A human cerebral deconnection syndrome

A preliminary report

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WE PROPOSE in this paper to present a patient whose clinical picture appears to us to be most simply explainable by a partial deconnection of the two cerebral hemispheres. He appears to behave as if there were 2 nearly isolated half-brains, functioning almost independently.

In the early years of this century several cases were described which showed some of the phenomena that are present in our patient. Sittig[1] reviews these cases in his monograph on apraxia. The earlier workers generally described these cases as showing apraxia and apractic agraphia of the left side and left-sided astereognosis and attributed these findings to lesions of the corpus callosum.

In the 1940's considerable doubt was cast on the role of the corpus callosum by the extensive studies of Akelaitis[2] and his co-workers on humans whose corpora callosa had been sectioned surgically (to prevent the interhemispheric spread of seizures) and who subsequently presented virtually no abnormalities. Earlier physiological work in animals also failed to show convincing disturbances. Bremer, Brihaye, and André-Balisaux[3] have reviewed this literature. By contrast, in the last five years, the work of Sperry[4] and his co-workers has convincingly proved that in animals, section of the callosum produces behavior which is most simply explained as resulting from deconnection of the 2 hemispheres. It was Sperry's work which alerted us to the possibility of deconnection syndromes in man.

Our patient shows behavior similar to that described by the earlier workers. In addition we have observed several manifestations not previously mentioned. Detailed anatomical confirmation of the localization of the lesion is not yet available. The patient continues to be studied actively at this time. However, in view of the unusual character of these findings, we are presenting this brief clinical description as a preliminary report in the hope of stimulating other workers to look for similar cases and to investigate their anatomical substratum. A more detailed report of this patient will be published at a later date.

CASE REPORT

P.J.K., (BVAH U-53490), a 41-year-old white, married police officer, was admitted to the Boston V.A. Hospital, Neurology Section, on March 2, 1961. One month before admission the patient had begun to develop dull headaches, primarily over the left orbit, lasting several hours, recurring 3 to 4 times a week, and frequently associated with nausea and vomiting. The members of the family had over the previous few months noticed increasing behavioral changes manifested by indifference; apathy; forgetfulness; diminished alertness; confusion for dates, events, and people; diminution in personal neatness; and increased friction in interpersonal relations, particularly at work.

The patient had no significant history of birth or childhood illness. He had been graduated from high school at 18, had served in the Navy from 1941 to 1945, and since 1949 had been a policeman. Past history and family history were otherwise not relevant.

General physical examination revealed a well-developed, well-nourished man. The temperature was 98.6° F., blood pressure was 110/90, and pulse, 80. There were no significant abnormalities in the remainder of the general examination.

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Neurological examination revealed a patient who was alert, cooperative, and oriented in all spheres. He exhibited inappropriate jocularity against a background of general apathy. He had no insight into his illness and appeared unconcerned about it. He kept repeating questions as if he did not quite understand them. He could remember only 1 of 3 items after five minutes. He repeated 6 digits forward and 4 backward. He made many errors in subtracting sevens serially from 100. His proverb interpretations were very poor, being little more than restatements without interpretation. He did simple written arithmetic correctly but failed on more complex material such as multiplying 214 by 35. When asked to draw a clock face at a certain hour, he frequently reversed the large and small hands.

The patient was right-handed. Except for a few paraphasias and some hesitancy in naming objects, speech was normal. He drew a rough map of the United States on which his localization of many cities and states was correct except for New Mexico which was included twice in different parts of the Southwest. There was no right-left disturbance.

On examination of the cranial nerves, the optic disks were indistinct but without papilledema. Visual fields to confrontation showed a questionable binasal lower quadrant defect, but this was not confirmed by perimetry. The right pupil was slightly larger than the left, but both showed normal responses to light and convergence. Optokinetic reflexes were present bilaterally. There was questionable flattening of the left nasolabial fold. Cranial nerves were otherwise intact.

Motor examination showed normal bulk, tone, strength, and coordination throughout. Deep tendon reflexes were 1-2+ throughout but equal on both sides. Abdominals were 2+ bilaterally. Plantars were flexor, and grasping, sucking, and snout reflexes were said to be absent. Sensory examination showed no abnormality of touch, pin-prick, position sense, vibration, two-point discrimination or stereognosis. Stance and gait were both normal.

Laboratory examination showed a hematocrit of 45 per cent and a hemoglobin of 14.3 grams. White blood count was 6,200 with a normal differential. Corrected sedimentation rate was 15 mm. per hour; fasting blood sugar, 94 mg.; blood urea nitrogen, 23 mg.; prothrombin time, 100 per cent; bleeding time, 1 minute; and coagulation time, 18 minutes. Spinal fluid showed an opening pressure of 160 mm. and a closing pressure of 80 mm. The fluid was clear and colorless with no cells. Protein was 60 mg.; sugar, 110; chloride, 118 mEq.; colloidal gold, 011232100; and zinc sulfate test, 4+. Serology was negative in spinal fluid and blood.

