Article abstract

Cerebral commissurotomy or the "split-brain" procedure may be a valuable adjunct to anticonvulsants for the control of seizures in people whose epilepsy cannot be relieved by anticonvulsants alone, and who are not candidates for the standard methods of surgery. Corpus callosotomy, a revised form of the usual division of many commissures, is a safer operation and appears to be equally effective. The complex clinical aspects of cure and treatment are emphasized.

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Cerebral commissurotomy for control of intractable seizures

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The corpus callosum (with its underlying hippocampal commissure), anterior commissure, fornix, and massa intermedia are the cerebral commissures that have been divided in man for relief of intractable seizures. Results have been encouraging in several small series,[1-5] and the surgery produced no obvious physical or mental deficits. Gazzaniga and co-workers[6,7] and Sperry and associates[8] showed that subtle and permanent defects in the transfer of information from one hemisphere to the other did occur after commissurotomy, but this did not affect everyday behavior. We are reporting a new series of 10 patients who underwent partial or complete commissurotomies, with emphasis on the complex clinical aspects of treatment.

Methods and procedures. We adopted the classification of the epilepsies, approved by the International League Against Epilepsy in 1970.[9] Thus, focal motor and temporal lobe attacks are partial seizures, and petit mal and grand mal are generalized seizures.

The outcome of surgery was measured by the reduction of incapacity, as Taylor and Falconer[10] recommended using ictal, mental, psychologic, and social status to determine the results of treatment.

We modified Crandall's[11] criteria to evaluate the effect of surgery after 1 year: Group A: three seizures or less, excellent; group B: reduction of seizures by 50 percent or more *or* change from generalized seizure to a partial and more manageable attack, good; group C: no change in number or quality of seizures, poor; group D: seizures worse, poor.

"Complete" commissurotomy means division of the entire corpus callosum (together with the underlying hippocampal commissure), one fornix, and the anterior commissure. "Frontal" commissurotomy means division of the anterior commissure, one fornix, and the anterior half of the corpus callosum.

Our decision to perform these operations was based on the following premises: The forebrain commissures, especially the corpus callosum, are the preferred pathways for seizure discharges from one hemisphere to the other, while subcortical pathways appear to play a smaller role.[2,12]

Most epilepsy appears to be of cortical origin. Evidence now seems to indicate that the brain stem is rarely the primary source of seizures, although it may support or "kindle"[13,14] them. For this reason, we attributed special significance to three-per-second spike-and-wave discharges[15] when they occurred.

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Bilateral, seemingly independent discharges may actually originate in one hemisphere, and we did not exclude patients who did not have signs of unilateral brain damage. Goldring[16] stressed the limitations of the electroencephalogram (EEG) in localizing focal electrical discharges, especially when there is more than one focus in one hemisphere, and Tores and French[17] demonstrated that it is often impossible to distinguish a primary discharge from a propagated one.

Other surgeons have reported that forebrain commissurotomy is safe and effective.[1-5] Gordon and associates[18] refined the operation by modifying the amount of tissue removed according to the site of discharge. They spared the splenium of the corpus callosum in those patients whose foci were "anterior," confined to frontal or temporal lobes.

Surgical procedure. Our initial technique for performing forebrain commissurotomy was described previously.[19] It is still evolving. In general, our operations differ from others because of our use of the operating microscope and microsurgical procedures. We use smaller openings,[20] and recently made every attempt to stay out of the ventricles. The present technique of cerebral commissurotomy will be published elsewhere.

Patient selection. All patients were incapacitated by seizures for at least 4 years despite vigorous, carefully supervised anticonvulsant medication, and none were considered candidates for standard methods of surgery. "Incapacitated" meant a minimum of four daytime seizures per month and an inability to lead a reasonably normal life. Thus, occupation and severity of attacks were additional determinants.

Patients had to be capable of understanding the seriousness of their disease and the innovative nature of the operation. Informed consent was obtained from both parents and concerned relatives in several interviews, and they were given printed discussions to read. If the seizures were relieved or reduced by surgery, patients had to have the physical and mental capacity to lead a reasonably productive life.

