Carotid Artery Blood Flow Velocity Related to Transient Ischemic Attack and Stroke in a Population Study of 69-Year-Old Men

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A population-based sample of 478 men aged 69 years living in Malmö, Sweden, underwent Doppler ultrasonic examination of their carotid arteries; cerebrovascular symptoms and signs were recorded independently. Among 471 men with complete examinations, 117 (25%) showed significant abnormalities in carotid blood flow velocity (moderate stenoses [30–60% diameter reduction] in 20%, severe stenosis [≥60% reduction] or occlusion in 5%). The latter seemingly formed a group separate from the main distribution curve. Stroke was reported in 28 men (6%), during the year before examination in nine (2%). Carotid transient ischemic attack (TIA) was clinically confirmed in one man during this year, while unconfirmed symptoms were reported in 63 (13%). There was a relation between ipsilateral hemispheric stroke/TIA and severe carotid disease ($p<0.001$). Four of seven men with total occlusion had a stroke or a clinically confirmed TIA. Nevertheless, the majority of carotid stenoses (including severe stenoses) were asymptomatic. Cerebrovascular symptoms were not significantly more frequent among the men having moderate stenosis than among those having healthy arteries. (Stroke 1989;20:1327–1330)

Studies regarding the prevalence and incidence of carotid artery disease in representative samples from the general population have so far been based on the finding of cervical bruits1,2 rather than on the more exact and sensitive ultrasound technique used in patients with either atherosclerotic disease of the legs or symptomatic carotid artery disease.3–7 Studies of a general population are important for the evaluation of the natural course of this disease. It is also of clinical interest to determine the proportions and characteristics of asymptomatic compared with symptomatic carotid disease since it is often difficult to assess the relevance of carotid changes for the development of transient ischemic attacks (TIAs) and stroke in a clinical setting. To assess fully the clinical significance of carotid artery stenoses, it is necessary to follow a cohort representative of the general population. In a clinical setting, associated selection bias may occur.

"Men Born in 1914" is a prospective population study of cardiovascular morbidity and mortality and their major determinants in elderly men. One aim of the study was to assess the prevalence and incidence of symptomatic and asymptomatic carotid artery disease by inviting a representative cohort to repeated Doppler ultrasound examinations of their carotid arteries and by following their morbidity and mortality from cerebrovascular disease. The aim of this part of the study was to describe the prevalence of moderate and severe carotid artery stenoses and to study the relation between abnormal blood flow rates in the carotid arteries and symptoms compatible with cerebrovascular disease.

Subjects and Methods

The study population consisted of all men born in even-numbered months in 1914 (February, April, etc.) and living in Malmö, Sweden. The cohort comprised 621 men who were 69 years old at the start of the study, but only 500 men (80.5%) attended the examinations; of the 121 who declined, 94 (15.1%) were contacted and agreed to participate in a telephone interview, 11 men (1.8%) died before the examination, and 16 (2.6%) could not be located. There were no significant differences between the group of men that participated fully and the group of
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men who participated only in the phone interview regarding social class, housing, contact with a doctor, use of medication, or smoking habits.8

To investigate the internal carotid arteries (ICAs), we used a continuous-wave Doppler system with a position-sensing arm and spectral analysis with digital printout (Dopscan 1050, Carolina Medical Electronics Inc., King, North Carolina). In our experience,9,10 this ultrasound technique detects stenosis reducing the diameter of the ICA by >30%, with a sensitivity of 97% and a specificity of 100% compared with angiography, and gives the relation between maximum systolic Doppler frequency shift and percent diameter reduction shown in Figure 1. The reproducibility of this ultrasound technique was tested by recalling 30 random men for a second investigation. The error of a single observation (e) was determined according to Dahlberg11 as 
\[ e = \sqrt{\frac{\sum d^2}{2n}} \]
where d denotes the difference 1−2 and n denotes the number of ICAs studied; e of maximum systolic frequency shift was 0.40 kHz.

Only 478 men appeared for Doppler ultrasonography. In seven, only unilateral recordings were considered to be technically satisfactory. Thus, Doppler data from 949 ICAs and 471 men were available for complete analysis.

Clinical examination and interview were performed by a doctor who was unaware of the results of Doppler ultrasonography. The men were asked to specify in terms of frequency and duration any visual symptoms, disturbance of speech, sensory and motor symptoms of face and limbs, vertigo, loss of consciousness, and memory loss, all defined to be of sudden onset and occurring during the year before examination. A complete routine neurologic examination was performed in a standardized way. Clinical stroke before the last year was recorded, but no attempt was made to elicit a history of possible TIA >1 year before the examination.12 The supervising neurologist made the final clinical judgment (stroke or TIA) unaware of the results of Doppler ultrasonography.

