EASILY ADMINISTERED WRITTEN TEST FOR LATERALIZING BRAIN LESIONS*

ROBERT F. HEIMBURGER, M.D.†, AND RALPH M. REITAN, Ph.D.‡

Department of Neurological Surgery and Neuropsychology Laboratory,
Indiana University Medical Center, Indianapolis, Indiana

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owledge that lesions of the right and left cerebral hemispheres produce separate distinctive neurological changes, aside from those related to contralateral sensory and motor functions, is not new. This knowledge has not been exploited routinely in the performance of the neurological examination. The standard neurological examination emphasizes changes that a lesion produces in the contralateral extremities. Too little recognition is given the fact that lesions of each cerebral hemisphere also alter distinctive, fairly easily differentiated functions that are not lateralized to the opposite side of the body. These changes can be demonstrated in a number of ways. Reitan7 and others1 have shown that patients with lesions of the right cerebral hemisphere do relatively poorly on the performance part of the Wechsler-Bellevue Intelligence Scale, and fairly well on the verbal tests. The reverse is found to be true for patients with lesions of the left cerebral hemisphere, who do poorly on verbal testing, but do better with the tests of performance. These differences can be demonstrated for lesions in any part of the cerebral hemisphere, but are most striking if the lesion lies in or adjacent to the parietal lobe.

Differences in the functions of the right and left parietal lobes were emphasized by Critchley in 1953.2 His findings have been confirmed by others. In most human brains, lesions of the left parietal lobe produce dysfunction of language6 while spatial orientation is distorted by lesions that involve the right cerebral hemisphere.2,4,5

With the expectation that tests can be devised to detect more subtle dysfunctions of the brain than are demonstrated during the usual careful neurological examination, a neuropsychology laboratory has been established at Indiana University Medical Center. During the past 9 years about 2,000 individuals, some with lesions of the nervous system, and some normal controls, have taken a battery of tests based on those used by Dr. Ward C. Halstead of the University of Chicago, with some additions and subtractions. The routine psychological testing requires about a day and a half for administration, and a wide variety of functions are scrutinized. Among other things, the results of the tests can lateralize accurately lesions to the right, the left, or both cerebral hemispheres. One of the several methods by which lateralized lesions of the brain can be detected is the subject of this investigation.

METHOD OF TESTING

Language dysfunction and distortion of spatial orientation are tested routinely during the administration of a modification of the Halstead-Wepman Aphasia Screening Test.3 Four of the 36 aphasia subtests administered to the patients are especially pertinent to this study, and will be discussed and demonstrated. Three of the 4 tests are designed to detect difficulty in copying simple geometric figures, and all 4 are used to

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† Address: Indiana University Medical Center, 1100 West Michigan Street, Indianapolis, Indiana.

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detect dysfunction of language. In the first 3 tests, the patient is shown separately line drawings of a square, a Greek cross and a triangle (Drawing 0). He is asked: 1) to copy the outline of these figures without lifting his pencil from the paper; 2) to name each of the figures; and 3) to spell the name of each one. In the fourth test, the examiner says the sentence, “He shouted the warning!”. From this auditory stimulus, the patient is asked to repeat the sentence, explain it, and then write it.

Requiring the patient to perform a task seldom practised, such as drawing a geometric figure or writing a rarely used sentence or thought, is a meaningful test of language and related abilities. If he is directed to write or perform a frequently practised act, such as signing his name, this “overlearned” function often can be reproduced when many other aspects of the function of language are impaired severely.

