AN EVALUATION OF THE PHYSICAL AND MENTAL CAPABILITIES FOLLOWING REMOVAL OF THE RIGHT CEREBRAL HEMISPHERE*

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DR. W. JAMES GARDNER: It has long been recognized that the loss of a considerable amount of brain tissue in the human subject may occasion surprisingly little alteration of function. Since in right-handed persons the left cerebral hemisphere is the seat of the mechanisms concerned with language, the right frontal lobe may be removed and leave the patient with little or no alteration of function. Similarly in order to accomplish the extirpation of an invasive tumor, the right temporal or occipital lobe may be removed with little disadvantage to the patient, aside from a left homonymous hemianopsia. However, the excision of the motor area and the neighboring portion of the parietal lobe results in permanent motor paralysis and profound sensory disturbances in the left half of the body.

Frequently the neurologic surgeon is confronted by a patient who has been or is about to be rendered hemiplegic by an invasive tumor near the center of the right cerebral hemisphere. Occasionally such a patient and his relatives will desire a curative rather than a palliative operation even though it means a permanent hemiplegia and homonymous hemianopsia. Because of the location of the blood supply and disposition of the nervous pathways, it is no more disabling to the patient for the surgeon to remove virtually the entire hemisphere than to attempt to excise just the midportion. This operation was described by Dandy[1] in 1928.

The purpose of this presentation is to demonstrate the physical and mental capabilities of the human subject who has had the right cerebral hemisphere removed. The material consists of four patients, the first of whom lived four and one-half years after operation, the second twenty-nine days, and the last two still are living more than two years after operation.

I will now briefly describe these four cases, after which Dr. Karnosh will describe the neurologic and mental changes produced by the extirpations.

Case 1: A woman 31 years of age complained of convulsions, weakness of the left side of the body, headaches, and failing vision†. On examination this patient was found to exhibit clonic convulsions affecting the left side of the face and neck, and occasionally the left arm. There was a left hemiparesis, a left homonymous hemianopsia, and bilateral papilledema. The clinical diagnosis was right cerebral tumor.

Operation was performed on August 31, 1931. With the patient in a sitting

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†This case has been reported previously[2,3,4].

position, a right craniotomy was performed, disclosing a large, dark, cauliflower-like tumor appearing on the surface of the brain in the temporoparietal region. The tumor infiltrated deeply beneath the surface of the brain, and it was obvious that it could not be removed totally without causing a complete left hemiplegia. After consultation with the relatives, it was decided to proceed with an excision of the hemisphere in the hope that by this procedure we could accomplish a total removal of the growth.

The emerging cerebral veins to the sagittal sinus and those from the inferior surface of the occipital lobe were ligated, cut and coagulated with the electrosurgical unit. The hemisphere was retracted laterally and an incision was made through the corpus callosum into the body of the lateral ventricle. This incision was then carried about the posterior genu and forward about the anterior genu of the corpus callosum. The branches of the anterior and posterior cerebral arteries were secured with silver clips as they were severed. An incision was made in the floor of the body of the ventricle through the internal capsule and outer portion of the corpus striatum into the descending horn of the ventricle. The hippocampal gyrus was then incised from behind forward, a considerable portion of this gyrus and a portion of the mesial wall of the temporal horn of the ventricle and choroid plexus being left. The middle cerebral artery was located, clamped about 1 cm. from its point of origin, and severed. The hemisphere was removed.

Additional brain tissue in the region of the basal ganglia which appeared to be infiltrated by the tumor was trimmed away with the electrosurgical unit. The dura was closed, the cavity filled with saline solution, the section of bone replaced, and the scalp closed.

Examination of the removed tissue disclosed a superficial portion of the tumor weighing 65 gm. The excised portion of the hemisphere weighed 520 gm. The tumor was found to have invaded the hemisphere deeply and appeared mesially at the plane of resection. Microscopically, the tumor proved to be an oligodendroglioma of a moderate degree of malignancy.

The patient's convalescence was satisfactory and she was discharged from the hospital fifty-one days after operation. This patient lived four and one-half years after operation and died following a fall down the cellar stairs. Unfortunately, permission for necropsy could not be obtained, so we cannot be certain that all of the tumor was removed.

