Role of Carotid Stenosis in Ischemic Stroke

Chang Z. Zhu, MD, and John W. Norris, MD

Using Doppler ultrasonography, we evaluated the frequency and severity of carotid artery stenosis in 261 patients with carotid ischemic strokes, 813 patients with carotid transient ischemic attacks, 500 patients with asymptomatic neck bruits, and 500 controls. Most patients with strokes and transient ischemic attacks had no associated carotid artery disease (55% and 64%, respectively), and such patients without neck bruits were even more likely to be without carotid artery disease (69% and 77%, respectively). Carotid stenosis was more frequent and more likely to be severe in symptomatic than in asymptomatic patients (p<0.0002), even after adjusting for age and sex. Carotid stenosis is present in only a minority of patients with strokes and transient ischemic attacks, especially if neck bruits are absent, and the cause of the ischemic cerebral events in most of these patients remains unexplained. (Stroke 1990;21:1131-1134)

Carotid ischemic stroke is commonly attributed to atherosclerosis of the extracranial carotid arteries, with subsequent embolic or hemodynamic cerebral ischemia. However, data from stroke registers indicate that even after accounting for all carotid and cardiac disease, the etiology in most cases remains unexplained.

Neck bruits are commonly associated with underlying extracranial carotid artery disease and therefore are associated with an increased risk of stroke. Although community studies of patients with neck bruits indicated that subsequent strokes were unrelated to the side of the bruit, later reports including data on noninvasive carotid imaging with clinical follow-up suggest that the more severely stenosed carotid artery, which does not necessarily correspond to the side of the neck bruit, carries the greater stroke risk. We previously evaluated the frequency of carotid stenosis in 336 patients with asymptomatic neck bruits and found that 61% had ipsilateral and 28% had contralateral carotid artery stenosis. We also have investigated the laterality of ischemic cerebral events during follow-up in patients with asymptomatic carotid stenosis and found that 80% of the events occurred ipsilateral to the more stenosed artery; in symptomatic patients, this number was 72%. Risk of stroke therefore relates to both the presence of neck bruits and to the underlying carotid lesion, but the relation is still uncertain.

We compared the frequencies of neck bruits and carotid stenosis (determined by Doppler imaging) in asymptomatic patients with the frequencies in patients with transient ischemic attacks (TIAs) and ischemic strokes to determine the role of carotid artery disease in subsequent cerebral ischemic events.

Subjects and Methods

Data were collected between July 1982 and July 1986. The two symptomatic groups comprised 261 consecutive patients admitted with carotid ischemic stroke (in whom carotid Doppler ultrasonography is routinely performed) and 813 patients with carotid TIAs referred to our Doppler laboratory. Patients with vertebrobasilar TIAs were excluded. The two symptomatic groups were divided in subgroups of patients with and without neck bruits. The asymptomatic group consisted of 500 patients referred to our Doppler laboratory with asymptomatic neck bruits. A control group of 500 patients without neck bruits referred to the same vascular laboratory with nonvascular diagnoses had epilepsy, headache, or dizzy attacks.

Neck bruits are recorded in all patients referred to our Doppler laboratory after auscultation by a trained technician or the reporting physician. A previous comparison in our laboratory of the accuracy and consistency of neck bruit auscultation indicated a high concordance among observers.

The diagnoses of stroke were all made by referring neurologists from the admitting hospitals. The diagnoses of TIAs were screened by the neurologist or neurological fellow attending the Doppler laboratory. Patients with insufficient evidence or, in our opinion, incorrect diagnoses of TIAs were excluded. Carotid Doppler ultrasonography was performed in all patients with the continuous-wave method (Model 1050, Carolina Medical Electronics, Inc., King, N.C.) without B-mode imaging. We previously documented the accuracy, sensitivity, and specificity of this tech-
TABLE 1. Frequency and Severity of Carotid Artery Stenosis in Symptomatic and Asymptomatic Patients

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Male</th>
<th>Female</th>
<th>Age (mean±SEM yr)</th>
<th>With:stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>261</td>
<td>156</td>
<td>105</td>
<td>70±9</td>
<td>118, 45*</td>
</tr>
<tr>
<td>With bruit</td>
<td>66</td>
<td>38</td>
<td>28</td>
<td></td>
<td>57, 86‡</td>
</tr>
<tr>
<td>Without bruit</td>
<td>195</td>
<td>118</td>
<td>77</td>
<td></td>
<td>61, 31</td>
</tr>
<tr>
<td>TIA</td>
<td>813</td>
<td>430</td>
<td>383</td>
<td>69±8</td>
<td>292, 36</td>
</tr>
<tr>
<td>With bruit</td>
<td>222</td>
<td>117</td>
<td>105</td>
<td></td>
<td>156, 70§</td>
</tr>
<tr>
<td>Without bruit</td>
<td>591</td>
<td>313</td>
<td>278</td>
<td></td>
<td>136, 23</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>500</td>
<td>214</td>
<td>286</td>
<td>64±9</td>
<td>273, 55</td>
</tr>
<tr>
<td>Control</td>
<td>500</td>
<td>228</td>
<td>272</td>
<td>66±11</td>
<td>33, 6.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sex</th>
<th>Total</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke With bruit</td>
<td>118</td>
<td>43</td>
<td>75</td>
</tr>
<tr>
<td>Stroke Without bruit</td>
<td>57</td>
<td>17</td>
<td>40</td>
</tr>
<tr>
<td>TIA With bruit</td>
<td>292</td>
<td>143</td>
<td>149</td>
</tr>
<tr>
<td>TIA Without bruit</td>
<td>156</td>
<td>60</td>
<td>96</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>273</td>
<td>188</td>
<td>85</td>
</tr>
<tr>
<td>Control</td>
<td>273</td>
<td>188</td>
<td>85</td>
</tr>
</tbody>
</table>