As wide a variety of patients as possible were tested for this study. The patients were tested once, or more often if changes in status seemed sufficient to indicate repetition. Each patient was subjected to the standard battery of tests, administered in a standard way to eliminate, as much as possible, uncontrolled variables in the testing situation. Without learning the results of the aphasia testing, the clinical record of each patient was scrutinized carefully to determine the accuracy with which lesions of the brain could be detected and localized by all available diagnostic measures. Patients were selected for inclusion in the study only if sufficient information was presented from the neurological examination, roentgen-ray contrast studies, surgery or autopsy to state that a lesion of the brain was demonstrated. They were included if enough evidence was gathered to place the lesion in one cerebral hemisphere or to demonstrate that it involved both. Three groups were formed: 1) patients with lesions of the left hemisphere; 2) patients with lesions of the right hemisphere; and 3) patients with lesions involving both hemispheres. If any questions arose regarding the presence or location of a lesion, the patient was not included in the study. The clinical evidences from which conclusions about the localization of the lesion in each patient were drawn were those that guide a neurological surgeon in the choice of patients for surgical management. Since the decision regarding the need for surgery must be made frequently by the clinician who deals with diseases of the nervous system, we concluded that any test of function of the brain should be required to add information pertinent to this decision. The position of the clinician will be strengthened by development of additional methods that contribute reliable and valid information. Ease and briefness in administration of such tests are advantageous, but it is also important to realize that the information upon which a diagnosis is based should be drawn from as broad a domain of evidence as possible in order to understand more fully the complete significance of the brain lesion for each patient.

Patients with multiple sclerosis were not considered with the group discussed, because signs of unilateral destruction of the brain can so often be misleading in this disease. On the other hand, patients with a variety of pathological entities which may offer misleading localizing information were included, if there was definite evidence of involvement of the right cerebral hemisphere, the left cerebral hemisphere, or both. Lesions caudal to the tentorium or between the cerebral hemispheres were omitted, because the magnitude of secondary involvement of the cerebrum is so variable in these cases. Lesions caused by trauma, neoplasms, and vascular anomalies or occlusions were included, because the position of maximal involvement usually can be localized. Since the full details of cerebral pathology probably cannot be discerned with the usual clinical diagnostic
WRITTEN TEST FOR LATERALIZING BRAIN LESIONS

TABLE 1

Distribution according to difficulties in copying geometric figures or writing in 239 patients with lesions of the brain

<table>
<thead>
<tr>
<th>Type of Difficulty</th>
<th>Lesion</th>
<th>Left Cerebral Hemisphere</th>
<th>Right Cerebral Hemisphere</th>
<th>Both Cerebral Hemispheres</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Per Cent</td>
<td>Per Cent Aphasic</td>
<td>No.</td>
<td>Per Cent</td>
</tr>
<tr>
<td>Difficulty with geometric figures only</td>
<td>8</td>
<td>10</td>
<td>50</td>
<td>44</td>
<td>48</td>
</tr>
<tr>
<td>Difficulty with writing only</td>
<td>35</td>
<td>45</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Both difficulties</td>
<td>13</td>
<td>17</td>
<td>100</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Neither difficulty</td>
<td>22</td>
<td>28</td>
<td>50</td>
<td>39</td>
<td>42</td>
</tr>
<tr>
<td>Totals</td>
<td>78</td>
<td>33</td>
<td>81</td>
<td>92</td>
<td>38</td>
</tr>
</tbody>
</table>

methods, recognition was given to the fact that both cerebral hemispheres are often involved in any of these pathological entities, one primarily and the other secondarily. However, the customary clinical and pathological diagnostic methods probably are adequate for reliable identification of the cerebral hemisphere involved maximally.

RESULTS

Individuals with focal lesions of the right cerebral hemisphere often have difficulty copying the geometric figures mentioned above, particularly the Greek cross, even though they are able to write the dictated sentence with relative ease and few errors. Patients with lesions of the left hemisphere usually copy the figures, including the Greek cross, with relative ease and accuracy, but often have great difficulty writing the dictated sentence. It is possible for these functions to be reversed in the two hemispheres in left-handed individuals. However, the function of language is so rarely subserved by the right cerebral hemisphere, even in left-handed individuals,\(^5\) that the possibility will not be discussed further in this presentation.

Complete aphasia testing was performed on each of the patients included in the study. The incidence of aphasia was greatest in the group with left cerebral lesions, next most frequent in the group with involvement of both cerebral hemispheres, and least frequent in the group with principal involvement of the right cerebral hemisphere.

