Opacity Pulse Propagation Measurement and Thermometry in the Evaluation of Carotid Occlusive Vascular Disease: Correlations With Angiography

BY THOMAS R. PRICE, M.D., AND ALBERT F. HECK, M.D.

Abstract:
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A correlative study of four-vessel angiography with measurements of opacity pulse propagation times and skin temperatures over the medial supraorbital areas of the forehead was carried out in 46 patients. Differences in propagation times of greater than 12 milliseconds and/or in thermometric measurements of 1°F or more were always associated with angiographically demonstrable carotid occlusive disease. In patients with positive angiographical findings, prolongation of pulse propagation time was associated with lower skin temperature when the latter occurred. Test results indicated abnormality in six of seven patients with bilateral carotid occlusive disease. By these methods, unilateral occlusive lesions of 30% to 50% of the vascular lumen were detected in three of five instances where such lesions occurred; occlusive lesions greater than this degree were detected in 15 of 18 patients. The tests identified as “normal” 18 of 23 patients whose four-vessel angiograms were either totally unremarkable or showed lesions compromising less than 30% of the carotid lumen. Combination of these screening tests is more useful than either test employed alone and may be helpful in clinical evaluation of patients with cerebrovascular disease.

Additional Key Words
carotid stenosis, bilateral cerebrovascular disease screening tests

Previous communications from this institution have dealt separately with the value of opacity pulse propagation times and thermometry in the atraumatic assessment of patients for extracranial cerebrovascular disease. Studies in which supraorbital facial skin temperatures, measured by means of a thermostor probe and displayed on a degree scale, were correlated with results of four-vessel angiography in 100 patients have shown that the magnitude of difference between supraorbital temperatures on the two sides of the face is helpful in defining the probability of presence of carotid artery disease. A difference from one side to the other of 1°F or more was associated in every case with carotid occlusion or stenosis greater than 50% of the lumen as demonstrated on the angiogram. With differences of 0.5°F to 0.9°F, 46% of patients had carotid lesions of this magnitude. With differences less than 0.5°F, only 16% had occlusion or stenosis greater than 50% of the lumen.

Opacity pulse propagation time is defined as the time in milliseconds from the occurrence of the R-wave of the ECG until the arrival of the corresponding opacity pulse wave in the vascular bed monitored. Previous studies have also demonstrated the usefulness of comparing

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mean values of opacity pulse propagation time to homologous sites on either side of the body in detecting occlusive vascular disease in carotid and subclavian arteries. 8-10

Basic problems encountered in the development and evaluation of results of these atraumatic screening procedures include: (1) the minimal degree of vascular pathology which can be detected, (2) false-positive and false-negative results, and (3) interpretation of results when the disease process occurs bilaterally. In a previous communication, 4 it has been intimated that combining the results of two or more screening techniques may be helpful in overcoming these obstacles.

The purpose of this paper is to present preliminary results of correlating opacity pulse propagation measurements and medial supraorbital thermometric measurements with the results of four-vessel angiographical studies in 46 patients.

**Methods**

Methods employed in the two screening techniques have been described elsewhere. 1-8 In the present study, opacity pulse propagation and thermometric measurements were performed in patients prior to four-vessel angiography and without knowledge of the patient's clinical status. Evaluation of angiograms, as in previous studies, was made separately by one of the investigators (TRP) without knowledge of the results of the screening procedures.

Twenty-three of the patients in this series had normal angiograms or stenosis less than 30% of the lumen. Five patients had 30% to 50% unilateral stenosis; six patients had greater than 50% unilateral carotid artery occlusion and of these, two had, in addition, stenosis of the contralateral carotid artery.

On the basis of previous studies, 1 differences in thermometric measurements over the medial supraorbital areas obtained in these patients were assigned to one of three categories: Category 1: differences of less than 0.5°F; Category 2: differences of 0.5°F to 0.9°F; and Category 3: differences of 1.0°F or greater.

The accuracy of opacity pulse propagation time measurement during any one cardiac cycle when measured manually is approximately eight milliseconds. 8 For purposes of the present study, differences encountered in the mean values of opacity pulse propagation time to the medial supraorbital areas obtained during 30 consecutive cardiac cycles were also assigned to one of three categories: Category 1: differences from side to side of less than eight milliseconds; Category 2: differences of 8 to 12 milliseconds, i.e., half again the magnitude of measurement error; and Category 3: differences greater than 12 milliseconds.

