.0%)	231 (7.1%)
PRIND	15 (1.0%)	20 (1.1%)	35 (1.1%)
Transient ischemic attack >10 minutes	30 (2.1%)	44 (2.4%)	74 (2.3%)
Transient ischemic attack <10 minutes	32 (2.2%)	79 (4.3%)	111 (3.4%)
Transient monocular blindness	7 (0.5%)	4 (0.2%)	11 (0.3%)

*Including 2 angiography-related strokes and 1 retinal embolism in patients in whom CAS was not actually attempted.

In 97% (n=3100) of the successful procedures, a stent was implanted, 2784 (89%) of which were self-expanding. Predilatation was performed in 1756 (56%) patients before stent placement, most frequently using a balloon with a diameter of 3.5 mm (range 1.5 to 8 mm) in the internal carotid artery. In 2334 (75%) procedures, the stent was placed with its proximal end in the common carotid artery and its distal end in the internal carotid artery.

Periprocedural Medication

Platelet inhibitors were given in preparation for the intervention in 3228 (99%) cases, mostly a combination of aspirin and clopidogrel (n=2891; 89%) or aspirin and ticlopidine (n=123; 4%). Aspirin alone was given in 138 (4%) cases, clopidogrel alone in 73 (2%), and ticlopidine alone in 3 (0.1%). The aspirin dose used most frequently was 100 mg/d (range 30 to 900 mg/d), that of clopidogrel 75 mg per day (range 75 to 500 mg per day). During the procedure, heparin (median 5000 international units [IU]; range 1000 to 20 000 IU) was given to all but 3 patients who were given lepirudin (n=2) or danaparoid (n=1). Glycoprotein IIb/IIIa inhibitors were administered in 24 cases and fibrinolytic agents in 6 cases. At discharge, 2845 (87%) patients were on a combination of aspirin and clopidogrel, 80 (2.4%) on aspirin alone, and 61 (1.9%) on clopidogrel alone. To prevent bradycardia and hypotension during balloon inflation and stent deployment, prophylactic atropine was administered as a routine to all patients at two thirds of the centers, and at one third of the centers, atropine was used only as needed; the dosages used most frequently were 0.5 mg and 1.0 mg. One center used 0.2 mg of glycopyronium bromide instead of atropine. A temporary venous pacemaker was placed routinely at 1 center, and 4 centers did so occasionally.

Technical Results

CAS was successful in 3207 (98%) cases, and in 3038 (95%) of these, there was no residual stenosis or it did not exceed 19% diameter reduction by NASCET criteria; the residual

stenosis exceeded 50% in 19 (0.6%) cases. Main reasons for lack of success were failure to reach the common carotid artery (0.7%; 16 of 23 cases left-sided), passing the target lesion with the guiding wire (n=19; 0.6%), or following the guiding wire with the catheter in extremely tight stenoses (n=8; 0.2%). In 7 cases (0.2%), the stent could not be placed properly. In 1 case each, the procedure had to be stopped without success because of massive calcification, excessive coiling, and bleeding at the puncture site.

Clinical Outcome

A total of 18 patients died between 1 and 69 days (median 8 days) after the intervention, resulting in a mortality rate of 0.6%; 10 of them died as a direct consequence of a major stroke caused by the intervention, and another died of a subarachnoid hemorrhage caused by fibrinolytic therapy with urokinase for a major stroke caused by carotid occlusion. Four patients died of myocardial infarction/acute myocardial failure. One death each was caused by retroperitoneal hemorrhage, cerebral edema with diffuse secondary hemorrhage, and septic shock (in a patient who had already been experiencing septic events of unknown origin for 10 years). A permanent neurological or visual deficit occurred in 83 (2.5%) cases, including 2 angiography-related major strokes and a retinal embolism in patients who did not actually proceed to CAS (major stroke 1.2%; minor stroke 1.3%; retinal ischemia 0.1%). The combined mortality and permanent neurological event rate was 2.8%. Transient ischemic attacks or transient monocular blindness lasting <24 hours were observed in 196 (6.0%) cases, almost half lasting <10 minutes; a PRIND with complete reversal of a neurological deficit within 7 days occurred in 35 (1.1%) of patients. Only small differences in the frequency of neurological complications were observed between asymptomatic and symptomatic patients (Table 3) and between interventions performed with or without protection devices (Table 4).