A total of 239 patients with brain lesions were examined. As shown in Table 1, 33 per cent had lesions involving principally the left cerebral hemisphere, 38 per cent had lesions involving principally the right cerebral hemisphere, and 29 per cent had diffuse or bilateral cerebral lesions.

Table 1 also presents the distribution of these groups with respect to the deficits in writing or in copying geometric figures that may have been demonstrated. Of the left cerebral hemisphere group 17 per cent had difficulties with both of these tasks, but when isolated deficits were present, they far more often involved writing than copying geometric figures (45 per cent to 10 per cent). Several patients in the right cerebral group also demonstrated deficits in performing both tasks (10 per cent), but 48 per cent had isolated difficulty copying the geometric figures while none had exclusive deficits of writing. The group with involvement of both cerebral hemispheres had isolated difficulties with the two types of tasks at a frequency intermediate to that of the groups with lateraled lesions.
Table 1 indicates that 36 per cent of the entire group of patients showed negative findings on these tests. It is somewhat surprising, however, that 64 per cent of the total group showed deficits in the performance of such simple tasks. The results indicate that the procedure is not adequate to effect perfect classification of the subjects into their respective groups even when positive findings occurred. A number of patients with lateralized lesions demonstrated both deficits, and a few patients in the left group had difficulty only with copying the geometric figures. In addition, nearly half of the patients with involvement of both cerebral hemispheres had difficulty with only one or the other of the tasks involved. Nevertheless, the distribution of results indicates definite differences between the groups that promise additional help in the complex clinical problems concerned with diagnosis of cerebral damage.

As an illustration of the usefulness of these tests, brief summaries of 8 patients will be presented with outlines of the estimated extent of the brain lesions. Reproductions of their attempts to copy the square, the cross and the triangle, and to write, "He shouted the warning!" are also presented. Examples have been chosen with striking abnormalities in test performance to demonstrate the extent of disparities that may be found in comparing intact and impaired abilities. Not all patients with cerebral damage produce such strikingly abnormal copies of the geometric figures, or have such difficulty in writing as those illustrated. However, many of the abnormal results of the test that we have observed are similar to the ones presented, some being more and some less bizarre. Six patients with lesions of the right cerebral hemisphere are illustrated. Only 2 patients with lesions on the left are included, since the effects of left cerebral lesions are better known. Three examples of lesions in the right parietal region are presented. Two of these patients have almost identical glioblastomas multiforme, and the third had a subcortical hemorrhage in the same region. As examples of lesions placed more anteriorly, 1 temporal, 1 posterior frontal and 1 frontotemporal are presented to indicate that lesions in any part of the right hemisphere can cause difficulty in copying the geometric figures.

CASE REPORTS

Case 1. L.B., a 59-year-old right-handed sales clerk, had occasional episodes of tingling in the right fingers progressing to the right arm and neck, then the left arm, for 30 years. The episodes were accompanied by blurred vision, difficulty in saying words, and severe headache. He had 4 attacks of severe epigastric pain in the 8 months prior to admission. He also had pain in the right eye and disturbance of vision in the left eye for 1 month.

Neurological examination revealed slight bilateral papilledema, left homonymous hemianopia, left facial weakness, and protrusion of the tongue to the left. There was dysesthesognosis with imperception of bilateral simultaneous tactile stimulation on the left. There were also disregard for space and tactile dysgnosia of the fingers on the left.

Aphasia testing, Mar. 3, 1955 (pre-operatively), showed no disturbance of speech or language symbolism. He had difficulty copying geometric figures (Drawing 1). His Verbal I.Q. was 117, and Performance I.Q. was 63.
Roentgenograms of the skull were normal. Bilateral carotid angiograms showed a "tumor stain" in the right occipital area.

Operation, Mar. 4, 1955, revealed a right occipitoparietotemporal tumor.

Diagnosis. Glioblastoma multiforme of the right posterior cerebral hemisphere (Fig. 1).

Comment. This patient spoke fluently and intelligently. He wrote the test sentence, "He shouted the warning!," without hesitation but with some perseveration of letters. When asked about his copy of the Greek cross, he claimed it looked like the sample and did not think he could improve on it (Drawing 1). His drawing of the triangle showed failure to close the figure on the left side.

