Management of Carotid Artery Stenosis

Corneliu T. Vulpe M.D.
Downstate Medical Center
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Case Presentation

- 60 year old female
- DM, HTN, COPD, asthma
- Ethanol, smoker
- Now with lethargy
- No focal neurologic deficits
- Admitted to MICU for DKA
Case Presentation

- CT head – left occipital infarct with hemorrhagic component, no mass effect, subacute
  - Confirmed with MRI
- Carotid duplex – left ICA stenosis 90-99%
  - Confirmed with MRA
Case Presentation

- patient with symptomatic severe left carotid artery stenosis without large infarctions, neurologically stable
Case Presentation

- 10 days after admission the patient underwent CEA (cleared by Cardiology, Neurology, Neurosurgery)
- Shunt used
- A Dacron patch was used
- POD#3 – fever spike – phlebitis left forearm – iv abx and warm compresses
  WBC 14
Case Presentation

- POD#5 – left neck cellulitis, no drainage, then swelling
- Cellulitis subsided with iv abx
- Pseodoaneurysm ruled out with duplex
- Possible hematoma
- POD#7 – 30 cc pus drained
Case Presentation

- The patient underwent reexploration
- 100cc pus drained
- Shunt used
- Dacron patch removed
- Saphenous vein patch angioplasty
- Bilateral forearm thrombosed veins excised
- MRSA treated, discharged POD#16
Management of Carotid Artery Stenosis
Overview

- Stroke
- Clinical presentation and work-up
- CEA history
- Current indications
- Operative management
- Complications
- Ongoing issues
Stroke

- Third leading cause of death in US
- 50% survivors alive after 5 years
- 25% survivors will have a second neurologic event, leading to death >50%
- Substantial morbidity - 18% unable to return to work, 4% require total custodial care
- $10 billion health care cost annually
Stroke Risk Factors

- Hypertension - the single most important modifiable risk factor for ischemic stroke
- cigarette smoking
- sickle cell disease
- transient ischemic attack (TIA)
- asymptomatic carotid stenosis
- cardiac diseases - atrial fibrillation, infective endocarditis, mitral stenosis, and recent large myocardial infarction
A, complex reversal of flow along the posterior wall of the carotid sinus, most vulnerable to plaque development

B, Established plaque at the carotid bifurcation

C, Soft, central necrotic core with an overlying thin fibrous cap, prone to plaque rupture

D, Disruption of the fibrous cap allows necrotic cellular debris and lipid material from the central core to enter the lumen of the internal carotid artery - atherogenic emboli. The patient may experience symptoms (transient ischemia, stroke, or amaurosis fugax) or remain asymptomatic depending on the site of lodgment and the extent of tissue compromise

E, The empty necrotic core becomes a deep ulcer in the plaque. The walls of the ulcer are highly thrombogenic and reactive with platelets. This leads to thromboembolism in the internal carotid artery circulation
Clinical Presentation

- TIAs are defined as brief episodes of focal loss of brain function due to ischemia that can usually be localized to that portion of the brain supplied by one vascular system (left or right carotid or vertebrobasilar), lasting less than 24 hours. TIAs commonly last 2 to 15 minutes and are rapid in onset (no symptoms to maximal symptoms in < 5 minutes and usually in < 2 minutes).

- Left carotid system TIAs manifest as (1) motor dysfunction (dysarthria, weakness, paralysis, or clumsiness of the right extremities and/or face); (2) loss of vision in the left eye (amaurosis fugax); (3) sensory symptoms (numbness, including loss of sensation or paresthesia involving the right upper and/or lower extremity and/or face); and (4) aphasia (language disturbance).