Patients who were seen by a neurologist before and after intervention had a higher rate of neurological complications

TABLE 4. Neurological Complications Without and With Protection Device (Patients Treated From October 2000 to June 2003) and in Patients Treated Before October 2000

	No Protection Device	With Protection Device	Treated Before October 2000
No. of interventions	923 (100%)	1609 (100%)	735 (100%)
Mortality	2 (0.2%)	9 (0.6%)	7 (1.0%)
Combined mortality/permanent neurological deficit	20 (2.2%)	33 (2.1%)	34 (4.6%)
Permanent deficit (total)	19 (2.1%)	27 (1.7%)	34 (4.6%)
Major stroke	9 (1.0%)	13 (0.8%)	14 (1.9%)
Minor stroke	10 (1.1%)	12 (0.7%)	19 (2.6%)
Visual defect	0	2 (0.1%)	1 (0.1%)
Transient symptoms (total)	42 (4.6%)	122 (7.6%)	67 (9.1%)
PRIND	9 (1.0%)	16 (1.0%)	10 (1.4%)
Transient ischemic attack >10 minutes	11 (1.2%)	39 (2.4%)	24 (3.2%)
Transient ischemic attack <10 minutes	20 (2.2%)	61 (3.8%)	30 (4.1%)
Transient monocular blindness	2 (0.2%)	6 (0.4%)	3 (0.4%)

than those who were not (Table 5). This might be partially attributable to a negative selection bias because the highest rate of complications is found in the subgroup of patients who were not seen by a neurologist before the intervention but who were presented to him/her after the intervention, suggesting that interventionalists will be more prone to present their patients to a neurologist after the intervention when they observe a neurological problem.

Asymptomatic carotid occlusion was seen in 3 patients, and successful and uneventful repair by carotid thrombendarterectomy was performed in 1 of them. Puncture site complications were observed in 94 (2.9%) procedures: hematoma or prolonged bleeding in 1.8% and false aneurysms in 1%. Bleeding distant from the puncture site occurred in 0.3%. Cardiovascular reactions (mainly transient bradycardia and hypotension) were noticed in 1.7%.

Discussion

Randomized trials are undisputedly essential in establishing equivalence or superiority of new treatment modalities compared with established therapeutic standards. However, they are performed on more or less selected patient groups with specified (ie, restricted) therapeutic modalities in specialized trial hospitals and, therefore, they do not truly reflect all the facets of everyday clinical reality. However, the latter can be documented in well-conducted, comprehensive, and prospec-

tive registries. Thus, registries are not an inferior substitute for randomized trials when those are lacking or controversial, but they hold a value of their own as a supplement to randomized trials by giving a more complete picture of the patient population to be treated, the range of methods and materials that may be used, and the results as they can be obtained in a cross-section of clinical institutions working under routine conditions.

Several peculiarities of the German health system favor the establishment of such a registry. Cardiologists, radiologists and interventional angiologists (coming from different backgrounds and favoring different materials and differing techniques) are all actively engaged in CAS, and new forms of therapy may be offered to any patient after informed consent as "Heilversuch" ("therapeutic attempt") outside of formal clinical trials, and medical devices can be used freely in a variety of anatomic sites within a specified category as soon as they have obtained certification from Comité Européen de Normalization for that category by national regulation authorities. Thus, our registry gives a comprehensive and relatively unrestricted, variegated picture of the possibilities of CAS while transparency and objectivity are maintained at the same time by patient pretreatment registration and data evaluation by an independent quality assurance agency.

Although the greatest benefit from carotid stenosis repair is seen in patients with symptomatic stenosis, only 56% of the

TABLE 5. Neurological Complications in Patients Who Were Seen by a Neurologist Before and After the Intervention Compared With All Others

	Neurologist Before and After Intervention	All Other Patients	Neurologist Only After Intervention
No. of interventions	2079 (100%)	1188 (100%)	54 (100%)
Mortality	14 (0.7%)	4 (0.3%)	2 (3.7%)
Combined mortality/permanent neurological deficit	72 (3.5%)	15 (1.3%)	5 (9.3%)
Permanent deficit	69 (3.3%)	11 (0.9%)	3 (5.6%)
Transient symptoms	171 (8.2%)	60 (5.1%)	4 (7.4%)

Right column shows subgroup of those who were seen by a neurologist only after the intervention.

patients in our registry were symptomatic, and the remaining 44% were asymptomatic. However, these figures are in good agreement with data reported by US interventionalists for CAS (48% asymptomatic patients³) and by American and European surgeons for carotid thrombendarterectomy in controlled trials (54% asymptomatic patients¹²), and outside the setting of randomized controlled trials (40%¹³). So it appears that the relative freedom to perform CAS did not result in inappropriate overuse of the intervention.

