Cerebral hemispherectomy for seizures with hemiplegia

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CEREBRAL hemispherectomy has an interesting history, starting in 1928 when Dandy at Johns Hopkins[1] and L'Hermitte[2] in France independently introduced the operation in an effort to cure patients with malignant gliomas of the cerebral hemisphere. Experience soon showed, however, that neither prolongation of life nor palliation was any more effectively achieved than with more conservative surgical and medical tactics. Cerebral hemispherectomy for brain tumors has rarely been performed since the late 1930s and 1940s.

The procedure was revived, however, as a result of the 1950 report by the South African neurosurgeon Krynauw on cerebral hemispherectomy carried out in 12 patients with infantile hemiplegia and severe, medically refractory seizures.[3] His impressive results in reducing seizure tendency in this small, highly selected patient population were quickly verified in neurosurgical centers in various parts of the world.[4–24] Although the operation was applicable only to a tiny fraction of the overall population of patients with seizure disorders, by 1961 reports on nearly 300 cases had been published,[25] and by 1972 the number of cases reported had risen to 400.[26] Most centers reported essentially similar results, with a complete or nearly complete reduction of seizure tendency occurring in 80% to 85% of the patients. Severe behavioral disturbances, which often occur in this patient population, were also markedly lessened in nearly as high a proportion of cases.[27–31]

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ANATOMICALLY COMPLETE HEMISPHERECTOMY

The first hemispherectomy at the Montreal Neurological Institute (MNI) was carried out by Penfield in 1952. By 1968 the series consisted of 29 patients. In 24 of these 29 patients, the cerebral hemisphere was removed at one operation. In the remaining five patients, hemispherectomy was completed 2 to 11 years after a lesser cortical excision had failed to produce satisfactory reduction of the seizure tendency. A complete or nearly complete reduction of the seizure tendency was observed in 86% of the 27 patients who survived the first postoperative year (*Figure 1*), with 41% becoming and remaining seizure-free for 7- to 35-year follow-up periods.

Eleven patients had one or several attacks after being seizure-free for 3 to 20 or more years and had to be removed to the third follow-up group. One patient averaged less than two attacks per year over the follow-up period. Thus, these 12 patients are considered to have had a marked but not quite complete reduction of their seizure tendencies. The four patients with the poorest results derived considerable benefit, however, with two having 5% or less of their preoperative seizure rate and severity and the other two about a 50% reduction.

The effectiveness of hemispherectomy in reducing seizure tendency is illustrated by the case of patient W (*Figure 2*).

CASE REPORT

W's birth, early history and development were normal except for measles at 1 year of age. At 5 years of

Results of Anatomically Complete Hemispherectomy for Seizures
operated 1952 through 1968

Seizure free since discharge	9 pts.	11 pts. (41%)	23 pts. (86%)	27 pts. with follow-up data of 7-35 yrs. (median 23 yrs.)
Became seizure free after some early attacks	2 pts.			
Free 3 or more years, then rare or occasional attacks	11 pts.	12 pts. (45%)		
Marked reduction of seizure tendency	1 pt.			
Moderate or less reduction of seizure tendency	4 pts. (15%)			
Died in 1st postoperative year	2 pts.			
Total	**29 pts.**			

FIGURE 1. Results of anatomically complete hemispherectomy for seizures (operations 1952 through 1958).

