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Guidelines for Carotid Endarterectomy

A Statement for Healthcare Professionals From a Special Writing Group of the Stroke Council, American Heart Association

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Since the 1950s carotid endarterectomy has been performed in patients with symptomatic carotid artery stenosis, based on suggestive but inconclusive evidence for its effectiveness. Only during the last 5 years have randomized studies clarified the indications for surgery. In preparing this report, panel members used the same rules of evidence used in the previous report[1,2] (Table).

Management of Risk Factors

Few studies have analyzed control of risk factors in a randomized, prospective manner following carotid endarterectomy. However, a wealth of data are available regarding the general relationship between risk factor control and stroke risk. These data provide some guidance for the care of endarterectomy patients.

Hypertension

Hypertension is the most powerful, prevalent, and treatable risk factor for stroke.[3] Both systolic and diastolic blood pressure are independently related to stroke incidence. Isolated systolic hypertension, which is common in the elderly, also considerably increases risk of stroke. Reduction of elevated blood pressure significantly lowers risk of stroke. Meta-analyses of randomized trials found that an average reduction in diastolic blood pressure of 6 mm Hg produces a 42% reduction in stroke incidence.[3,4] Treatment of isolated systolic hypertension in people older than 60 years also reduces stroke incidence by 36% without an excessive number of side effects such as depression or dementia.[5] Long-term care of patients after endarterectomy should include careful control of hypertension (Grade A recommendation for treatment of hypertension in general; Grade C recommendation for postendarterectomy care).

Perioperative treatment of hypertension after carotid endarterectomy represents a special situation. Poor control of blood pressure after endarterectomy increases risk of cerebral hyperperfusion syndrome.[6–9] This complication is characterized by unilateral headache, seizures, and occasionally altered mental status or focal neurological signs. Neuroimaging may show intracerebral hemorrhages[10–12] or white matter edema.[13] Transcranial Doppler ultrasound shows elevated middle cerebral artery blood velocity ipsilateral to the endarterectomy and occasionally in the contralateral middle cerebral artery as well.[12,14,15] The syndrome is thought to arise from impairment of autoregulation. At greatest risk are patients with severe preoperative internal carotid stenosis and chronic hypertension. The risk is increased when a contralateral severe stenosis is present.

Blood pressure should be carefully monitored after carotid endarterectomy, and elevated blood pressure should be aggressively treated, particularly in those with early symptoms of cerebral hyperperfusion syndrome (Grade C recommendation). In patients thought to be at risk for hyperperfusion syndrome, blood pressure should be monitored for several days after surgery and for at least 7 days in patients with headaches or new neurological symptoms. Such monitoring may be performed on an outpatient basis as appropriate (Grade C recommendation).[13] Transcranial Doppler ultrasound shows promise in early identification of the syndrome and possibly for monitoring therapy but has not been rigorously studied.

Cigarette Smoking

Cigarette smoking substantially increases risk of stroke with relative risk values of 1.5 to 2.2.[16–18] Risk of stroke increases with the number of cigarettes smoked. Smoking cessation promptly reduces risk of stroke.[16,17,19] Cigarette smoking has been identified as a risk factor for carotid restenosis. Although no prospective studies have specifically assessed smoking cessation after carotid endarterectomy, efforts directed at smoking cessation should be part of the postoperative care of these patients (Grade C recommendation).

Blood Lipids

Increased serum lipid levels have not been clearly related to the overall incidence of stroke in individual population studies,

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†Deceased.

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Levels of Evidence and Grading of Recommendations

Level of evidence	
Level I	Data from randomized trials with low false-positive (alpha) and low false-negative (beta) errors
Level II	Data from randomized trials with high false-positive (alpha) or high false-negative (beta) errors
Level III	Data from randomized concurrent cohort studies
Level IV	Data from randomized cohort studies using historical control
Level V	Data from anecdotal case series
Strength of recommendations	
Grade A	Supported by Level I evidence
Grade B	Supported by Level II evidence
Grade C	Supported by Levels III, IV, or V evidence

and a meta-analysis of lipid-lowering trials found no benefit in terms of stroke risk reduction.[20] However, these studies were heterogeneous in terms of agents used, degree of cholesterol reduction, and diagnosis of stroke. Recently the Scandinavian Simvastatin Survival Study (4S)[21] reported a 30% reduction in fatal and nonfatal strokes in patients taking simvastatin. Other lipid-lowering trials using statin drugs found a slowing of the progression of carotid atherosclerosis by ultrasound.[22,23] Thus, lipid lowering may be effective in reducing risk of some kinds of cerebrovascular disease. Elevated cholesterol has been found to be a risk factor for carotid restenosis in numerous studies. Finally, even in the absence of coronary artery symptoms, a significant portion of patients with carotid artery disease will have concomitant coronary artery disease. Thus, a growing body of evidence suggests that serum cholesterol in patients with carotid artery disease should be evaluated and treated according to the guidelines of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults[24] (Grade A recommendation for coronary artery disease; Grade C recommendation for postendarterectomy care).