Case 2: A woman, 25 years of age, had had symptoms of a right cerebral tumor for about a year.* Craniotomy was performed on July 9, 1934 and an infiltrating glioma of the right temporal lobe was found and a large portion of it was removed. On microscopic study, the tumor proved to be an astrocytoma. The convalescence following this operation was not satisfactory and a paralysis of the left arm occurred. After consultation with the relatives, it was decided to remove the right cerebral hemisphere in the hope of obtaining a permanent cure. Therefore, on July 17, 1934 the right cerebral hemisphere was removed as described in the previous case. This patient developed a postoperative wound infection and died twenty-nine days after operation. The surgical specimen, from which a considerable portion of the temporal lobe had been removed at the previous operation, weighed 538 grams. A postmortem examination was made which showed that the outer portion of the basal ganglia had been removed, consisting of the larger portion of the caudate nucleus, all of the putamen, about two-thirds of the globus pallidus, and a goodly portion of the anterolateral and posterior portions of the thalamus.

*This case also has been reported previously.[5].

Case 3: This case was particularly interesting because the patient was left-handed and, therefore, the speech centers were presumably in the right cerebral hemisphere. He was a man 35 years of age who had had a progressive left hemiparesis of three months' duration with jacksonian convulsions which began in the left great toe. The patient presented no symptoms or signs of increased intracranial pressure. The clinical diagnosis was a brain tumor in the right motor area. On January 31, 1938 a right craniotomy was performed. An incision through the cortex in the right premotor area disclosed a subcortical astrocytoma. No attempt was made to remove the tumor. Following this operation the paralysis of the left arm and leg was almost complete, but there was no weakness of the facial muscles and no aphasia. The patient had been left-handed since birth, he was also left-eyed and the father of the patient was left-handed, indicating that left-handedness was a familial trait, and that the right hemisphere was dominant. The patient was anxious to have the tumor completely removed even though it meant that he would have a permanent left hemiplegia. However, we were reluctant to attempt a radical extirpation of the growth because of the fear that it would leave him with an aphasia. It was decided therefore to inject novocain into the brain in an effort to determine whether the speech centers were on the right side.

Nineteen days after the first operation, a trephine opening was made in the right frontotemporal region just in front of the motor center for the face. A hypodermic needle was introduced beneath the cortex of the brain and 27 cc. of ¾ per cent novocain was injected in various directions. Following this procedure, the patient had a definite paresis of the left angle of the mouth but no

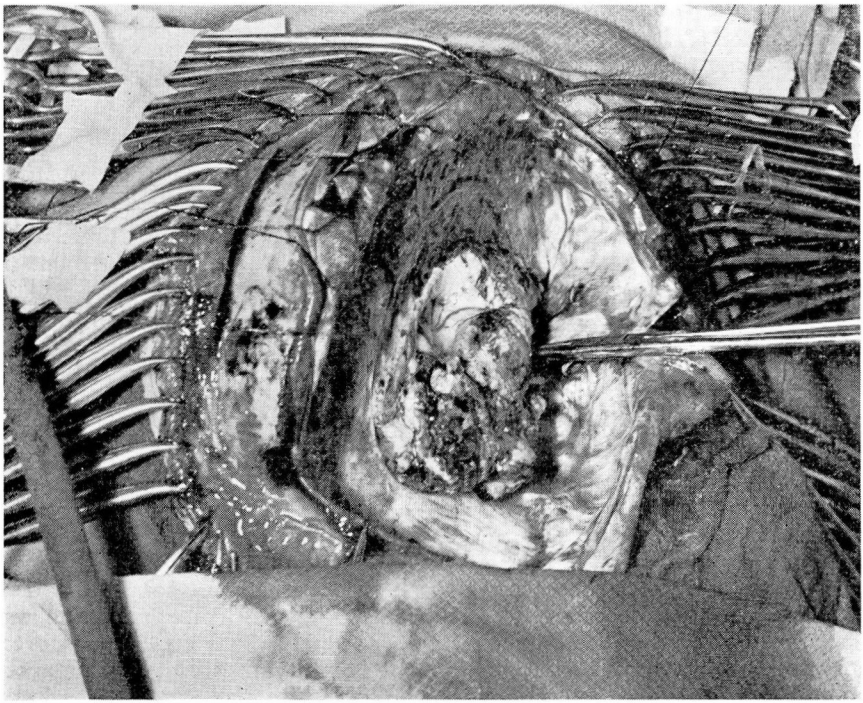

FIGURE 1 (Case 3): Photograph of the operative field after the right hemisphere had been removed, looking from behind, forward. The hemostat is on the middle cerebral artery.