His drawing of a daisy demonstrates his disregard for the left side of space. Use of the daisy has been discontinued in our laboratory because the patient with a damaged brain is frequently too occupied in capturing the idea of a daisy to produce a drawing of any kind. More meaningful results are obtained when the patient is asked to copy a geometric figure held in plain view. Even under these optimal circumstances, drawing the cross is difficult for patients with lesion in the right cerebral hemisphere.

Notice the striking difference between the Verbal I.Q. score of 117 and the Performance I.Q. score of 63. This much difference in the two scores is additional evidence for a lesion in the right cerebral hemisphere.1,7

Case 2. M.H., a 41-year-old right-handed housewife, experienced episodes of weakness of the left arm and leg on 2 successive evenings 3 years prior to examination. Treatment for hypertension and "heart trouble" was started at that time. One month before admission she suddenly became comatose, and remained so for 30 hours. She had headaches and occasional vomiting following that. These symptoms were gradually subsiding.

Roentgenograms of the skull and bilateral carotid angiograms were interpreted as normal.

Operation, Feb. 17, 1955. Ventriculography outlined a large cystic space in the right parieto-occipital region. An old hematoma was evacuated.

Aphasia testing, Mar. 4, 1955 (postoperatively), showed no disturbance of language symbolism, but there was marked difficulty in copying geometric figures (Drawing 2).

Diagnosis. Subcortical hematoma, right parieto-occipital, secondary to hypertension (Fig. 2).

Comment. The patient had trouble "closing" the geometric figures on the left side. This was particularly true of her copy of the Greek cross. In spite of these difficulties with copying geometric figures, she wrote "He shouted the warning!" without hesitation or error (Drawing 2). Her cerebral lesion, which

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**Fig. 1. Case 1.** A large mass (glioblastoma multiforme) in the occipitoparietal region of the right cerebral hemisphere altered the patient's ability to copy simple geometric figures, but not his ability to write the prescribed sentence (see Drawing 1).

**Drawing 2. Case 2.** This patient with a right parietal intracerebral hemorrhage could not effect closure of any of the simple geometric figures she copied. The marked distortion of the Greek cross is characteristic of patients with lesions of the right parietal lobe (see Fig. 2).

**Neurological examination** revealed bilateral papilledema. There was an homonymous hemianopia on the left, with weakness of the left lateral rectus muscle, and disregard for the left side of space. The left hand and leg were weak and tendon reflexes were slightly hyperactive on the left.

Roentgenograms of the skull were normal. Bilateral carotid angiograms showed a "tumor stain" in the right occipital area.

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**Fig. 2. Case 2.** A cystic mass in the right cerebral hemisphere altered the patient's ability to copy simple geometric figures, but not to write the prescribed sentence (see Drawing 2).
was static and regressing at the time of testing produced spatial disorientation that was as severe as that produced by a large, rapidly growing tumor like the one demonstrated in Case 1.

Case 3. P.H., a 67-year-old right-handed salesman, had severe frontal headaches with dizziness, fatigability and blurred vision for 3 months. Weakness and numbness of the left extremities were present for 1 week.

Neurological examination revealed a sluggish, confused, apathetic man with left homonymous hemianopia. He had hemihypalgesia, sensory inattention, astereognosis, and finger agnosia on the left. Acalculia was present. There was spastic left hemiparesis, more marked in the arm than in the leg. Hyperreflexia and Babinski's response were present on the left.

Cerebrospinal fluid was under normal pressure, but showed 100 white blood cells, all lymphocytes. The protein was 120 mg. per cent.

Electroencephalogram showed a delta focus (Grade III) in the region of the Sylvian fissure on the right.

Roentgenograms of the skull were normal. Bilateral carotid angiograms showed a mass in the mid-temporal lobe on the right.

Operation, July 16, 1958. A tumor was partially removed.

Diagnosis. Glioblastoma multiforme, right mid- and posterior temporal lobe (Fig. 4).