Alcohol Consumption

The relationship between use of alcohol and stroke is complex. Heavy use of alcohol is associated with excessive risk of stroke whereas moderate consumption may have no effect or a slightly protective effect.[25–27] The effects for ischemic and hemorrhagic stroke may differ. Moderate consumption of alcohol may raise HDL cholesterol and lower risk of atherosclerotic heart disease.[28,29] Heavy use of alcohol should be avoided (Grade C recommendation).

Postmenopausal Use of Estrogen

The cardiovascular and cerebrovascular risk associated with postmenopausal estrogen replacement is not clear. In the Framingham study, women reporting postmenopausal use of estrogen had a more than twofold increased risk for cerebrovascular disease.[30] However, subsequent large studies found a decreased risk[31] or no effect.[32,33] Overall these studies support a beneficial effect of estrogen replacement on coronary heart disease, but the effect on stroke is still uncertain. There is no need to discontinue postmenopausal hormone therapy in women who undergo carotid endarterectomy (Grade B recommendation).

Antiplatelet Therapy

Antiplatelet therapy has been shown in individual trials and meta-analysis to reduce risk of stroke and other vascular events in patients at high risk (Grade A recommendation). The Antiplatelet Trialists Collaboration[34] overview found a 23% reduction in risk for nonfatal stroke with antiplatelet therapy compared with placebo among persons with a history of transient ischemic attack (TIA) or stroke. There was a 22% reduction in risk for the vascular events cluster "nonfatal stroke, nonfatal myocardial infarction, and vascular death." The relative benefit of antiplatelet therapy was independent of sex, age (younger than 65 versus older than 65), diabetes, or hypertension.[34]

Controversy remains regarding the optimal dose of aspirin to prevent stroke.[35–38] At present there is no compelling evidence that higher or lower doses are more efficacious. The range of acceptable management includes daily doses of aspirin between 30 and 1300 mg. In view of the slightly lower incidence of side effects with lower doses and the possibility of increased compliance, the American Heart Association consensus statement "Guidelines for the Management of Transient Ischemic Attacks"[39] recommended 325 mg/d as an initial dose for stroke prevention.

The role of perioperative antiplatelet agents at the time of endarterectomy has not been comprehensively studied. Antiplatelet therapy might decrease the perioperative stroke rate, long-term risk of stroke after surgery, and rate of coronary artery events at the time of surgery or afterward. In the first randomized trial of aspirin for preventing stroke in carotid endarterectomy in the United States, patients in the surgical arm received either aspirin 1300 mg/d or placebo, started within 5 days of carotid endarterectomy. Patients were followed for a minimum of 6 months. There were fewer strokes or deaths in the group treated with aspirin, but the number of events was very small.[40] In a small randomized trial, Kretschmer et al[41] reported a decreased mortality rate in endarterectomy patients treated with aspirin 1000 mg/d compared with placebo. The stroke rate was not reported. A Danish trial[42] comparing very-low-dose aspirin (50 to 100 mg/d) with placebo reported no significant difference in survival. However, treatment was not begun until 1 to 12 weeks after surgery. A Swedish trial[43] compared aspirin 75 mg/d begun before surgery with placebo in patients undergoing endarterectomy. Investigators found a decrease in intraoperative or perioperative stroke in patients treated with aspirin (P .01) and a trend toward decreased mortality in the aspirin group (P .12). In another randomized trial the combination of aspirin 325 mg/d and dipyridamole 75 mg three times a day did not reduce the incidence of restenosis after carotid endarterectomy.[44]

The North American Symptomatic Carotid Endarterectomy Trial (NASCET) retrospectively examined the association between aspirin dose and perioperative stroke in patients with 70% to 99% stenosis who underwent carotid endarterectomy. The ipsilateral stroke rate at 30 days was 2.1%, 1.1%, 6.5%, and 7.8% in patients receiving 1300 mg, 650 mg, 325 mg, or no

aspirin, respectively.[35] These data were not randomized and are now being prospectively tested in a double-blinded randomized trial.

