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## Carotid Artery Tandem Lesions: Frequency of Angiographic Detection and Consequences for Endarterectomy

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Fredric B. Meyer, and Thomas C. Bower

**BACKGROUND AND PURPOSE:** Several prospective trials have shown that ischemic stroke can be prevented by performing an endarterectomy in patients with high-grade carotid stenosis. Our purpose was to ascertain the frequency of carotid artery tandem lesions and to determine whether their presence alters the surgeon's decision to perform an endarterectomy.

**METHODS:** We retrospectively reviewed the cerebral angiograms obtained between January 1994 and June 1996 in 853 patients with carotid occlusive disease. Studies were analyzed for the presence of internal carotid artery (ICA) stenosis as well as for tandem lesions (defined as  $\geq 50\%$  diameter stenosis) within the common carotid artery, carotid siphon, or proximal intracranial arteries. The frequency of intracranial saccular aneurysms was determined.

**RESULTS:** Six hundred seventy-two of the 853 patients had a carotid bifurcation stenosis of 70% or greater or underwent an endarterectomy. Of these, a carotid siphon stenosis of 50% or greater was noted in 65 patients (9.7%) and was ipsilateral to an ICA stenosis in 37 patients (5.5%). A common carotid stenosis was present in 29 patients (4.3%), ipsilateral to an ICA stenosis in 14 patients (2.1%). A stenosis of 50% or greater within the proximal intracranial circulation was present in 28 patients (4.2%), ipsilateral to an ICA stenosis in 15 patients (2.2%). Four patients had tandem stenoses at more than one site. Tandem stenoses in the siphon or intracranial segments were noted in 13.5% with a bifurcation stenosis and in 8.8% of those with no bifurcation stenosis. Endarterectomy was performed in 48 of the 66 patients with tandem stenotic lesions.

**CONCLUSION:** The presence of a tandem lesion infrequently alters the surgeon's decision to perform an endarterectomy. However, the importance of detecting tandem stenoses cannot be underestimated, since they may have important implications for long-term medical management in symptomatic patients.

Several prospective trials have shown that ischemic stroke can be prevented by performing an endarterectomy in patients with a high-grade carotid stenosis (1–3). Conventional angiography has been the accepted technique for evaluating the internal carotid arteries (ICAs) for the presence of stenosis. Conventional angiograms typically include intracranial views to detect carotid siphon and intracranial stenosis as well as to ascertain the presence of intracranial aneurysms. As carotid endarterectomy

has been established as an effective treatment, interest in noninvasive techniques for evaluating the ICA has grown. These techniques, including sonography, MR angiography, and CT angiography, are less expensive than, and do not have the risks of stroke and hemorrhage associated with, conventional angiography. As the preendarterectomy workup evolves from conventional angiography to noninvasive techniques, it is important to determine which of the cerebral vasculature segments must be imaged. For instance, do noninvasive techniques need to evaluate the carotid arteries remote from the bifurcation as well as the intracranial circulation with an accuracy similar to conventional angiography?

The purpose of this study was to determine the frequency of carotid siphon, common carotid, and proximal intracerebral artery tandem stenoses as well as the frequency of incidental intracranial saccular aneurysms in patients undergoing cerebral an-

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giography for carotid occlusive symptoms. In addition, the study sought to determine the consequence on the surgeon's decision-making process when tandem stenoses or an aneurysm was detected during the preoperative evaluation.

### Methods

All cerebral angiograms performed for carotid occlusive disease between January 1994 and June 1996 were reviewed retrospectively. When the report indicated that more than mild or minimal disease was present, the angiograms were reviewed by two of the authors. Studies were analyzed for the presence of ICA stenosis as well as for tandem stenoses within the common carotid artery at the origin or remote from the bifurcation, carotid siphon, or proximal intracranial vessels. A significant ICA stenosis was defined as a narrowing of 70%, according to the criteria established by the North American Symptomatic Carotid Endarterectomy Trial (NASCET), or that an endarterectomy had been performed (4). For purposes of this study, a stenosis of the common carotid (remote from the bifurcation), carotid siphon, or first segment of the major intracranial vessels (A1, M1, P1) was defined as a 50% or greater narrowing in vessel diameter. This was measured with a jeweler's eyepiece with the stenosis as the numerator and adjacent normal vessel as the denominator. The number, location, and size of incidental intracranial saccular aneurysms were also determined.