Every candidate was admitted to the hospital for the following tests: physical examination, plain x-rays, brain scan, serial EEGs, cerebral angiography, and pneumoencephalography. Each received a battery of neuropsychologic tests that consisted essentially of Reitan's modification of the Halstead battery.[19,21] The results allowed inferences to be made about the nature and location of dysfunction of the cerebral hemisphere.

Attempts were made to define the area or areas of the brain damage. After surgery, each patient was followed at regular intervals by a team composed of a neurosurgeon, neurologist, clinical psychologist, and research psychologist.

Cases one to eight, which comprise the first series, are analyzed in the table. The first patient underwent cerebral commissurotomy as an alternative to hemispherectomy, and this case was described in a separate report.[19]

Case 9. D. H., a 10-year-old boy, had herpes simplex encephalitis with coma and left hemiparesis. A right subtemporal decompression was performed. He recovered and, except for left lower facial weakness and left arm drift, he was perfectly well for 1 year, when he had his first seizure. This was a complex partial attack characterized by a dreamy state with déjà vu and an emotional component of fear, head turning to the right, and inability to speak. The spell lasted for 1 minute. An EEG showed spike-slow wave complexes in the right temporoparietal area. The complex partial seizures increased in frequency to eight a day and were not controlled by various anticonvulsants. By the time he was 12 years old, seizures appeared to be intractable and his personality changed. He was irritable, moody, careless, violent, and unmanageable at school and at home. He had formerly been very popular, a good student, and a fine athlete. Neuropsychologic tests in August 1972 revealed an IQ of 82 and diffuse dysfunction of the right hemisphere.

Then the EEGs began to change. Seizure discharges, formerly confined to the right hemisphere, became bilateral, diffuse, and synchronous. The character of the seizures changed in that the complex partial attacks were no longer associated with head turning, but were followed by generalized akinetic attacks and automatisms. Phenytoin, phenobarbital, primidone, carbamazepine, and ethosuximide in various combinations gave no relief.

The boy was admitted at age 15, in June 1975. He had a slight left hemiparesis as before. Skull x-ray showed silver clips in the anterior portion of the right middle fossa. The pneumoencephalogram revealed dilatation of the right ventricular system, including the temporal horn, which was intact. EEGs showed bilateral, diffuse charges.

On July 18, 1975, he underwent a complete division of the corpus callosum. He was given 500 mg ampicillin every 6 hours by mouth 2 days before surgery. This was continued intravenously during and after the operation for 5 days. Dexamethasone, 10 mg every 6 hours, was started on the day before surgery and continued in diminishing doses for 1 week after operation. The approach was unchanged except that no bridging veins were sacrificed, and retraction, especially of the right frontal lobe, was minimal. Only the corpus callosum (together with the underlying hippocampal commissure) was sectioned. The anterior commissure and fornix were spared. The ventricular roof was opened in only one small place, and the hole was quickly covered over with Gelfoam®. He awakened promptly from surgery. He had marked neglect of his left side to the point of paralysis. The left hand exhibited athetoid movements. He had a few partial motor seizures of the left arm and left side of his face and low-grade fever. His affect was flat. Within 3 days, these abnormal signs cleared. An EEG on July 28 was normal except for a slight background dysrhythmia.

More than any other patient, he was aware of competition between his right and left hands: "They want to do opposite things." This, too, subsided, and he was discharged on July 30 feeling well.