The electrocardiogram was normal. Visual fields by perimetry were normal. X-rays of the chest and skull were felt to show no definite abnormality. A pneumoencephalogram with 20 cc. of air was consistent with a left frontal space-occupying mass. A left carotid arteriogram was consistent with a left frontal mass, probably a glioma.

Psychological testing on March 8, 1961, revealed a Wechsler Adult Intelligence Scale full scale I.Q. of 81 with a verbal I.Q. of 79 and a performance I.Q. of 87. On the Wechsler Memory Scale, he achieved a score of 87. Memory for visual forms showed impairment but copying was normal. The results of psychological testing were regarded as clearly consistent with intellectual deterioration.

On March 16, 1961, the patient underwent a left frontal craniotomy. On inspection, all of the visible left frontal lobe was markedly softened. A cyst deep in this lobe was aspirated through the middle frontal gyrus. A frontal amputation was performed revealing tumor in the depths. Because of edema, the anterior border of the corpus callosum was not identified. A large branch of the anterior cerebral artery on the medial surface of the frontal lobe was amputated. This was thought to be most likely the frontal polar artery. The ventricular system was not entered. The patient received 3 liters of blood and tolerated the procedure well.

The pathologist described the specimen as left frontal lobe, weighing 107 gm., and identified the tumor microscopically as a glioblastoma multiforme.

Postoperatively the patient showed a dense right hemiplegia and a marked aphasia. He improved steadily and was returned to the Neurology Service. On the 49th postoperative day, neurological examination revealed a patient disoriented in time, but correctly oriented to place and person. He was apathetic but smiled most of the time. He confabulated in response to questions about the reasons for his admission to the hospital. There was impairment of recent memory, calculation, and abstraction. His speech showed at most a few mild paraphasic errors. He followed complex commands poorly. There was a dense weakness of the right leg and moderate weakness of the hand and arm with equal involvement of flexors and extensors. The finger-nose test was well done.

There was a mild tremor in the outstretched fingers of the right hand as well as a marked grasp reflex. The tendency to grasp was most marked when the zone between thumb and forefinger was stroked. Traction on the arm further intensified the grasp. When the examiner's hand was brought near the palmar surface of the patient's right hand without actual contact, the patient's hand followed the examiner's.

In the left limbs, tone, power, and coordination were completely normal and there was no trace of grasping in either the left hand or foot. Deep tendon reflexes were symmetrically hyperactive and both plantars were flexor.

Sensory examination on the right showed a mild loss of position sense in the fingers and a denser loss in the foot. Vibration and stereognosis were intact and localization of touch was grossly accurate. Two-point discrimination was mildly impaired and pin-prick appeared to be mildly dimin-

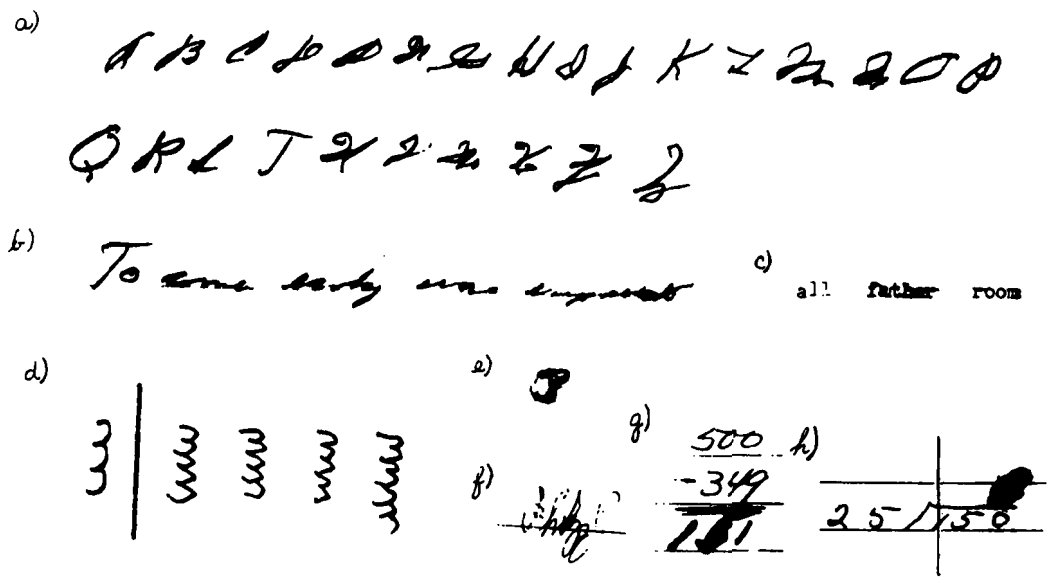

Fig. 1. Samples of performances with the right hand, demonstrating the effect of the grasp reflex: (a) the alphabet; (b) the sentence, "To come early was impossible" written to dictation; (c) the words, "all," "father," and "room" typed with the right index finger; (d) to the left of the vertical line examiner's model three-looped figure, to the right of the line patient's successive attempts to copy the model; (e) the number "3" written to dictation; (f) the patient's preoperative writing of his first name; (g) and (h) the heavily written numbers are the patient's solutions to the problems written by the examiner (preoperative).

