**Stroke prevention: carotid stenting versus carotid endarterectomy**

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**Abstract**

Revascularization of the extracranial carotid arteries is a commonly performed surgical procedure to prevent stroke. Open surgery (i.e., carotid endarterectomy [CEA]) is a well-established stroke prevention procedure but is being ‘challenged’ by a less invasive percutaneous procedure (i.e., carotid artery stent [CAS] placement). Clinical trials comparing CAS and CEA for average-surgical-risk patients have demonstrated mixed results, whereas the data for CAS compared with CEA in high-surgical-risk patients have demonstrated non-inferiority. The impending Carotid Revascularization Endarterectomy Versus Stenting Trial (CREST) results will have a major impact on the utility of CAS relative to CEA in average-surgical-risk patients.

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**Introduction and context**

Stroke is the third leading cause of death in the US after coronary artery disease and cancer and it is the leading cause of disability. There are two main types of stroke: ischemic and hemorrhagic. Ischemic stroke is most often caused by atherothrombotic emboli. Extracranial atherosclerotic carotid artery disease accounts for slightly more than half of the 731,000 strokes per year in the US. Hemorrhagic stroke includes primary cerebral hemorrhages or hemorrhage secondary to an ischemic event.

Cerebrovascular events are classified as transient ischemic attacks (TIAs) or as strokes. A TIA is a transient episode of neurological dysfunction caused by focal brain, spinal cord, or retinal ischemia, without acute infarction [1]. An ischemic stroke is defined as an infarction of central nervous system tissue [1]. The current definitions of TIA and stroke no longer include a duration requirement. Ischemic strokes may be either symptomatic or silent. Symptomatic ischemic strokes are manifested by clinical signs of focal or global cerebral, spinal, or retinal dysfunction caused by central nervous system infarction. Hemispheric or focal symptoms relate to a single carotid distribution, causing contralateral hemiparesis or hemiparesis, aphasia, and/or ipsilateral monocular blindness (amaurosis fugax). Non-hemispheric symptoms that often occur with vertebrobasilar insufficiency include dysarthria, diplopia, vertigo, syncope, and/or transient confusion. A silent stroke is a documented central nervous system infarction that was asymptomatic.

Carotid endarterectomy (CEA) is the currently established surgical procedure for stroke prevention in patients with extracranial carotid artery disease. Some of CEA’s technical issues such as the benefits of an intraoperative shunt or of a patch closure versus primary repair continue to be debated. The comparability of data from highly selected patient populations enrolled in clinical trials of CEA with results obtained in everyday practice has been questioned [2]. There were markedly higher mortality rates in Medicare patients who underwent CEA at clinical trial hospitals than in the selected patients treated in clinical trials. Caution is advised in translating the efficacy of carefully controlled studies of CEA to effectiveness in everyday practice [2].

There has been significant variability or heterogeneity in the reporting of CEA outcomes in the literature, making comparison of studies difficult and confusing. In a meta-analysis of CEA in symptomatic patients (n = 51 studies), the strongest predictor of stroke or death was who (neurologist or surgeon) performed the post-operative...
assessments [3]. When a neurologist evaluated postoperative patients, the risk of 30-day stroke and death was 7.7%, but when a single author who was a surgeon performed the evaluation, the reported risk was only 2.3%. There is a strong bias in favor of CEA in the current literature comparing Medicare or specialty outcomes data [4-6]. The bias is one of ascertainment; that is, independent neurological examination is mandated for reimbursement for most carotid artery stent (CAS) procedures but is rarely done for CEA. To obtain Medicare reimbursement, all but a very few CAS procedures must conform to US Food and Drug Administration (FDA) protocols, which require independent neurological examination. This independent neurological examination is not required for CEA reimbursement by Medicare. Performing an independent neurological examination markedly increases the number of events that are detected following a procedure. When comparing CEA and CAS, it is critical that the methodology for detecting events (the ascertainment of events) is similar, or the outcomes will be unfairly slanted.