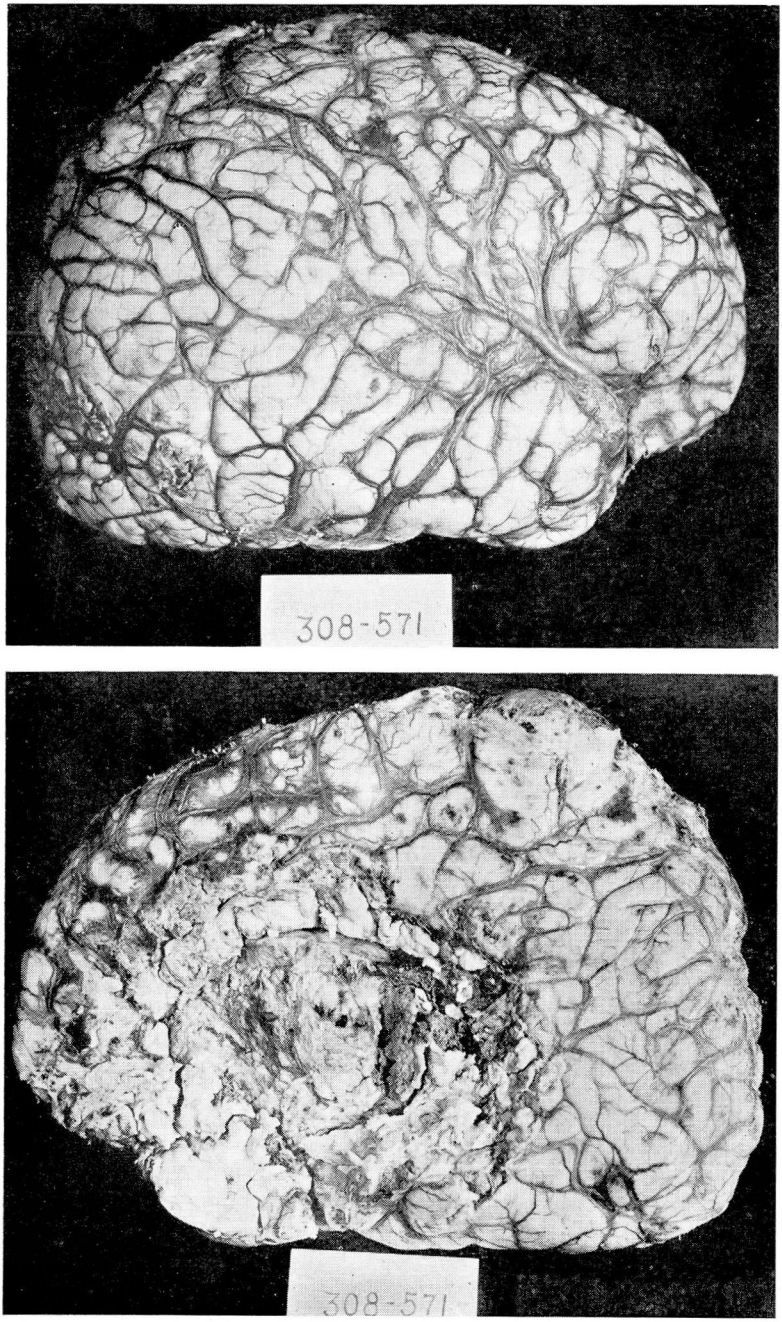

FIGURE 2 (Case 3): The surgical specimen
A. Outer surface
B. Mesial surface

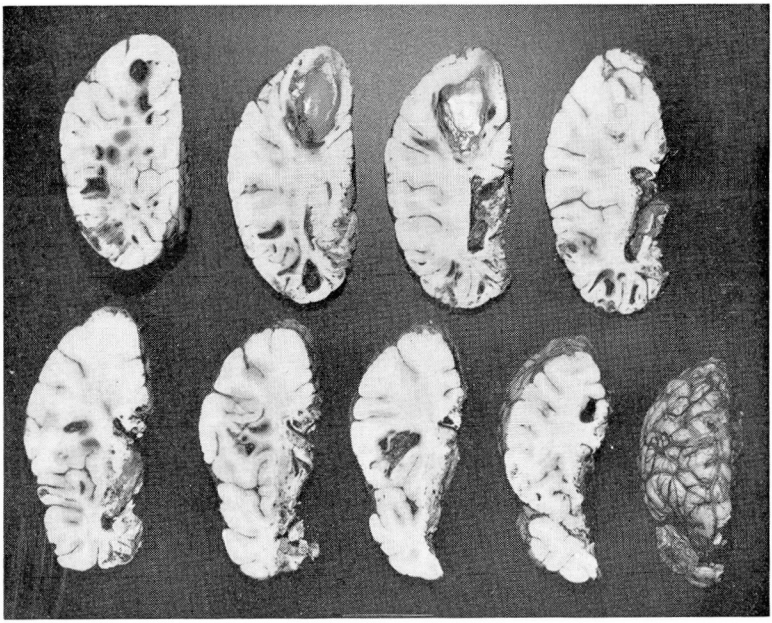

FIGURE 3 (Case 3): Coronal sections. The lower right is the frontal pole and the upper left, the occipital. The cystic portion of the growth is seen clearly. The site of the novocaine injection is represented by the dark cystic area in the middle section, lower row.

aphasia was demonstrable. This we felt proved that the speech center was on the left side of the brain, even though the patient was left-handed. Accordingly, on March 3, 1938 the right cerebral hemisphere was removed with the enclosed tumor (Fig. 1). His convalescence following this procedure was satisfactory, there was no sign of aphasia, and he was discharged on the twenty-sixth post-operative day. This patient gets about well with the aid of a cane. His intellectual processes show about the same degree of impairment as has been observed in right-handed persons who have had a similar operation. Physically, however, he is less dexterous due to the fact that he has lost the use of the dominant hand. He has not yet trained himself to write with the right hand. He is still living three years after operation.

The specimen weighed 760 grams (Figs. 2 and 3). Examination showed that the entire hemisphere had been removed except for a thin layer of cortex of the medial aspect of the frontal lobe just in front of and below the anterior genu and the mesial portion of the gyrus hippocampus. The caudate nucleus, all of the putamen and a small portion of the globus pallidus were removed. The thalamus was spared. The tumor consisted of an astrocytomatous cyst in the upper parietal region with a solid portion which extended into both the frontal and the occipital lobes. There were some small cystic areas at the site where the novocain had been injected twelve days previously. The tumor apparently had been entirely removed.

Case 4: A young man of 27 years had had headaches for a year and convulsions preceded by gustatory aura for some three weeks. There were no neurological findings in his case, and no increase in the intracranial pressure.

Encephalography performed on May 14, 1938 indicated the presence of a right temporal lobe tumor. A right temporal craniotomy was performed on May