Although the benefit of antiplatelet therapy in reducing perioperative or postoperative stroke is unresolved, aspirin may decrease perioperative coronary events. In the Mayo Asymptomatic Carotid Endarterectomy Study,[45] patients with asymptomatic carotid artery stenosis were randomly allocated to receive either carotid endarterectomy or aspirin 80 mg/d. Aspirin use was discouraged in the surgical group. After 30 months of recruitment, only 71 patients had been enrolled, but the study was terminated early because there were eight myocardial infarctions in the surgical group and none in the medical group (P .0037). The Antiplatelet Trialists Collaboration found a 36% reduction in myocardial infarction and a 16% reduction in vascular death in patients with stroke or TIA treated with antiplatelet agents.[34]

Patients who are undergoing endarterectomy should receive aspirin therapy beginning before surgery unless there are contraindications (Grade B recommendation). The optimal dose of aspirin is uncertain.

Update on Carotid Endarterectomy in the Treatment of Persons With Asymptomatic Carotid Stenosis

Since the first publication of "Guidelines for Carotid Endarterectomy," which appeared simultaneously in *Stroke* and *Circulation* in January 1995, major contributions to understanding of asymptomatic carotid disease have been derived from publication of the Asymptomatic Carotid Atherosclerosis Study (ACAS)[46] in its entirety. The original guidelines incorporated data from the Clinical Alert issued by the National Institute of Neurological Disorders and Stroke on September 28, 1994, but not information in the final manuscript, which appeared May 10, 1995.

In the randomized ACAS trial, 1662 patients from more than 42 000 were screened at 39 centers in North America between 1987 and 1993. Among the inclusion criteria was an age requirement (40 to 79 years). Patients with ipsilateral cerebrovascular events, vertebrobasilar distribution events, or contralateral symptoms within the previous 45 days were excluded. Seventy percent of patients were asymptomatic in distribution of both carotid arteries, whereas 25% had a prior (45 days) hemispheric event in the contralateral carotid distribution. A significant stenosis was defined as a 60% reduction in diameter by arteriography, Doppler examination within 60 days (95% positive predictive value by frequency or flow velocity), or in a separate study Doppler examination within 60 days confirmed by oculopneumoplethysmography (90% positive predictive value). Patients randomly assigned to surgery then underwent preoperative cerebral arteriography. Arteriography was not mandatory in the medical arm, but 319 (37.5%) of the medical patients had arteriography before randomization. Arteriographic diameter reduction was calculated in the same manner as in the NASCET study (minimum residual lumen at the point of maximum stenosis referenced to the diameter of the distal lumen of the internal carotid artery at the first point at which the arterial walls became parallel). Eight percent of patients who underwent presurgical arteriography after randomization based on Doppler criteria had arteriographic stenoses 60%, consistent with the Doppler predictive value estimates used for the study. Of 825 patients randomly assigned to surgery, 101 (12%) were excluded for a variety of reasons, including 45 patients who refused surgery after randomization and 27 who had 60% stenosis on presurgical arteriography. All 825 patients were retained in the surgical arm of the study on the basis of intent-to-treat analysis. Of the 834 randomly assigned to the medical arm, 45 (5%) crossed over and received carotid endarterectomy without a verified ipsilateral TIA or stroke.