He returned to school, where his parents claimed he had become a "model" student. His personality underwent a remarkable reversion to his former kindness, cooperation, and concentration. In September, he foolishly began to play football and received a severe blow to the head, causing him to become unconscious. When he recovered consciousness, he had three generalized tonic-clonic seizures, which he had never experienced before, and three partial spells lasting for a few seconds, described as a sense of "fading." Before and since this time (to July 1976), he has experienced a partial motor-sensory seizure of the left arm about once a month without loss of consciousness. He was taking phenytoin and primidone. In

Table. Analysis of first series

Case	Age at onset of seizures	Seizure type and frequency	Preoperative EEG	Neurologic examination	Other pertinent laboratory data
T.O.	6 yrs	Generalized: Tonic-clonic and akinetic, 20-30 day	Diffuse RT spike-wave paroxysms with diffuse LT secondary synchrony	LT hemiparesis since birth	Dilated ventricular system
J.H.	14 yrs	Generalized: Tonic-clonic, 1/week	Bilateral diffuse 3/sec spike-wave; RT frontal spiking with depth electrodes	Normal	
J.K.	4yrs	Complex partial Partial motor RT, 5-10/day Generalized: Tonic-clonic, 4/week	RT frontotemporal spike and slow waves with diffuse bilateral spread	Normal	
T.C.	19 yrs	Complex partial and generalized tonic-clonic and akinetic, 15/month	Bilateral frontotemporal spiking with RT temporal predominance	Normal	
J.K.	18 yrs	Complex partial, 15-20/day	Bitemporal spike paroxysms	Normal	Dilated RT temporal horn
J.C.	10 yrs	Complex partial, 10/day Generalized: Tonic-clonic, 1/month	Bilateral diffuse, synchronous spike and slow wave; RT predominance	Normal	
P.G.	Birth	Complex partial, 5/day	Bitemporal spike and slow wave; RT predominance diffuse bilateral paroxysms	Normal	
C.E.	18 yrs	Complex partial and generalized: Tonic-clonic, 3/day	Diffuse bilateral paroxysms	Normal	

February 1976, his psychometric intelligence had increased from the dull normal (82) to the average range (94). There was evidence of continued moderate right hemisphere dysfunction, "but his overall level of cognition appears to have improved since his preoperative testing."

Summary. Operation: complete corpus callosum section, ventricles not opened, fornix and anterior commissure not divided. Complications: none. Postoperative hospital stay: 12 days. Followed: 12 months. Reduction of incapacity: ictal: generalized akinetic seizures, group A—excellent: complex partial seizures, group A—excellent: partial motor seizure, group B—good. Mental: improvement in concentration and cognitive abilities. Emotional: mature, friendly. Social: not handicapped for future employment, integrated again in family. Overall evaluation of surgery: excellent result, but too early for definitive statement.

Comment. Not only were his seizures relieved, but the striking improvement in personality suggests that his violent behavior may have been related to his seizures. This seems to be supported by reports of those children with hemiplegia who underwent hemispherectomy for intractable seizures. Control of seizures was usually accompanied by a marked improvement in behavior and affect.

Case 10. P. S. At 20 months of age, a boy who previously had been well developed a high fever and had many right-sided [illegible] seizures, which became generalized. They were controlled in 8 hours and treated with phenobarbital. He then showed hyperactivity and disruptive behavior but was well [illegible] until age 4, when he experienced "absences" [illegible] month. At age 6, an EEG was reported as "normal." [illegible] he began to have right-sided partial seizures characterized by adversive movement of the head, posturing of the [illegible] walking around in circles. These lasted for 2 minutes, [illegible] which he slept for several hours. The EEG showed slowing over the left hemisphere and spikes with spike-wave [illegible] in the left temporal leads, occasionally propagated to the right side. The only physical abnormality was impaired ability to recognize objects placed in his right hand. [illegible] sensorineural hearing loss. Diazepam and phenytoin were started. Phenobarbital was added, but the partial seizures increased in frequency. Phenytoin was increased to toxic [illegible]

By January 1974, when the boy was age 14, seizures were occurring 10 times monthly, and manipulation of the anticonvulsants such as phenytoin, phenobarbital, mephobarbital, and primidone was to no avail. [illegible]

Table. Analysis of first series (cont.)