**Results**

The results of the analysis are shown in Table 1. Categories of results of the screening techniques are shown on the left: ΔOPPT-category of opacity pulse propagation time difference/ΔT-category of thermometric measurement difference.

Sixteen of 21 patients in whom the difference in mean values of opacity pulse propagation time was less than eight milliseconds and in whom difference in thermometric

<table>
<thead>
<tr>
<th>Category</th>
<th>No pts</th>
<th>% normal angle</th>
<th>Normal</th>
<th>ΔOPPT/ΔT</th>
<th>Angiographical findings</th>
<th>Unilateral occlusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1</td>
<td>21</td>
<td>76</td>
<td>16</td>
<td></td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>2/1</td>
<td>5</td>
<td>40</td>
<td>2</td>
<td></td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1/2</td>
<td>7</td>
<td>43</td>
<td>3</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2/2</td>
<td>3*</td>
<td>67*</td>
<td>2*</td>
<td></td>
<td>1*</td>
<td>1</td>
</tr>
<tr>
<td>3/1</td>
<td>2</td>
<td>0</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3/2</td>
<td>2</td>
<td>0</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3/3</td>
<td>6</td>
<td>2</td>
<td></td>
<td></td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Categories: Δ Opacity Pulse Propagation Time
1. Less than eight msec
2. Eight to 12 msec
3. Greater than 12 msec

Δ Thermometry
1. 0 to 0.4°F
2. 0.5°F to 0.9°F
3. Greater than 1°F

*See text.
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measurement between the two sides was 0.4°F or less (1/1) had normal angiograms. In 12 patients where either test was in Category 2 (1/2 or 2/1), angiograms were normal in only five. Two of three patients in whom opacity pulse propagation and thermometric differences were both in Category 2 had normal angiograms (vide infra).

In patients in whom opacity pulse propagation differences exceeded 12 milliseconds or in whom thermometric differences were 1°F or greater (3/1, 3/2 or 3/3), angiograms were always positive.

In all patients in this series with unilateral carotid occlusive disease, prolongation of mean values of propagation time was associated with cooler skin temperature on the ipsilateral side when a difference in medial supraorbital temperatures was detected.

Discussion

The finding of opacity pulse propagation time or skin temperature differences in Category 3 is regarded in this study as "positive," since, in this situation, angiography always revealed carotid arterial occlusive disease on the side of prolonged propagation time and/or lower skin temperature.

The tests were able to identify as normal 18 of 23 patients with negative angiograms (vide infra). When either test was in Category 2 or when both tests were in Category 2 with lower skin temperature on the same side as prolonged propagation time, carotid occlusive lesions greater than 30% were found at angiography on that side in eight of 13 patients. Results of either test in Category 2 are regarded as "suspicious."

Of the three patients in whom differences in both tests were in Category 2 (2/2), the lower skin temperature was on the side opposite the prolonged opacity pulse propagation time in the two patients in this group with normal angiograms, i.e., test results were contradictory and "cancelled out." In the remaining patient in this group, lower skin temperature and prolongation of opacity pulse propagation time both occurred on the side of 40% internal carotid arterial stenosis; these results were regarded, then, as "suspicious" and did, in fact, predict the presence of disease found on angiography.

Occlusive arterial disease commonly occurs in more than one location and often affects the carotid arteries bilaterally.\textsuperscript{6, 7} Bilaterality of the disease process has been a problem inherent in the development of all atraumatic screening techniques thus far.\textsuperscript{4} Therefore, it seems promising that, in this series, the tests were either "suspicious" or "positive" in six of seven patients with bilateral carotid occlusive disease.

It further seems significant that in this small series, occlusive lesions of 30% to 50% were detected in three of five instances where such lesions occurred.

Methods are currently under evaluation for the electronic measurement of opacity pulse propagation time intervals with an accuracy of ± one millisecond.\textsuperscript{8} On the basis of the preliminary results presented in this series, however, it seems likely that the use of opacity pulse propagation and thermometric measurements together may be more useful than the use of either test alone. Results obtained with these atraumatic techniques may provide a useful adjunct in screening and clinical evaluation of patients with extracranial cerebrovascular disease.

References

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