Recent advances

**High risk for carotid endarterectomy**

Patients with high-surgical-risk features (Table 1) treated with CAS have been proven to have outcomes ‘non-inferior’ to CEA in SAPPHIRE (Stenting and Angioplasty with Protection of Patients with High Risk for Endarterectomy), a randomized controlled trial (Figure 1) [7]. Three-year outcomes have confirmed the durability of the CAS [8]. Additional supporting peer-reviewed and published evidence include a meta-analysis [9] and multiple pre-market [10-18] and post-market [19-23] surveillance trials. Additionally, a multi-specialty endorsed professional society document from the American College of Cardiology (ACC) is consistent with the conclusions of the randomized controlled trial (SAPPHIRE) and supports the benefit of CAS in patients with high-risk features for both symptomatic (>50% stenosis) and asymptomatic (>80% stenosis) patients [24].

| Table 1. Carotid artery stent high-surgical-risk features |
|----------------------------------------------------------|
| **Anatomic features** | **Comorbid conditions** |
| Surgically inaccessible lesions at or above C2 spinal level or below the clavicle | Age of at least 75/80 years |
| Previous neck or head radiation therapy or surgery that included the area of stenosis/repair or ipsilateral radical neck dissection | Congestive heart failure (New York Heart Association class III/IV) |
| Spinal immobility of the neck due to cervical arthritis or other cervical disorders | Unstable angina (Canadian Cardiovascular System class III/IV) |
| Restenosis after a previous or unsuccessful attempt of carotid endarterectomy | Left main/at least two-vessel coronary disease |
| Contralateral laryngeal palsy | Recent heart attack (<30 days) |
| Presence of a tracheostoma | Left ventricular ejection fraction ≤30% |
| Contralateral carotid occlusion | Requirement for heart surgery within 30 days |
| | Severe lung disease |
| | Severe renal disease |

Recently, three very large, post-market surveillance trials evaluating CAS in a ‘real-world’ environment were published. The primary objective of the SAPPHIRE World-Wide (SAPPHIRE WW) post-market approval registry was to evaluate 30-day outcomes after CAS was performed in high-surgical-risk patients by CAS operators of varying experience [20]. Notably, independent neurological assessment was employed for outcomes assessment. The investigators reported 30-day safety and efficacy outcomes in 2,001 symptomatic and asymptomatic high-surgical-risk patients treated by carotid stent operators with varying clinical experience. The overall, independently adjudicated, 30-day stroke and death rate for CAS in 2,001 high-surgical-risk patients was 4.0% [20].

The results of more than 6,000 high-surgical-risk patients treated by CAS operators with varying levels of experience in two large prospective, multi-center, FDA-mandated post-market surveillance trials (Emboshield and Xact Post-Approval Carotid Stent Trial [EXACT] [n = 2,145] and Carotid Acculink/Accunet Post-Approval Trial to Uncover Unanticipated or Rare Events-2...
[CAPTURE-2] were recently published and demonstrated excellent outcomes [23]. Both trials included independent neurological assessment of outcomes to reinforce the rigor for ascertaining adverse events. The overall rates of incidence of 30-day stroke and death were 4.1% for the 2,145 EXACT patients and only 3.4% for the 4,175 CAPTURE-2 patients. Importantly, for patients who would have been comparable to patients included in the 2006 American Heart Association (AHA) published guidelines (<80 years of age) [25], the CAS results met the threshold recommendations for 30-day stroke and death rate at 5.3% (benchmark for CEA ≤6%) for symptomatic patients (i.e., those with ≥50% stenosis) and 2.9% (benchmark for CEA ≤3%) for asymptomatic patients (i.e., those with ≥80% stenosis) (Figure 2) [23]. These studies demonstrate equipoise for CAS and CEA in community settings on the basis of data collected during the decade of the 1990s with the large CEA versus best medical therapy trials, and the AHA expert consensus panel suggested that the perioperative risk of stroke and death should not exceed 3% for asymptomatic patients, 6% for symptomatic patients, or 10% for repeat CEA [25,26].

