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SUMMARY In 38 patients who underwent cerebrovascular evaluation followed by angiography the Doppler ultrasound scanning technique was found to be an excellent screening procedure for detecting marked stenosis (>50%) or occlusion of the internal carotid artery (93% correlation). It is noninvasive, easily reproducible and can be performed by a qualified technician. The major problems are: the inability to detect ulcerated plaques without marked stenosis, the requirement for patient cooperation (lying still for periods of 15 minutes), and the fact that it assesses only the extracranial circulation.

Screening with just the directional ophthalmic Doppler flow signal yielded a high percentage of false negatives (13%). The presence of a cervical bruit may indicate an underlying stenosis of the internal carotid artery, but may also be due to stenosis of the external carotid artery or other factors such as increased blood flow, vessel tortuosity, etc. (12% false positives). Absence of a cervical bruit does not exclude internal carotid artery disease (ulcerated nonstenotic plaque or occlusion).

Even though Hunt in 1914 speculated on the importance of atherosclerotic disease in extracranial carotid arteries as a cause of cerebral infarction, it remained for Moniz et al. in 1937, by means of cerebral angiography, to document antemortem occlusion of cervical internal carotid arteries in 4 cases with cerebral infarction. Fisher in 1951 reemphasized the need to examine the cervical vessels at post-mortem in patients having cerebrovascular dysfunction and stressed the clinical picture with which these patients presented. Shortly thereafter, surgical reconstruction of stenosed atherosclerotic internal carotid arteries in the cervical region was performed and advocated for some patients having transient cerebral ischemic symptoms in the appropriate carotid artery distribution.

Cerebral angiography remains the best procedure for delineating extracranial carotid artery occlusive disease, but since it is not without risks (albeit small), various physical findings and noninvasive diagnostic procedures have been advocated to help select the patients having transient cerebral ischemic attacks who would most benefit from cerebral angiography.

Spencer et al. have described a technique utilizing a continuous wave Doppler ultrasonic flowmeter to image the carotid bifurcation and assess the velocity flow signals and from this determine the presence of marked stenosis (>50%) or occlusion in these vessels. We have examined 137 patients utilizing the Spencer technique, and from 38 of these who underwent cerebral angiography determined the correlation between the 2 procedures. These results were then compared with those reported in the literature using similar techniques. A correlation was also made with cervical bruits, ophthalmic Doppler flow and findings at angiography.

Methods

Instrumentation

Figure 1 is a schematic representation of the scanning system. The scan console contains a continuous wave Doppler flowmeter connected to a transducer which can be used attached to or apart from the scanning arm. Audible Doppler sounds from the flowmeter are distributed to the speaker and to 1 channel of the stereo tape recorder (the other channel is used for recording the operator's voice). The velocity signal is distributed to a strip chart recorder for permanent velocity tracings and to display the monitor which also contains a pulse signal and adjustable threshold. The velocity signals, when greater than the adjustable threshold, send a beam signal to the Z axis of the storage oscilloscope to intensify the spot on this monitor. Potentiometers located in scanning arm circuitry provide input to storage oscilloscope for X and Y axis location of beam signal.

Permanent records of evaluation include Doppler sounds with the technician's comments on the tape recorder, velocity tracings recording from the strip chart recorder and a polaroid picture of the velocity flow map from the storage oscilloscope.

Technique

The patient is initially interviewed, usually by the technician, with emphasis on TIA symptoms, relevant risk factors and present medications. This is followed by recording of blood pressures, palpation of peripheral arteries and auscultation over precordium, supraclavicular, paracervical and orbital regions. Bruit radiating from precordium or supraclavicular region is recorded as such and only a bruit which is maximal at midcervical region or below the angle of the jaw is noted as a cervical bruit.

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While in a supine position the patient's head is slightly extended by placing a small pillow underneath his neck. The transducer on the scanning arm is directed cephalad approximately 60°, to obtain a significant Doppler shift signal. Aqueous coupling gel is applied liberally along the paracervical region in the suspected course of the common carotid artery. By means of a continuous up and down movement the probe is moved from the supraclavicular region to the angle of the jaw until the carotid bifurcation is well visualized. Stereotape recording of Doppler signals throughout the course of the vessels visualized, with appropriate comments by the technician, is obtained. Synchronized recording of the velocity flow signal from the strip chart recorder is also obtained. A polaroid photograph is taken of the image on the storage oscilloscope and the procedure is repeated on the opposite side. The 5 mHz probe is then removed from the transducer arm and the direction of the ophthalmic artery flow is found (normal being toward the probe) by directing the beam retroorbitally through the closed eyelid. The procedure takes approximately 45 minutes and is performed by a technician unless problems arise. Evaluation interpretation is performed by a physician and requires approximately 5–10 minutes.