The surgical and medical records of all patients with tandem lesions were reviewed to document the surgeon's knowledge of the patient's angiographic results and comorbid disease. Because angiograms are typically performed to 1) better evaluate the degree of extracranial stenosis, 2) clarify the presence of intracranial stenosis, and 3) establish the presence of an intracranial saccular aneurysm, it would have been likely that the surgeon would have reviewed the study and been aware of the results before making a decision regarding a surgical procedure. The documented reasons for performing or not performing an endarterectomy were noted. The medical records of patients with tandem lesions who underwent an endarterectomy were also reviewed to assess surgical outcomes.

### Results

Eight hundred fifty-three patients underwent angiography for carotid occlusive disease between January 1994 and June 1996. Of these, 672 patients had a carotid bifurcation diameter stenosis of 70% or greater or underwent an endarterectomy. One hundred thirty-eight patients had complete ICA occlusions, nine of which were bilateral. Of the 672 patients, a stenosis within the carotid siphon of at least 50% was found in 65 (9.7%) (36 men and 29 women) (Table 1). The carotid siphon stenosis was tandem to a carotid bifurcation stenosis in 37 (5.5%) of the patients (21 men and 16 women), and occurred without a tandem carotid bifurcation stenosis in 28, or 4.2%. Twenty-six patients with a tandem lesion in the carotid siphon underwent endarterectomy. The degree of siphon stenosis for patients who underwent endarterectomy ranged from 50% to 90% (mean, 58%), with an ipsilateral ICA stenosis of 60% to 99% (mean, 81%). Two of these 26 patients had relatively minor postoperative complications (Table 2). One patient suffered a small non-Q wave myocardial infarction (MI) on the first

**TABLE 1: Frequency of carotid tandem lesions in 672 patients with ICA stenosis**

Lesion	No. (%)
Carotid siphon stenosis	65 (9.7)
With tandem ICA stenosis	37 (5.5)
Without tandem ICA stenosis	28 (4.2)
Common carotid artery stenosis	29 (4.3)
With tandem ICA stenosis	14 (2.1)
Without tandem ICA stenosis	15 (2.2)
Intracranial stenosis	28 (4.2)
With tandem ICA stenosis	15 (2.2)
Without tandem ICA stenosis	13 (1.9)
Carotid siphon or intracranial stenosis	
With tandem ICA stenosis	(13.5)
Without tandem ICA stenosis	(8.8)

Note.—ICA indicates internal carotid artery.

**TABLE 2: Complications after endarterectomy in 48 patients with tandem stenoses**

Complication	Minor*	Major†	Death
Cerebral infarction	3‡		
Myocardial infarction	2		1
Severe cranial nerve palsy		2	

\* Resolved within 90 days.

† Persistent beyond 90 days.

‡ One person with minor cerebral infarction also had a severe persistent postoperative cranial nerve palsy.

postoperative day but made a complete recovery subsequently. The single neurologic complication occurred in a 68-year-old woman in whom persistent hypoglossal and facial nerve paralysis developed.

Eleven patients with ipsilateral carotid siphon stenosis did not undergo an endarterectomy. The degree of siphon stenosis in these patients ranged from 50% to 99% (mean, 66%), with an ipsilateral ICA stenosis of 70% to 99% (mean, 80%). According to our review of the patients' records, there was only one patient in whom the decision not to perform an endarterectomy was influenced by the presence of a tandem lesion. This 69-year-old woman presented with left hemispheric transient ischemic attacks (TIAs). An angiogram showed an 80% left ICA stenosis and 80% left carotid siphon stenosis (Fig 1). She also had a left orbital bruit, which was thought to be associated with the siphon stenosis. In addition, she had moderate coronary artery disease and a 5.2-cm thoracic aortic aneurysm. On the basis of the bilateral high-grade siphon stenosis and comorbidity it was thought that the patient would not benefit from an endarterectomy and was treated with Coumadin.