- Right carotid system TIAs produce similar symptoms on the opposite side, except that aphasia occurs only when the right hemisphere is dominant for speech (left-handed individual).
Clinical Presentation

Vertebrobasilar system TIAs are characterized by the rapid onset of

- (1) motor dysfunction (weakness, paralysis, or clumsiness) of any combination of upper and lower extremities and face (left and/or right)
- (2) sensory symptoms (loss of sensation, numbness, or paresthesia involving the left, right, or both sides)
- (3) loss of vision in one or both homonymous visual fields
- (4) loss of balance, vertigo, unsteadiness or disequilibrium, diplopia, or dysarthria

These last symptoms are characteristic but are not considered as a TIA when any of these symptoms are alone.
Work-up

A, Arterial flow (red) is displayed in the internal (ICA) and common (CCA) carotid arteries. Peak systolic and end-diastolic velocities are measured on a representative wave, and in the example, these are 0.58 m/sec (58 cm/sec) and 0.25 m/sec (25 cm/sec), respectively.

B, The peak systolic velocities approach 4 m/sec (400 cm/sec) and the end-diastolic velocity is 1.41 m/sec (141 cm/sec). In addition, spectral analysis shows broadening from nonlaminar flow. These findings are characteristic of significant stenosis - can be estimated accurately.
cerebral angiography is unnecessary in most patients presenting with clear-cut symptoms and high-grade stenosis on duplex ultrasonography
1950s, Fisher - predilection for atheroma to occur at the carotid bifurcation in the neck

- the internal carotid artery distal to the bifurcation and the intracranial vessels were usually free of disease

- important cause of strokes but also suggested the possible form of therapy to prevent stroke.

1951 - Carrea, Mollins, and Murphy performed the first successful surgical reconstruction of the carotid artery in Buenos Aires

1953 – DeBakey - the first successful carotid endarterectomy

1954 - Eastcott, Pickering, and Robb – the case was a woman who had recurrent TIAs associated with stenosis of the left carotid bifurcation. She underwent resection of the bifurcation with restoration of blood flow by anastomosis of the internal carotid artery to the common carotid artery. The patient was completely relieved of symptoms, and the operation dramatically demonstrated that removal of carotid bifurcation atherosclerosis could halt TIAs and, presumably, prevent strokes.
CEA

- Number of cases increased annually

![Graph showing the number of CEA cases increasing over time.](image-url)
CEA Trials

- Randomized trials comparing CEA to medical therapy. The percentage relative risk reduction from carotid endarterectomy is indicated by the downward-pointing arrows.
- The length of follow-up for each trial is indicated below the bars.
- ACAS - Asymptomatic Carotid Atherosclerosis Study
- CASANOVA - Carotid Artery Stenosis with Asymptomatic Narrowing: Operation Versus Aspirin
- ECST - European Carotid Surgery Trial
- NASCET - North American Symptomatic Carotid Endarterectomy Trial
- VA, Veterans Administration Trial
VA study

Carotid endarterectomy reduces stroke, but not endpoint of stroke and death, in asymptomatic men. Medical versus surgical (carotid endarterectomy) therapy in 444 men with asymptomatic carotid stenosis ≥50 percent. Top panel: Carotid endarterectomy reduced the four year incidence of ipsilateral stroke or TIA compared to medical therapy (6 versus 20.6 percent, p<0.001). Bottom panel: There was no difference between the two groups in the incidence of stroke and death (41 versus 44 percent) (lower panel). (Data from Hobson, RW, Weiss, DG, Fields, WS, et al, N Engl J Med 1993; 328:221.)
ACAS study

Carotid endarterectomy in asymptomatic men

In the ACAS trial, 1662 patients with an asymptomatic carotid stenosis ≥60 percent were randomized to medical therapy with aspirin or carotid endarterectomy (CEA) and followed for a mean of 2.2 years. Top panel: There was no difference between the two groups in the incidence of major stroke or death. Bottom panel: The incidence of any ipsilateral TIA or stroke or death was lower in the surgical group (p = 0.004). (Data from Executive Committee for the Asymptomatic Carotid Atherosclerosis Trial. JAMA 1995; 273:1421.)
ACST study

Risk of any stroke and perioperative death in ACST. The net five-year risk for all strokes or perioperative death in the CEA group was reduced by nearly half compared with the CEA deferral group. Reproduced with permission from: MRC Asymptomatic Carotid Surgery Trial (ACST) Collaborative Group. Prevention of disabling and fatal strokes by successful carotid endarterectomy in patients without recent neurological symptoms: randomised controlled trial. Lancet 2004; 363:1491. Copyright © 2004 Elsevier.