Age at operation	Type of operation	Complications	Hospital stay	Followed
[illegible] yrs	1. Complete intraventricular commissurotomy Jan. 25, 1972 2. Ventriculoperitoneal shunt	Hydrocephalus Aseptic meningitis	26 days (2 admissions)	48 months
[illegible] yrs	"Complete" intraventricular commissurotomy Dec. 12, 1972	Meningitis (Aseptic and septic) Hydrocephalus Loculated RT ventricle Loss of recent memory LT hemiplegia	60 days (3 admissions)	38 months
[illegible] yrs	"Complete" extraventricular commissurotomy Jan. 9, 1973	None	17 days	32 months
[illegible] yrs	"Frontal" extraventricular commissurotomy Feb. 6, 1973	None	13 days	29 months
[illegible] yrs	"Frontal" extraventricular commissurotomy Feb. 20, 1973	None	22 days	31 months
[illegible] yrs	"Frontal" extraventricular commissurotomy March 2, 1973	None	18 days	30 months
[illegible] yrs	"Frontal" extraventricular commissurotomy May 1, 1973	Stupor, partial motor seizures Hydrocephalus Meningitis	132 days	30 months
[illegible] yrs	"Frontal" extraventricular commissurotomy Feb. 15, 1974	Died	— —	— —

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[illegible]us spike-wave discharges in the left frontotemporal and [illegible]or temporal regions, with dysrhythmia over the entire left [illegible]sphere. Generalized akinetic seizures were added to his [illegible] partial motor and complex attacks. The latter seizures were [illegible]acterized by rocking back and forth, shouting, and bizarre [illegible]ations. Between seizures, his hyperactive, disruptive, [illegible] often violent behavior continued. Then the partial motor [illegible] began to occur on his left side as well.

He was admitted in December 1975 at age 15. Physical [illegible]nation, skull x-ray, and brain scan were normal, as was [illegible]encephalography and pancerebral angiography. EEGs [illegible] diffuse seizure discharges over the left hemisphere, [illegible] marked in the temporal area, with slight secondary [illegible]chrony in the right temporal area. There was a discrepancy [illegible]een verbal IQ (83) and performance IQ (99). The total IQ [illegible] 89, in the dull normal range. The tests suggested distinct [illegible] hemisphere damage.

Complete extraventricular division of the corpus callosum [illegible] accomplished without incident. The patient recovered [illegible]ciousness quickly and showed all the characteristics of an [illegible] disconnection syndrome: mutism, immobility of the left [illegible], left homonymous visual neglect, bilateral Babinski [illegible]ses, and alternating periods of stupor and alertness. Mild [illegible]natremia and hypokalemia were corrected. Although the [illegible]ricular systems were not entered at all, the quadrigeminal cistern and the corpus callosum "cistern" were breeched as usual. Low-grade fever was associated with mild aseptic meningitis. Ampicillin had been started 2 days before surgery and was continued for 5 days after operation. Dexamethasone was continued in diminishing doses for 10 days. Within a few days, he was afebrile, and the cerebrospinal fluid (CSF) although xanthochromic and under high pressure, contained no white cells.

By the second week after surgery he was able to walk, eat, and dress himself. The acute disconnection syndrome subsided, but the most outstanding characteristic of the postoperative course was a regression to infantile behavior. He was querulous and demanded constant attention. He shouted constantly until someone sat with him, when he would talk rationally. In addition to phenytoin, he was placed on haloperidol. He complained of headaches. Lumbar punctures revealed normal fluid under high pressure. By the third postoperative week, CSF pressure was normal, but an infusion test was distinctly abnormal. Computerized axial tomography (CAT) scan showed small ventricles in normal position.

The final lumbar puncture was followed by staphylococcal meningitis, which was quickly controlled. The patient was discharged on March 24, when his behavior was normal and he had no neurologic deficit. He was discharged on phenytoin, having experienced no seizures since operation. An EEG

Table. Analysis of first series (cont.)