Despite little preselection concerning target lesion morphology (about half of the patients had no angiography before the angiography that was performed as a part of the planned intervention), <1% of patients were denied an intervention for anatomical reasons, and in only an additional 2%, insurmountable anatomical obstacles were encountered during the procedure. Thus, it appears that from a merely technical point of view, nearly all patients who are candidates for carotid endarterectomy could be offered CAS as an alternative to surgery.

Although there is little truly objective evidence for the superiority of any technical peculiarity, general agreement has been found concerning preferred access and stent type and position; almost unanimously, the femoral artery was chosen for access. Stents were used in nearly all cases, the majority (89%) being the self-expanding type, overlapping from the common to the internal carotid artery in almost three quarters of the patients.

In contrast to these similarities, preferences varied widely concerning the use of guiding catheters or shuttle sheaths versus an over-the-wire-technique, and protection devices were used only in fewer than two thirds of the cases. The latter fact may appear surprising in view of the fact that protection devices are almost considered standard in some parts of the world and are mandatory in some large-scale trials such as CREST and EVA-3S. However, this conservative attitude toward the routine use of protection devices does not appear unjustified at the present time because reports of deployment problems, device failure, and adverse neurological reactions in a number of cases¹⁴ document that protection devices may cause complications of their own. And their clinical value may have been overestimated by those reporting positive results compared with historical controls because the decreased frequency of neurological complications observed in such studies¹⁵ may rather be attributable to the learning curve, technical progress in catheterization materials, and improved periprocedural antithrombotic regimens and not to the use of protection devices.¹⁶ Our data show no clear advantage for use of protection devices, and their clinical value still has to be proven in randomized trials.

Good morphological results without hemodynamically relevant residual stenosis were obtained in 96% of the patients, which is close to the results obtained in specialized high-volume centers that report technical success in 98% to 99% of cases.²⁻⁵ The 2.8% combined rate of mortality and permanent neurological deficit found in our registry is situated in the lower range of 2.9% to 7.4% reported by the centers mentioned above.²⁻⁵ The results of our registry also compare favorably to those of a large retrospective registry that compiled 12 392 interventions from 53 international centers

and reported 98.9% technical success and a combined stroke and death rate of 4.75%.¹⁷

Interestingly, the rate of neurological complications was only moderately higher in symptomatic patients compared with asymptomatic patients, a finding that has also been reported by others.³ The combined rate of death and permanent neurological deficit of 3.1% in symptomatic patients remains well within American Heart Association/Society of Vascular Surgery guidelines,¹⁸ whereas the rate of 2.4% in asymptomatic patients is close to the proposed upper limit of 3%.

Complications at the puncture site and bleeding distant from the puncture site occurred in ≈4% of the patients, and were thus less frequent than comparable wound complications with carotid surgery (8.9% wound complications rate and 7.6% cranial nerve palsy¹⁰).

Our data suggest that CAS yields favorable results not only when practiced by highly specialized centers on selected patient groups and under study conditions but also when it is offered on a broader scale by nontrial hospitals to a relatively unselected patient population.

Appendix

Participating Centers and Investigators

Austria: A. Ahmadi, Wien; F. Leisch, Linz. Germany: E. Altmann, Dresden; S. Beil, Augsburg; J.C. Dembski, Koblenz; K. Haerten, Wesel; W.L. Heindel, Münster; L. Heuser, Bochum; F.-J. Hoffmann, Neunkirchen; H. Kaiser, Kusel; R. Kerner, Kevelaer; M. Kessler, Sulzbach/Saar; N. Ludwig, Mönchengladbach; K. Mathias, Dortmund; E. May, Duisburg; H. Mudra, München-Neuperlach; H. Mühlhling, München; N. Reifart, Bad Soden; P. Reindl, Deggendorf; G. Rupp-Heim, Göppingen; K. Schlotterbeck, Traunstein; K.-L. Schulte, Berlin; H. Sievert, Frankfurt; M. Stengel, Bruchsal; T. Störk, Stuttgart; J. Waigand, Berlin; K. Theisen, München; W. Theiss, München; P. Urban, Krefeld; K. Vogel, Koblenz; M. Weber, Dachau; E. Wedell, Bad Neustadt; M. Wilaschek, Berlin; L. Wöstenberg, Lippe-Lemgo; T. Wuppermann, Darmstadt; T. Zeller, Bad Krozingen; C. Zur, Bad Saarow; Switzerland: E. Kirsch, Basel.

