



Diagnosis and treatment of carotid artery stenosis

BRUCE L. MINTZ, DO
ROBERT W. HOBSON II, MD

Diagnosis and management of carotid arterial occlusive disease and its ensuing comorbid illnesses have been the focus of extensive debate during the past two decades. The development of sophisticated ultrasound technology has enabled us to objectively define the severity of carotid stenosis in regions commonly accountable for stroke. Results from several well-designed prospective randomized trials have enhanced our understanding of the epidemiology of this disease and have guided our judgment with regard to aggressive diagnosis and intervention. As clinicians, we have been charged to address underlying risk factors, including hyperlipidemia and smoking abuse, as well as concomitant coronary, renal, and lower extremity artery disease. Carotid endarterectomy coupled with optimal medical management is superior to medical management alone in asymptomatic patients with high-grade carotid stenosis (>70% diameter reduction) and recently has been shown to have value for symptomatic patients with stenosis of 50% to 69%.

(Key words: carotid stenosis, duplex scan, carotid endarterectomy)

Emerging catheter technologies have stimulated us to investigate endovascular interventions in the treatment of carotid artery stenosis.¹⁻³ These ongoing studies have shown initial promise with regard to both low morbidity and adequate end results, allowing us to make responsible recommendations to patients regarding their care.

Carotid and vertebral arterial disease

Atherosclerotic disease at the carotid bifurcation has been shown to be responsible for greater than 20% to 25% of all strokes.² When the origin of ischemic premonitory symptoms to stroke are related to the carotid artery, the etiology of these symptoms is commonly due to atheroemboli. The mechanism for these symptoms is usually the result of rupture of the

fibrous cap within the carotid artery into the content of a complex plaque. Controversies related to the management of high-grade stenosis (70% to 99%) have largely been quelled in the face of several large multicenter prospective and randomized trials that have clearly shown diminished morbidity and mortality when symptomatic patients with high-grade stenosis are offered a surgical option over medical management alone.^{2,4} There remains, however, continued skepticism in some circles regarding asymptomatic carotid artery disease in a lesser, moderate degree of percent stenosis.⁵ As a result of these evidence-based studies, however, the number of carotid endarterectomies associated with high-grade or critical stenosis on duplex ultrasound examination has steadily risen.

Complications associated with carotid endarterectomy are well recognized, and the ad hoc committee on carotid surgery has set guidelines for acceptable morbidity in this procedure. This committee analyzed the statistical risks of stroke and death from both asymptomatic and symptomatic stenosis (Table 1) and concluded stroke and death rates of 3% in asymptomatic patients to be acceptable, with a 5% stroke and death rate in symptomatic disease.²

Symptomatic carotid artery disease is commonly manifested by transient asymmetric loss of function. Clinical evolution in the management of both asymptomatic and symptomatic carotid arterial disease has mandated an accurate and straightforward diagnostic tool to monitor this dynamic process. The charge of this technology has been to provide a reproducible and highly accurate study that would distinguish discrete differences in arterial wall narrowing, allowing the clinician to prognosticate prospectively and make recommendations regarding the patient's care.⁶ Although various diagnostic modalities have been developed during the past three decades, the duplex ultrasonography scan, done in qualified laboratories, has met the expectations of this mandate to quantify percent stenosis in the carotid distribution.⁷