**Table 1** Correlations of Doppler Evaluation with all Angiograms

<table>
<thead>
<tr>
<th>Artery</th>
<th>False negative*</th>
<th>False positive†</th>
<th>Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common carotid (CC)</td>
<td>0</td>
<td>0</td>
<td>73/73 (100%)</td>
</tr>
<tr>
<td>Internal carotid (IC)</td>
<td>2/73 (3%)</td>
<td>3/73 (4%)</td>
<td>68/73 (93%)</td>
</tr>
<tr>
<td>External carotid (EC)</td>
<td>4/73 (5%)</td>
<td>3/73 (4%)</td>
<td>66/73 (91%)</td>
</tr>
</tbody>
</table>

*Artery reported normal by Doppler evaluation and found to have marked (> 50%) stenosis or occlusion on angiography.†Artery reported markedly stenosed on Doppler evaluation and found to be normal or mildly (< 50%) stenosed on angiography.

**Table 2** Correlation of Doppler Evaluation with Positive Angiograms

<table>
<thead>
<tr>
<th>Artery</th>
<th>Mild (&lt;50%) stenosis</th>
<th>Marked (&gt;50%) stenosis</th>
<th>Occluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>0/2</td>
<td>11/12 (92%)</td>
<td>0</td>
</tr>
<tr>
<td>IC</td>
<td>1/11 (9%)</td>
<td>4/5 (80%)</td>
<td>0</td>
</tr>
<tr>
<td>EC</td>
<td>0/2</td>
<td>1/5 (20%)</td>
<td>0</td>
</tr>
</tbody>
</table>

*In one patient auscultation for a cervical bruit on one side was not recorded by technician.†Four evaluations were either not performed (2) or uninterpretable (2) because of weak Doppler signal.

**Table 3** Correlation of Cervical Bruit (CB*) and Ophthalmic Doppler Flow (ODF†) with all Angiograms

<table>
<thead>
<tr>
<th>No.</th>
<th>False negative</th>
<th>False positive†</th>
<th>Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB</td>
<td>4/72 (6%)</td>
<td>9/72 (12%)</td>
<td>59/72 (82%)</td>
</tr>
<tr>
<td>ODF</td>
<td>9/69 (13%)</td>
<td>1/69 (2%)</td>
<td>59/69 (85%)</td>
</tr>
</tbody>
</table>

*In one patient auscultation for a cervical bruit on one side was not recorded by technician.†Four evaluations were either not performed (2) or uninterpretable (2) because of weak Doppler signal.

**Results**

Of the 137 patients evaluated by the above technique, 38 underwent transfemoral angiography with adequate visualization of 73 carotid bifurcations. Three carotid bifurcations were not visualized angiographically in 3 patients because their physicians chose to obtain an angiogram from only 1 of the 2 bifurcations examined by Doppler scan. All 38 patients underwent Doppler evaluation prior to angiography and results were recorded in their hospital chart. The percent stenosis noted at angiography was determined from the average stenosis on AP and lateral projections. The results from angiography were determined independently from Doppler cerebrovascular evaluation. Table 1 summarizes our results of cerebrovascular evaluation (CVE) correlated with all angiograms. Table 2 compares CVE only with angiograms showing some degree of stenosis or occlusion (positive angiograms). We then compared our findings from auscultation for a cervical bruit and determination of
TABLE 4  Correlation of CB and ODF with Positive Angiograms

<table>
<thead>
<tr>
<th></th>
<th>Mild (≤50%) stenosis</th>
<th>Marked (&gt;50%) stenosis</th>
<th>Occluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB</td>
<td>2/11 (18%)</td>
<td>12/12 (100%)</td>
<td>1/5 (20%)</td>
</tr>
<tr>
<td>ODF</td>
<td>0/9</td>
<td>3/11 (27%)</td>
<td>4/5 (80%)</td>
</tr>
</tbody>
</table>

TABLE 5  Comparison of Doppler Evaluation with Angiographic Results (3 Series)

<table>
<thead>
<tr>
<th>Artery</th>
<th>Spencer et al.11</th>
<th>Blackwell et al.12</th>
<th>Our Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>147/148 (99%)</td>
<td>118/145 (81%)</td>
<td>73/73 (100%)</td>
</tr>
<tr>
<td>IC</td>
<td>142/148 (96%)</td>
<td>99/144 (60%)</td>
<td>68/73 (93%)</td>
</tr>
<tr>
<td>EC</td>
<td>144/148 (97%)</td>
<td>106/142 (75%)</td>
<td>66/73 (91%)</td>
</tr>
</tbody>
</table>

Directional ophthalmic Doppler flow signal, independently, with all angiograms (table 3) and only positive angiograms (table 4). Ophthalmic Doppler flow signal was interpreted only as to direction and not evaluated as to quality or intensity. There were no arterial compressions performed during our evaluation. Finally, Table 5 compares our results with those of other investigators using a similar technique.