ished. On the left side sensory examination was at first very confusing because the patient gave extremely variable reports. However, when for reasons which will become apparent later, technics for testing sensation on the left side were developed in which the patient was required to respond nonverbally (for example, pointing up and down in position sense testing, tapping once or twice for two-point discrimination), it could be shown that position sense, vibration, two-point discrimination, pin-prick, and touch localization were all normal in the left arm and leg. Discussion of stereognosis in the left hand will be deferred to the section on Results of Special Studies.

On May 22, 1961, it was discovered by one of us (E.K.) that he could not write with his left hand. At this time a program of special investigations was instituted, the results of which are given later.

Psychological testing on May 28 and September 13 showed no essential differences from preoperative testing.

The patient remained in the hospital until September 4, 1961, by which time he had improved considerably. He was oriented in all spheres but still had little insight into his illness and showed unchanged intellectual impairment. The right hemiplegia had improved markedly. In the right arm there was only mild weakness of abduction of the right shoulder; in the right leg there was only mild weakness in flexion and extension at the knee and inability fully to dorsiflex the ankle. The patient could now walk unaided. The grasping responses were markedly diminished in all respects except that with the diminution of the paralysis of the right leg, a mild grasp reflex had now become apparent in the right foot. Improvement observed during follow-up after discharge from the hospital will be discussed below.

RESULTS OF SPECIAL STUDIES

When it was discovered that the patient was unable to write correctly with his left hand, a program of carefully planned testing was set up. The results of these examinations are now given.

At the time of testing the patient showed no evidence of aphasia in his spontaneous speech although there was a mildly halting quality to his language productions. The patient showed no evidence of word-finding difficulty. There was at most a mild difficulty in comprehension of complex spoken or written material which was felt to be consistent with his intellectual impairment. He correctly repeated numbers, letters, words, and sentences presented verbally.

Writing with the right hand. When asked

to write with this hand the patient produced normal sentences and made no errors in spelling. There were certain characteristic disturbances in the motor performance (Fig. 1). His writing tended to get smaller with letters closer together; eventually one letter would be written over the preceding one (Fig. 1b). In writing single letters or numbers he tended to keep going over the outline (Fig. 1e). He would add extra loops when writing 3's or m's or three-looped figures (Fig. 1d). Review of his preoperative writing revealed that similar defects had been present although they had passed unnoticed (Fig. 1f, g, h). Bouman and Grünbaum[5] in their study of patients with grasp reflexes described similar graphic disturbances.

Similarly, letters, numbers, words, and sentences were correctly written to dictation. He copied all forms of written material correctly. When presented with printed material, he would copy it in script, which is the typical response of normal people to this task.

In typing with the right hand (using one finger), he produced his name and words to dictation with no errors (Fig. 1c).

Writing with the left hand. By contrast, when asked to write with this hand he made many errors. In writing the alphabet, he produced many incorrect or completely unrecognizable letters (Fig. 2a). On dictation he would generally write a clearly recognizable letter or number but usually not the one demanded. When asked to write words and sentences to dictation, he would usually produce an unrecognizable scrawl (Fig. 2b). On occasion, however, the response consisted of well-written but clearly incorrect words such as yonti for yesterday (see also Fig. 2e, f). He copied printed and written material correctly but would reproduce printed material with block letters and not script. There was no trace of the motor difficulties seen in the productions of the right hand (Fig. 2c).

In typing with his left hand, he could not produce his own name correctly nor could he type words correctly to dictation (Fig. 2d).

When he had seen the incorrect productions of his left hand, he was quite astonished. However, spontaneous attempts to correct generally resulted in repeated difficulty (Fig 2d).

Object and letter identification with the right hand. With his eyes closed, the patient correctly and rapidly named objects and cardboard letters placed in his right hand. Similarly, he could, after the object was taken away, correctly draw the object which had been in his hand. If letters or numbers were traced on his right hand, he generally named them correctly.

Object and letter identification with the left hand. By contrast, when objects, numbers, or letters were placed in the left hand, the patient (with eyes closed) generally named them incorrectly. The errors usually bore no resemblance to the stimulus object. For example, a ring was identified as "an eraser," a watch as "a balloon," a padlock as "a book of matches," and a nail as "an elastic." The errors were not constant. Thus, on another occasion he called a ring "a package of some sort;" a screw driver on one test was "a spoon" and on another "a piece of paper."