Standard statistical methods were used to calculate frequency distributions, means, and standard deviations. Fisher's exact two-sided test was used to examine the significance of differences between groups.

Results
The mean±SD maximum systolic frequency of the Doppler shift recorded from the ICA was 2.40±0.06 kHz on the right and 2.34±0.05 on the left side. Figure 1 shows the skewed distribution of the Doppler frequency shift in 949 ICAs; 815 ICAs (86%) had Doppler shifts within the normal range (0–3 kHz), 112 (12%) showed moderate stenosis (3.1–6 kHz, 30–60% diameter reduction), and severe stenosis (≥6.1 kHz, >60%) or occlusion was noted in 22 ICAs (2%). The distribution of frequency shifts was similar on the two sides; occlusion was found in three right ICAs and in four left ICAs.

Among the 471 men with satisfactory bilateral ultrasonograms, 28 had a history of stroke (in nine ≤1 year before the examination); 12 of the 28 men had focal sequelae. Short-lasting cerebral symptoms (<24 hours, indicating TIA) were reported by 65 men; however, 63 of these reported mild episodes of vertigo or diplopia or other visual disturbances. Only three men reported lateral visual field defects; no case of amaurosis fugax was found. One man reported a definite episode of right hemiparesis and aphasia; TIA could be clinically verified only in this one man. The other 378 men reported no symptoms indicating TIA or stroke. Table 1 shows the Doppler findings in the different clinical groups. Severe stenosis or occlusion were found more significantly frequently in the stroke group (18%) than in the asymptomatic group (3%); the TIA group exhibited only a slight tendency toward increased frequency. Moderate stenosis occurred in 20% of the men (no differences between groups).

In nine of 22 ischemic hemispheres (21 stroke and one TIA, 41%), carotid artery disease was found in the ipsilateral ICA compared with abnormal findings in 12–13% of the ICAs ipsilateral to normal hemispheres (Table 2). ICAs supplying an ischemic
TABLE 1. Doppler Ultrasonographic Findings in Internal Carotid Arteries of 471 69-Year-Old Men by History

<table>
<thead>
<tr>
<th>Clinical history</th>
<th>Row No.</th>
<th>% of row</th>
<th>% of col</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>28</td>
<td>17</td>
<td>61</td>
</tr>
<tr>
<td>Transient ischemic attack</td>
<td>65</td>
<td>49</td>
<td>75</td>
</tr>
<tr>
<td>Ischemia</td>
<td>93</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>No symptoms</td>
<td>378</td>
<td>288</td>
<td>76</td>
</tr>
<tr>
<td>Column</td>
<td>471</td>
<td>354</td>
<td>75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Doppler shift (kHz)</th>
<th>Mild stenosis 3.0-6.0</th>
<th>Severe stenosis or occlusion &gt;6.1</th>
<th>Occlusion only</th>
<th>Any abnormality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>% of row</td>
<td>% of col</td>
<td>No.</td>
<td>% of row</td>
</tr>
<tr>
<td>Stroke</td>
<td>28</td>
<td>17</td>
<td>61</td>
<td>6</td>
</tr>
<tr>
<td>Transient ischemic attack</td>
<td>65</td>
<td>49</td>
<td>75</td>
<td>12</td>
</tr>
<tr>
<td>Ischemia</td>
<td>93</td>
<td>69</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>No symptoms</td>
<td>378</td>
<td>288</td>
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<td>77</td>
</tr>
<tr>
<td>Column</td>
<td>471</td>
<td>354</td>
<td>75</td>
<td>95</td>
</tr>
</tbody>
</table>

*p=0.004 different from no symptoms by Fisher’s exact two-sided test.
†p=0.012, 0.032, respectively, different from normal by Fisher’s exact two-sided test.

The prevalence of cerebral ischemia, the frequency of TIA did not significantly differ with Doppler findings (Table 1). Doppler findings of cerebral ischemia were significantly related to clinical ischemia, but even among these 22 men, carotid artery disease was usually asymptomatic. Among the seven men with ICA occlusion, however, most had symptoms of ischemia. Among the 354 men with normal Doppler findings, 81% had no ischemic symptoms or signs.