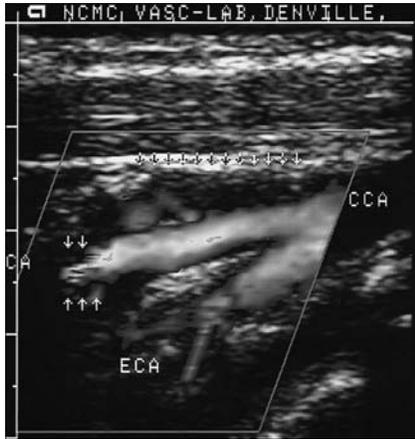
Angiography as the "gold standard" has amply been replaced by duplex ultrasonography in most diagnostic circumstances. Positive experience with carotid duplex ultrasonography scanning (Figure 1) unassisted by angiography in the setting of an impending surgical intervention has been embraced by a growing number of our colleagues in many vascular centers.⁸ In our institution, because of the known risk of iatrogenic stroke associated with angiography (1.2% stroke risk) in the setting of carotid surgery, duplex ultrasonography as the singular diagnostic tool has become more the rule than the exception. Corollary studies involving magnetic resonance angiography (MRA) imaging and ultrafast contrast computed axial tomography (CT scanning) have also begun to emerge in vascular centers around the country. Although MRA imaging may be helpful in defining stenosis, without the necessity of formal angiography, its relatively high cost and propensity for overestimation of the degree of stenosis has mitigated against its use as a routine screening tool in most centers. The addition of CT scanning has also enjoyed considerable recent interest. Unfortunately, technical problems with currently available software and common interference by calcific plaque have attested to the immaturity of this technology. Formal angiographic studies have to a great extent now been delegated to road mapping in carotid endovascular intervention.

Indications for diagnostic testing

Indications for duplex ultrasonography

Dr Mintz is director of vascular medicine and an assistant professor of internal medicine, University of Medicine and Dentistry of New Jersey, Newark, NJ, and director, Vascular Laboratory, St Clares Hospital, Denville, NJ. Dr Hobson is chief, Division of Vascular Surgery, and professor of surgery, University of Medicine and Dentistry of New Jersey, New Jersey Medical School, Newark, NJ.

Correspondence to Bruce L. Mintz, DO, 16 Pocono Rd, Suite 313, Denville, NJ 07834.
E-mail: blm55@pol.net



Stenosis	Risk, %
<input type="checkbox"/> Asymptomatic carotid stenosis	3
<input type="checkbox"/> Symptomatic carotid stenosis	5
<input type="checkbox"/> Prior stroke with carotid stenosis	7
<input type="checkbox"/> Restenosis	10

◀ **Figure 1.** Duplex ultrasonography showing high-grade stenosis of internal carotid along with image of external carotid branches.