It was striking to observe that when handling the objects he would move them actively about within his fingers and would focus on their salient features. For example, he inserted his finger into a thimble, ran his thumb over the teeth of a comb, rubbed the bristles of a tooth brush, and retracted the point of a ballpoint pen. Despite his appropriate handling of the dominant features of these objects, he misnamed them all.

When it was made clear to him that he was to show how the object placed in his hand was to be used, the subject (with eyes closed) proceeded with little hesitation to manipulate the item correctly, usually giving simultaneously an incorrect verbal account. Thus, given a hammer, he made hammering movements correctly while saying "I would use this to comb my hair with it." Given a key, he went through the motions of inserting it into a lock and turning it but said that he was "erasing a blackboard with a chalk eraser." Holding a pair of scissors correctly, he made cutting movements in the air but said that "I'd use that to light a cigarette with." When his eyes were open he correctly identified the objects in his left hand.

Still another method was employed to study identification with the left hand. The patient,

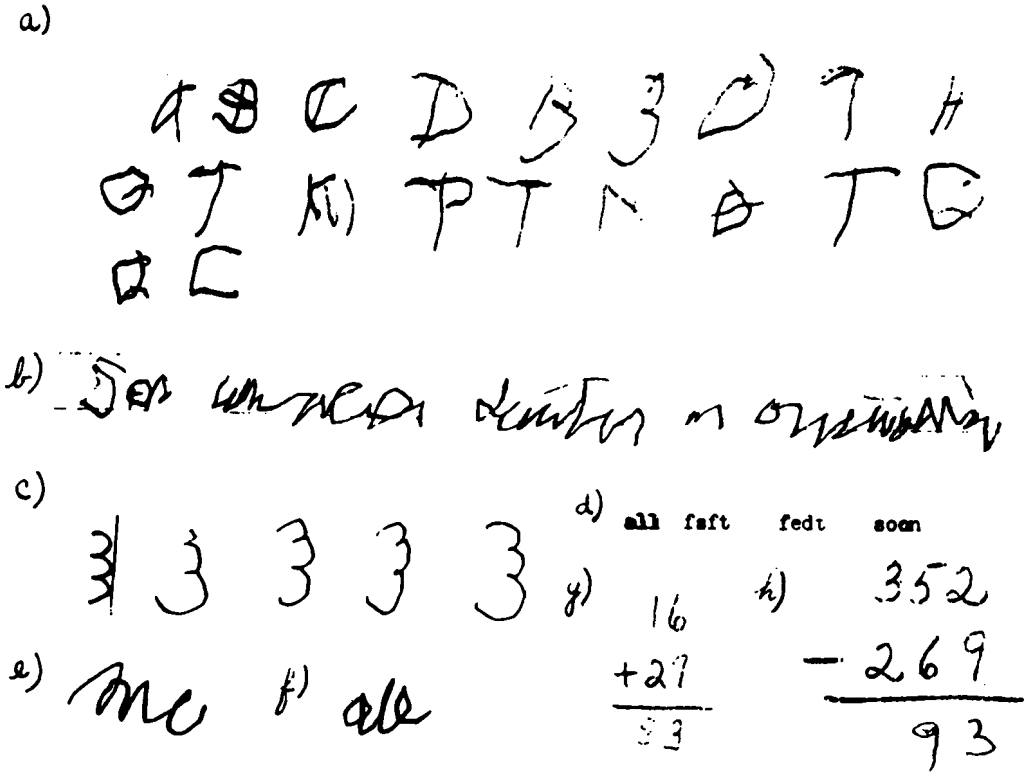

Fig. 2. Samples of performances with the left hand, demonstrating errors in language and calculation along with the absence of disturbances due to grasp reflex: (a) the alphabet; (b) the sentence, "To come early was impossible" written to dictation; (c) to the left of the vertical line examiner's model three-looped figure, to the right of the line patient's successive copies of the model; (d) attempts with left index finger to type the words, "all," "father," "father" (the second being a spontaneous attempt to correct the first error), and "room;" (e) attempt to write "run" to dictation; (f) attempt to write "go" to dictation; (g) and (h) the patient's solutions to the problems set by the examiner.

with eyes closed, was given an object in this hand. The object having been taken away, the left hand of the patient (whose eyes still were closed) was placed in a box containing a number of items including the test object. He selected the correct object. Similarly, with eyes open, he would without hesitation point to the object in a group without touching it. He was also able to make a correct drawing with his left hand of an object that had been previously placed in this hand and then removed.

Objects placed in one hand with identification by the other hand. If an object or letter was placed in the left hand behind the patient's back, he generally was unable with the right hand (1) to select it correctly from a group of objects presented to him either visually or tactually, (2) to write the name of the object, or (3) to draw a picture of the object. For example, a letter which would have been drawn correctly with the right hand after having been held in the right hand was drawn incorrectly with the right hand if the letter was placed in the left hand. Similarly, if objects were placed in the right hand, the patient was usually incapable of performing any of these maneuvers with his left hand.

