Radionuclide Angiography and Doppler Sonography to Detect Patients with Cerebrovascular Disease

A Correlation with Radiographic Angiography

U. Buell, M.D., D. Leschem, M.D., M. Rath, M.D., M. Rose, and F. Marguth, M.D.

SUMMARY Cerebral radionuclide angiography with $^{99m}$Tc pertechnetate (RNA) and directional Doppler sonography (DS) were employed to study patients with cerebrovascular disease (CBVD). The 86 patients investigated were divided following radiographic angiography (RGA) into normals (n = 26) and into patients with intracranial (n = 22) and extracranial (n = 38) vascular lesions. Of the patients with angiographically demonstrated CBVD, RNA detected 90%, DS 53.3%. The combined evaluation had a sensitivity of 93.3%. If intracranial arterial disease was excluded, the sensitivity of the studies was 92.1% for RNA and 84.2% for DS and combined evaluation had a sensitivity of 93.8%. The diagnostic accuracy by combined evaluation was 97.4% for the extracranial arterial lesions if the clinical findings were also used in patients with normal RGA pattern. RNA and DS complement each other as RNA contributes to the detection of intracranial blood flow alterations indicating vascular changes in either the extra- or intracranial vessels and helps confirm and complete DS findings.

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CEREBRAL radionuclide angiography with $^{99m}$Tc- pertechnetate or DTPA (RNA) as part of cerebral serial scintigraphy has considerable sensitivity in detecting cerebrovascular disease.1 We recently have published an algorithm which is useful in planning non-invasive diagnostic tests (RNA, Doppler sonography and transmission-computed tomography) for patients suspected of having cerebrovascular disease.9 Within this algorithm, the role of Doppler sonography (DS) was not well defined as there are no comparative data on sensitivity, specificity and diagnostic accuracy of this well established non-invasive method.9,10 Since DS is not expected to provide information on major intracranial cerebral artery lesions, and RNA can fail to detect extracranial lesions, the present study was designed to show whether the data obtained from DS would complement that of RNA and, thereby, increase the sensitivity of these non-invasive diagnostic methods. Efforts were made to compare the results of RNA and DS to findings obtained from radiographic angiography (RGA) by studying patients identified by RGA as having vascular alterations.

Material and Methods

A total of 216 patients, all suspected clinically of having cerebrovascular disease, were studied by RNA and DS. Among these patients 86 had biplane RGA using the Seldinger technique. The results of this procedure were used to divide the patients into 3 groups: a) patients with normal angiogram, b) patients with arterial stenosis (more than 30% of the luminal diameter) or occlusion of intracranial or c) extracranial arteries. The examinations are listed in table 1.

RNA was performed, following a blocking dose of 300 mg of potassium perchlorate, by bolus injection of 10–12 mCi of $^{99m}$Tc pertechnetate into an antecubital vein, followed by 10 ml of saline. Whenever possible the patient was in a sitting position when examined, resulting either in an anterior (a-p) or posterior (p-a) projection. Radionuclide images were obtained with an Ohio-Nuclear Series ON 110 gamma camera (Ohio-Nuclear, Solon, Ohio) equipped with a high-sensitivity parallel hole collimator. Polaroid photographs recorded the total counts accumulated over a 3 sec period. Data were also fed into an on-line computer system (Cine 200, Intertechnique, Paris, France) at a rate of 2.5 frames/sec for later sequential display and to establish flow curves. The curves were derived from 2 regions of interest (light-pen) including one hemisphere each. To complete serial scintigraphy, static imaging was performed 3 to 10 min and again at 60–80 min in at least 3 projections. These images were not included in the following evaluation but were used to exclude intracranial tumors.7