Case 4. C.C., a 46-year-old right-handed housewife, had increasingly severe headaches for 8 weeks, nausea and vomiting for 6 weeks and decreased hearing on the left for 2 weeks.

Neurological examination revealed a lethargic, depressed woman with facial weakness and decreased hearing on the left. There was imperception of bilateral tactile and visual stimulation on the left and dysgnosia of the left fingers. She had slight left hemiparesis.

Aphasia testing, July 14 and 15, 1958 (preoperatively), showed a central dysarthria, but no other disturbance of language function. She had difficulty copying the geometric figures and writing the dictated sentence (Drawing 4).

Roentgenograms of the skull were normal. Bilateral carotid angiograms showed a mass in the mid-temporal lobe on the right.

Operation, July 16, 1958. A tumor was partially removed.

Diagnosis. Glioblastoma multiforme, right mid- and posterior temporal lobe (Fig. 4).

Fig. 3. Case 3. A glioblastoma multiforme in the right occipitoparietal area, plus amputation of this patient's right occipital lobe altered his ability to copy simple geometric figures, but not to write the prescribed sentence (see Drawing 3).
Comment. This patient had less trouble than the preceding patients in drawing the square and triangle, although the superior border of the square suggests perseveration. Her cross was markedly distorted on the left side. Her writing was not as good as in the preceding cases, since she missed parts of the word "warning." It was surprisingly good, however, considering that she had excruciating headache and was nauseated when she sat while being tested. Her attempts to print the word "square" were suggestive of a lesion of the left hemisphere, but the considerable predominance of difficulty in copying geometric figures as compared to her difficulties in writing suggested structural cerebral damage in the right hemisphere.

This patient illustrates that difficulties in copying the geometric figures and abnormalities in writing are not always easy to interpret. Sometimes additional information is required to permit the lateralization of a cerebral lesion, just as is true for any single test in the neurological examination. Lesions causing approximately equal involvement of both cerebral hemispheres frequently produce abnormalities both of the patient's ability to copy geometric figures and to write. If both hemispheres are involved in the lesion, but the right has sustained more extensive damage than the left, ability to copy geometric figures customarily is impaired more severely than ability to write. The reverse is true if the left hemisphere has sustained more serious damage than the right.

Case 5. P.M., a 42-year-old right-handed farmer, had frontal headache, lethargy, nausea and vomiting for 4 weeks. His speech and actions became increasingly slow for 2 weeks.

Neurological examination revealed astereognosis on the left. There were weakness and slowness of the left extremities, with hyperreflexia, ankle clonus and Babinski's response on the left.

Roentgenograms of the skull were normal. Ventriculogram showed a shift to the left and posteriorly.

Operation, Feb. 28, 1952, disclosed a tumor confined grossly to the frontal pole of the right cerebral hemisphere. The right frontal and anterior temporal areas were amputated (Fig. 5).

Aphasia testing, April 9, 1952 (postopera-
Case 5. A glioblastoma multiforme in the right frontal pole, plus ablation of the right frontal and anterior temporal areas, altered the patient’s ability to copy a simple geometric figure, but did not alter his ability to write (see Drawing 5).

Diagnosis. Glioblastoma multiforme, grossly involving only the right frontal pole, microscopically involving the entire frontal lobe but not the temporal lobe.

Comment. It is surprising that this patient functioned as well as he did, in view of the large area of ablation and widespread extension of tumor in the remainder of the brain. Although his drawing of a cross was distorted to the left, it was not as abnormal as the crosses produced by patients with tumors of the right cerebral hemisphere placed more posteriorly. His writing was fluent and without error in spite of the fact that he had not written for 3 months before these tests, and had one quarter of his brain removed surgically.

Case 6. C.B., a 45-year-old right-handed housewife, had a single generalized convulsion 2 years prior to admission. Her memory had been impaired for an unknown period. She had complained of headache and blurred vision for 6 weeks, and had become progressively more lethargic and confused for 2 weeks.

Neurological examination revealed a disoriented woman with blurred margins of the optic discs. She had a homonymous defect in the left lower quadrant of her visual fields. There was tactile and visual imperception, and Hoffmann’s and Babinski’s signs were present on the left.