Case	Postoperative EEG	Ictal	Postoperative anticonvulsants	Mental	Emotional	Social
T.O.	Diffuse RT spike-wave with occasional LT synchrony	Group A	None	I.Q. 74	Mature, friendly	Not handicapped for future employment; integrated family relationship
J.H.	RT frontal spike-wave with occasional bilateral synchrony	Group B complex partial 1/week	Phenytoin Primidone Carbamazepine	I.Q. 84 Loss of recent memory	Friendly, cooperative	Permanently handicapped for employment. Works in sheltered workshop; dependent on parents. Independent for personal needs.
J.K.	RT frontotemporal spike and slow waves	Group B	Phenytoin Carbamazepine Primidone	I.Q. 81 Memory intact; conceptual activity good	Well-adjusted	Handicapped for future employment by partial seizures
T.C.	RT frontotemporal spiking	Group B	Phenytoin Phenobarbital	I.Q. 74 No impairment of cognitive abilities	Mild depression; normal affect	Lives alone; given total disability under social security preoperatively
J.K.	Normal	Group A	Phenytoin	I.Q. 112 Normal	Mature	Works steadily as welder
J.C.	Bilateral asynchronous spiking	Group B	Phenytoin Primidone	I.Q. 84 Fair cognitive abilities	Immature, selfish, friendly	Sheltered workshop
P.G.	RT temporal spike and slow wave with occasional generalization	Group D undocumented	Phenytoin Primidone	"Witless"	Infantile	Nursing home
C.E.	— — —	— —	— —	— — —	— — — —	— — — — —

showed the same discharges in the left frontotemporal area. Activity in the right hemisphere was normal. In August 1976, he had a single generalized tonic-clonic seizure. His phenytoin level was only 3.2 μg per milliliter.

Summary. Operation: complete extraventricular corpus callosum section, fornix and anterior commissure not divided. Complications: mild aseptic meningitis, high intracranial pressure, presumably from CSF malabsorption, bacterial meningitis. Postoperative hospital stay: 61 days. Followed: 7 months. Reduction of incapacity: ictal: generalized akinetic seizures, group A—excellent but under 1 year; complex partial seizures, group A—excellent but under 1 year. Mental: improved cognitive abilities. Emotional: open, friendly, hyperactive. Social: employable; no longer a burden at home.

Comment. The high intracranial pressure following surgery, supported by an abnormal infusion test, suggested a difficulty in absorbing CSF, possibly due to widespread compression of the subarachnoid spaces over the right hemisphere and plugging of the arachnoid granulations by inflammatory cells and detritus.

Observations. Ten patients underwent cerebral commissurotomy: Three were complete, five were frontal, and two had total division of the corpus callosum (with hippocampal commissure) but no other commissures.

With the possible exception of case 7, no seizures were worse after surgery (table). Commissurotomy seemed to halt convulsions, reduce them, or alter their character for the better. Generalized seizures either stopped entirely or were converted to partial seizures. The operation also seemed to have a good effect on complex partial seizures. It was apparent, however, that anticonvulsants would be required after commissurotomy, for partial seizures still occurred in some patients to a variable and unpredictable extent.

The operation seemed to be most effective in those patients with obvious, proved, unilateral brain damage, as in cases 1 and 9. However, some patients did well, even though focal brain damage could not be clearly determined, as in case 5.

Invasion of the ventricular system was hazardous. Ventriculitis (septic and aseptic) and hydrocephalus were the most serious complications. The hydrocephalus was of the communicating variety and possibly due to a large volume of CSF welling up into a nonabsorbing subdural space, when the subarachnoid space along the anterior portion of the right hemisphere was compressed by

Table. Analysis of first series (cont.)