All patients received aspirin (325 mg/d) with risk factor reduction counseling. Follow-up evaluations were obtained at 1 month and every 3 months thereafter, with Doppler ultrasound at the initial 3-month visit and every 6 months thereafter for 2 years and then annually until completion of the fifth-year interval or end points were reached. Primary end points included stroke and death, and those that occurred within 30 days of surgery or 42 days (to account for the average of 12 days between randomization and operation in the surgical arm) of medical randomization were considered perioperative. The surgical group incurred a 2.3% perioperative risk for stroke or death (19 patients, including 8 with an event *before* surgery) and a 5.1% risk of ipsilateral stroke or perioperative stroke or death on the basis of Kaplan-Meier projections at the fifth-year interval (median follow-up of 2.7 years). This included risk of stroke with arteriography in the surgical group. The medical group had a lower risk (0.4%) in the equivalent perioperative (42 day) period but a higher risk (11%) for end points after 5 years by Kaplan-Meier projections. Surgery reduced absolute risk by 5.9% and relative risk by 53% at 5 years (P .004, 95% confidence interval). The relative risk reduction for major disabling stroke or perioperative death and major stroke was 43%, which was not statistically significant (6% for the medical arm versus 3.4% for the surgical arm, P .12). Major stroke was defined by the Glasgow Outcome Scale criteria (2 to 5) characterized by moderate to severe disability, persistent vegetative state, or death. Analysis with exclusion of the 146 patients who crossed over demonstrated a 55% relative risk reduction at 5 years. The benefit associated with surgery was realized within the first-year interval, and 89% of patients survived long enough to achieve that benefit with the mean age at entry of 67 years. Relative risk reduction for patients at or younger than the mean age of 67 was 60%; the comparable risk reduction for those older than 67 was 43%. This difference was not statistically significant. While ACAS was not powered for gender differences, men had an absolute risk reduction from 12.1% to 4.1%, (a relative risk reduction of 66%); the benefit for women was less (1.4% absolute risk reduction and a relative risk reduction of 17%). Although the explanation is not clear, more women had perioperative complications (3.6%) than men (1.7%). The gender difference was not statistically significant. Finally, degree of stenosis did not alter the magnitude of benefit provided by surgery. Importantly, the described surgical benefit was achieved with approximately 70% of patients in both the medical and surgical arms of the trial having stenoses 80%.

Postrandomization, presurgical arteriography was complicated by stroke in five patients (1.2%), a risk not incurred by

the medical group. If the 101 excluded patients initially randomly assigned to surgery had undergone arteriography and assumed the same risk for stroke, the absolute risk of achieving the primary end point at 5 years for the surgical group would have increased from 5.1% to 5.6%. In contrast, if arteriography was avoided (as is increasingly the practice in many centers) in all patients, the absolute risk of reaching the primary end point in the surgical group would have fallen from 5.1% to 3.9%. If only the 724 patients who actually had carotid endarterectomy in the surgical arm were included and if "perioperative" events that occurred before surgery are excluded (comparable to other surgical series), the 30-day stroke mortality risk in ACAS was 1.5%. This commendably low operative morbidity/mortality rate must be considered when extrapolating the results of this trial to other patients and surgeons.

It is important to realize that all patients with 60% to 99% carotid stenosis were analyzed together by ACAS. The trial was not designed to break down the event rates by deciles. In ACAS the only statistically significant differences were for all ipsilateral stroke. In addition, the overall reduction of 1% per year by Kaplan-Meier estimate was extrapolated from only 2.7 years of follow-up. On the basis of the extremely low event rate, many cerebrovascular investigators would qualify surgery only for a much tighter (80%) stenosis. This issue was evaluated by the European Carotid Surgery Trialists (ECST) Collaborative Group.[47] Using data from 2295 patients in the ECST trial, it was determined that the overall Kaplan-Meier estimate of stroke risk at 3 years was 2.1% in the distribution of the asymptomatic internal carotid artery. More striking was that patients in each decile up to 80% stenosis of the asymptomatic internal carotid artery had a very low risk of stroke (2%). Also, stroke risk was 9.8% in the 80% to 89% internal carotid artery stenosis decile and increased to 14.4% in patients with 90% to 99% asymptomatic stenosis. These observations are confounded by the fact that the ECST measured stenosis differently than ACAS (ECST criteria assign a higher degree of stenosis to most lesions than ACAS).

While some investigators consider it acceptable to delay surgery until there is 80% carotid stenosis, the writing group recommends updating the 1995 AHA guidelines as follows:

Patients With Asymptomatic Carotid Artery Disease

For patients with a surgical risk 3% and life expectancy of at least 5 years:

1. Proven indications: Ipsilateral carotid endarterectomy is acceptable for stenotic lesions (60% diameter reduction of distal outflow tract with or without ulceration and with or without antiplatelet therapy, irrespective of contralateral artery status, ranging from no disease to occlusion [Grade A recommendation]).
2. Acceptable indications: Unilateral carotid endarterectomy simultaneous with coronary artery bypass graft for stenotic lesions (60% with or without ulcerations with or without antiplatelet therapy irrespective of contralateral artery status [Grade C recommendation]).[1]
3. Uncertain indications: Unilateral carotid endarterectomy for stenosis 50% with B or C ulcer[48] irrespective of contralateral internal carotid artery status (Grade C recommendation).