A carotid bruit was registered in 11 men (on the right side in three, on the left side in two, and on both sides in six). Five of these 11 men had abnormal Doppler findings (two men had a history of stroke) while the other six had normal Doppler findings.

**Discussion**

The prevalence of cerebral ischemia in a population study as defined by Doppler ultrasound findings has not been reported previously. Our present study shows that significant (≥30%) stenosis of the ICA occurs in 25% of 69-year-old men and that severe stenosis or occlusion occurs in 5%. These figures cannot be extrapolated to populations of other ages as clinical carotid artery disease increases with age.\(^5\)\(^13\); however, the population we studied was representative of a stroke-prone age group. The prevalence of carotid artery disease is probably relevant to a major age group in the stroke population. Cervical bruits are reported in approximately 4% of people >45 years old.\(^1\)\(^2\) Bruits were rare in our study and were poorly associated with the Doppler findings. Other studies have shown that bruits are unreliable indicators of carotid artery disease.\(^7\) The prevalence of stroke (6%) was rather high but compatible with that found in other studies.\(^14\)\(^15\) The prevalence of stroke during the last year (2%) was similar to that reported in this age group by others.\(^14\)\(^15\) The results further corroborate a high frequency of less specific TIA symptoms such as vertigo, dizziness, and visual symptoms in this age group (approximately 15%). There were few confirmed TIA (<1%), which confirms results from Copenhagen.\(^12\)

The distribution of the degree of ICA stenosis is interesting since it may reflect the pathogenetic process involved in the progression of carotid stenosis and relates to the clinical findings (Figure 1). It thus seems that the frequencies of most changes (i.e., stenoses of 30–60%) taper off like the extremes of a normal distribution. These may represent uncomplicated plaques. A small proportion of stenoses may undergo more rapid progression to severe stenosis and occlusion. The factors involved in this rapid progression may be ulceration, hemorrhage, and thrombosis, giving rise to complex,

**TABLE 2. Doppler Ultrasonographic Findings in Internal Carotid Arteries of 69-Year-Old Men by Cerebral Hemisphere**

<table>
<thead>
<tr>
<th>Hemisphere</th>
<th>n</th>
<th>No. of row</th>
<th>% of row</th>
<th>% of row</th>
<th>% of row</th>
<th>% of row</th>
<th>% of row</th>
<th>% of row</th>
<th>% of row</th>
<th>% of row</th>
<th>% of row</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemispheres with definite ischemia</td>
<td>22</td>
<td>13</td>
<td>59</td>
<td>4</td>
<td>18</td>
<td>5</td>
<td>23</td>
<td>9</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All other hemispheres</td>
<td>927</td>
<td>802</td>
<td>86</td>
<td>108</td>
<td>12</td>
<td>17</td>
<td>2*</td>
<td>125</td>
<td>13*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemispheres in asymptomatic men</td>
<td>756</td>
<td>666</td>
<td>88</td>
<td>77</td>
<td>10</td>
<td>13</td>
<td>2*</td>
<td>90</td>
<td>12*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p<0.001, 0.002, respectively, different from hemispheres with ischemia by Fisher’s exact two-sided test.
unstable plaque. This bimodal distribution curve for stenoses has also been found in angiographic studies of symptomatic patients. The relation between carotid artery disease and clinical symptoms of stroke is evident in the men with severe stenosis or occlusion. Our results are in accordance with those from recent follow-up studies of asymptomatic carotid stenosis, which showed a significantly increased risk of TIA and stroke among persons with high-grade stenosis. Stroke had occurred in most of our men with ICA occlusion. Stenoses of <60% are seemingly not accompanied by an increased risk of cerebral ischemic events. It should also be recognized that we found 77% of all stenoses and 59% of severe stenoses or occlusions to be asymptomatic.

Our findings may have implications for the clinical evaluation of patients with hemispheric TIA or stroke. Minor changes (i.e., stenoses of <60%) are common and are probably usually innocent and unrelated to cerebral ischemic events unless the changes are complicated by ulceration. Also, major stenoses and occlusions are often asymptomatic and thus are commonly not considered for surgical treatment. These major changes, however, seem to represent a specific group within the distribution curve of carotid artery disease, being the result of a malignant development. During this development, carotid artery disease seems to bear a significant risk of stroke. Our findings support the generally accepted attitude that mainly symptomatic patients with high-grade stenosis should be referred for surgical treatment. The definite role of carotid stenosis in the development of ischemic cerebral disease will require a long-term follow-up, which is planned.

References

KEY WORDS • carotid artery disease • cerebrovascular disorders • ultrasonics
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