Overall evaluation of surgery	Comment
Excellent	Cerebral commissurotomy may be a better alternative to hemispherectomy.
Improved	Surgery changed character of seizures and made them manageable, but complications unacceptable.
Improved	Since one deficit not substituted for another, and generalized seizures stopped, considered improved. But partial seizures continue.
Improved	Living reasonably normal life. Has not injured himself since surgery; no longer toxic doses of anticonvulsants; independent.
Excellent	Had long seizure-free interval before surgery. Seizures were bizarre. Puzzling that EEGs became normal. Marked improvement in psychologic tests could be due to diminished doses of anticonvulsants.
Improved	RT temporal lobectomy March 1972 revealed old, ruptured angiomatous malformation. Seizures continued until commissurotomy achieved control.
Poor	Lost to follow-up. Angry disappointed mother. RT temporal lobectomy at age 9.
–	Sudden death 12 days postoperatively after seemingly excellent recovery from surgery. Autopsy showed hemorrhagic infarct RT frontal lobe.

obliterated by retractors. The aseptic meningeal reaction that followed surgery in most of these cases may also have contributed to occlusion of the arachnoid granulations. Septic ventriculitis and aseptic ventriculitis are well-known complications that follow entry into the ventricles.[22,23] The severity of these complications was reduced by leaving the ventricular system intact.

The acute disconnection syndrome occurred to a greater or lesser degree in all our patients. This is defined as a constellation of transient signs and symptoms that immediately follows commissurotomy, lasts for days or weeks, and is attributed to both surgical division of the forebrain commissures and compression of the right hemisphere. The syndrome, in part, seems to be a manifestation of those very subtle deficits in the transfer of sensory information that Gazzaniga and co-workers[6,7] discovered by complicated tests and Bogen[3] demonstrated by routine office examination. The severity of the acute syndrome seems to be directly proportional to the extent of division of the corpus callosum; the syndrome is characterized by mutism, bilateral grasp reflexes, bilateral Babinski responses, and focal motor seizures on alternating sides without loss of consciousness. Left-sided apraxia is often severe and may be mistaken for hemiplegia, probably resulting from sudden inability of the "aphasic" right hemisphere to translate verbal comprehension into action. This weakness, particularly in the leg, also may be due to compression of the medical part of the right hemisphere by retractors. A less acute variation is the "stranger's hand" sign,[24] in which the patient feels that his left hand no longer belongs to him. Agnosia for objects in the left visual field may be mistaken for hemianopsia, and there are competitive movements between the left and right hands. Confusion, lack of concentration, and regression to childish behavior may occur in varying degrees.

The acute disconnection syndrome may be confused with an untoward complication of surgery, such as intracranial hemorrhage or infarct, in the immediate postoperative period.

Discussion. *Historical perspective.* In 1940, Erickson[12] described experiments on the spread of epileptic discharge from one hemisphere to another in monkeys. He concluded that this discharge occurred largely or entirely by way of the corpus callosum. At the same time, and independently, Van Wagenen and Herren[1] began to

perform forebrain commissurotomies on epileptic patients. His rationale for surgery was based on clinical observations. He recognized that epileptics who subsequently had tumors or infarcts of the corpus callosum were often relieved of seizures. His operations varied considerably, but usually included division of one fornix and the anterior one-half of the corpus callosum. Occasionally, he sectioned the anterior commissure. He showed that patients could survive the operation without obvious mental or physical complications. His descriptions of the postoperative course, however, were too brief to be of value, and his longest follow-up was 5 months. He reported 10 cases, but Akelaitis[2,5] later indicated that Van Wagenen had operated on 26 patients. Akelaitis followed a few of them, but he was less interested in the effect of commissurotomy on seizures than in its effect on mental processes. He concluded that the operation had no effect on everyday behavior. Little was learned about the effect of Van Wagenen's operations on seizures beyond a few optimistic references.

In 1962, Bogen and Vogel started another series of commissurotomies for relief of intractable seizures, and by 1965 they had operated on 10 patients. They have now operated on more than 20, but they have not yet published their results on the whole series. They have published reports on various aspects of commissurotomy in selected patients.[3] They showed that the operation is safe and effective in controlling intractable seizures; that it produces no outward changes in everyday behavior; and that, as a by-product, it is a fruitful field for further understanding of brain function. Bogen and Vogel collaborated with Gazzaniga and associates[7] and Sperry and associates,[8] who performed special tests and showed that commissurotomy did disconnect one cerebral hemisphere from the other and that each acted as a single brain with "its own" thoughts and feelings. Memory stored in one hemisphere could not be retrieved by the other. The right hemisphere was "aphasic" and "agraphic," but superior to the left in recognizing visuospatial relationships.

