Comparison of Oculoplethysmography/Carotid Phonoangiography with Duplex Scan/Spectral Analysis in the Detection of Carotid Artery Stenosis

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DAVID THOMAS,‡ AND DONALD E. BOWES, M.D.¶

SUMMARY The accuracy of the duplex scan with spectral analysis (DS/SA) in predicting the presence of arteriographic carotid stenosis was compared to that of oculoplethysmography/carotid phonoangiography (OPG/CPA) in 234 vessels from 117 patients who had had both non-invasive studies in addition to independently interpreted arteriograms. The DS/SA with 212/234 (91%) overall correct responses was superior to the OPG/CPA which properly classified 181/234 (77%) of the vessels (p < .01). Of major clinical impact was the superiority of the DS/SA (p < .001) in identifying the 72 vessels with 50–99% stenosis. The OPG/CPA had a discouraging 39/72 (54%) false-negative rate in this group whereas the DS/SA missed only 9/72 (12%) of these arteries. Of those 39 incorrect responses for the OPG/CPA, 26/39 (67%) were in patients with a 50% or greater stenosis on the contralateral side. This is a recognized area of weakness for that test. Based on the results of this study, we have abandoned the use of the OPG/CPA in the evaluation of patients with suspected carotid stenosis and rely solely on the duplex scan with spectral analysis.

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OCCULOPLETHYSMOGRAPHY (OPG) in combination with carotid phonoangiography (CPA) is often used in evaluating patients with suspected stenosis of the extracranial cerebral vasculature. Some reports have questioned the accuracy of this test and have reported a high incidence of false-negative results for stenotic lesions 50% or greater.1,2 The duplex scanner used in conjunction with a Fast Fourier Transform spectral analyzer is a relatively new method of evaluating the area of the carotid bifurcation.3-4 Real-time, two-dimensional ultrasonography is employed to generate an image of the vessel to be examined and this allows accurate positioning of the range-gated pulsed Doppler beam in the lumen of the artery. The audible sound from this one cubic millimeter sample volume is then routed through the spectral analyzer which gives a real-time display of frequency (in HZ) throughout the cardiac cycle. The Doppler equation5,6 relates velocity of blood flow to this measured frequency and the angle of the incident Doppler beam. Based on the equation we have formulated numerical objective criteria that may be applied to the spectral analysis patterns to predict the presence of a stenotic internal carotid lesion.

A comparison of the predicted accuracy of both examinations was carried out by analyzing the results for each test from 234 carotid arteries in 117 patients who had had both non-invasive evaluations in addition to carotid angiography.

Materials

One hundred seventeen patients who had carotid angiograms at our institution in the last 18 months also had both an OPG/CPA and a duplex scan with spectral analysis (DS/SA) performed concurrently. In every case, the non-invasive studies were done before or without knowledge of the arteriogram results. For the purposes of statistical analysis in this study, each artery was considered separately for a total of 234 comparisons. None of the patients evaluated was included in a previously published, in-depth study of the OPG/CPA performed at our institution.5

Methods

A Mark V Duplex scanner (Advanced Technology Laboratories) was utilized to generate an image of the artery to be examined and that image was used to position the sample volume of the pulsed Doppler beam in the lumen of the vessel. The angle of that incident Doppler beam was kept at 60° so that frequency ratios could be used interchangeably. The sound signal obtained was then processed by an Angioscan Fast Fourier Transform Spectral Analyzer (Unigon Industries). Hard copy of the sound patterns was by Polaroid picture. Areas examined included the common carotid artery, the carotid bulb, the external carotid and the proximal and distal portions of the internal carotid artery.

A ratio of the peak frequency in systole of the internal carotid artery to the peak frequency in systole of the common carotid artery was obtained for each vessel and this was designated Test A. A total of the

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Statistical analysis performed by Dr. Paul Nelson, Department of Mathematics, Bucknell University.
diastolic peak frequencies at 50%, 70% and 90% points in the cardiac cycle was obtained and this value was called Test B. The areas of the spectral patterns for one cardiac cycle for both the internal and common carotid arteries were measured with a Numonics computer and an internal to common carotid area ratio was designated Test C. If no flow signal was obtained the artery was considered totally occluded.