These results contrast with data given earlier in which we demonstrated that if an object was placed in one hand, it could afterward be identified by drawing or selection by the same hand. In addition, we may note here that if letters were traced on the left hand, the patient could afterward trace them correctly on the ground with his left foot. If letters

were traced on the right hand, he could not reproduce them correctly with the left foot. The right foot could not be tested in this way because of paralysis.

Ability to perform commands. When the patient was asked to perform actions with his right hand, he did so correctly and without hesitation. For example, he could draw a square, wave goodbye, salute, and pretend to brush his teeth or comb his hair.

When asked to perform actions with his left hand, he made many errors, and even the correct responses were performed with a considerable delay. Thus, when asked to draw a square, he drew a circle. When asked to draw a triangle (which he had done earlier with his right hand without hesitation), he paused, asked if the examiner meant the figure with 3 corners, and finally drew the figure. When asked to point to the examiner with his left index finger, he pointed to his own eye with his left index and middle fingers. Immediately afterward he performed this action correctly with his right hand. Requested again to perform with his left hand, he pointed to the floor with his index finger. When asked to show how he would brush his teeth with his left hand, he on one occasion made the motions of lathering his face and on another went through the motions of combing his hair.

When asked to imitate the examiner's movements or to manipulate objects, the patient performed correctly with *either* hand.

Transfer of learning. We attempted to perform a version of Sperry's[4] experiment on transfer of learning. We intended to have the patient learn (when blindfolded) a simple maze with the index finger of one hand, and then test the index finger of the other hand. In our normal controls such learning always transferred in 1 or 2 trials. However, this experiment could not be carried through successfully. The patient learned the maze with his left hand but was totally incapable of running the maze with the right hand. This failure to perform with the right hand appeared to be due to the grasping responses. The patient would either hold his finger fixed at one point or, in an effort to free it, suddenly jerk his finger erratically out of the maze.

Bilateral movements. The patient could make circles in the air with both hands, tap with both hands, or perform alternating movements with both arms. It was observed, however, that in these symmetrically performed activities the two hands would on most occasions move at first at the same speed but after a time become desynchronized; on other occasions they moved at different speeds right from the onset.

Previously learned movements requiring the cooperation of both hands such as threading a needle, catching a ball, tying shoelaces, and dressing himself were performed without difficulty.

Parietal lobe testing. On the right side we have already noted evidence of mild position sense and two-point discrimination loss. On the left side both of these functions were normal. Pin-prick was identified correctly on both sides, but there was more withdrawal on the left. Touch and vibration were normal on both sides. Stereognosis, when appropriately tested for, was fully normal on both sides. Localization of touch was normal on both sides. Bilateral simultaneous stimulation gave highly variable results, but there was no consistent evidence of extinction on either side.

Using his right hand, he could correctly point out fingers on both hands and other body parts on both sides. With his left hand he made many errors on this test but no more than in performing any other movements to verbal command with this hand. He could correctly name parts of the examiner's body. With his right hand he made only 1 error out of 8 in a screening test of right-left orientation (indicating body-parts on the examiner and on himself). With his left hand, on the same test, he made 6 errors but again his difficulty was no more profound than in performing other verbal commands with this hand.

He showed no evidence of topographic disorientation. On one occasion he was being taken from his home to the hospital in the car of one of the authors. He suggested a complicated short-cut and correctly gave all the directions for following it. He had no difficulty finding his way around the hospital. On a map he correctly located Europe, the Atlantic Ocean, the Mississippi River, the Rocky Mountains, New York, Chicago, San Francisco, and Miami.

In setting a clock face he often reversed the large and small hands but made no other errors. He copied complex stick figures perfectly with the model present. On one occasion he pointed out correctly to the examiner that he had been given one stick too few to complete the design. He made 50 per cent errors with the model absent. He performed normally on the Block-Design subtest of the Wechsler Adult Intelligence Scale. He drew and copied figures with either hand although on the right the proportions were poorer and he tended to make extra strokes. There was no evidence of neglect of either half of space in his drawings.

The patient dressed himself correctly and without difficulty. There was no neglect of the left side of the body. If neglect existed at all, it was manifested only on the right. He complained that his right hand was dead or useless and would use his left hand preferentially in many tasks (for example, in picking up objects from the floor). Objects placed in the left hand were always handled vigorously and correctly. The left arm showed no evidence of catatonic postures nor any responses of avoidance.

Simple written calculations were correct with the right hand, but he failed on more complex problems. With the left hand his calculations were grossly incorrect, even on the simplest problems (Fig. 2g, h). His calculation difficulty with the right hand ran parallel to his poor performance on tests of abstraction such as proverb interpretation and similarities.