Risk of fatal or disabling stroke or perioperative death in ACST. The net five-year risk for fatal or disabling strokes or perioperative death in the CEA group was reduced by nearly half compared with the CEA deferral group. About one-half of the strokes in the trial were fatal or disabling. Reproduced with permission from: MRC Asymptomatic Carotid Surgery Trial (ACST) Collaborative Group. Prevention of disabling and fatal strokes by successful carotid endarterectomy in patients without recent neurological symptoms: randomised controlled trial. Lancet 2004; 363:1491. Copyright © 2004 Elsevier.
Benefit of carotid endarterectomy after recent cerebral ischemic episode  The NASCET trial included 659 patients with a recent transient ischemic attack or nondisabling stroke and a 70 to 99 percent carotid stenosis who were randomized to medical therapy or carotid endarterectomy. After a two year follow-up, the cumulative risk of any ipsilateral stroke was lower in those who underwent surgery compared to the medical group (9 versus 26 percent, p<0.001). There was also a benefit for the combined endpoints of major stroke or death (not shown). (Data from North American Symptomatic Carotid Endarterectomy Trial Collaborators. N Engl J Med 1991; 325:445.)
Current Indications

- carotid stenosis of 50% or greater with ipsilateral TIAs, amaurosis fugax, a reversible neurologic deficit, or small stroke and in selected cases of recurrent, symptomatic carotid stenosis.

- Patients with lesser degrees of symptomatic stenosis if they have failed medical therapy (have ongoing symptoms), particularly if there is evidence of ulceration of the lesion or if contralateral occlusion is present.

- Progressive stroke, progressive retinal ischemia, acute carotid occlusion, global cerebral ischemia caused by multiple large-vessel occlusive disease, and in certain cases of symptomatic carotid dissection and true or false aneurysm.
Current Indications

- The indications for endarterectomy in asymptomatic patients remain less clear cut.
- ACAS demonstrated significant benefit for all patients randomized to operation with 60% to 99% carotid stenoses; it is likely that those with advanced stenoses benefited most.
- Because the benefit-to-risk ratio in asymptomatic patients is much less than that of symptomatic patients, it is appropriate to reserve carotid endarterectomy only for good risk, asymptomatic patients with advanced stenoses.
- The presence of ulceration or contralateral occlusion may lower the threshold for recommending operation.
Contraindications

- vertebrobasilar distribution TIA's
- multi-infarct dementia
- patients with severe neurologic deficits
- evidence of intracranial hemorrhage or large infarcts
- uncontrolled congestive heart failure
- recent myocardial infarction
- unstable angina
- Dementia
- advanced malignancy
- uncertain diagnosis
Preoperative Evaluation

- History
- EKG
- Cardiac cath
- Swan-Ganz
- ASA, Plavix, Heparin
- Control HTN, DM
Operative Management
Postoperative Complications

- Stroke or TIA within first 12 hours postop – heparinization and reexploration; 12-24 hrs – CT scan

- Hyperperfusion syndrome and intracerebral hematoma - 0.3-1% - paralysis of autoregulation due to chronic ischemia - ipsilateral headache, seizures, postictal paralysis - angiogram. Risk factors: high-grade (>70%) stenosis; poor collateral hemispheric flow; contralateral carotid occlusion; evidence of chronic ipsilateral hypoperfusion; preoperatative and postoperative hypertension; preexisting ipsilateral cerebral infarction; preoperative anticoagulation or antiplatelet therapy

- Intracranial hemorrhage - 0.5% to 0.7% of patients undergoing CEA and may account for up to 20% of perioperative strokes
Postoperative Complications