Tables of values for the above parameters were formulated by tabulating the means and standard deviations for each of the three tests in 70 other previously studied arteries that had normal angiograms. For each of the three parameters the mean plus two standard deviations (95% confidence level) was considered the upper limit of normal. Any score above this value was indicative of a stenotic lesion. For the arteries in the study, if two out of three of the tests were abnormal the vessel was considered to have a significant stenosis. None of the patients used in constructing the tables of values were included in the comparative study.

The OPG tracings and the CPA patterns were obtained with the Kartchner fluid-filled OPG/CPA and scored as described by Kartchner and McRae at the Tucson Medical Center.6,7

The angiograms were independently interpreted by a vascular radiologist and the degree of stenosis ascertained using two planes. Based on the arteriogram, the arteries were classified into Group I (normal-49% stenosis), Group II (50-99% stenosis) and Group III (total occlusion). The DS/SA response was counted as correct for Group I if at least two out of three of the test scores fell within the normal range. For Group II the reading was correct if at least two out of three scores fell in the abnormal range and for Group III the DS/SA was correct if no flow signal was noted. The OPG/CPA reading was counted as correct if it had been read as normal for the vessels with less than 40% stenosis by radiography or as Kartchner Grade II (mild) for the vessels with 40-50% angiographic narrowing (Group I). For arteriogram Groups II and III, any abnormal tracing (Kartchner Grades II-V) was classified as correct — a very liberal classification.

Results

There were 137 arteries in Group I, 72 in Group II and 25 in Group III (total = 234). The overall accuracy for the DS/SA was 212/234 (91%) compared to that of the OPG/CPA with 181/234 (77%) correct responses ($p < .001$) (fig. 1). Group I had 130/137 (95%) correct for the DS/SA and 128/137 (94%) for the OPG/CPA. In Group III there were 19/25 (76%) right with the DS/SA and 20/25 (80%) with the OPG/CPA. Neither difference was statistically significant. The main factor then, accounting for the overall superiority of the DS/SA, was the marked difference in the accuracies for the tests for Group II vessels (50-99% stenosis). The DS/SA correctly identified 63/72 (88%) of the stenotic arteries whereas the OPG/CPA was right in only 33/72 (46%) of the cases. This difference was significant ($p < .001$).

Since the OPG/CPA depends on comparative timing of pulse waves, a recognized weakness of that test is its increased false-negative rate with bilateral stenotic lesions. Of the 39/72 (54%) false-negative OPG/CPA responses in Group II vessels, 26/39 (67%) were in patients who had a narrowing of 50% or greater on the opposite side (fig. 2). Of the nine incorrect predictions with the DS/SA, four had a stenotic lesion on the opposite side and five did not.

One difficulty in comparing the results of non-invasive examinations to angiographic data is the inter- and intra-observer variability that occurs in the arteriogram interpretations of lesions in the range of 50% stenosis. This had little effect on our study since we were comparing the results of two non-invasive examinations performed on the same patient population.

### Table 1. Breakdown of the number of correct and incorrect responses for the OPG/CPA and DS/SA in the three study groups.

<table>
<thead>
<tr>
<th></th>
<th>GROUP I</th>
<th>GROUP II</th>
<th>GROUP III</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong># CORRECT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DS/SA</td>
<td>130 (95%)</td>
<td>63 (86%)</td>
<td>19 (76%)</td>
</tr>
<tr>
<td>OPG/CPA</td>
<td>128 (93%)</td>
<td>33 (46%)</td>
<td>20 (80%)</td>
</tr>
<tr>
<td><strong># INCORRECT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DS/SA</td>
<td>7 ( 5%)</td>
<td>9 (12%)</td>
<td>6 (24%)</td>
</tr>
<tr>
<td>OPG/CPA</td>
<td>9 ( 7%)</td>
<td>39 (54%)</td>
<td>5 (20%)</td>
</tr>
</tbody>
</table>

**OVERALL ACCURACY DS/SA = 212/234 (91%)**

**OVERALL ACCURACY OPG/CPA = 181/234 (77%)**

### Table 2. Degree of stenosis on the contralateral side in those Group II patients whose non-invasive test results were incorrect.