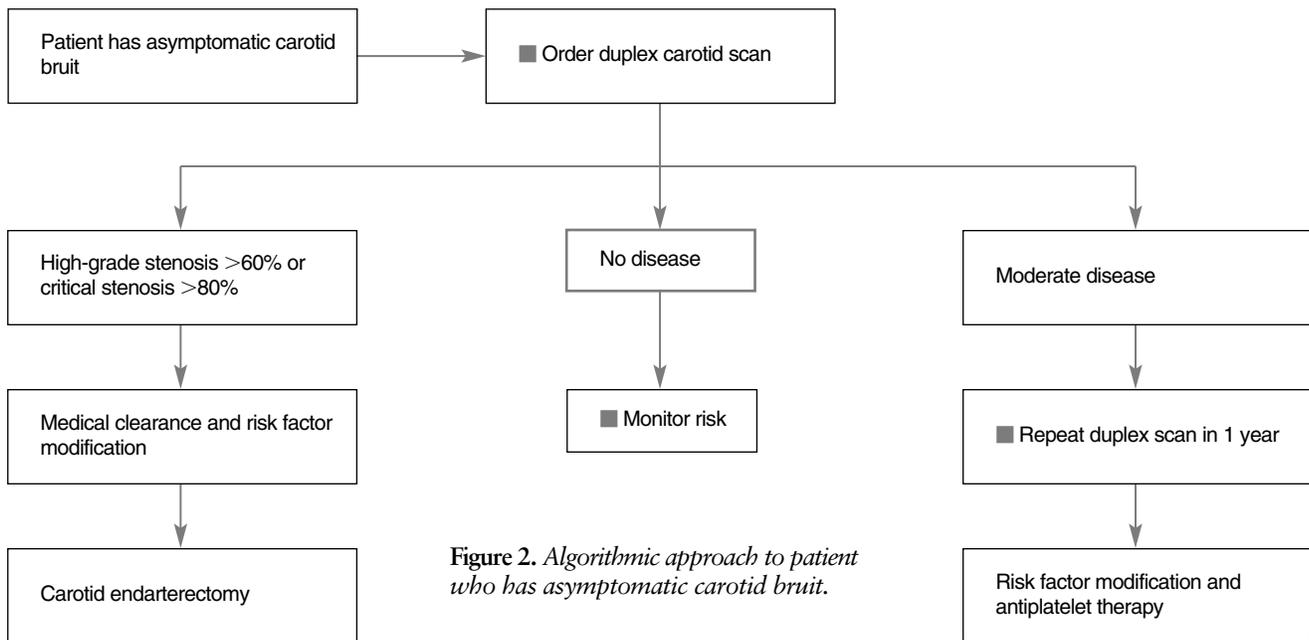


Figure 2. Algorithmic approach to patient who has asymptomatic carotid bruit.

Diameter stenosis (%)	Peak systolic velocity, cm/s	End diastolic velocity, ratio cm/s	Systolic velocity ratio (ICA/CCA†)	Diastolic velocity ratio (ICA/CCA)
<input type="checkbox"/> 1 to 39 (mild)	<110	<40	<1.8	<2
<input type="checkbox"/> 40 to 59 (moderate)	<130	<40	<1.8	<2.6
<input type="checkbox"/> 60 to 79 (severe)	>130	>40	>1.8	>2.6
<input type="checkbox"/> 80 to 99 (critical)	>200	>100	>3.7	>5.5
<input type="checkbox"/> 100‡				

* Source: Adapted from Bluth EL, Stavros AT, Marich KW, Wetzner SM, Aufrichtig D, Baker JD. Carotid duplex sonography: A multicenter recommendation for standardized imaging and Doppler ultrasonography criteria. *Radiographics* 1988;8:487-506.
 † ICA = internal carotid artery; CCA = common carotid artery.
 ‡ No Doppler signals are recorded.

imaging have traditionally been broad. Major indications for testing include carotid bruits (Figure 2), amaurosis fugax, hemispheric transient ischemic attacks (Figure 3), and recent stroke. One can also assess a possible reversible cause of a patient's symptoms, monitor previous lesser stenosis, or follow up after carotid endarterectomy, as well as directly visualize suspected carotid dissection or carotid body tumors. Other reasons for ordering this study may involve an attempt to objectively exclude stenosis of the posterior circulation. These patients commonly present with dizziness, uncommonly syncope and atypical paresthesia. An abnormal study of the posterior circulation is reflected by reversal of normal direction of flow in the vertebral arteries. Unfortunately, although we can infer from duplex ultrasonography that disease is present in the vertebral circulation, intralaboratory reproducibility with duplex ultrasonography has a lower yield in the accurate assessment of percent stenosis in these vessels.⁹

Plaque characterization

The duplex ultrasonography scan utilizes brightness-mode (B-mode) (Figure 4) imaging to display an ultrasonic differentiation between structures of dissimilar acoustic impedance. When adjacent structures reflect their dissimilarity, an image is displayed. The greater the reflection, the brighter the picture at the point of insonation. Because atherosclerotic plaque varies in uniformity, the reflective capacity of this segment also varies, giving us visual insight into plaque characteristics. Great promise remains with regard to qualification of irregular (ulcerative) plaque (Figure 5); our current experience in this regard can be characterized as immature. This is particularly the case even in the most experienced hands when patients present with higher degrees of stenosis.¹⁰ Enhanced processing with color and an array of ultrasonic contrast agents may alter this shortcoming in the future. Other limitations of this technique include tortuous vessels, the differentiation of occlusion from high-grade stenosis, and contralateral occlusion with ipsilateral high-grade stenosis. In the latter, an arbitrary downgrading of the category of percent stenosis is assigned to compensate for artifactually increased velocities secondary to turbulent flow.