Findings of RNA were evaluated visually and semi-quantitatively as published elsewhere.1,8 The RNA study was designated as positive if the hemispheric distribution of radioactivity was not symmetric. In intracranial areas both total (one hemisphere) and regional (supply areas of a main cerebral artery) delays were taken equally. The visual findings were substantiated by computing left to right ratios of perfusion obtained from the time-radioactivity curves, using a Fortran program.8 In extracranial studies only the unequivocal absence of radioactivity in the internal carotid artery (ICA) was taken as a positive sign. No effort was made to describe systematically the
TABLE 1  Localization and Type of Arterial Lesion in 60 Patients

<table>
<thead>
<tr>
<th>Artery</th>
<th>No.</th>
<th>Occlusion</th>
<th>Stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Intracranial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle cerebral artery</td>
<td>MCA</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Branches of MCA</td>
<td></td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Anterior cerebral artery</td>
<td>ACA</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Internal carotid artery</td>
<td>ICA</td>
<td>2†</td>
<td>—</td>
</tr>
<tr>
<td>II. Extracranial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICA</td>
<td>35</td>
<td>20‡</td>
<td>9</td>
</tr>
<tr>
<td>Common carotid artery</td>
<td>CCA</td>
<td>3</td>
<td>—</td>
</tr>
</tbody>
</table>

†In one patient with stenosis of MCA.
‡In five patients combined with stenosis of contralateral ICA (not included).

origin of unilateral delayed hemispheric flow. RNA, in contrast to DS, is unable to evaluate a single ICA. With RNA study, only the patient could be evaluated and, as a consequence, RNA was used to classify patients as normal or with cerebrovascular disease.

DS was performed with a directionally sensitive device (Debitmetre Ultrasonique Directionnel, Delalande, Paris, France). The patients were in a supine position for study. Permanent analog recordings were obtained on a strip chart recorder with forward flow registered above and reversed flow below the zero velocity baseline. Using coupling gel, the Doppler probe was gently positioned over the common carotid arteries (CCA) and external (ECA) and internal carotid (ICA) arteries. The frontal arteries, branches of the ophthalmic artery, were examined in addition. Sequentially, all branches of the ECA were compressed. Compression was not applied to the CCA and ICA. Results were obtained by earphone and by evaluating the analog recordings. A Doppler examination was designated to be positive if signals of obstructed flow (i.e. of high frequency, occasionally of high intensity) were found in the frontal arteries.

The physicians interpreting both the RNA or DS knew the patient’s clinical findings but they were not informed of the results of the cerebral angiograms.

Results

The DS and RNA studies were identical (normal and positive) in 69.9% of the patients tested. Discrepant results were found in 30.1% of the 216 patients examined comparatively (table 2). In the patients who had RGA, the percentage of discrepant results was somewhat higher (37.2%) than in the 130 patients who did not have angiography (RGA) (25.4%). In the group of 86 patients evaluated by DS, RNS and RGA, DS and RGA gave identical findings in 62.8%, and RNA and RGA gave identical findings in 88.4% (p < 0.01). Excluding 22 patients with an RGA finding of only intracranial vascular lesions, similar percentages of identical results for DS and RGA or RNA and RGA were found (84.4% vs 89.1%) (table 2).

The localization and type of vascular change demonstrated by RGA in 60 patients (26 patients had normal findings in RGA) are listed in table 1. In view of the limitation of RNA (see above), the lesion causing greatest morphological change (occlusion > stenosis) was determined for each patient. The relation of these vascular alterations to the results of DS and RNA are given in table 3 for the 86 patients. Of 3 patients with intracranial lesions not detected by RNA, one had stenosis of 50% and one occlusion of the middle cerebral artery (MCA). In the patient with middle cerebral artery occlusion there was stenosis of the contralateral ICA. The third patient had occlusion of MCA branches.

Patients with positive RGA findings in the extracranial arteries not detected by DS (6 false negatives) had ICA occlusion (n = 2) and ICA stenosis (n = 4) with 50%, 60%, 70%, and 90% narrowing of the arterial lumina. Patients with vascular lesions in extracranial arteries not detected by RNA (3 false negatives) had occlusion of the ICA (n = 2) and stenosis of the CCA (50%).