For patients with a surgical risk of 3% to 5% and for patients with a surgical risk of 5% to 10%, indications are unchanged from the original guidelines[1]:

For patients with a surgical risk of 3% to 5%

1. Proven indications: None
2. Acceptable but not proven indications: ipsilateral carotid endarterectomy for stenosis 75% with or without ulceration but in the presence of contralateral internal carotid artery stenosis ranging from 75% to total occlusion
3. Uncertain indications:

   Ipsilateral carotid endarterectomy for stenosis 75% with or without ulceration irrespective of contralateral artery status, ranging from no stenosis to occlusion
   Coronary bypass graft required, with bilateral asymptomatic stenosis 70%, unilateral carotid endarterectomy with coronary artery bypass graft (CABG)
   Unilateral carotid stenosis 70%, CABG required, ipsilateral carotid endarterectomy with CABG

4. Proven inappropriate indications: None defined

For patients with a surgical risk of 5% to 10%

1. Proven indications: None
2. Acceptable but not proven indications: None
3. Uncertain indications

   Coronary bypass graft required with bilateral asymptomatic stenosis 70%, unilateral carotid endarterectomy with CABG
   Unilateral carotid stenosis 70%, CABG required, ipsilateral carotid endarterectomy with CABG

4. Proven inappropriate indications:

   Ipsilateral carotid endarterectomy for stenosis 75% with or without ulceration irrespective of contralateral internal carotid artery status
   Stenosis 50% with or without ulceration irrespective of contralateral carotid artery status

Update on Carotid Endarterectomy in the Treatment of Symptomatic Patients

The first multicenter trial, the Joint Study of Extracranial Arterial Occlusion,[49] failed to show benefit of the operation due to the high morbidity and mortality associated with the procedure. Although a subset of patients with TIAs and minor strokes had half as many strokes in a 42-month follow-up as did patients treated with conventional medical therapy,[50] after accounting for surgical mortality and morbidity the results were not statistically significant. This trial included carotid endarterectomy for acute stroke from carotid occlusion in patients who had a 42% perioperative mortality rate.[51] In a follow-up to the joint study, Hass and Jonas[52] suggested that if the surgical mortality and morbidity had been as low as 3%, the difference in cumulative stroke and death rate between surgical

and nonsurgical groups would have reached statistical significance. The surgical morbidity and mortality in this study ranged from 2% to 35%, attesting to the need for quality control in selection of surgeons for clinical trials.[1,52–55]

Three recent trials of carotid endarterectomy showed that when acceptably low surgical morbidity and mortality are achieved, carotid endarterectomy improves outcome in symptomatic patients with severe carotid stenosis. Although direct comparisons among studies are not possible due to differences in inclusion and exclusion criteria, end points, and methods of determining severity of carotid stenosis, analysis of these three trials has shown that carotid endarterectomy is of benefit in symptomatic patients with severe carotid occlusive disease.[56–60]

The ECST[61,62] was a randomized, controlled trial using transient cerebral ischemia, nondisabling stroke, transient monocular blindness, or retinal infarction as qualifying symptoms for entry if both the treating surgeon and neurologist were "substantially uncertain" about whether or not to recommend surgery. Eighty European centers contributed 455 surgical and 323 medical patients with 70% to 99% stenosis who were followed for a mean duration of 2.7 years. Time from symptom onset to entry was 6 months. Exclusion criteria included carotid occlusion, severe intracranial stenosis, cardioembolic stroke, uncontrolled diabetes or hypertension, renal failure, and chronic obstructive pulmonary disease. The degree of carotid stenosis was determined using the minimum residual lumen compared with the estimated normal lumen at the level of greatest stenosis. Primary end points were disabling or fatal ipsilateral stroke or perioperative death. The ECST did not mandate quality control standards for surgeons to participate in the trial, and no uniform medical therapy was required.

For medically treated patients with 70% to 99% stenoses, there was a significantly increased risk of outcome events. During the 3-year follow-up, risk of ipsilateral stroke and perioperative death was 10.3% for patients who had surgery and 16.8% for patients treated without surgery. Risk of death due to carotid endarterectomy or stroke from any cause during follow-up was 12.3% for surgical patients and 21.9% for nonsurgical patients. No benefit from carotid endarterectomy was found in 374 patients with 0% to 29% stenosis.[55] The ECST recently reported that after randomization of 1590 symptomatic patients with 30% to 69% stenosis (as determined by the ECST protocol), patients could not expect to benefit from carotid endarterectomy over a 4- to 5-year postoperative period.[63]