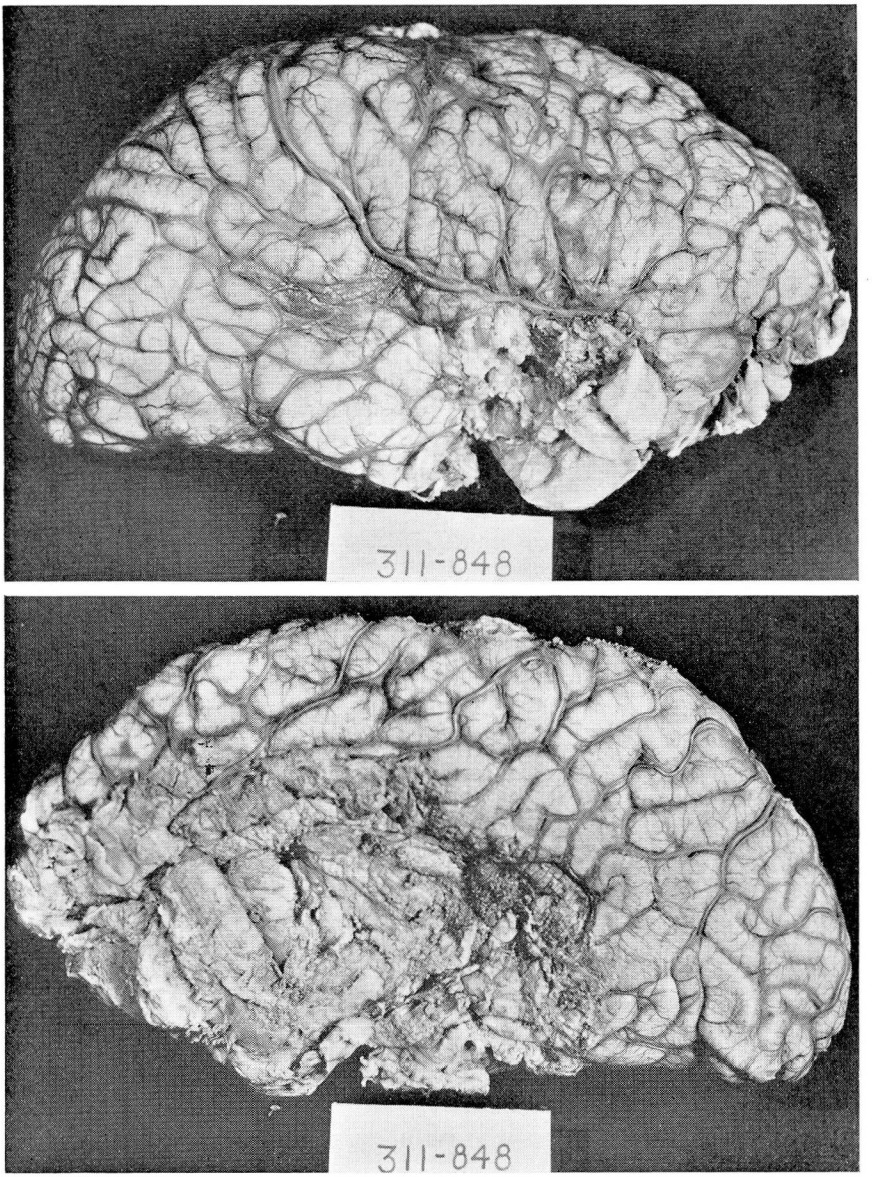

FIGURE 4 (Case 4): The surgical specimen
A. Outer surface
B. Mesial surface

22, 1938 and an astrocytoma of the tip of the right temporal lobe was found and excised. The tumor was not completely removed and during the operation the right middle cerebral artery was damaged and had to be ligated. Following this operation the patient had a left hemiplegia, but a homonymous hemianopsia was not present. The patient and his relatives were told that the tumor was not entirely removed and that a total removal of the growth would leave him with a

left homonymous hemianopsia, a complete paralysis of the left arm and a marked weakness of the left leg.

After considering the matter for six weeks, the patient returned for the radical operation. On September 7, 1938 the right cerebral hemisphere was removed as described in the preceding cases. During the operation, tumor tissue was encountered in the region of the basal ganglia so that the incision at this point was perhaps carried a little further medially than in the preceding cases. After the hemisphere had been removed, the suspicious area of the basal ganglia was treated with electrocautery in an attempt to destroy any tumor cells that might still remain. The patient's convalescence following this procedure was satisfactory, and he was discharged on the nineteenth postoperative day. He still is living two and one-half years after operation.

The specimen weighed 395 grams several months after fixation. The anterior half of the temporal lobe which was removed at the previous operation is missing from the specimen (Fig. 4). In other respects it resembled very much the specimen of the previous case. The caudate nucleus, the putamen and adjacent portions of the globus pallidus are included. The tumor extended from a point 1.5 inches behind the anterior pole, through the temporal and lower portion of the parietal lobe into the occipital lobe. It appeared that some tumor tissue may have been left in the mesial portion of the hippocampal gyrus which was spared.

DR. LOUIS J. KARNOSH: The resection of large portions of the right cerebral hemisphere for tumor is a daring and formidable procedure. If the subject survives the acute ordeals of shock, hemorrhage and infection, the clinical results at first hand are definitely consoling and are looked upon by some as something short of the miraculous. This optimism can be readily understood. The patient often comes to the neurosurgeon in semistupor, or is dulled by convulsions, headaches, blindness and maudlin mentality. These malignant symptoms generally are relieved by this operation and in this sense the contrast is striking.