The addition of pulsed-wave Doppler ultrasonography further complements the

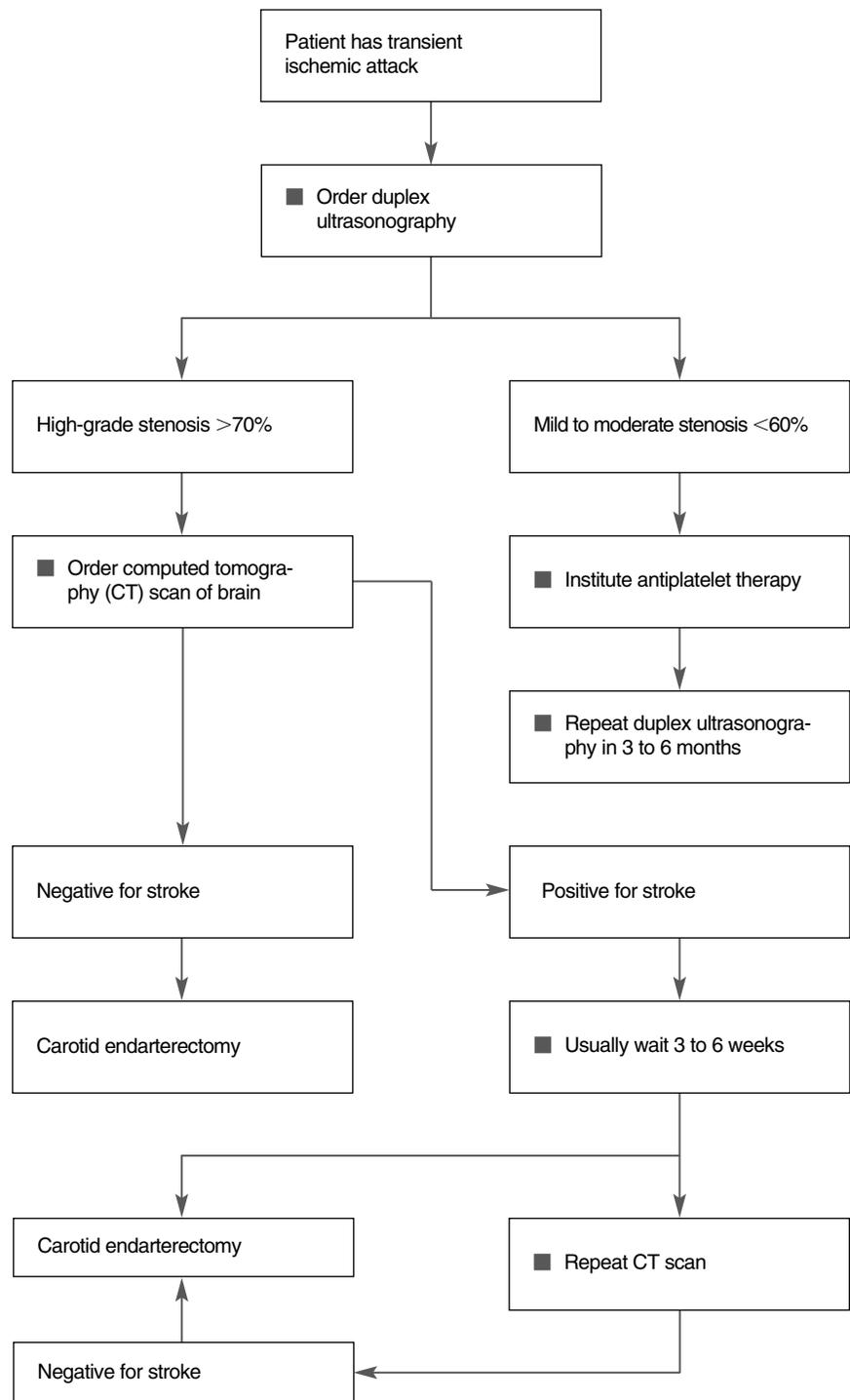
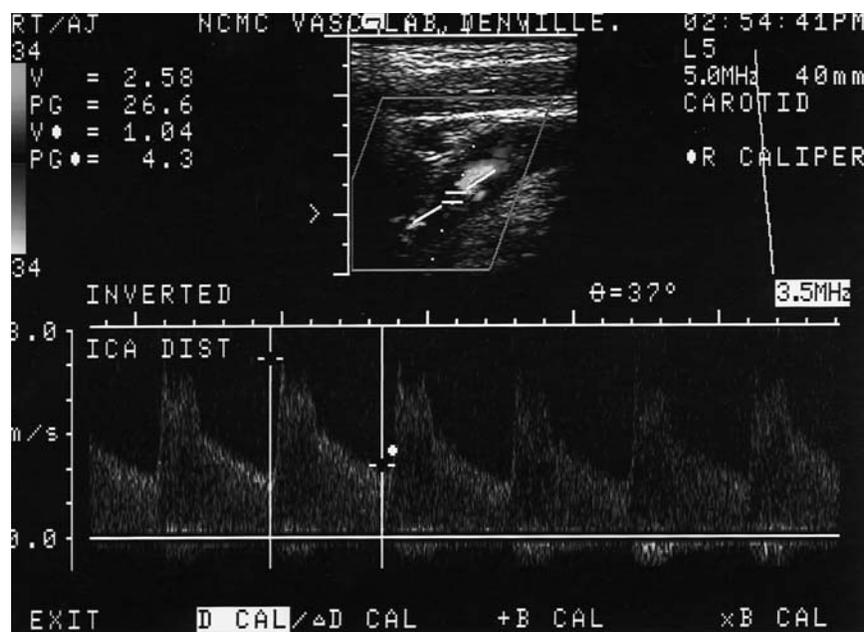