Published data have suggested that very old patients (≥75-80 years of age) are at increased risk for not only a higher complication rate of CEA [2,27,28] but also worse outcomes for CAS [11,23,29,30]. However, three peer-reviewed manuscripts published in the past year have reported excellent outcomes in high-surgical-risk patients ≥80 years of age undergoing CAS [31-33]. The very favorable overall 30-day stroke and death rates with independent neurological assessment in these octogenarians were 3.3%, 2.7%, and 0.8% [31-33]. The authors emphasized the importance of operator experience and careful case selection to avoid difficult aortic arch access, excessive lesion tortuosity, and heavy calcification [30]. The improved outcomes for octogenarians are consistent with the data reported in the CAPTURE-2 and EXACT trials demonstrating reduced CAS complications with expanding operator experience. The published peer-reviewed evidence does not support denying CAS to very old patients but does show that the best results are obtained with careful patient selection and experienced operators.

Low- or average-surgical-risk patients

The EVA-3S (Endarterectomy versus Angioplasty in Patients with Symptomatic Severe Carotid Stenosis) trial randomly assigned 527 symptomatic (≥60%) low- or average-surgical risk patients to CAS or CEA [34]. The 30-day incidence rates of stroke or death were 3.9% for CEA and 9.6% for CAS. Early in the trial, the use of embolic protection devices (EPDs) was not required and this generated a stroke rate of 25% (5 of 20). This caused the trial to be stopped and restarted with EPD use required. The inexperience of the interventionalists, particularly the surgical operators, is a significant limitation of this study. The patients in EVA-3S had risk profiles similar to those of CREST (Carotid Revascularization Endarterectomy Versus Stenting Trial) roll-in patients, but CREST required at least 20 cases of carotid stent experience with audited results and mandated the use of an EPD. In contrast to the high rate of stroke and death in EVA-3S, the most recent report of 1,246 lead-in patients demonstrated a 30-day stroke and death rate of 5.6% for symptomatic CREST lead-in registry patients [35].

Physician specialty-specific data from CREST were presented by Donald V Heck at the 2009 Society of NeuroInterventional Surgery meeting. He reported 30-day stroke and death by subspecialty during the lead-in phase of the CREST trial. Subspecialty training in catheter-based techniques – cardiology, radiology, and neuroradiology – had a statistically lower event rate than did the non-catheter-based specialty of vascular surgery. Vascular surgeons had a statistically significant, twofold increase in their complication rate (stroke and death) compared with the physicians trained in catheter-based techniques.

The SPACE (Stent-Supported Percutaneous Angioplasty of the Carotid Artery versus Endarterectomy) trial showed no difference between CEA and CAS in average surgical risk in symptomatic patients with optional use of EPDs [36]. The 30-day stroke and death rates were
6.8% for CAS and 6.3% for CEA and were not clinically or statistically different. One drawback of the study was the lack of EPD use in 73% of the study subjects. After 2 years of follow-up, there continued to be no difference in outcomes between CEA and CAS; however, for patients who were younger than 69 years of age at randomization, CAS was significantly better (30-day stroke and death and ipsilateral stroke for 2 years; 4.8%) compared with CEA (8.0%; $P < 0.005$) [37,38].

A major impact on the field has been made with proximal embolic occlusion (PEO) devices by lowering post-procedural complication rates [39]. These PEO devices have an advantage in that when the carotid lesion is crossed with a guidewire for the entire procedure, no antegrade flow occurs, thus the patient is protected against procedure-related emboli. A recent trial reported a 1.4% 30-day stroke and death rate with a PEO in 1,288 procedure-related emboli. A recent trial reported a 1.4% 30-day stroke and death rate with a PEO in 1,288 consecutive patients [40]. The risks of 30-day stroke and death were less than 1% in asymptomatic patients and near 3% in symptomatic patients [40].