- BP instability - 1/2-1/3 patients limited to first 12h; NTG drip to maintain SBP around 140, Dopamine preferred for hypotension
- Wound hematomas 1.4 -3 % - combination antiplatelet
- Rupture saphenous patch – 0.5% 1-7 days postop – use veins no smaller than 4-5 mm in diameter. Risk of stroke and death 48%
Postoperative Complications

- Operative damage to nerves: recurrent laryngeal nerve, 5% to 7%; hypoglossal nerve, 4% to 6%; marginal mandibular nerve 1% to 3%; superior laryngeal nerve, 1% to 3%; and spinal accessory nerve, 0.5% to 1%

- Also glossopharyngeal, facial (mandibular subluxation)
Ongoing Issues

- **Surgical expertise and training** - carotid endarterectomy should be performed with low morbidity and mortality in selected patients with appropriate symptoms and that the limits of perioperative morbidity and mortality should be categorized by clinical presentation. The combined morbidity and mortality of the procedure should not exceed 3% for asymptomatic patients, 5% for TIAS, and 7% for ischemic stroke. In addition, the 30-day mortality rate from all causes related to endarterectomy should not exceed 2%.

- **Increasing the cost/benefit ratio** - patients have been observed in an intensive care unit for 12 to 24 hours after the operation. Only 10% to 20% of patients required this expensive monitoring. Predictors of the need for intensive care unit observation include preoperative history of hypertension, myocardial infarction, arrhythmia, recent stroke, and chronic renal failure.

- Duplex ultrasonography alone or in combination with magnetic resonance angiography (MRA) and the elimination of contrast angiography in the preoperative work-up of patients undergoing endarterectomy - 0.5% to 1% incidence of major neurologic complications, puncture site complications 5% of patients, contrast-induced renal dysfunction in 1% to 5%.
Indications for adjunctive arteriography

1. Discrepancy among the history, physical examination, duplex scan, and CT scan
2. Patients presenting with vertebrobasilar symptoms, since they often have proximal brachiocephalic disease
3. Patients suspected of proximal disease involving branches of the aortic arch (patients with unequal arm blood pressures or duplex ultrasonographic evidence of abnormal flow characteristics in the proximal common carotid arteries)
4. Patients presenting with focal cerebrovascular symptoms and a stenosis in the 40% to 59% (moderate) range according to duplex criteria (this is the range where even slight overestimation or underestimation may inaccurately categorize the patient)
5. Patients with duplex findings suggestive of distal internal carotid artery or carotid siphon disease
6. Patients with duplex evidence of total carotid occlusion in the presence of ongoing ipsilateral hemispheric symptoms (patients may have near-total occlusion or a “string sign”)
7. Patients with contralateral carotid occlusion or severe carotid stenosis since ipsilateral duplex results are often overestimated because of increased ipsilateral flow velocities
8. Patients with nonatherosclerotic disease such as fibromuscular dysplasia and patients with recurrent carotid stenosis because plaque morphology and extent of disease are sometimes unusual in these patients
9. Patients with duplex scans that are equivocal or of poor quality
Ongoing Issues

- **Recurrent carotid stenosis** - 10% in the first year after primary endarterectomy, 3% in the second year, and 2% in the third year. Long-term risk has been estimated to be approximately 1% per year. Symptomatic recurrent carotid disease occurs in about 0.6% to 3% of patients after endarterectomy. Asymptomatic lesions occur with a much greater frequency (7% to 49%).

- Systemic factors that have been associated with the development of recurrent disease include female sex, continued smoking after endarterectomy, hypercholesterolemia, diabetes mellitus, hypertension, young age at original endarterectomy, and associated severe atherosclerotic disease.