Electroencephalography showed a Grade II delta focus, maximal in the right Sylvian region. Roentgenograms of the skull were normal. Ventriculography showed depression of the frontal horn of the right lateral ventricle, and a shift of the entire ventricular system to the left.

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Aphasia testing, July 9, 1956 (pre-operatively), demonstrated no disturbance of speech or language function. She had difficulty copying the geometric figures (Drawing 6).

Operation, July 11, 1956. The right frontal lobe containing a large mass of tumor was removed.

Diagnosis. Oligodendroglioma, right frontal (Fig. 6).

Comment. Relatively little distortion of the drawings of the geometric figures occurred in this instance. Nevertheless, evidence of real difficulty is present in the patient’s failure to effect proper closure of the triangle and in the almost exact duplication on the second attempt of the error that occurred in her first drawing of the cross. Her writing was done quickly and with ease compared to the deliberate and painstaking efforts that she applied in copying the figures. The difference in her ability to perform these two tasks was obvious to the examiner as he observed her labor to produce the drawings. In spite of the fact that the end result of the drawings was relatively good, lateralization of the lesion to
the right hemisphere was clearly implied through observation of the patient during the testing. Although the lesion was large, the comparatively good drawings may be a reflection of the anterior placement of the tumor and its slow growth.

Case 7. V.S., a 56-year-old right-handed accountant, was found to be making mistakes in bookkeeping 2 months before admission. She had noticed difficulty in writing and speaking for 1 month, and progressive confusion for 2 weeks.

Neurological examination revealed a noticeable dysphasia. She had hemihypesthesia on the right. There was imperception of bilateral simultaneous auditory and visual stimulation on the right. Dysstereognosis was present in the right hand.

Roentgenograms of the skull were normal. Bilateral carotid angiograms outlined a very distinct tumor stain in the parietal region of the left cerebral hemisphere.

 Aphasia testing, June 10, 1957 (pre-operatively), showed widespread aphasic symptoms. These included dysnomia, dyslexia, visual-letter dysgnosia, auditory-verbal dysgnosia, spelling dyspraxia and agraphia (Drawing 7). She also had right-left disorientation, but no acalculia or finger agnosia. There was no difficulty or hesitation in drawing the geometric figures. Verbal I.Q. was 89, Performance I.Q. was 114.

Operation, June 17, 1957. A tumor was partially removed from the left parietal area.

Diagnosis. Glioblastoma multiforme, left parietal (Fig. 7).

Comment. Drawings of the geometric figures, although not perfect, are symmetrical and closed like those produced by most normal individuals. In contrast, the writing and ideation of language are very abnormal (Drawing 7), unquestionably placing the lesion in the left hemisphere. The severity of the language dysfunction and the pronounced receptive component of aphasia indicate that the temporoparietal area is involved by the lesion. Notice the disparity of the I.Q. scores, with the Verbal I.Q. 25 points below the Performance I.Q. This finding contrasts with those of the patients with large lesions of the right cerebral hemisphere, whose Performance I.Q. scores were decreased markedly, while the Verbal I.Q. scores were maintained at relatively normal levels.

Case 8. E.W., a 45-year-old left-handed house painter, had many episodes of twitching of the right side of his face and his right hand lasting 5 to 10 minutes during the year before admission. Accompanying these episodes were tingling in the right side of his body and ringing in his right ear. For 3 months he had dizziness, blurring vision and difficulty saying the words he was thinking. He experienced pain in the left temporoparietal region for 3 months.

Neurological examination revealed no apparent difficulty with speech. There was diminished hearing on the right, and hemihypalgiesia on the right.

Electroencephalography showed a Grade I delta focus in the Sylvian region of the left cerebral hemisphere.

Roentgenograms, including films of the skull, bilateral carotid angiography and pneumoencephalo- graphy, were thought to be normal. The patient was discharged without a diagnosis.

He was re-admitted in 2 months, because of increasing generalized weakness and headache, and increasing difficulty with vision, more marked on the right than on the left.