**Implications for clinical practice**

**High risk for surgery**

There now exists the highest level of evidence (AHA/ACC class I, level of evidence A) that there is clinical equipoise between CAS and CEA for patients at increased surgical risk for CEA. This applies to both symptomatic and asymptomatic patients with anatomic or comorbid features that place them at increased risk for CEA. This conclusion is supported and reinforced by the three recently published post-market surveillance trials (CAPTURE-2, EXACT, and SAPPHIRE WW) [20,23]. In these patients at high risk for CEA (both symptomatic and asymptomatic patients) younger than 80 years of age, the AHA benchmark levels were met. The current recommendation for patients at increased risk for CEA is that CAS should be considered a reasonable alternative for stroke prevention.

**Usual or average risk for surgery**

There is no consensus regarding the relative outcomes of CAS versus CEA in average-risk patients. Clinical trials in this patient population over the past 2 years have ranged from EVA-3S, which strongly favored CAS over CEA, to the most recently reported PEO system with extremely low stroke and death rates in both symptomatic and asymptomatic patients. The SPACE trial split the difference, showing a benefit for CAS in patients younger than 69 years old and an advantage for CEA in older patients. The results of CREST, a large randomized controlled trial in average-surgical-risk patients, will be reported within the next few months and will go a very long way toward informing our recommendations in the low- or usual-surgical-risk population.

**Abbreviations**

ACC, American College of Cardiology; AHA, American Heart Association; CAPTURE-2, Carotid Acculink/Acumen Post-Approval Trial to Uncover Unanticipated or Rare Events-2; CAS, carotid artery stent; CEA, carotid endarterectomy; CREST, Carotid Revascularization Endarterectomy Versus Stenting Trial; EPD, embolic protection device; EVA-3S, Endarterectomy versus Angioplasty in Patients with Symptomatic Severe Carotid Stenosis; EXACT, Emboshield and Xact Post-Approval Carotid Stent Trial; FDA, US Food and Drug Administration; PEO, proximal embolic occlusion; SAPPHIRE (WW), Stenting and Angioplasty with Protection of Patients with High Risk for Endarterectomy (World-Wide); SPACE, Stent-Supported Percutaneous Angioplasty of the Carotid Artery versus Endarterectomy; TIA, transient ischemic attack.

**Competing interests**

The author is the national principal investigator for the CABANA (Carotid Stenting Boston Scientific Surveillance Program) trial, a carotid stent trial sponsored by Boston Scientific (Natick, MA, USA).

**References**

1. Easton JD, Saver JL, Alberts GW, Alberts MJ, Chaturvedi S, Feldmann E, Hatsukami TS, Higashida RT, Johnston SC, Kidwell CS, Lutsep HL, Miller E, Sacco RL. **Definition and evaluation of transient ischemic attack: a scientific statement for healthcare professionals from the American Heart Association/American Stroke Association Stroke Council; Council on Cardiovascular and Stroke Prevention; and the Interdisciplinary Council on Peripheral Vascular Disease.** The American Academy of Neurology affirms the value of this statement as an educational tool for neurologists. *Stroke* 2009, 40:2276-93.

2. Wennberg D, Lucas F, Birkmeyer J, Bredenberg C, Fisher E. **Variation in carotid endarterectomy mortality in the Medicare population.** JAMA 1998, 279:1278-81.

3. Rothwell PM, Slattery J, Warlow CP. **A systematic review of the risks of stroke and death due to endarterectomy for symptomatic carotid stenosis.** Stroke 1996, 27:260-5.

4. McPhee JT, Hill JS, Ciocca RG, Messina LM, Eslami MH. **Carotid endarterectomy was performed with lower stroke and death rates than carotid artery stenting in the United States in 2003 and 2004.** J Vasc Surg 2007, 46:1-12.