The NASCET[64] also demonstrated the effectiveness of carotid endarterectomy for patients with severe (70% to 99%) internal carotid artery stenosis. Investigators analyzed data from 50 centers in the United States and Canada whose surgeons had documented a carotid endarterectomy stroke morbidity and mortality rate of 6% for at least 50 consecutive cases over a 2-year period.[65] All patients received advice about risk factor reduction. Patients were eligible for randomization if they were younger than 79 years and had experienced cerebral or retinal transient ischemia or a nondisabling stroke within 120 days. Exclusion criteria included carotid occlusion, severe distal internal carotid artery stenosis, cardiac embolism, prior carotid endarterectomy, or medical illness that would preclude a 5-year life expectancy. Carotid stenosis was determined by measuring the diameter of the minimum residual lumen and comparing it with the lumen of the internal carotid artery at a point well beyond the region of greatest stenosis. In very severe disease where decreased pressure distal to the stenosis caused narrowing of the artery, the diameter of the ipsilateral external carotid artery or the contralateral internal carotid artery were used to estimate the degree of stenosis.

The NASCET collaborators reported on data from 659 patients with 70% to 99% stenosis, 328 of whom underwent carotid endarterectomy. The 30-day stroke morbidity and mortality rate for the surgical group was 5.8%. The cumulative risk of any ipsilateral stroke at 2 years was 9% for surgical patients and 26% for patients treated without operation. The incidence of major or fatal ipsilateral stroke was 2.5% for the surgical group and 13.1% for patients treated with medicine alone. Study investigators concluded that carotid endarterectomy is highly beneficial to patients with recent hemispheric or retinal transient ischemia or nondisabling strokes and ipsilateral severe carotid stenosis. Patients with retinal or hemispheric symptoms and moderate (30% to 69%) carotid stenosis are still being evaluated in NASCET as of this writing.

Subgroup analyses of the NASCET patients have been performed. One such study demonstrated that early carotid endarterectomy for severe stenosis after nondisabling stroke can be performed with a rate of surgical morbidity and mortality comparable to that achieved with delayed carotid endarterectomy. Therefore, delaying carotid endarterectomy for 30 days exposed these patients to an unnecessary risk of recurrent stroke. Another group of patients with symptomatic 70% to 99% ipsilateral carotid stenosis and contralateral internal carotid artery occlusion were found to have a 69% risk of stroke within 2 years if treated without surgery. Despite somewhat higher perioperative morbidity and mortality in the presence of contralateral carotid occlusion, carotid endarterectomy significantly reduced risk of stroke for these patients.[66]

The Carotid Endarterectomy and Prevention of Cerebral Ischemia in Symptomatic Carotid Stenosis study[67] attempted to determine whether carotid endarterectomy provides protection against subsequent cerebral ischemia in men with ischemic cerebral hemispheric symptoms and 50% ipsilateral internal carotid artery diameter stenosis as measured by arteriography. Sixteen university-affiliated Veterans Affairs medical centers with a stroke morbidity and mortality rate of 6% for carotid endarterectomy recruited 193 patients who had symptoms within 120 days of entry. The study randomly assigned 92 patients to carotid endarterectomy plus best medical management and 101 patients to best medical management alone. Each group received aspirin 325 mg/d. The study was terminated when the results of NASCET and ECST became available. For patients with 70% diameter stenosis, the stroke rate was 7.9% for the surgical group and 25.6% for the medical group. The authors concluded that carotid endarterectomy provided significant risk reduction for symptomatic men with high-grade carotid stenosis. The small numbers of patients made it impossible to determine whether carotid endarterectomy was beneficial for patients with lesser degrees of stenosis.

In summary, carotid endarterectomy is beneficial for symptomatic patients with recent nondisabling carotid artery ischemic events and ipsilateral 70% to 99% carotid artery stenosis

(Grade A recommendation). Carotid endarterectomy is not beneficial for symptomatic patients with 0% to 29% stenosis (Grade A recommendation). There is yet uncertainty about the potential benefit of carotid endarterectomy for symptomatic patients with 30% to 69% stenosis. Until the NASCET data are available, the ECST results do not support surgery for patients with 50% stenosis outside a randomized study.

Complications of Carotid Endarterectomy

Carotid endarterectomy is the most frequently performed noncardiac vascular procedure. Recent randomized prospective clinical trials have clearly showed that carotid endarterectomy is a highly beneficial treatment modality compared with the best medical treatment for patients with hemispheric and retinal TIAs or nondisabling strokes and ipsilateral high-grade stenosis of the internal carotid artery.[61,64] Carotid endarterectomy is three times as effective as medical therapy alone in reducing incidence of stroke in patients with symptomatic stenosis of 70% to 99%.[61–64] However, carotid endarterectomy itself has intraoperative and postoperative risks. The complication rate after carotid endarterectomy should be maintained at an extremely low rate (3%) by surgeons to keep the beneficial effects of carotid endarterectomy over medical therapy (Grade B recommendation).