Neurological examination this time revealed an obtunded man with dysphasia and bilateral
Fig. 8. Case A. A glioblastoma multiforme of the left parietal area altered the patient's ability to write, but not his ability to copy simple geometric figures (see Drawing 8).

papilledema. He had astereognosis, and imperception of bilateral simultaneous tactile, visual and auditory stimulation on the right. He had a mild hemiparesis with increased reflexes on the right.

Review of the roentgenograms made during the previous admission showed a definite tumor stain, missed previously, in the temporoparietal region of the left cerebral hemisphere.

Aphasia testing, Aug. 23, 1958 (pre-operatively during his second admission), showed extensive expressive and receptive dysphasia including dysnomia, central dysarthria, visual-number and -letter agnosia, dyslexia, auditory-verbal dysgnosia, dysgraphia, dyseaculgia, right-left disorientation and tactile finger dysgnosia. He had no difficulty copying the geometric figures (Drawing 8). Verbal I.Q. was 67, Performance I.Q. was 112.

Operation, Aug. 25, 1958. A temporoparietal tumor was partially removed.

Diagnosis. Glioblastoma multiforme of left temporoparietal region (Fig. 8).

Comment. The geometric figures produced by this man are symmetrical, closed and can be considered normal. The writing of simple words seems to be normal, but when confronted with an idea used infrequently, perseveration and difficulties in writing appear. This finding and the other aphasic symptoms indicate the presence of a lesion in the left hemisphere. Although this lesion was found to have been present in the carotid angiogram made during his first admission, no definite dysfunction of language was present at that time. During the 2 months between admissions, the patient’s functions of language deteriorated strikingly, but his ability to copy geometric figures showed no change. In addition, his Verbal I.Q. dropped from 114 to 67, whereas his Performance I.Q. dropped only to 112 from 122. The difference between this patient’s ability to copy geometric figures and to produce written words provides striking evidence of dysfunction of the left cerebral hemisphere (Drawing 8). The fact that the patient showed no such evidence upon his first admission, however, indicates that the test may not always demonstrate an abnormality early in the course of development of a rapidly growing brain tumor, just as the neurological examination often reveals no abnormality under similar circumstances.

DISCUSSION

To substantiate the localizing value of a test for neurologic function, several criteria must be met. First, all the patients with a lesion in the designated area of the brain must have the dysfunction ascribed to it. Second, all the patients who demonstrate the dysfunction must have a lesion in the same area of the brain. Third, patients with lesions of the brain that do not involve the designated cerebral area must not demonstrate the specific dysfunction.

In order to be sure that the same function is being elicited each time a certain test is administered, it must be given in a completely standardized and routine fashion. If variations are introduced in the routine of testing, there is no certainty that the same function is being tested or the same dysfunction is being demonstrated. Much of the dispute regarding certain localizing signs and symptoms arises from differences in methods of testing. Only dysfunctions demonstrated
by identical methods of testing can be compared and used for purposes of cross-validation. This is true particularly in testing for the complex dysfunctions of language.

The choice of patients and lesions for inclusion in a group designed to demonstrate a given neurological dysfunction must be made carefully. Human pathological material is far from ideal for this purpose. The clinician finds himself delineating an area of maximal involvement of the nervous system in many human pathological conditions, with the recognition that other areas must be affected also, either primarily or secondarily. It would, of course, be desirable to study neurological dysfunctions in a group of patients with completely delineated and focal lesions, without secondary involvement of other areas of the nervous system. Since this is not possible, one must derive the maximal information from the material at hand.

Our results indicate that the procedures used in this investigation do not meet entirely ideal criteria for localizing lesions of the brain. However, the distinct differences that appeared in the test performances by patients with lesions of the right cerebral hemisphere, when compared with those with lesions of the left cerebral hemisphere, indicate that the results of the test can separate many of the patients tested into correctly lateralized groups. This separation is reliable enough to recommend that the procedure be used for additional study. Larger groups can determine more fully the value of these tests in supplementing data obtained from the routine clinical neurological examination.