5. Sidawy AN, Zvolak RM, White RA, Siami FS, Schmerhorn ML, Sicard GA. **SYS carotid vascular registry: CAS vs CEA outcomes comparison.** Paper presented at the Society of Vascular Surgery's Vascular Annual Meeting; 5-8 June 2008; San Diego, CA. Abstract SS18.

6. Groeneveld PW, Yang L, Greenhut A, Yang F. **Comparative effectiveness of carotid arterial stenting versus endarterectomy.** J Vasc Surg 2009, 50:1040-8.

7. Yadav JS, Wholey MH, Kuntz RE, Fayad P, Katzen BT, Mishkel GJ, Bajwa TK, Whitlow P, Strickman NE, Jaff MR, Popma JJ, Snead DB, Cutlip DE, Firth BG, Ouriel K. **Protected carotid-artery stenting versus endarterectomy in high-risk patients.** N Engl J Med 2004, 351:1493-501.
8. Gurm HS, Yadav JS, Fayad P, Katzen BT, Mishkel GJ, Baiwa TK, Ansel G, Strickman NE, Wang H, Cohen SA, Massaro JM, Curtin DE: Long-term results of carotid stenting versus endarterectomy in high-risk patients. N Engl J Med 2008; 358:1572-9.

9. Gurm HS, Nallamothu BK, Yadav J: Safety of carotid artery stenting for symptomatic carotid artery disease: a meta-analysis. Eur Heart J 2008; 29:113-9.

10. SECURITY Investigators: United States Food and Drug Administration, Center for Devices and Radio logical Health: Abbott Xact® Carotid Stent System - Summary of the Safety and Effectiveness Data. [http://www.accessdata.fda.gov/cdrh_docs/pdf4/P040038b.pdf]

11. Iyer SS, White CJ, Hopkins LN, Katzen BT, Russell ME: Carotid artery revascularization in high-surgical-risk patients using the Carotid WALLSTENT and FilterWire EX/EZ: 1-year outcomes in the BEACH Pivotal Group. J Am Coll Cardiol 2008, 51:427-34.

12. Gray W: Two-year composite endpoint results for the Archer Trials: Acculink for revascularization of carotids in high risk patients [abstract]. Am J Cardiol 2004, 94:62E.

13. Safian RD, Bresnahan JF, Jaff MR, Foster M, Bacharach JM, Maini B, Turco M, Mysa S, Eles G, Ansel GM: Protected carotid stenting in high-risk patients with severe carotid artery stenosis. J Am Coll Cardiol 2006, 47:2384-9.

14. Whitlow P: Security: more good data for protected carotid stenting in high-risk surgical patients. [http://www.medscape.com/viewarticle/461721_print]

15. White CJ, Iyer SS, Hopkins LN, Katzen BT, Russell ME: Carotid stenting with distal protection in high surgical risk patients: the BEACH trial 30 day results. Catheter Cardiovasc Interv 2006, 67:503-12.

16. Ramee S, Higashida R: Evaluation of the Medtronic self-expanding carotid stent system with distal protection in the treatment of carotid artery stenosis [abstract]. Am J Cardiol 2004, 94:61E.

17. Hopkins LN, Mysa S, Grube E, Wehman JC, Ley EJ, Bersin RM, Joyce JD, Allocco DJ, Kelley L, Baim DS: Carotid artery revascularization in high surgical risk patients with the NexStent and the Filterwire EX/EZ: 1-year results in the CABERNET trial. Catheter Cardiovasc Interv 2008, 71:950-60.

18. Gray WA, Hopkins LN, Yadav S, Davis T, Wholey M, Atkinson R, Cremonea A, Fairman R, Walker G, Verte P, Popma J, Verrani R, Cohen DJ: Protected carotid stenting in high-surgical-risk patients: the ARCHeR results. J Vasc Surg 2006, 44:258-68.