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References

1. Diethrich EB, Ndiaye M, Reid DB. Stenting in the carotid artery: initial experience in 110 patients. *J Endovasc Surg*. 1996;3:42-62.
2. Mathias K, Jäger H, Gissler HM. Die endoluminale therapie der carotisstenose. *Z Kardiol*. 2000;89(suppl 8):19-26. In German.
3. Roubin GS, New G, Iyer SS, Vitek JJ, Al-Mubarak N, Liu MW, Yadav J, Gomez C, Kuntz RE. Immediate and late clinical outcomes of carotid artery stenting in patients with symptomatic and asymptomatic carotid artery stenosis: a 5-year prospective analysis. *Circulation*. 2001;103:532-537.
4. Shawl FA. Carotid artery stenting: acute and long-term results. *Curr Opin Cardiol*. 2002;17:671-676.
5. Wholey MH, Tan WA, Toursarkissian B, Bailey S, Eles G, Jarmolowski C. Management of neurological complications of carotid artery stenting. *J Endovasc Ther*. 2001;8:341-353.
6. CAVATAS. Endovascular versus surgical treatment in patients with carotid stenosis in the carotid and vertebral artery transluminal angioplasty study (cavatas): a randomized trial. *Lancet*. 2001;357:1729-1737.
7. Brooks WH, McClure RR, Jones MR, Coleman TC, Breathitt L. Carotid angioplasty and stenting versus carotid endarterectomy: randomized trial in a community hospital. *J Am Coll Cardiol*. 2001;38:1589-1595.
8. Naylor AR, Bolia A, Abbott RJ, Pye IF, Smith J, Lennard N, Lloyd AJ, London NJ, Bell PR. Randomized study of carotid angioplasty and

- stenting versus carotid endarterectomy: a stopped trial. *J Vasc Surg.* 1998;28:326–334.
9. Bettmann MA, Katzen BT, Whisnant J, Brant-Zawadzki M, Broderick JP, Furlan AJ, Hershey LA, Howard V, Kuntz R, Loftus CM, Pearce W, Roberts A, Roubin G. Carotid stenting and angioplasty: a statement for healthcare professionals from the Councils on Cardiovascular Radiology, Stroke, Cardio-Thoracic and Vascular Surgery, Epidemiology and Prevention, and Clinical Cardiology, American Heart Association. *Stroke.* 1998;29:336–338.
 10. North American Symptomatic Carotid Endarterectomy Trial Collaborators (NASCET). Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. *N Engl J Med.* 1991;325:445–453.
 11. van Swieten JC, Koudstaal PJ, Visser MC, Schouten HJ, van Gijn J. Interobserver agreement for the assessment of handicap in stroke patients. *Stroke.* 1988;19:604–607.
 12. Taylor DW, Barnett HJ, Haynes RB, Ferguson GG, Sackett DL, Thorpe KE, Simard D, Silver FL, Hachinski V, Clagett GP, Barnes R, Spence JD, for the ASA and Carotid Endarterectomy (ACE) Trial Collaborators. Low-dose and high-dose acetylsalicylic acid for patients undergoing carotid endarterectomy: a randomized controlled trial. *Lancet.* 1999;353:2179–2184.
 13. Goldstein LB, Samsa GP, Matchar DB, Oddone EZ. Multicenter review of preoperative risk factors for endarterectomy for asymptomatic carotid artery stenosis. *Stroke.* 1998;29:750–753.
 14. Schluter M, Tubler T, Mathey DG, Schofer J. Feasibility and efficacy of balloon-based neuroprotection during carotid artery stenting in a single-center setting. *J Am Coll Cardiol.* 2002;40:890–895.
 15. Kastrup A, Groschel K, Krapf H, Brehm BR, Dichgans J, Schulz JB. Early outcome of carotid angioplasty and stenting with and without cerebral protection devices: a systematic review of the literature. *Stroke.* 2003;34:813–819.
 16. Eckert B, Zeumer H. Editorial comment—carotid artery stenting with or without protection devices? Strong opinions, poor evidence! *Stroke.* 2003;34:1941–1943.
 17. Wholey MH, Al-Mubarek N, Wholey MH. Updated review of the global carotid artery stent registry. *Catheter Cardiovasc Interv.* 2003;60:259–266.
 18. Biller J, Feinberg WM, Castaldo JE, Whittemore AD, Harbaugh RE, Dempsey RJ, Caplan LR, Kresowik TF, Matchar DB, Toole J, Easton JD, Adams HP Jr, Brass LM, Hobson RW 2nd, Brott TG, Sternau L. Guidelines for carotid endarterectomy: a statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. *Stroke.* 1998;29:554–562.