The four patients presented in this discussion afforded excellent opportunity to study the end results of complete or subtotal resection of the right hemisphere. The data from one patient, however, are rather meager, for she lived only twenty-nine days after operation and satisfactory cooperation was impossible. The remaining three patients have had survival periods extending beyond two years at this time.

What manner of man or woman can be salvaged from this operation, and what the total performance of the individual may be are questions whose answers should reveal the ultimate value of the procedure. By means of periodic clinical examination, simple mental tests, moving picture records, and above all, through careful inquiries directed to relatives and friends, an attempt was made to garner the data and to formulate an intelligent answer.

The Physical Aspects

Most obvious and understandable in these four patients were the motor difficulties. Essentially this involvement consisted of a hemiplegia of the left side of the body which differs in little respect from the

orthodox picture of a paralysis following apoplexy. The left side assumed the posture which is so characteristic of a spastic paralysis. The upper extremity became flexed at the elbow, the forearm and hand were supinated, later taking on the familiar claw-like appearance. Movement in the fingers was almost nil; there was no power of movement at the shoulder joint and only with a great effort could the deformed hand be elevated toward the face. The left arm was therefore a rather useless appendage, its activity being reduced to a few crude reflexive responses.

The lower extremity was not so helpless. The thigh and knee in all instances could be extended or flexed on command although these movements were slow and clumsy. Neither ankle nor the toes could be activated and the foot was ordinarily found in a dropped position. Defense reactions in the leg were exaggerated. Despite these motor difficulties in the lower extremity, the three patients who successfully survived the operation were able to sit up, to stand and eventually to walk. Walking was possible even without the use of a cane or crutch, although this performance was somewhat awkward and frequently led to accidents. In a sitting position all three patients could elevate the defective leg and cross it over the normal extremity. The contrast between the relatively useful leg as against the distinctly useless arm and hand is demonstrated in most hemiplegias and again tends to support the general idea that the lower extremity is less dominated by the higher cortical centers than is the upper. It is almost needless to say that on the paralyzed side all reflexes were extremely exaggerated and the familiar Hoffmann and Babinski reaction usually was elicited.

Paralytic symptoms in the cranial nerves were surprisingly mild. The most striking defect was a weakness of muscle activity about the left angle of the mouth while speaking or displaying emotion. Elsewhere all facial movements were symmetrical; the brows were evenly elevated and the lids were normally raised or lowered. Ocular movements were complete in every direction.

The tongue deviated slightly to the left in one patient. The pharyngeal mechanisms were not disturbed, and chewing and swallowing presented no particular difficulty.

The function of speech as a motor performance was not radically altered in any of the three patients. In one there was noted a slight monotony of tone and a mild loss of inflection, but this was evident only in the first few weeks of the postoperative period. It already has been pointed out by Dr. Gardner that in one of our patients the speech function was demonstrated as being in the left cerebrum while handedness was found to have been in the right, or nondominant hemisphere. It is obvious that this individual was far more handicapped than the other two, for he lost the use of his more skillful hand and as a result was so helpless that he could not dress himself and all voluntary acts of his right

hand were very clumsy and tremorous performances.

More unique but less in evidence were the sensory disturbances on the paralyzed left side of these patients. There was no great subjective discomfort except a feeling of heaviness in the arm and leg. As in every spastic hemiplegia, deep pain was elicited on attempting to extend the elbow or to straighten out the spastic fingers.

Appreciation of a single stimulus with a camel's-hair brush was absent over the entire left side except on the face. Two point discrimination was equally impaired over the same area. However, if a light touch stimulus was dragged over a distance of two or three inches, it was recognized as a vague, dull pressure but its exact site could not be given. Usually the patient referred it to remote portions of the body, sometimes as much as ten or twelve inches away from the true point of stimulation. Again on the face this error was not so pronounced and the patient was able to indicate the site of stimulus with a fair degree of accuracy. This same observation was made by Dandy[6] and like him we have no adequate explanation except to say that the face or the trigeminal area may have connections with both hemispheres.