Figure 3. Algorithmic approach to patient who has transient ischemic attack.

B-mode study. In this modality, the signal is directed into the vessel at an (beam/flow) angle of insonation of 60 degrees. Color flow is then assigned to aid in the interrogation of a specific arterial segment. High peak systolic velocities as well as high end diastolic velocities and spectral broadening correlate with high-grade per-

cent stenosis. When the B-mode and the pulsed Doppler ultrasonography are combined, the accuracy of the percent stenosis reading should be excellent. It should be noted that because of the highly technical nature of these studies, and their operator dependence, an inexperienced technologist may create an inaccurate



◀ **Figure 4.** High-grade distal carotid artery stenosis by B-mode imaging. Corollary high peak systolic velocities corroborate image finding.



Figure 5. Plaque characteristics. Left: Homogeneous, smooth surface; Right: Heterogeneous irregular surface.

reading. As a consequence, we recommend that procedures should be done in accredited vascular laboratories, by registered vascular technologists. Further, the interpreters of these studies should have an in-depth appreciation of ultrasound as well as the pathophysiology of the disease entities being studied.

Current therapeutic possibilities

Subsequent to recent validation trials that have supported the use of carotid endarterectomy in both symptomatic and asymptomatic stenosis, there has been a revolution in the field of catheter technology.^{11,12} The performance of carotid angioplasty-stenting (CAS) has been recommended by some clinicians as an alternative to standard endarterectomy for patients who have symptomatic extracranial carotid occlusive disease (Figure 6). The emergence of a position of clinical equipoise on the relative equivalent value of these alternatives has resulted in one randomized clinical trial in Great Britain comparing the efficacy of carotid endarterectomy and CAS.¹ In the United