19. Gray WA, Yadav JS, Verta P, Scioli A, Fairman R, Wholey M, Hopkins LN, Atkinson R, Raabe R, Barnwell S, Green R: The CAPTURE registry: results of carotid stenting with embolic protection in the post approval setting. Catheter Cardiovasc Interv 2007, 69:34-8.

20. Massop D, Dave R, Metzger C, Bachinsky W, Solis M, Shah R, Schütz G, Schreiber T, Ashchi M, Hlibbard R; SAPPHIRE Worldwide Investigators: Stenting and angioplasty with protection in patients at high-risk for endarterectomy: SAPPHIRE Worldwide Registry first 2,001 patients. Catheter Cardiovasc Interv 2009, 73:129-36.

21. Gray WA, Yadav JS, Verta P, Scioli A, Fairman R, Wholey M, Hopkins LN, Atkinson R, Raabe R, Barnwell S, Green R: CAPTURE Trial Collaborators: The CAPTURE registry: predictors of outcomes in carotid artery stenting with embolic protection for high surgical risk patients in the early post-approval setting. Catheter Cardiovasc Interv 2007, 70:1025-33.

22. Katzen BT, Ciano FD, Ramee SR, Massop DW, Hopkins LN, Donohoe D, Cohen SA, Mauin L: Carotid artery stenting with embolic protection surveillance study: thirty-day results of the CASES-PMS study. Catheter Cardiovasc Interv 2007, 70:316-23.

23. Gray WA, Chaturvedi S, Verta P, Investigators and the Executive Committees: Thirty-day outcomes for carotid artery stenting in 6320 patients from 2 prospective, multicenter, high-surgical-risk randomised clinical trial registries. Catheter Cardiovasc Interv 2009, 2159-66.

24. Bates ER, Babb JD, Casey DE Jr, Cates CJ, Duckwiler GR, Feldman TE, Gray WA, Ouriel K, Peterson ED, Rosenfield K, Rundback JH, Safian RD, Sloan MA, White CJ: ACCF/SCAI/SVMB/SIR/ASITN 2007 clinical expert consensus document on carotid stenting: a report of the American College of Cardiology Foundation Task Force on Clinical Expert Consensus Documents (ACCF/SCAI/SVMB/SIR/ASITN Clinical Expert Consensus Document Committee on Carotid Stenting). J Am Coll Cardiol 2007, 49:126-70.

25. Sacco RL, Adams R, Albers G, Alberts MJ, Benavente O, Furie K, Goldstein LB, Gorfinkel P, Halperin J, Harbaugh R, Johnston SC, Katzan I, Kelly-Hayes M, Keston EJ, Marks M, Schwamm LH, Tomick T: Guidelines for prevention of stroke in patients with ischemic stroke or transient ischemic attack: a statement for healthcare professionals from the American Heart Association/American Stroke Association Council on Stroke: co-sponsored by the Council on Cardiovascular Radiology and Intervention: the American Academy of Neurology affirms the value of this guideline. Stroke 2006, 37:577-617.

26. Biller J, Feinberg WM, Castaldo JE, Whitemore AD, Harbaugh RE, Dempsey RJ, Caplan LR, Kressow TF, Matchar DB, Toole J, Eaton JD, Adams HP Jr, Brass LM, Hobson RW 2nd, Brott TG, Strentz L: Guidelines for carotid endarterectomy: a statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. Stroke 1998, 29:534-62.

27. Kazmers A, Perkins AJ, Huber TS, Jacobs LA: Carotid surgery in octogenarians in Veterans Affairs medical centers. J Surg Res 1999, 81:87-90.

28. Miller T, Comerota AJ, Tzallinis A, Daoud Y, Hammerling J: Carotid endarterectomy in octogenarians: does increased age indicate ‘high risk‘? J Vasc Surg 2005, 41:213-7.

29. Hobson RW 2nd, Howard VJ, Roubin GS, Brott TG, Ferguson RD, Popma J, Graham DL, Howard G: Carotid artery stenting is associated with increased complications in octogenarians: 30-day stroke and death rates in the CREST lead-in phase. J Vasc Surg 2004, 40:1106-11.