All these patients could appreciate the pain of a pinprick on the left side. It was not, however, a normal experience as compared with the right side. The prick of the pin gave rise to a very disagreeable and diffuse feeling, often interpreted as a stinging or a chilling or a burning sensation, which could not be accurately located and as one patient expressed it, "took in a large territory."

The special senses of sight, smell and hearing showed certain deficiencies, but apparently produced no great subjective discomfort in any of these patients. In all of them there was a consistent and typically left homonymous hemianopsia. Yet there was no complaint of partial blindness, and no acute inconvenience in reading. Perimetric studies explain this by showing an intact macular field in every instance.

The loss of smell could be elicited in one patient, this being on the right side and could be readily explained by the fact that the right olfactory bulb was removed in the brain resection.

There was no serious impairment of hearing except in the one individual who had the shortest survival period. This woman claimed that she could not hear in the left ear but the value of this observation is to be questioned because the patient was seriously ill with meningitis. Three patients insisted that hearing was good in both ears and this was confirmed by the audiometer in two cases.

To summarize the physical features following the removal of the right cerebral hemisphere, we present an individual who has a pronounced spastic weakness of the left arm and leg, who has little use of his upper limb but who is able to walk, who can carry out many simple

manual performances such as eating, dressing himself, writing a fair hand, and whose speech is normal. On the subjective side he is not particularly uncomfortable, although he has some difficulty in seeing objects in his left visual field and there is some blunting of fine sensation on the left side of the body.

Mental Aspects

While the physical residues in these patients could be displayed readily, the mental changes were extremely elusive. From previous reports the general impression is gained that there is very little or no psychic weakness following the operation. However, Dandy himself has some misgivings as to such negative findings. "It is still difficult," he states, "to believe that some functions of the mind are not stored or at least activated in the right hemisphere."[6]

What mental peculiarities actually existed in these patients after the resection were not readily disclosed in the routine mental tests. Actually these examinations tended at first to give the superficial impression that the subjects were quite alert, quick in reparteé and in general more vivacious than before. A more careful evaluation of this apparent animation of intellect revealed that it largely took the form of facetiousness, clowning and punning.

In none of these patients could one find any disorientation which could be called pathologic. Dates and places usually were given clearly. There was no evidence of hallucinosis or any ideas which could be called delusional.

In the matter of mood, all three patients seemed to show a definite change in the direction of wide swings in tone feeling. There was an easy trend toward dejection and moroseness with an equal tendency to mild elation and unwarranted gaiety.

The routine tests for intellectual accomplishment produced no striking abnormalities. Since accurate psychometric tests were not made of these patients before the onset of the brain tumor symptoms, no reliable comparison can be offered. The greatest difficulty lay in the inability to concentrate, to deliberate at great length and to carry out a concerted, protracted mental procedure.

The more subtle changes can only be appreciated by reviewing the behavior of these three patients as they were reimplanted upon their normal environment and as they attempted with varying degrees of success to adjust themselves to their occupations and to their social settings. The simplest way to present this phase of personality change is to give in concrete manner the story of each individual.

Case 1: The operation was done on September 23, 1931. No important mental changes were noted in the postoperative period except that she was abnormally optimistic, reacted very slowly to questions but did not seem to be

aware of this retardation. She returned to her family and after several months of wheelchair convalescence she was able to get up and carry on with some of the simpler household chores. These she did very well. The members of her family who were greatly impressed by her relative recovery were loath to admit that she had any great deviations from normal behavior. Nonetheless, they humored her in every way possible, carefully avoided direct criticism of her behavior, and lauded her greatly for any minor accomplishment. She was never asked to assume a great deal of responsibility in managing such things as the budget or in initiating any new program involving the various members of the family. She was never asked to make any major decisions. The family admitted that she was easily brought to tears, was occasionally maudlin and abnormally elated. She wrote a good letter but was inclined to repeat herself without being aware of it. The attitude of the family clearly showed that they appreciated an innate deficiency but were not willing to admit it openly. Overtures on the part of a psychiatrist to probe into her mental processes were bluntly discouraged. The patient apparently underestimated her physical handicap which was a left spastic hemiplegia. She insisted on walking about without a cane and even ventured going up and down stairs. Apparently this was the reason for her serious fall which resulted in intracranial hemorrhage and this in turn, in her death which occurred on March 6, 1936. She survived the fall by several months and during this time she become badly disoriented, showed a great loss of memory for recent events and developed periods of great excitement.