Tandem stenoses within the proximal common carotid artery at its origin or separate from the bifurcation were found in 29 (4.3%) of the patients (15 men and 14 women). This number is an un-

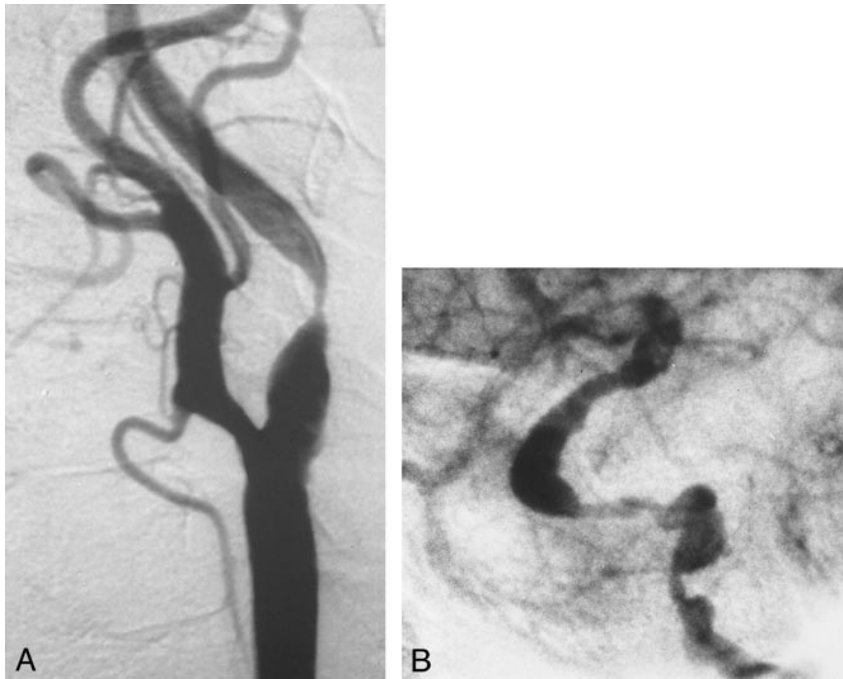


FIG 1. 69-year-old woman with left hemispheric TIAs and left orbital bruit.

A and B, Cerebral angiograms show an 80% left ICA stenosis (A) and an 80% left carotid siphon stenosis (B). This is the only patient in whom the chart review indicated that the presence of tandem stenoses was the reason an endarterectomy was not performed.

derestimation of the frequency of common carotid stenosis, because not all angiograms included the aortic arch to evaluate the carotid artery origins. Common carotid stenosis was considered a tandem lesion in 14 (2.1%) of the patients (eight men and six women) and occurred without carotid bifurcation stenosis in 15, or 2.2%. Eleven of these patients underwent a carotid endarterectomy ipsilateral to the common carotid stenosis. The degree of common carotid stenosis for patients who underwent endarterectomy ranged from 50% to 95% (mean, 62%), with the ipsilateral ICA stenosis ranging from 60% to 95% (mean, 85%). Three of these patients had complications related to surgery. A 53-year-old woman died of an MI on the fourth postoperative day. A 71-year-old man had an ipsilateral cerebral infarction (CI) on the fourth postoperative day, but made a complete recovery by 90 days after the endarterectomy. A 64-year-old woman experienced an immediate postoperative CI and significant cranial nerve palsy; she recovered from the CI but had a persistent severe cranial nerve palsy.

Three patients with ipsilateral common carotid stenosis did not undergo endarterectomy. The degree of common carotid stenosis in these patients ranged from 50% to 88% (mean, 63%), with the ipsilateral ICA stenosis ranging from 70% to 95% (mean, 80%). None of the three underwent endarterectomy, for reasons unrelated to the tandem lesion in the common carotid artery.

A tandem stenosis was found in the proximal intracranial vessels in 28 (4.2%) of the patients (19 men and nine women). The proximal intracranial stenosis was a tandem stenosis in 15 (2.2%) of the patients, 11 of whom underwent a carotid endarterectomy. A proximal intracranial stenosis oc-

curred without a tandem carotid bifurcation stenosis in 13 (1.9%) of the patients. The degree of intracranial stenosis ranged from 50% to 100% (mean, 68%), with ipsilateral carotid bifurcation stenosis of 60% to 99% (mean, 82%). Two patients in this group had neurologic complications related to surgery. One was a CI ipsilateral to the side of surgery that occurred in a 66-year-old woman on the first postoperative day; her left upper arm weakness completely resolved within 8 days. A 74-year-old man with minor perioperative CI also made a complete recovery.