30. Roubin GS, Iyer S, Hallix A, Vitek J, Brennan C: Realizing the potential of carotid artery stenting: proposed paradigms for patient selection and procedural technique. Circulation 2006, 113:2021-30.

31. Henry M, Henry I, Polydorou A, Hugel M: Carotid angioplasty and stenting in octogenarians: is it safe? Catheter Cardiovasc Interv 2008, 72:309-17.

32. Veley CA, White CJ, Reilly JP, Jenkins J, Collins TJ, Grise MA, McMullan PW, Ramee SR: Carotid artery stent placement is safe in the very elderly (> or =80 years). Catheter Cardiovasc Interv 2008, 72:303-8.

33. Mas JL, Chatellier G, Bessayon B, Branchereau A, Moulin T, Becquemin JP, Larroue V, Lievre M, Leys D, Bonniveille JF, Waterlet J, Prubo JP, Albucher JF, Viguer A, Fiquet P, Garnier P, Vlader F, Toueze E, Giroud M, Hosseini H, Pillet JC, Favrole P, Neau JP, Ducrocq X: Endarterectomy versus stenting in patients with symptomatic severe carotid stenosis. N Engl J Med 2006, 355:1660-71.

(f1000 Factor 6.0 Must Read Evaluated by Norman Herzer 27 Jul 2007

35. Roubin G, Clark W, Chakhtoura E, Brooks W, Hye R, Howard V, Hughes S, MeeLee T, Roberts J, Goldstein LB, Brott T, Hobson RW 2nd: Low complication rates for carotid artery stenting in the credentialing phase of the carotid revascularization endarterectomy versus stenting trial. Stroke (International Stroke Conference Oral Presentations) 2006, 37:620. Abstract 2.
36. Ringleb PA, Allenberg J, Bruckmann H, Eckstein HH, Fraedrich G, Hartmann M, Hennerici M, Jansen O, Klein G, Kunze A, Marx P, Niederkorn K, Schmiedt W, Solymosi L, Stingele R, Zeumer H, Hacke W: 30 day results from the SPACE trial of stent-protected angioplasty versus carotid endarterectomy in symptomatic patients: a randomised non-inferiority trial. Lancet 2006, 368:1239-47.

37. Eckstein HH, Ringleb P, Allenberg J, Berger J, Fraedrich G, Hacke W, Hennerici M, Stingele R, Fiehler J, Zeumer H, Jansen O: Results of the Stent-Protected Angioplasty versus Carotid Endarterectomy (SPACE) study to treat symptomatic stenoses at 2 years: a multinational, prospective, randomised trial. Lancet Neurol 2008, 7:893-902.

38. Stingele R, Berger J, Alfke K, Eckstein HH, Fraedrich G, Allenberg J, Hartmann M, Ringleb PA, Fiehler J, Bruckmann H, Hennerici M, Jansen O, Klein G, Kunze A, Marx P, Niederkorn K, Schmiedt W, Solymosi L, Zeumer H, Hacke W: Clinical and angiographic risk factors for stroke and death within 30 days after carotid endarterectomy and stent-protected angioplasty: a sub-analysis of the SPACE study. Lancet Neurol 2008, 7:216-22.

39. Kelso R, Clair DG: Flow reversal for cerebral protection in carotid artery stenting: a review. Perspect Vasc Surg Endovasc Ther 2008, 20:282-90.

40. Stabile E, Salemme L, Sorroppago G, Tesorio T, Nammas WL, Miranda M, Popusoi G, Cioppa A, Ambrosini V, Cota L, Petroni G, Della Pietra G, Aussania A, Fontanelli A, Biamino G, Rubino P: Proximal Endovascular Occlusion For Carotid Artery Stenting: Results From A Prospective Registry of 1300 Patients. J Am Coll Cardiol 2010, in press.