Luessenhop[4,5] performed commissurotomies on four children. He divided the entire corpus callosum, one fornix, and the anterior commissure, as did Vogel and Bogen, although he did not perform their frontal commissurotomy[1,8] (in which the splenium was spared for seizures originating in the frontal or temporal lobes). Luessenhop declared the results excellent in "children with clear-cut hemispheric lateralization...."[5]

In our 10 patients, we were disconcerted that postoperative complications were more frequent and more debilitating than other authors have described, despite microsurgical techniques and smaller exposures. When patient 8 died, we decided to perform no more commissurotomies until we could be reasonably certain that the operation would be safe, helpful, and rooted in the scientific method. After a year and one-half of analyzing our records, we concluded that commissurotomy would be safer if we did not violate the ventricles; that cases 1, 5, and 9 had proved its potential worth; and that in the future, we must refine the surgery by dividing only the corpus callosum and, necessarily, the underlying hippocampal commissure. This would make the operation uniform and give us information about the function of these commissures on the propagation of seizures and their role in the normal function of the brain.

There is considerable evidence that the corpus callosum plays the major role in the spread of seizure discharges,[12,13,16] weaker evidence for the role of the anterior commissure, and still weaker evidence for the part played by the fornix or massa intermedia. Division of the anterior commissure and the anterior half of the corpus callosum can diminish seizures,[1,8] but the same result might be obtained by dividing only the anterior commissure or only the anterior part of the corpus callosum. A stepwise approach seems necessary.

If we begin by dividing the whole corpus callosum, we may eventually be able to control seizures by dividing only a part, depending on the site of origin of the seizures. For example, there is already persuasive evidence that large areas of the neocortex of the temporal lobe project through the central portion of the corpus callosum, while the rest project through the anterior commissure.[3,17]

It may be necessary to divide the fornix or anterior commissure for certain forms of complex partial seizures. But unless we start with the major commissure, the corpus callosum, we will never know. For these reasons, we have embarked on a second series of commissurotomies beginning with case 9. Briefly, the following conditions must be fulfilled:

The patient must have intractable seizures that are refractory to a long, intensive program of anticonvulsants managed by neurologists and not amenable to standard methods of resection. The careful monitoring of blood levels of anticonvulsants is now an important addition to the medical treatment of seizures, as Peppenger and his associates[2,8] showed. Reliable values were not available at the time that most of our patients were referred for surgery. Such monitoring is now routine in the management of epileptics.

The patients must have a reasonable chance for independent life if their seizures can be controlled. No patient will be deemed a candidate for surgery on the grounds that "there is nothing to lose." Relatives must be concerned, attentive, and willing to see the patient through a long convalescence.

Patients must undergo neurologic examination and observation in the hospital with studies that include skull x-ray, cerebral angiography, pneumoencephalography, CAT scan, serial EEGs, neuropsychologic tests, and in some patients, depth electrode studies.

With respect to the surgical procedure, dexamethasone and prophylactic antibiotics will be used. The operation itself will be carried out using the operating microscope under 16 power and the same small craniotomies, but only the corpus callosum (and hippocampal commissure) will be sectioned, sparing the ependymal lining that covers the roof of the ventricles. Postoperatively, a close follow-up will be the rule, by a neurosurgeon, neurologist, clinical psychologist, and research psychologist. Until we know more, we will not exclude patients solely because

have no clear-cut unilateral brain damage, although we believe that if this can be proved, they will have a better chance for relief of seizures.

Conclusions. Cerebral commissurotomy may, eventually, play a small but definitive role in the treatment of intractable epilepsy. However, the operation must be refined and the criteria for selection of patients clarified. Achievement of these goals requires a carefully controlled, multidisciplinary approach whereby each patient is given the benefit of all previous experience, and provides valuable clues to better treatment of the next patient.

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