Four patients with ipsilateral proximal intracranial stenosis did not undergo endarterectomy. The degree of stenosis in these patients ranged from 60% to 100% (mean, 75%), with ipsilateral carotid bifurcation stenosis ranging from 70% to 99% (mean, 84%). One patient did not have surgery because of the presence of near total ICA occlusion (thought to represent a physiological occlusion) and occlusion of the ipsilateral middle cerebral artery.

In this series, eight adverse postoperative outcomes occurred in seven of the 48 patients who had tandem stenotic lesions and underwent carotid endarterectomy (Table 2). One patient died on the fourth postoperative day of an MI. Three patients experienced a CI that resolved within 90 days. Two patients had MIs and subsequently recovered. Two patients had significant cranial nerve palsies that persisted for more than 90 days. One patient who recovered from a postoperative CI had a persistent cranial nerve palsy. Overall, the complication risks, using NASCET criteria, including the 2.1% ipsilateral major stroke and death risk, were similar to those for the selected patients with symptomatic ICA stenosis reported by the NASCET investigators (1).



Overall, a stenosis of 50% or greater in the siphon or intracranial segments occurred in 13.5% of patients with a bifurcation stenosis. Of the 181 patients without a carotid bifurcation stenosis, 16, or 8.8%, had a carotid siphon or proximal intracranial stenosis.

An occluded intracranial carotid artery was found in 138 patients. In this group, 39 patients did not have a stenosis in the patent ICA. Seven (18%) of the 39 patients had a siphon (5) or intracranial (2) stenosis.

Incidental intracranial saccular aneurysms were discovered in 46 patients (21 men and 25 women) of the total 853 cases reviewed (5.4%). The size of the 46 incidentally discovered aneurysms varied from 1 to 13 mm. Thirty-two were less than 5 mm; of which none are known to have been treated. Twelve aneurysms measured 5 to 10 mm, three of which were treated with either clipping or coil embolization. The number of treated aneurysms is most likely an underestimation, since some of the patients may have subsequently had surgery at other institutions.

Eleven patients had aneurysms in the same distribution as a carotid bifurcation stenosis; 10 of these patients had an endarterectomy. The one patient with a "tandem" aneurysm who did not undergo surgery had a 2-mm aneurysm of the left ophthalmic origin and an asymptomatic 70% stenosis of the left ICA.

Twenty-seven patients with aneurysms underwent carotid endarterectomy. Only one patient with an aneurysm had a neurologic complication related to surgery. This patient was an 86-year-old man with a 4-mm basilar caput aneurysm in whom brain stem ischemia occurred immediately after a left carotid endarterectomy, leading to a persistent visual deficit.

Two patients had aneurysms that measured more than 10 mm. One was in a 65-year-old woman with a 13-mm right cavernous ICA aneurysm, which was managed conservatively because it had not changed in 4 years and was thought to be at low risk for subarachnoid hemorrhage, owing to its extradural location. The second large aneurysm was found in a 72-year-old man with an 11 × 6-mm anterior communicating artery aneurysm. This aneurysm was not treated because the patient had severe coronary artery disease and the risk of an interventional procedure was thought to outweigh the potential benefit.

Several other vascular lesions were found incidentally at angiography. These lesions included three arteriovenous malformations, three carotid body tumors (one patient had bilateral tumors), one venous angioma, one dural arteriovenous fistula, two fusiform basilar artery aneurysms, and one pituitary adenoma.

### Discussion

The presence of a tandem carotid stenosis has been thought by some to be a relative contraindi-

cation to carotid endarterectomy. Tandem stenoses have been viewed as a source of thrombus formation at the endarterectomy site because of persistent slow flow through the stenotic segment. Goldstein et al (5), in a retrospective study, found that patients with one or more risk factors (including age >75 years, carotid occlusion, intraluminal thrombus, and carotid siphon stenosis) were twice as likely to have an adverse outcome, defined as postoperative stroke, MI, or death after carotid endarterectomy as those without risk factors. Within this study, however, the independent contribution to these complications from carotid siphon stenosis or tandem lesions was not reported. Other articles have discounted the significance of a tandem carotid stenosis for the outcome of patients after endarterectomy. One study even reported a reversal of carotid stenosis in patients after endarterectomy (6).