Patients who undergo carotid endarterectomy use intensive care unit (ICU) resources as recommended in major surgery texts. However, different standards of monitoring have recently been proposed to decrease the cost of these procedures.[68] Currently, reliable data for defining an acceptable duration and intensity of postoperative monitoring are lacking.

Postoperative Complications of Carotid Endarterectomy

Perioperative complications of carotid endarterectomy include stroke, myocardial infarction, and death, and postoperative complications are cranial nerve injuries, wound hematoma, hypertension, hypotension, hyperperfusion syndrome, intracerebral hemorrhage, seizures, and recurrent stenosis. Of these, cranial nerve injuries and recurrent stenosis are the only ones not directly related to early postoperative care of patients with carotid endarterectomy.

Wound Hematoma

Wound hematomas are relatively common following carotid endarterectomy. In the NASCET study,[64] 5.5% of patients had documented wound hematomas. The majority are relatively small and cause little discomfort. Larger hematomas or those that expand precipitously require emergency treatment. If there is no loss of airway, the patient should undergo emergency evacuation of the hematoma in the operating room. If the airway has been obstructed by a hematoma, it is better to open the wound at the bedside. In 1119 carotid endarterectomies performed in 1016 patients, reexploration of the neck for wound hematoma was necessary in 1.4% of patients.[69] In the early postoperative period, special attention should be paid to detect neck discomfort and expansion of the wound. Fein[70] reported two cases of wound hematoma requiring prompt evacuation among 265 patients after carotid endarterectomy. Meticulous hemostasis during closure of the wound after carotid endarterectomy is the most important factor in reducing this complication.

Hypertension

One of the most important risk factors after carotid endarterectomy is hypertension. Poorly controlled hypertension increases the risk of postoperative complications, including neck hematoma and hyperperfusion syndrome.

Preoperative hypertension has been found to be the single most important determinant for development of postoperative hypertension.[71] Towne and Bernhard[71] reported that the incidence of preoperative hypertension in patients who developed postoperative hypertension was 79.6%, compared with 57.4% in patients who did not develop this complication. Moreover, they found a significantly increased incidence of neurological deficit and operative mortality rate in the group who developed postoperative hypertension. Bove et al[72] reported a 19% incidence of postoperative hypertension after carotid endarterectomy and noted a 10% incidence of fixed neurological deficits in these patients. Caplan et al[73] reported an increased risk of intracerebral hemorrhage after carotid endarterectomy when uncontrolled postoperative hypertension persisted.

About 21% of normotensive patients may have increased blood pressure after carotid endarterectomy.[71,74] The particular peak of risk is highest in the first 48 hours after surgery. The pathophysiology of this usually episodic hypertension might be related to surgically induced abnormalities of carotid baroreceptor sensitivity. Particular attention is important during dissection of the common carotid artery to avoid damaging the vagus nerve and the carotid sinus and to prevent carotid baroreceptor dysfunction. Unstable blood pressure occurs in 73.5% of patients during the first 24 hours after carotid endarterectomy.[70] Although this is a temporary phenomenon and persistence of hypertension is quite rare, an increase in blood pressure and its variability 12 weeks after surgery has recently been demonstrated and characterized as *baroreflex failure syndrome*.[75] Occurrence of this syndrome after carotid endarterectomy is associated with bilateral surgical procedures. Because baroreceptor insensitivity has been found in hypertensive patients, baroreflex failure syndrome might be a potential complication in hypertensive patients with severe bilateral atherosclerotic lesions, even after unilateral carotid endarterectomy.

Postoperative Hypotension

Postoperative hypotension (systolic blood pressure 120 mm Hg) occurs in approximately 5% of patients,[76] responds well to fluids and low-dose phenylephrine infusion, and usually resolves in 24 to 48 hours. Patients with significant postoperative hypotension should undergo serial ECGs and cardiac enzyme studies to rule out myocardial infarction.