States, another trial has recently been approved for funding by the National Institute of Neurological Disease and Stroke (NINDS): the CREST (Carotid Revascularization Endarterectomy versus Stent Trial).¹³ This study of patients with symptomatic stenosis emphasizes rigid credentialing criteria for participation in it, mandating the perioperative combined stroke/death risk be less than 6% for symptomatic patients and less than 3% for asymptomatic patients. It is the recognition that carotid angioplasty-stenting remains a relatively new procedure that has dictated the need for prospective randomized investigation in the setting of proven catheter-based skills to reassure our colleagues of the responsibility of these pioneering endeavors.¹⁴

Clinical approach to the patient

Patients with asymptomatic carotid stenosis are most commonly found by physical examination of a carotid bruit. A bruit is produced when the lining of a vessel is stenosed, much like a bent hose. On auscultation, the clinician is clued both to



Checklist

- Contralateral hemi-paresthesia
- Dysphasia
- Ipsilateral monocular blindness
- Residual blurriness
- Syncope (rarely)
- Confusion
- Seizure

Figure 6. Symptoms associated with carotid occlusive disease.

the possibility of carotid stenosis as well as other stenoses of various adjacent branches of the vascular tree.

When a carotid bruit is auscultated, a duplex ultrasound examination should be done with quantification of the plaque stenosis. The report of the duplex ultrasonography findings should stratify the degree of stenosis based on a combined view of spectral Doppler ultrasonography velocity broadening (Table 2) and plaque characterization. If stenosis of less than 60% is found, the patient is generally followed up conservatively, and the study should be repeated in 6 months, absent any new symptoms. If an asymptomatic stenosis is evaluated and shows no significant progression at the next ultrasound examination, then generally our practice is to reevaluate the patient in 1 year. In this circumstance, antiplatelet therapy should be instituted and risk factors such as smoking, diabetes, and the low-density-lipoprotein-cholesterol level should be attended to.

If the patient is found to have a greater than 60% asymptomatic stenosis, then evaluation of other risk factors such as concurrent coronary artery disease should be attempted, by way of potential preoperative clearance. If no other critical coronary stenosis exists, then carotid endarterectomy should be considered.¹⁵

When symptomatic carotid artery disease is encountered, a similar pathway is taken; however, such evaluation should include the addition of a CT scan or MRI. If this study is negative for stroke or bleed-

ing and the patient has a stenosis greater than 60%, then a carotid endarterectomy should be considered. When intercurrent stroke is encountered, then a wait of 6 weeks is recommended. After 6 weeks, a carotid endarterectomy should be done if resolution of an acute process is noted on a repeated CT or MRI scan.

Management of lesions that are less than 60% stenotic and symptomatic remains disputed. It is generally agreed, however, that antiplatelet therapy is the best treatment for this subset of patients. Stratification of several studies speaking to this circumstance remain ongoing, and recommendations will take several years to be set forth.

Treatment of patients with recurrent carotid stenosis remains controversial; however, it is agreed that this lesion is usually not as malignant as a virgin carotid stenosis and, in experienced hands, may be an ideal circumstance for carotid angioplasty with stent.¹⁴ Carotid occlusion, in contrast, is dealt with conservatively. In contradistinction to the management of 100% coronary lesions or lower extremity lesions, in the carotid artery distribution, occlusion cannot be treated by endarterectomy or bypass. When a carotid artery is occluded, it thromboses proximally and is not accessible to surgical interventions. As a consequence, the only intervention to management with any carotid artery occlusion is to pay meticulous attention to potential stenosis on the contralateral side.

Comment

The approach to the patient with carotid artery disease, symptomatic or asymptomatic, should always involve recognition of this disease as a specific manifestation of generalized arteriopathy. It has been clear for several decades that a close relationship exists between carotid artery disease and coronary artery disease. Armed with this information along with current understanding of carotid pathophysiology and surgical treatment, the clinician should evaluate coronary artery disease and recognize its intimate relationship to other vascular beds. Patients with carotid artery stenosis must be treated in their entirety, and, as a consequence, should have a thorough medical assessment, with close attention to modifying those risk factors where possible. Varied medical presentations of carotid stenosis have spawned several clinical pathways for their management. These pathways rep-

resent a rational convergence of good medical care with state-of-the-art interventional and surgical care.