Discussion
Comparison of our data with those reported by Spencer et al.11 produced very similar results, while there is some discrepancy with results from Blackwell et al.12 We reported a positive angiogram as showing a stenosis of 50% or greater, as did Spencer, but this was not specified by Blackwell. If the latter considered a lesser stenosis as being positive, this may account for the variance.

CVE utilizing Doppler scanning of the carotid arteries is excellent for screening patients suspected of having extracranial carotid artery disease, but, as can be seen in table 2, one of the major shortcomings of this evaluation is the inability to detect a mild (<50%) stenosis which in certain circumstances may be ulcerated and a source of embolic material causing TIAs.13 There are changes in the Doppler signal which may indicate a nonstenosing plaque (inverted and biphasic analogue tracing, coarse and low frequency signals, nonsounding gaps in Doppler image), but do not definitely connote ulceration. In fact, we have found at least 1 of the above changes at the carotid bifurcation in most patients evaluated who were 45 years-of-age or older and we feel it indicates early atherosclerosis with calcification, as suggested by Spencer.10

Marked stenosis is most frequently noted as a high frequency Doppler signal occasionally associated with a fluttering or thumping distal to the stenosed segment (fig. 2). Occlusion of the internal carotid artery is characterized by a nonvisualized segment distally (fig. 3) and usually a reversed ophthalmic artery signal. The latter finding may be misleading as it was in the 1 case, early in our clinical trial, with occlusion, which we misinterpreted. The Doppler visualized picture was compatible with occlusion of the internal carotid artery, but the ophthalmic artery flow signal was in the appropriate direction. On angiography it was apparent that the internal carotid artery was occluded and that the appropriate ophthalmic flow signal was due to collateral circulation from the vertebrobasilar system and opposite internal carotid artery. Determination of directional ophthalmic Doppler flow signal by itself was a poor indicator of mild (0%) or marked internal carotid stenosis (27%), but was significantly better for occlusion (80%), indicating that this, by itself, would be a poor screening test.

A noncardiac transmitted cervical bruit has variably been reported to indicate carotid stenosis.14-16
We found a cervical bruit in all 12 patients with marked stenosis of the internal carotid artery and in 1 of the 5 patients with an occluded internal carotid artery (felt to be due to increased flow through ipsilateral external carotid artery). The major deficiencies of screening patients by auscultation for a cervical bruit is the high incidence of false positives (12% in our series) and inability to detect an individual with a nonstenotic ulceration or occlusion of internal carotid artery.

Acknowledgment

The authors wish to thank Lee D’Alessandro and Betty Gamoke for their excellent technical assistance.

References


Technique for Multi-View Radionuclide Angiography

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SUMMARY A new method utilizing computer subtraction allows 2 separate radionuclide angiograms to be performed during a single laboratory visit. Two separate intravenous injections of the radionuclide are given so that the patient's head can be imaged in 2 different projections. Background activity from the first injection is subtracted by the computer to allow good resolution of blood flow following the second injection. A static brain scan is performed after the second injection. Although single-view radionuclide angiography is widely used in the diagnostic evaluation of the brain, the addition of a second projection provides additional important diagnostic information. The views obtained, however, must be determined individually for each patient on the basis of the clinical history and neurologic signs. The selection of appropriate views, the diagnostic quality of the studies, and the practical clinical application of this technique are illustrated by 2 case reports.

SINGLE-VIEW radionuclide angiography is widely used in the diagnostic nuclide evaluation of the brain. However, the performance of radionuclide angiography in 2 different projections of the head provides further diagnostic information and is more helpful than a single view. We present a method utilizing computer subtraction which allows 2 separate nuclide angiograms to be performed during a single visit to the laboratory.

Collection and Processing of Scintigraphic Data

A catheter with a 3-way stopcock was inserted into the patient's antecubital vein. The patient was then positioned under a scintillation camera (Pho/Gamma IV, Model 6406, G. D. Searle and Co., Des Plaines, Ill.) for an anterior Townes, lateral, or vertex view. A rapid bolus (10-20 mCi) of the nondiffusible radionuclide 99mTc-diethylene-triamine penta-acetic acid (99mTc-DTPA) was injected through the catheter. Flow data were collected by a computer (DEC PDP-11/45) in 1.25-second histograms (64 × 64 matrix) for 50 sec following the injection.
Cerebrovascular evaluation: assessment of Doppler scanning of carotid arteries, ophthalmic Doppler flow and cervical bruits.

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