<table>
<thead>
<tr>
<th></th>
<th># WRONG</th>
<th>≥ 50%</th>
<th>&lt; 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS/SA</td>
<td>9</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>OPG/CPA</td>
<td>39</td>
<td>26 (67%)</td>
<td>13</td>
</tr>
</tbody>
</table>
OPG/CPA DS/SA COMPARISON/Keagy et al.

<table>
<thead>
<tr>
<th>AMOUNT OF STENOSIS</th>
<th>NUMBER</th>
<th>PERCENT</th>
<th>GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>75</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>MURAL</td>
<td>49</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>10 - 29%</td>
<td>6</td>
<td>3</td>
<td>I</td>
</tr>
<tr>
<td>30 - 39%</td>
<td>4</td>
<td>2</td>
<td>II</td>
</tr>
<tr>
<td>40 - 49%</td>
<td>3</td>
<td>1</td>
<td>III</td>
</tr>
<tr>
<td>50 - 59%</td>
<td>11</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>60 - 69%</td>
<td>10</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>70 - 89%</td>
<td>22</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>90 - 99%</td>
<td>29</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>OCCLUSION</td>
<td>25</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

FIGURE 3. Breakdown of the degree of angiographic stenosis of the 234 vessels in this study.

rather than obtaining an absolute accuracy rate for one test. In addition, there were only 14/234 (6%) vessels whose amount of stenosis was in the range of 40-59% (fig. 3).

Discussion

This study shows a clear superiority of the duplex scan with spectral analysis over the OPG/CPA in identifying stenotic lesions in the range of 50-99%. One of the reasons is the physiological basis behind the two tests. The DS/SA is a direct evaluation of the flow characteristics of the artery in question and is not influenced by the condition of the contralateral vessel whereas the OPG/CPA is an indirect measurement dependent on comparative flow delays to the optic vasculature and false-negative results may occur with bilateral stenotic lesions. Indeed 67% of the false-negative OPG/CPA errors in this study were in individuals with arteries narrowed by 50% or more on both sides.

This study revealed no significant difference in accuracy rates for the DS/SA, 19/25 (76%), and the OPG/CPA, 20/25 (80%), with regard to total occlusions. However, our experimental protocol counted any abnormal OPG/CPA reading as correct for Group III vessels. Thus, in reality, of the 20 responses counted as correct for the OPG/CPA, two were, in reality, Kartchner Grade II (mild), seven were Grade III (moderate) and three were Grade IV (severe). Six were interpreted as showing bilateral disease and only two were reported as actually revealing total occlusion. The six errors with DS/SA were due to placement of the Doppler sample volume in the wrong vessel, most commonly the external carotid or the vertebral artery. The latter has the same flow characteristics as the internal carotid vessel.

The test is performed in the supine position and good quality studies may be obtained in stroke victims or comatose patients, a population in whom the OPG/CPA test is difficult to perform. The application of eyeball appliances is avoided and the scan head used with the DS/SA is associated with no discomfort.

Disadvantages of the new technique include time and expense. The equipment is more costly than that required for an OPG/CPA and the testing time is slightly longer. An average complete examination at our institution takes about 25-30 minutes in addition to the time required for application of the spectral pattern objective measurements. The most clinically significant aspect of the study was the marked difference in the detection of Group II (50-99% stenosis) vessels. Of the 72 arteries so classified by angiography, 39 (54%) were incorrectly classified as normal by the OPG/CPA whereas only nine (12%) were missed by DS/SA. It is this group of patients in whom an incorrect response may result in failure to obtain an angiogram, thus adversely affecting the subsequent treatment plan. At our institution the results of this study have led us to abandon the OPG/CPA in the evaluation of patients with suspected carotid stenosis and to rely exclusively on duplex scan with spectral analysis as the non-invasive test of choice.

References

Comparison of oculoplethysmography/carotid phonoangiography with duplex scan/spectral analysis in the detection of carotid artery stenosis.

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