References

1. MRC European Carotid Surgery Trial. Interim results for symptomatic patients with severe (70-99%) or with mild (0-29%) carotid stenosis. European Carotid Surgery Trialists Collaborative Group. *Lancet* 1991;337:1235-1243.
2. Beneficial effects of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. North American Symptomatic Endarterectomy Trial Collaborators. *N Engl J Med* 1991;325:445-453.
3. Mayberg MR, Wilson SE, Yatsu F, Weiss DG, Messina L, Hershey LA, et al. Carotid endarterectomy and prevention of cerebral ischemia in symptomatic carotid stenosis. Veterans Affairs Symptomatic Cooperative Studies Program 309 Trialist Group. *JAMA* 1991;266:3289-3294.
4. Fields WS, Maslenikov V, Meyer JS, Hass WK, Remington RD, MacDonald M. Joint study of extracranial arterial occlusion. V. Progress report of prognosis following surgery or nonsurgical treatment for transient cerebral ischemic attacks and cervical artery lesions. *JAMA* 1970;211:1993-2003.
5. Barnett HJM, Taylor DW, Eliasziw M, Fox AJ, Ferguson GG, Haynes RB, et al. Benefit of carotid endarterectomy in patients with symptomatic moderate or severe stenosis. American Symptomatic Carotid Endarterectomy Trial Collaborators. *N Engl J Med* 1998;339:1415-1425.
6. Langsfeld M, Gray-Weale AC, Lusby RJ. The role of plaque morphology and diameter reduction in the development of new symptoms in asymptomatic carotid arteries. *J Vasc Surg* 1989;9:548-557.
7. Katz M. The sensitivity of real time B-mode carotid imaging in the detection of ulcerated plaques. *BRUIT VII* September 1983;13-17.
8. Cartier R, Cartier P, Fontaine A. Carotid endarterectomy without angiography. The reliability of Doppler ultrasonography and duplex scanning in preoperative assessment. *Can J Surg* 1993;36:411-416.
9. Hughes JP, Rush MP, Hansen S, et al. Cerebrovascular testing in patients with symptoms of vertebrobasilar insufficiency. *Journal of Vascular Technology* 1999;23(3):123-127.

10. Rubin JR, Bondi JA, Rhodes RS. Duplex scanning versus conventional arteriography for the evaluation of carotid plaque morphology. *Surgery* 1987;102:749-755.

11. Endarterectomy for asymptomatic carotid stenosis. Executive Committee for the Asymptomatic Carotid Atherosclerosis Study. *JAMA* 1995;273:1421-1428.

12. Inzitari D, Eliasziw M, Gates P, Sharpe BL, Chan RK, Meldrum HE, et al. The causes and risk of stroke in patients with asymptomatic internal-carotid artery stenosis. North American Symptomatic Carotid Endarterectomy Trial Collaborators. *N Engl J Med* 2000;342:1693-1700.

13. Alberts MJ, McCann R, Smith TP, et al. A randomized trial: carotid stenting versus endarterectomy in patients with symptomatic carotid stenosis, study designs. *Journal of Neurovascular Disease* Nov-Dec 1997;2:228-234.

14. Joint Council of the Society of Vascular Surgery and the International Society of Cardiovascular Surgery, North American Chapter. Point of view: Statement regarding carotid angioplasty and stenting. *J Vasc Surg* 1996;24:900.

15. Hobson RW 2d, Weiss DG, Fields WS, Goldstone J, Morre WS, Towne JB, Wright CB. Efficacy of carotid endarterectomy for asymptomatic carotid stenosis. Veterans Affairs Cooperative Study Group. *N Engl J Med* 1993;328:221-227.