Hyperperfusion Syndrome

Postendarterectomy hyperperfusion syndrome occurs in patients with high-grade stenosis and long-standing hypoperfusion and leads to paralysis or severe impairment of cerebral autoregulation. The cerebral hemodynamics of hyperperfusion syndrome are thought to be similar to the normal perfusion pressure breakthrough seen after resection of some arterio-

venous malformations.[10,76] In the preoperative state a condition of chronic relative hypoperfusion exists in the hemisphere distal to the high-grade stenosis. Small blood vessels in this region remain maximally dilated to ensure adequate blood flow. This chronic vasodilation results in a loss of autoregulation. After correction of a high-grade stenosis, blood flow at a normal or elevated perfusion pressure is restored to the previously hypoperfused hemisphere. Because of paralyzed autoregulation, sufficient vasoconstriction to protect the capillary bed is not possible, and breakthrough perfusion pressure results in edema and hemorrhage. The profound increase in cerebral blood flow may cause a severe unilateral headache that is characteristically improved by upright posture. Sundt et al[6] found an increase in cerebral blood flow from mean preoperative values of 43 16 to 83 39 ml/100 g per minute postoperatively in six patients with postoperative unilateral headache.

Intracerebral Hemorrhage

The most catastrophic event that can occur secondary to hyperperfusion is intracerebral hemorrhage. The Mayo Clinic[77] experience in 2362 consecutive carotid endarterectomies revealed that intracerebral hemorrhage occurred in 0.6% of patients within 2 weeks after surgery. Hemorrhages were large and often fatal (60%) or associated with poor outcome (25%) in this series. Risk factors for developing intracerebral hemorrhage after carotid endarterectomy include advanced age, association with hypertension, presence of high-grade stenosis, poor collateral flow, and slow flow in the middle cerebral artery territory on angiography. The same study[77] reported that angiographic evidence of hypoperfusion is the most important factor, occurring in 13 (93%) of 14 patients with intracerebral hemorrhage of 2362 patients who underwent carotid endarterectomy. Of these 14 patients, 7 (50%) presented with postoperative intracerebral hemorrhage within 48 hours.

Strict control of blood pressure in patients who are at risk for hyperperfusion can prevent or limit the severity of hyperperfusion syndrome.

Seizures

Seizures following carotid endarterectomy are uncommon. Nielsen et al[78] reported that seizures developed in 5 of 158 patients (3%) who were hemodynamically compromised (all had ipsilateral high-grade stenosis of the internal carotid artery 80%) 5 to 7 days after carotid endarterectomy. Seizures occurring in the absence of postoperative cerebral infarction or postendarterectomy intracerebral hemorrhage are attributed to cerebral hyperperfusion syndrome and the early stages of hypertensive encephalopathy. Brain edema due to hyperperfusion is an important cause of seizures.[13] Reigel et al[7] reported on 10 cases of seizures in a series of 2439 patients who had carotid endarterectomy. Cerebral blood flow studies carried out in seven patients showed a significant increase in flow immediately after surgery, and the authors concluded that the events were part of a hyperperfusion syndrome.

Because of these possible life-threatening complications, short-term admission to an ICU for close monitoring of neurological and vital signs has been recommended for patients who have carotid endarterectomy. However, there have been no controlled studies that evaluate the efficacy of ICU admission to avoid the complications associated with carotid endarterectomy. A study reported by O'Brien and Ricotta[79] found that only a few patients benefit from ICU care. They recommended that admission to the ICU be based on treatment required in the recovery room. Regardless of whether or not ICU care is provided, high-risk patients, such as those with preoperative hypertension, should be closely monitored for the first 24 hours after surgery. Medical risk factors such as advanced age, previous myocardial infarction, poorly controlled hypertension, and evidence of angiographic risk factors such as extremely high-grade ipsilateral carotid stenosis with or without contralateral occlusion, poor collateral blood flow, or slow flow in the middle cerebral artery territory, should be carefully evaluated. Patients who have carotid endarterectomies should be closely monitored, at least for the first 24 hours after surgery. Technical adjuncts such as transcranial Doppler ultrasonography to evaluate hyperperfusion may be of benefit in predicting potential life-threatening complications, but no prospective study has documented their value in improving overall outcome after carotid endarterectomy.[12,14] Strict control of blood pressure before surgery may also reduce postoperative complications associated with hypertension. For the patient who is hemodynamically and neurologically stable during the first 24 hours after surgery, early discharge is often possible. However, if hemodynamic or neurological instability is demonstrated, close monitoring and hospital observation is recommended until the patient's clinical situation is clearly stabilized. After discharge from the hospital, patients should be made aware of the significance of unilateral headache, any new neurological symptoms, and the importance of maintaining good control of blood pressure.

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KEY WORDS: AHA Medical/Scientific Statements stroke carotid arteries carotid endarterectomy