In addition to potential implications of tandem stenoses for the risk of carotid endarterectomy, one must also consider issues of medical management. In patients with both extracranial and intracranial stenosis, it is difficult in those with ipsilateral ischemic symptoms to define which stenosis is causing the symptoms. Because of data suggesting that Coumadin may be better than aspirin for symptomatic intracranial stenosis (7), knowledge of the presence of intracranial stenosis may lead to use of Coumadin regardless of whether an endarterectomy is performed.

Several studies have evaluated the outcome of patients with ipsilateral carotid siphon stenosis who have undergone carotid endarterectomy. Mackey et al (8) examined the records of 597 patients who had angiography before carotid endarterectomy and found no significant difference in short- or long-term prognosis for the 134 patients with significant intracranial disease as compared with those without intracranial disease. Mattos et al (9) studied the outcomes of 393 patients after carotid endarterectomy and found no difference in the short- and long-term stroke morbidity rates for patients with or without carotid siphon disease. Late death was more common in patients with siphon disease, mostly because of the presence of coronary artery disease. The authors concluded that the presence of carotid siphon stenosis should not influence the decision to perform carotid endarterectomy in patients with appropriate indications. Roederer et al (10), in a retrospective study of 141 patients, found no correlation between the severity of siphon disease and recurrent symptoms after endarterectomy.

Of the 66 patients with tandem lesions in our study, 48 proceeded to carotid endarterectomy. Of the 18 who did not undergo carotid endarterectomy, a review of the charts to understand the decision-making process revealed only one case in which it was stated that a carotid tandem lesion was responsible for not performing the procedure. Similarly, the presence of an intracranial aneurysm did not deter the performance of endarterectomy. End-

arterectomy was performed in 27 of the 46 patients with intracranial aneurysms, and 10 of the aneurysms were in the distribution of the treated carotid artery. No adverse outcomes related to the aneurysms tandem to a carotid endarterectomy occurred. An 86-year-old man with a 4-mm basilar caput aneurysm underwent a left carotid endarterectomy for a symptomatic 80% stenosis. Postoperatively, basilar ischemia was present and the patient suffered an MI on the second postoperative day. He recovered from the MI but had a persistent skew deviation convergence.

It is not apparent that complications occurred at a higher rate in the perioperative period in patients undergoing endarterectomy with tandem lesions. Some investigators have stated that occurrence of a tandem lesion is a marker of severe systemic vascular disease. Therefore, the tandem lesion itself may not be the specific cause of a complication but merely a marker of an increased risk for MI or CI.

Determining the frequency of tandem lesions is important, because some have held that the presence of tandem stenoses often alters patient management. If tandem stenoses are relatively common and do frequently alter surgical management of carotid lesions that would otherwise benefit from an endarterectomy, noninvasive techniques must accurately characterize these tandem lesions. Our results help focus the development of these noninvasive techniques. Typically, surgeons have required conventional angiography before an endarterectomy, with sonography as a screening study. Recent advances in bolus-contrast MR angiography are changing the preoperative examination of these patients (11, 12). The paradigm is now shifting to a screening sonogram followed by a bolus-contrast MR angiogram. While it is possible to obtain a bolus-contrast MR angiogram with a field of view to include the carotid origins extending to the carotid siphon, the accuracy of this technique has yet to be determined for stenotic lesions remote from the carotid bifurcations. The results of our study show that concentrated efforts to optimize the bolus MR angiogram of the bifurcation is appropriate. In our practice, tandem stenotic lesions are relatively infrequent and, when present, do not alter the surgeon's decision to perform an endarterectomy. However, the finding of a tandem stenotic lesion may impact long-term medical management, and noninvasive means of screening for tandem lesions should be optimized.

## Conclusion

Tandem stenoses within the internal carotid system are relatively uncommon in patients undergoing cerebral angiography for carotid occlusive disease. We found that the presence of a tandem lesion altered the surgeon's decision to perform an endarterectomy in only one patient. For the vast majority of patients, the presence of tandem stenotic lesions or an aneurysm did not appear to alter the decision to perform an endarterectomy, and the surgical risk is not high. Although the presence of tandem stenoses did not impact the decision to perform carotid endarterectomy, additional medical management of symptomatic patients with Coumadin as a stroke preventative should be considered, even after an endarterectomy.

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