SUMMARY
Two hundred thirty-nine patients were chosen for study because they had lesions that could be placed in the right, the left, or both cerebral hemispheres. These patients were subjected to a comprehensive series of tests of cerebral function in the neuropsychology laboratory at Indiana University Medical Center. Tests of writing and copying of simple geometric figures were selected for study in this investigation. Patients with lesions of the right cerebral hemisphere frequently had difficulty in copying geometric figures, but none in writing. Difficulty with writing and ease in copying geometric figures occurred frequently in the group with left cerebral lesions. The results suggest that these simple tests may provide valuable supplementary information to the data obtained in the clinical neurological examination. Test performances of 8 individual patients are presented to illustrate the types of results obtained and their interpretation.

REFERENCES

DISCUSSION
Dr. Lamar Roberts: I should like to congratulate Dr. Heimburger for the presentation of a simple test which can be used clinically with reasonable expectation that it will distinguish lesions of the right hemisphere from those of the left. I have followed his and Reitan's work for a number of years, and this is another evidence of their fruitful endeavors.

I should like to present briefly what we know now about tests that are helpful in determining whether the nondominant hemisphere is involved in pathological processes. About a quarter of a century ago Weisenburg and McBride showed that their 32 patients with right hemispherical lesion were significantly inferior to those with left hemispherical involvement in arithmetic and nonverbal tests, particularly the Porteus maze test. In 1939, Hebb presented a case of right temporal lobectomy for an atrophic lesion producing seizures. The patient had a full scale I.Q. of 113, but a marked deficit in perception of form—both visual and tactual.

Hecaen, Critchley, and many others, have shown...
disturbance of the coordinants of visual space, poor performance on visual constructive tasks such as map drawing and block design and difficulties in dressing with lesions involving the right parietal lobe principally.

Milner showed definite inferiority of patients with right temporal removals of atrophic lesions on the McGill picture anomaly and the Wechsler picture-arrangement tests, as well as on visual and tactual spatial patterning.

Teuber and Weinstein demonstrated that the ability to discover hidden figures in the Gottschaldt test was less in the aphasic patient than in other brain-injured and less in all brain-injured patients than in the normal control. Also from Teuber's laboratory Ghent et al. have shown significant improvement in learning of a tactual discrimination in the ipsilateral hand but none in the contralateral one, regardless of the lobe involved in the pathological process. Teuber and Diamond have shown a greater difficulty in localization of sound with right posterior hemispherical lesions both as regards the time of arrival and intensity of the sound.

Mullan and Penfield have reported that visual illusions of dimension, intensity, and speed, as well as visual vestibular illusions occur during seizures or electrical stimulation involving the nondominant hemisphere usually. Also a sense of familiarity usually indicates lesion of the nondominant hemisphere.

In reviewing some of my own charts of patients operated on by Dr. Penfield for excision of atrophic lesions, I found the following: 5 of 19 patients with removals involving the right hemisphere had difficulty copying a simple figure made with matches. Only 1 of 16 with involvement of the left hemisphere had similar difficulty. None of these individuals had any difficulty when requested to make a triangle or a square with matches. One-fourth of these patients did not know what a rectangle was but these were divided equally among those with lesions of each hemisphere. Excluding these, 5 of 14 and 1 of 12 involving the right and left hemispheres, respectively, had difficulty in constructing a rectangle with matches.

Thirteen of the 19, and 5 of the 16 patients with involvement of the right and left hemispheres, respectively, had definite difficulty in arithmetic. All of the patients with right hemispherical involvement scored poorly on a Draw A Man test, as did 7 of the 16 with left hemispherical involvement. In addition, 2 of the 19 with right hemispherical involvement and none of those with lesions of the left missed the point in a simple picture of a man and woman sitting out in the rain.

I believe that my findings are in line with those reported in the literature. The deficits are not as marked as in some cases, which is true so frequently in comparing the effects of atrophic lesions with those of neoplasms or vascular disease.

In using a test such as Dr. Heimbarger has presented I should like to point out that one should be particularly cautious in cases of left-handed individuals, as they may show aphasic difficulties as well as difficulties in copying a Greek cross more frequently than the right-handed.

REFERENCES