Course since discharge. The patient has been observed frequently in follow-up. At the time of this writing (two months after discharge), there have been some changes in the clinical picture. There have been some signs of progression in that the position sense loss in the right fingers is clearly worse, and he shows difficulties in identifying block letters placed in this hand. He makes many more errors in right-left testing. On a more complex test of finger identification than was used in the earlier testing, he still performs correctly with the right hand. He made 2 errors out of 10 on the most difficult subtest. This test is one in which the patient was asked to show on his body a pair of fingers simultaneously pointed to by the examiner on a model hand.

By contrast, his writing with the left hand has improved in that he produces fewer illegible words, but the words produced are still usually grossly incorrect. He makes fewer errors now in following verbal commands with the left hand.

DISCUSSION

In the early 1900s several cases sharing certain similarities with our patient were reported. In general, these cases were described as showing an apraxia of the left side, agraphia of the left arm alone, and astereognosis on the left. Along with these findings, there were generally associated a hemiplegia, worse in the leg, and a powerful grasp reflex on the same side as the predominantly crural hemiplegia. We have critically examined these reports, and in a later paper we will present our analysis of them in detail. We would stress here that in our opinion some of these cases, when viewed in isolation, would be difficult to interpret. Thus, in Liepmann and Maas's[6] famous case, Ochs, there was a dense hemiplegia involving the right arm as well as the leg. Since no testing for praxis or writing could be done except very rudimentarily on the right, one might have doubts as to the unilaterality of the apraxia and agraphia. Our view as to the possible difficulty of drawing conclusions from such a case coincides with that of Hécaen and Gimeno-Alava.[7] In Goldstein's[8] case other difficulties arise. Here the right side was perfectly normal and apraxia, agraphia, and astereognosis were reported on the left. However, this patient had a left hemiplegia, worse in the leg, and a remarkably intense grasp reflex of the left hand. We agree with Denny-Brown[9] that careful study is needed to insure that apparent dyspraxic difficulties are not due to a grasp reflex.

Despite these difficulties, there are cases such as those of Van Vleuten[10] and Maas[11] in which the hemiplegia involved the right leg and not the right arm; where, despite the grasp reflex in the right hand, there were no right-sided agraphic or apraxic difficulties; and where the otherwise normal left side was reported to show agraphia, apraxia, and astereognosis.

The feature common to these early reports was a lesion in the distribution of the anterior cerebral artery, in some cases vascular, in some tumor, and in particular, in all instances involving corpus callosum. In many of these cases the localization was confirmed at postmortem examination; in the others the pattern of crural monoplegia with a marked grasp reflex in the homolateral hand (such as had generally been present in the autopsied cases) led to a similar clinical localization.

The early workers interpreted their data as being due to callosal deconnection. They believed that the left hemisphere was the leading hemisphere for movement and that the right hemisphere could not function properly in isolation. In the same manner, they felt that the left hemisphere was dominant for stereognosis and that the astereognosis of the left hand could be interpreted as due to separation of the right somesthetic cortex from the left.

Cases of this type have been described much more infrequently in recent years. Other cases of left-sided apraxia have been noted in which the associated clinical symptomatology has been quite different and strongly suggestive of right parietal disease.[7]

Our own case shows clear clinical affinities with the early group in its association of what superficially appear to be purely left-sided difficulties together with right crural monoplegia and a right grasp reflex. Had we not introduced certain new methods of study, we might have interpreted the findings as those of left-sided apraxia, apractic agraphia, and astereognosis.

Our data clearly rule out astereognosis in the left hand. As long as verbal responses were avoided, identification was perfect. The patient was thus simply unable to name objects or letters placed in the left hand. It is important to stress that unless a patient is tested in this way, one can neither ascribe the difficulty to a right parietal lesion nor use the term "astereognosis."

Our patient's agraphia of the left hand cannot be regarded as being secondary to elementary movement difficulties. The patient drew very well with this hand, and indeed his drawing was better with this hand than with the right. The written productions often consisted of perfectly formed letters or numbers which were incorrect. His difficulties in forming words appeared equally in writing, using anagram letters, or typing.

In addition, our testing showed certain unusual features in the apparently apraxic manifestations. Thus, the poor performance of commands by the left side would appear to fit the classical picture. However, we could apparently induce an apraxic difficulty of the right side by placing objects (concealed from vision) in the left hand and asking him to draw or otherwise identify them with the right hand. This was parallel to the inability to identify with the left hand, either by touch or pointing or drawing, objects that had been held (concealed from vision) in the right hand.

Certain interpretations of the data can be excluded. The possibility of hysteria or malingering must always be considered in cases with unusual manifestations, but this seems highly unlikely here. Classical hysterical manifestations were totally absent; the pattern of ability and disability was too complex, especially considering the patient's limited intellectual abilities; many features showed an affinity to the above-mentioned classical clinical pictures which could hardly have been known to the patient; and prolonged careful observation of his behavior militated against this interpretation. Similarly, the patient's intellectual impairment could not explain the differences on the 2 sides of the body. We will later discuss a possible indirect role of intellectual deterioration in the clinical picture.