Regrouping of DS results to evaluate a single ICA revealed 15% false negatives (6 out of 40 ICA with alterations) and 4.5% false positives (4 out of 88 normal ICA) when findings of cerebral angiograms were used as a reference. For the ICA, 24 of 26 occlusions (92.3%) and 10 of 14 stenoses (> 50% of the luminal diameter) (71.4%) were detected.

Sensitivity, specificity and diagnostic accuracy were determined for both of the non-invasive diagnostic methods relative to the number of normal and diseased patients (table 4). Since DS is not useful for in-

TABLE 2  Results of Doppler-Sonography (DS) and Radiouclide Angiography (RNA) in 150 Patients Compared to 86 Patients Examined with DS, RNA and Radiographic Angiography (RGA)

<table>
<thead>
<tr>
<th>No.</th>
<th>DS and RNA Identical</th>
<th>DS and RNA Discrepant</th>
<th>DS and RGA Identical</th>
<th>RNA and RGA Identical</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>97 (74.6%)</td>
<td>33 (25.4%)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>86</td>
<td>54 (62.8%)</td>
<td>32 (37.2%)</td>
<td>54 (84.4%)*</td>
<td>57 (89.1%)*</td>
</tr>
<tr>
<td>216</td>
<td>151 (90.0%)</td>
<td>65 (30.1%)</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

No. = number of patients.
*Extracranial vascular alterations only (n = 64).
tracranial findings, only sensitivity was determined for the sum of all vascular alterations (table 4). The sensitivity of DS (53.3%) was significantly ($p < 0.01$) lower than that of RNA (90%). Sensitivity, specificity, and diagnostic accuracy were identical or somewhat higher for RNA if determined only for extracranial arterial changes.

The inclusion of clinical findings (transient ischemic attack, prolonged reversible ischemic neurologic deficit) in patients where both DS and RNA were positive but RGA was "normal" increased specificity to 88.5% and diagnostic accuracy to 93.8% for the combined DS and RNA evaluation.

Discussion

DS and RGA are diagnostic procedures which allow evaluation of single cranial arteries. To evaluate RNA, the contralateral pattern and quantity of flow must be used as a reference. RNA can fail to detect less pronounced vascular lesions in the contralateral hemisphere, but data are unobtainable with RNA on the exact localization and on morphological appearance of a vascular lesion. We limited our interest, visually and quantitatively, to the functional data obtained from time course of appearance and from hemispheric quantities of $^{99m}$Tc pertechnetate which were expressed as right to left ratios. Five patients (table 1) with bilateral ICA lesions were detected since these arterial alterations rarely cause identical changes in blood flow. In contrast to Foo and Henrickson, we restricted the RNA evaluation to whether a patient had cranio- and cerebrovascular alteration or not. This was correct in 89.1% (table 4) if RGA was used as the reference. Respective diagnostic accuracy of DS was 84.4% if intracranial vascular
alterations were excluded. Inclusion of these changes resulted in a DS sensitivity of 53.3% vs an RNA sensitivity of 90.0% (table 4).

The results of DS must be interpreted from two points of view. First, in DS evaluation of a single ICA we found 15% false negatives and 4.5% false positives as compared to 3% and 4% reported by Shoumaker and Bloch. For ICA stenosis there were 71.4% correct positives and for ICA occlusion 92.3% correct positives as compared to 92% and 80%. We detected fewer ICA stenoses than others, who used DS plus Dopson direct examination of the carotid bifurcation. Sensitivity of DS may be increased by refinements in technique as proposed by Barnes et al. and changes in the intracranial portion of the ICA may also be detected.