Case 3: This patient was operated upon March 3, 1938. The mental symptoms in the immediate postoperative period were simply those of emotional blunting and some mental retardation. This man had operated a small restaurant in a small town nearby. In this venture he was assisted by his wife. When he returned home from the hospital, she was greatly impressed by the improvement in his mental state, and refused at first to concede that there were any deviations from normal. She stated that he returned to his previous position, was apparently aware of his responsibility and apart from his motor helplessness there was no personality change. When it was pointed out to her that he was unusually jocular, facetious and fond of "razzing" his friends, she insisted that this was a normal trait.

However, after six months she returned with quite another story. She now admitted that his memory was spotty, that he had trouble in concentrating, and that he took no keen interest in the welfare of the restaurant business. His ability to play bridge was showing certain deficiencies. He did not seem to be greatly concerned about the financial state of affairs in the family and was inclined to dispose of serious matters with a shrug of the shoulders and with some nonsensical remark. He became more restless and seemed of abnormal gaiety despite the progressive helplessness due to the fact that his most useful hand was paralyzed.

In a more recent clinical examination his mental state clearly manifested an abnormal euphoria and considerable loss of insight into his condition. He did concede that it was difficult for him to appreciate situations about him if there was too much commotion or excitement. In attending a ball game, he could not follow all the plays and could not keep an account of the score. At the present time he is badly incapacitated by reason of his hemiplegia, cannot dress himself, eats with great difficulty and has lost all interest in his business.

Case 4: This patient was operated upon September 7, 1938 and therefore has been subject to study for a period of over two years. The immediate mental reac-

tions to the operation were not outstanding. He was moderately depressed. His speech was rather laconic and toneless, and almost immediately the content of his conversation became coarse. He became an unsavory recanteur and took delight in making sarcastic remarks about physicians and nurses.

He had been a bookkeeper prior to his illness. He has never even attempted to resume his former occupation. His relatives are very frank in stating that he is "not the same individual" and freely expressed the opinion that his personality changes are such that "he would have been better off had he not survived." The patient is not greatly disturbed by his physical handicap, is continuously punning, declines to admit his future is bad, has great ambitions but is consistently unable to carry out any program for making a living. His parents have repeatedly financed him in small schemes whereby he could earn some money. In every instance the patient started out with a great deal of enthusiasm, worked unceasingly on the project, but in a few weeks lost all interest and desire to carry on. For instance, he planned a small mail-order business, bought considerable stock, but in a few days gave up his advertising campaign. On another occasion the parents purchased some peanut-vending machines which the patient placed in three or four lucrative sites in the neighboring town. Very soon it was found that he failed to refill them. He is exceedingly unstable, inconstant, and lacks perseverance. More serious a deficiency is his utter disregard for his personal appearance. He may appear in any garb that is at hand at any time, refuses to bathe, and prefers to remain unshaved. He becomes exceedingly angry and indignant if he is reminded of his loose personal habits. Otherwise he gives the impression of being a very smart young man, somewhat bold, but keenly alive to current affairs and very clever in reparteé.

The two male patients display their personality deficiencies more prominently than does the woman. This is because more is expected of them, and they come more directly in contact with a competitive world. Even if it were not for the hemiplegia, these patients can still be regarded as failures so far as total adjustment to life's normal responsibilities is concerned.

The concept that the right hemisphere is not essential to normal mentality cannot be borne out from these studies. The operation opens a great vista to future investigation of cerebral physiology. While it may be acknowledged that the left hemisphere is vastly more important in providing the fundamental language functions of mind, from these studies it appears that the right hemisphere is also essential, particularly for the higher integrative functions such as those which deal with insight, judgment and emotional control. This phase of mind which seems to be woefully lacking in these patients may be aptly called the "long haul" in mental accomplishment and consists of those powers that provide for a normal social and moral sense and for perseverance, stability of purpose and consistence of application.

It can be concluded, therefore, that removing the right cerebral hemisphere is not comparable to removing one kidney or one lung. One cerebral hemisphere is by no means a functional replica or an understudy of the other hemisphere. An individual deprived of his non-

dominant cerebral hemisphere is no longer a normal person in his community.

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