The data do not support a parietal lobe syndrome either right- or left-sided as the cause of the difficulties. He showed some mild position sense and two-point discrimination loss on the right but no astereognosis on either side. There was no loss of two-point discrimination or position sense on the left. Dressing and topographic difficulties were absent; copying difficulties were not present; and there was no finger agnosia or other autotopagnosia. In particular, we were very careful to verify the absence of neglect of the left arm (if anything, there was a preference for this arm) or of the left half of space, and there was no evidence of avoiding responses or catatonic postures on the left. The course since dis-

charge also supports this view. There has been evidence of progression of left parietal lobe signs: that is, increased position sense loss in the right hand, the appearance for the first time in this hand of an inability to idenitfy block letters, and increased difficulties in right-left orientation. Yet this has been accompanied by an amelioration of many of the distinctive features of this case: improved writing and increased ability to follow verbal commands with the left hand.

Could the disturbances of the left arm be due to unsuspected involvement of the right hemisphere? We have already excluded the possibility of right parietal disturbance. Against the notion that there is involvement of motor regions of the right cerebrum is the total absence of left-sided weakness, grasping, or incoordination. On the right side, where such signs were present, the left-sided deficits were conspicuously absent. Even if there were some heretofore unknown higher order reflex disturbance (similar to grasping or avoiding) in the left arm, it could hardly explain the aphasic nature of his writing difficulties and his inability to name objects placed in the left hand; nor could it explain the failures of the right hand to reproduce or identify material placed in the left hand.

It appears to us that the simplest description of this patient's most striking disturbances is that he behaved as if his two cerebral hemispheres were functioning nearly autonomously. Thus, we found that so long as we confined stimulation and response within the same hemisphere, the patient showed correct performance. If an object was placed in one hand when the patient had his eyes closed, the patient could manipulate it correctly. With the same hand he could select it afterward correctly from a group either tactually or visually or could draw it. By contrast, if the object was placed in one hand and any of the above responses demanded from the other hand, the performance was usually incorrect.

We interpret the difficulties in responding to or using language on the left in a similar way. Postoperatively, the patient was severely, although transiently, aphasic at the time that he had a dense right hemiplegia. This places his speech area almost certainly in the left hemisphere. His difficulties in producing language with the left hand or in responding to verbal commands requiring the use of the left side can be interpreted as resulting from deconnection of the right hemisphere from the speech area. The patient correctly named objects placed in the right hand and wrote correctly with the right hand both spontaneously and to dictation. Verbal commands were performed correctly with the right hand. By contrast, he generally was incorrect in naming objects in the left hand and wrote incorrectly with the left hand both spontaneously and to dictation. Verbal commands were frequently performed incorrectly with the left hand.

While the early cases were described as being apraxic in the left arm, we feel that a more precise delineation is possible in our patient. The patient showed no difficulties of performance of complex movements as long as stimulus and response were limited to the same hemisphere. The left hand showed difficulties only when the information had to be transferred from the left hemisphere, for example, in performing verbal commands, or drawing or otherwise identifying with the left hand objects held in the right (concealed from vision). But as we have shown, the right hand was equally poor in performing movements whose stimulus came from the right hemisphere, for example, in drawing objects held in the left hand. In other words, apparently apraxic difficulties could be induced in either hand.

Where is the lesion producing this disturbance? The interpretation that this functional deconnection of the 2 cerebral hemispheres is a result of damage to the corpus callosum appears to us to be the most likely one. It is in harmony with the earlier anatomical observations and is concordant with the evidence that puts a lesion into the distribution of the anterior cerebral artery. It is consistent with the observations of Sperry[4] and his students on the physiological functions of this commissure.

Sperry[4] used transfer of learning technics to show callosal deconnection. Such experiments were not possible in our patient. However, our evidence of lack of interhemispheric transfer is as direct as that which Sperry obtained by use of learning technics. In fact, certain of our experiments would be difficult

to do with animals, for example, drawing with one hand an object held with the other. Similarly, experiments on transfer of language are possible only in man.