Second, to compare DS and RNA, DS was evaluated with respect to the number of patients. The results listed in the tables reflect this. Intracranial alterations of the very distal portion of the ICA and of major cerebral arteries (table 1) are undetected by DS. This fact explains the discrepancies of DS and RNA findings illustrated in table 2. RNA failed to detect only 3 out of 22 (13.6%) patients with intracranial vascular lesions.

Since sensitivity in detecting intracranial alteration was exclusively derived from RNA, RNA complements DS in the detection of patients with cerebrovascular disease. The number of false negatives for extracranial arterial disease is too high for DS in the present study, but by using RNA in addition it was reduced to a single patient. The combined sensitivity for detection of patients with cerebrovascular disease in extracranial arteries was 97.4%; for both extra- and intracranial arteries it was 93.3% (table 4).

The specificity of DS was higher when related to the number of ICA (94.5%) as compared to the number of patients (84.6%). The latter percentage meant that 4 patients examined by DS were described as having cerebrovascular lesions when the angiogram was normal. There were identical problems with RNA. Among these 7 patients (one was "false positive" with either method) 4 had unequivocal clinical symptoms of cerebrovascular disease. The remaining 3 patients were definitely false positive. The combined specificity of DS and RNA, therefore, was 88.5% and the diagnostic accuracy was 93.8% (table 4).

DS, as well as RNA, is known to be less sensitive than RGA in detecting small vascular lesions. On the other hand, it has been reported that RGA studies in patients with transient ischemic attacks are normal in 26.9%. The results of rCBF measurements and of RNA are strongly correlated to clinical findings even when RGA is negative. Thus, to diagnose cerebrovascular disease definitely in a given patient, RGA must be supplemented by other diagnostic procedures, and if these are non-invasive they should be employed first.

When clinical symptoms warrant an investigation of the cranial vasculature, DS should be employed first. If the patient's problems are not identified, RNA
may be used to detect and quantify intracranial flow abnormalities. RGA is then employed if there are still unanswered questions or when a patient's clinical presentation, DS or RNA findings indicate need for surgery.

References


Quantitative Study of the Rate of Recovery From Aphasia Due to Ischemic Stroke


SUMMARY The extent of recovery from aphasia following ischemic stroke has been evaluated by a quantitative method. The greatest improvement was observed during the first 3 months following onset. The rate of recovery was similar for expression and for comprehension, but comprehension was usually less disturbed than expression. Final prognosis depends on the type of aphasia (the poorest prognosis was found for total or global aphasia) and on the severity of the initial insult.

ATASSEMENT of the rate of recovery is important in the study and management of aphasia. The rate of recovery in a population of patients with stroke was studied with particular attention to the correct patient classification and to a precise quantification of the disorders.

Patients and Methods

Seventy-five patients with aphasia following stroke were studied (mean age 67 years). There were 34 males aged 53 to 85 years (mean 66) and 41 females aged 27 to 88 years (mean 68).

All patients had a cerebral infarction (none had hemorrhage); all were right-handed (handedness determined according to Bryden1); all had an infarction in the left hemisphere as determined by EEG, WmTc pertechnetate scan and, in some, by angiography and CT scan.

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Nine patients were classified as having total or global aphasia, 46 Broca's aphasia and 20 Wernicke's aphasia. Patients with anomic aphasia, conduction aphasia or agrammatism were infrequently found and were not included in the study.

Classification of aphasia was based on verbal expression. In the patients classified as having Broca's aphasia, verbal expression was initially characterized by mutism or speech limited to one or more syllables, one or more words always the same, or by sentences involving the following abnormalities: omission of words, dysarthria, perseveration, paraphasia, iteration (repetition of a phoneme, a syllable, or a word, without completion of the message), palilalia (repetition of words, phrases or sentences, with completion of the message), ecolalia, agrammatism, dyssyntaxia. In the patients believed to have Wernicke's aphasia, neologisms were present as well as phonemic deformations, indeterminate, semantic and morphological paraphasias, dyssyntaxia, leading to a dysphonic (predominance of phonemic errors), dyssemann-
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