- The mean risk of stroke with reoperation is approximately 4%, with a death rate of approximately 1.2% and cranial nerve injury of approximately 12%.
Ongoing Issues

- Closure technique of carotid arteriotomy

Vein patch
- increasing operative time
- patch rupture
- false aneurysm formation, thromboembolism stemming from the dilated aneurysmal reconstructed bifurcation

Dacron or other prosthetic material
- potential for infection is present - can lead to catastrophic complications

In men, the use of vein patch closure does not significantly reduce the long-term follow-up incidence of recurrent carotid disease. However, in women, who have a higher incidence of recurrent carotid stenosis, vein patch closure significantly reduces the incidence of this long-term complication

Ongoing Issues

- Local vs. general anesthesia

- Carotid shunt and monitoring - only 10% to 15% of patients who are intolerant of temporary carotid clamping benefit from an internal shunt.


- Monitoring neurologic status during temporary carotid occlusion in an awake patient under local anesthesia, measurement of internal carotid artery back pressure (“stump pressure” of <50 mm Hg is the generally accepted criterion for need for shunt placement), isotopic regional blood flow measurements, transcranial Doppler monitoring, somatosensory evoked potential monitoring, and EEG monitoring
Ongoing Issues

- **Timing of operation after stroke**
  - 4 to 6 weeks in patients diagnosed with acute stroke, regardless of its severity, for fear of clinical deterioration associated with conversion of a bland infarct into a hemorrhagic one
  - an early operation without waiting 4 to 6 weeks is safe in patients with minor, nondisabling stroke
  - On the other hand, a higher incidence of perioperative stroke has been reported in patients undergoing operation within 5 to 6 weeks after presenting with stroke
  - a compelling reason for not delaying the operation is that patients may be placed at risk for recurrent stroke during the waiting period, particularly in circumstances where the stenosis is advanced or preocclusive
Ongoing Issues

Simultaneous CEA and CABG

- The incidence of hemodynamically significant carotid stenosis in screening studies of patients undergoing coronary artery bypass is 5% to 11%.

- Although many centers have reported favorable experiences in combined carotid endarterectomy and coronary artery bypass procedures performed simultaneously, others point out that the overall stroke and death rate with this approach is higher than with either procedure alone.


- Simultaneous operation - precarious coronary artery disease such as unstable angina or high-grade left main lesions who have symptomatic high-grade carotid stenoses, bilateral high-grade asymptomatic stenoses, or ipsilateral advanced, asymptomatic stenosis and contralateral occlusion.
Ongoing Issues

Eversion CEA

- introduced in the late 1950s
- division of the common carotid artery below the bifurcation and eversion endarterectomy of both the external and internal carotid arteries
- recent modifications of the technique involve transection of the internal carotid artery at the level of the bifurcation and reimplantation of the internal carotid artery after endarterectomy into the common carotid artery
- simplicity, faster operating times, ease of correction of elongated and tortuous internal carotid arteries and, possibly, a lower rate of carotid restenosis
- difficulty in shunting, the possibility of incomplete removal of distal intimal flaps, difficulties in obtaining complete endarterectomy of the external and common carotid arteries when these are extensively involved with the disease, and frequent need for extensive distal mobilization of the internal carotid artery with a higher rate of cranial nerve injury in some series
- Randomized studies to date demonstrate no differences in the major outcomes of stroke, death, and recurrent stenosis

Line of Division

Artery Everted

Plaque
Ongoing Issues

Carotid angioplasty/stent placement

- technical success rate of 97% to 98% and a stroke and death rate of 0% to 7.1%
  

- Cerebral protection devices that capture atherothrombotic debris at the time of angioplasty and stent deployment reduce the overall rate of periprocedural neurologic deficits by 40% to 50%
  
Carotid Angioplasty and Stenting

SAPPHIRE
- randomized trial 334 pts symptomatic $\geq 50\%$ and asymptomatic $\geq 80\%$
- CAS was not inferior to CEA
- Almost significant difference in the composite end point of stroke, MI or death at 1 year (12.2 vs 20%, $p=0.053$)

WALLSTENT
- 219 pts symptomatic 60-90% CEA vs. CAS – ipsilateral stroke 12 vs. 3.6% at 1 year

CAVATAS
- 504 pts - no difference risks but results similar SAPPHIRE
Carotid Angioplasty and Stenting

- Ongoing trials
- CREST
- SPACE
- CAVATAS-2