It is difficult to be certain of the pathological nature of the involvement. At first, infiltration by tumor would appear to be most likely. However, we do not know whether any of the findings of deconnection were present before operation. Furthermore, there has been steady improvement over the six months since operation in the right hemiplegia and grasp reflex and in the signs of deconnection. This would appear to us to be too long to be accounted for by surgical trauma or edema. The patient underwent an extensive frontal lobe resection and some branches of the anterior cerebral artery were ligated. We think it possible that the vessel supplying the corpus callosum on the left was either tied off or developed a thrombosis in response to surgical trauma. No postoperative angiogram was done so that we cannot at this time affirm the correctness of this hypothesis.*

The evidence also suggests that the lesion does not involve the posterior callosum. The patient read words tachistoscopically presented in either visual field as quickly as normals. It is interesting to compare the patient of Trescher and Ford,[12] the posterior end of whose callosum had been sectioned surgically. The patient could not read letters in the left visual field. In addition she could not name letters placed in the left hand but could name objects. The authors regarded this as a specialized tactile agnosia rather than as astereognosis on the basis of the excellent preservation of two-point discrimination and position sense and the dissociation between letters and objects. We feel it likely that if nonverbal identification of letters by the left hand had been tested, these authors would have found it intact and would have been able to strengthen their argument. The detailed differences between anterior and posterior callosal lesions will not be dealt with extensively at this point. This problem is dealt with more fully elsewhere (Geschwind[13]).

The one feature of the case that may at first appear to be somewhat perplexing is the retained ability of the patient to perform certain learned activities that require the cooperation of the two hands, such as threading a needle. It can readily be demonstrated, however, that 2 normals, one using the right hand and the other using the left, can combine to perform successfully such activities. It seems obvious that each hemisphere of the patient had learned its role in such tasks, and that if 2 normals can cooperate in performing an activity, 2 isolated cerebral hemispheres can do so equally well.

The most serious objection to our interpretation is the negative results obtained by Akelaitis[2] and his co-workers in their studies of humans with callosal sections. We are not certain of the reasons for these discrepancies but would suggest certain possibilities. Most, although not all, of Akelaitis' patients were young and had epilepsy dating from childhood. It is possible that early hemispheric lesions inhibit the development of unilateral dominance for language. Second, youth alone may be important—just as the young compensate for cerebellar removals while adults do not, it is possible that alternative pathways may be more readily available or more easily developed in the younger patient with a callosal section. It may also be significant that Akelaitis' patients, with only one exception, were epileptics of some years' duration. It is conceivable that the occurrence of multiple seizures might facilitate the availability of alternative pathways. Another possibility is that partial deconnection may be more seriously disturbing in man than total separation. Further, it is possible that only a small number of humans are as heavily dependent on the callosum as are lower animals, so that the syndrome might be seen only in such subjects. Finally, it should be considered that, in the presence of intellectual deterioration, the pa-

*The patient died on June 3, 1962 (after the submission of this paper). Dr. José Segarra, chief of neuropathology at the Boston Veterans Administration Hospital, examined the brain grossly on June 21, 1962, and found evidence which supports the validity of the hypothesis suggested in the text. There was massive involvement of the left hemisphere by tumor which had extended downward into the basal ganglia, but no tumor was present on the right side. The corpus callosum showed no infiltration by tumor but was, on the contrary, markedly thinned in its anterior two-thirds. The superior and medial surface of the left hemisphere extending back to the paracentral lobule was completely infarcted. The callosal and hemispheric lesions corresponded to the territory of the anterior cerebral artery.

Microscopic sections are now being prepared and a detailed description of all the pathologic findings will be presented in a later publication.

tient is somehow less able to compensate for the destruction of the callosum (just as denial of hemiplegia in right parietal syndromes is more likely to occur in the presence of intellectual impairment). We cannot with assurance support any of these hypotheses.

Much of the early physiological work on the corpus callosum received its impetus from clinical observations. The physiological studies by Sperry and his co-workers are now in turn acting as a stimulus to clinicians to reinvestigate this problem. Human material offers certain special advantages, particularly the unilaterality of the speech area, that permit studies to be done that are not open to the animal investigator. We hope that further clinical researches in man will help to clarify some of these problems.

SUMMARY AND CONCLUSIONS

A case of a 42-year-old man with a glioblastoma multiforme, who postoperatively was found to present many unusual findings, is reported. The patient's routine neurological examination showed a right hemiplegia worse in the leg with a very marked grasp reflex in the right hand and mild position sense loss on the right side. There were definite signs of intellectual deterioration.

Writing with the left hand was incorrect, both spontaneously and to dictation, while writing with the right hand was normal except for some disturbances caused by the grasp reflex. He named objects placed in the left hand (concealed from vision) incorrectly; he could select them afterward with his left hand by touch or pointing; and he could draw the object afterward with his left hand. Even while giving an incorrect verbal description, he could demonstrate correctly the use of the object being held in the left hand. If an object was placed in one hand (concealed from vision), he could not select it from a group or draw it with the other hand. He frequently performed verbal commands incorrectly with his left hand.

The authors feel that the simplest explanation of the phenomena is that the patient behaved as if his 2 cerebral hemispheres were disconnected and that the probable cause of this was a lesion of the corpus callosum. Alternative hypotheses and objections are considered, and a brief review is given of relevant earlier clinical observations as well as of the recent work of Sperry on callosal deconnection in animals.

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