Bruits refer to neck bruits only. Moderate stenosis, 35–75% diameter reduction (4–10 KHz); severe stenosis, >75% diameter reduction (11–20 KHz); TIA, transient ischemic attacks.

* ‡ p<0.01, 0.025, respectively, different from TIA by χ² test.
‡ p<0.0001 different from without bruit by χ² test.
§ p<0.0002 different from asymptomatic by analysis of variance, adjusting for sex and age.

Technology compared with angiography to be 90%, 89%, and 99%, respectively, in our laboratory for stenoses of >35% diameter reduction.11 When present, common carotid artery stenosis was equal to internal carotid artery stenosis. Stenosis of the external carotid artery was excluded. Carotid stenoses were classified as absent (<35% diameter reduction, <4 KHz), moderate (35–75% diameter reduction, 4–10 KHz), or severe (>75% diameter reduction, ≥11 KHz). All carotid stenoses were included in the analysis, irrespective of their laterality to the symptomatic hemisphere or the location of the neck bruits.

We compared the age and sex ratio and the frequencies and severities of carotid stenosis of the four groups using the χ² test and analysis of variance. Within each symptomatic group, we compared the subgroups with and without neck bruits. We also restricted our analysis to the two symptomatic subgroups and the asymptomatic group with neck bruits.

Five groups of patients were compared: TIA patients with and without neck bruits, stroke patients with and without neck bruits, and patients with asymptomatic neck bruits.

Using analysis of covariance, the differences in stenoses were compared for two factors, patient group and gender, using age as a covariant.

Differences in the frequency of carotid stenosis were compared between the symptomatic and asymptomatic groups (see Table 1) with bruits by χ² analysis.

Results

Among the 500 controls, 33 (6.6%) had more than mild carotid stenosis and six of these (1.2%) had severe carotid stenosis (Table 1). Six had bilateral carotid disease (Figure 1).

In the two symptomatic groups, carotid stenosis was significantly more frequent and more likely to be severe in patients with neck bruits than in those without (Table 1 and Figure 1, p<0.0001).

When the analysis was restricted to patients with neck bruits, symptomatic patients more frequently had severe carotid stenosis than did asymptomatic patients (Figure 2). There were more women, but the interaction of sex by group was insignificant (F(4,1,563))

FIGURE 1. Frequency and severity of carotid artery stenosis in symptomatic and asymptomatic patient groups. Dotted areas, 35–75% stenosis; shaded areas, >75% stenosis.

FIGURE 2. Frequency and severity of carotid artery stenosis in symptomatic and asymptomatic patients with neck bruits. White areas, <35% stenosis; dotted areas, 35–75% stenosis; shaded areas, >75% stenosis.
Carotid stenosis was also significantly more frequent ($p<0.01$) and significantly more likely to be severe ($p<0.025$) in patients with stroke than in those with TIAs (Table 1).

Discussion

Most symptomatic patients with neck bruits in our study population had an associated carotid artery stenosis detected by carotid Doppler ultrasonography, but carotid stenosis was present in only a minority of those without neck bruits, so the causes of their strokes and TIAs remain unexplained. Cardiac investigations, such as echocardiography, were not performed systematically in these patients so we cannot comment on the frequency of cardioembolism. Our data support the observations made in stroke data banks: our understanding of the basic mechanisms of stroke is still grossly deficient. Mohr$^{12}$ appropriately dubbed this idiopathic entity "cryptogenic stroke."

Since the carotid Doppler technique in our laboratory is inaccurate in diagnosing stenoses of <35% diameter reduction,$^{19}$ nonstenosing or only mildly stenosing carotid sources of potential emboli might escape detection. However, although nonstenosing carotid ulcers may occasionally cause cerebral embolism,$^{13}$ this point remains controversial,$^{14}$ and if it occurs it must be unusual. Also, in studies in which stroke risk is correlated with the degree of carotid stenosis, lesions of <50% diameter reduction carry a very low risk of stroke.$^{5,8}$ Therefore, even if minor degrees of carotid stenosis account for a few cases of cryptogenic stroke, they are unlikely to explain the majority.

Information from the National Institute of Neurological and Communicative Disorders and Stroke stroke data bank indicates that after neurologic investigation, approximately 22% of strokes can be attributed to carotid artery disease while 11.6% are considered lacunar$^{3}$; embolism of uncertain origin is very low risk of stroke.$^{5,8}$ Therefore, even if minor degrees of carotid stenosis account for a few cases of cryptogenic stroke, they are unlikely to explain the majority.

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**KEY WORDS** • bruit • carotid artery diseases • cerebral ischemia
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