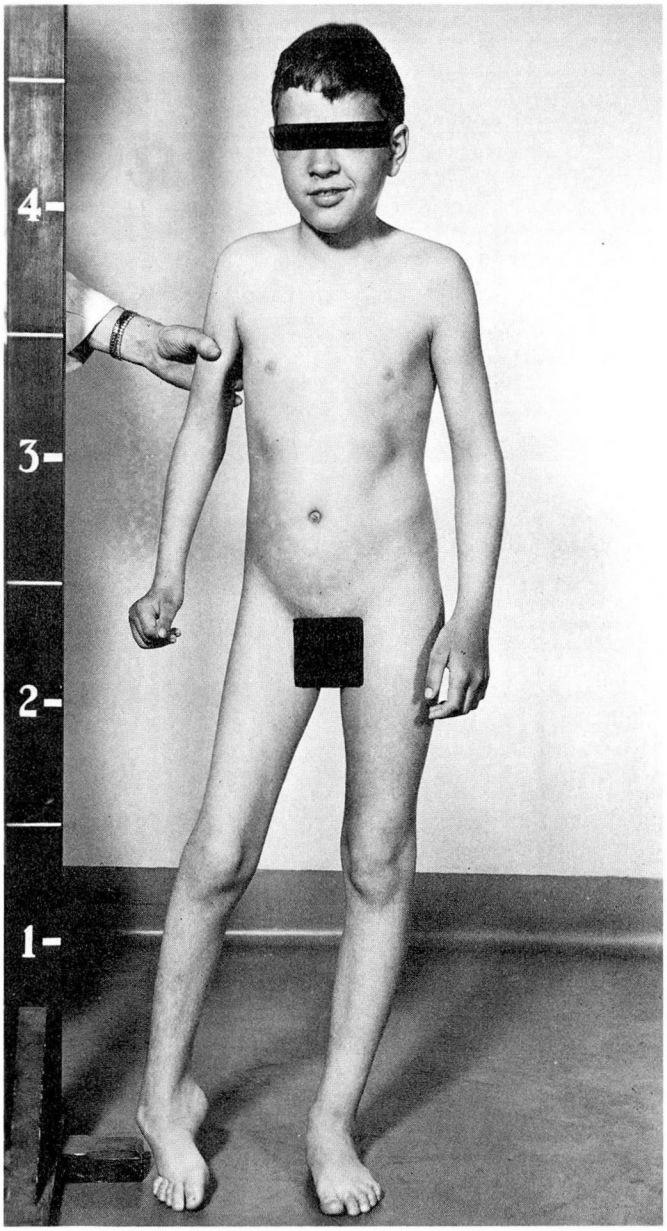

FIGURE 2. Patient W., aged 11 years.[32] Reproduced with permission.

age, without apparent cause, he developed minor right-sided somatomotor seizures. Soon after these began, he suffered two episodes of major status epilepticus, which left him with a right hemiplegia. The right-sided seizures increased in frequency until they often occurred at five- to ten-minute intervals for days or weeks at a time, and his seizure-free intervals rarely exceeded one to two days. The year before his operation he had been confined to bed most of the time because of the frequency of the seizures and as a result developed a contracture of the right ankle in a position of equinovarus (*Figure 2*).

At the onset, at 5 years of age, his pneumoencephalogram was normal, but four air studies over the next 6 years showed progressive destruction of the left cerebral hemisphere. Preoperatively we attributed this slowly progressive brain damage to the effect of the frequent right somatomotor seizures on the left hemisphere.

He was operated upon in 1955 and the left cerebral hemisphere removed in one piece superficial to the basal ganglia and the thalamus (*Figure 3*).

To our surprise, microscopic examination of the specimen showed the typical picture of encephalitis with perivascular cuffs of round cells, glial nodules and diffuse proliferation of microglia (*Figure 4*).

In other areas, there were scattered patches of spongy degeneration with few or no inflammatory cells remaining. Thus, our preoperative impression that the focal seizures were damaging the cerebral hemisphere was incorrect. Instead, both the slowly progressive brain destruction and the focal seizures were due to an underlying, unsuspected chronic brain disease.

Postoperatively his hemiplegia was unchanged, he was seizure-free (*Figure 5*), and his full-scale IQ rose slightly from 53 to 58.

He was able to go to school for the first time in 2 years, but in an ungraded class. He then attempted to

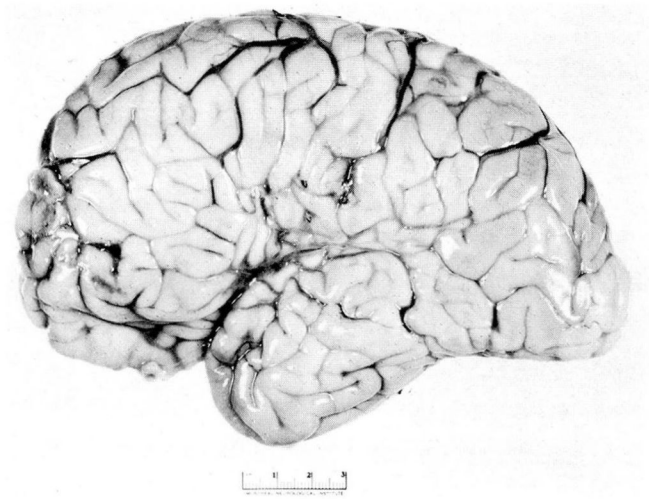

FIGURE 3. Patient W., Surgical hemispherectomy specimen.[32] Reproduced with permission.

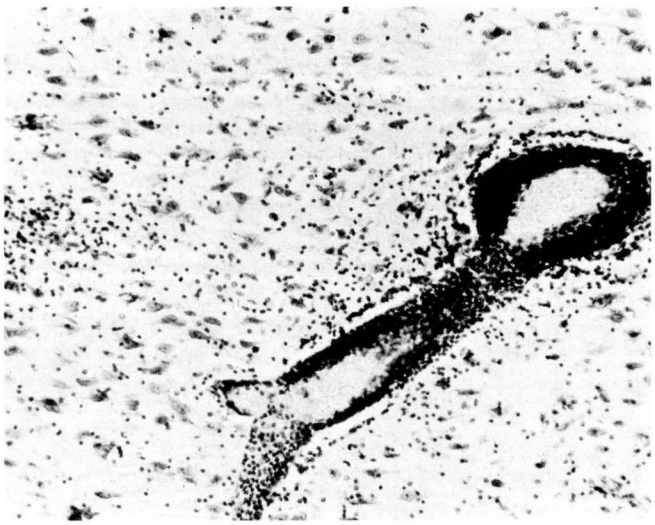

FIGURE 4. Patient W., surgical specimen, microscopic.[32] Reproduced with permission.

go to a trade school, but was unable to cope with the work. He subsequently kept busy helping with light chores at home and in his neighborhood and was a happy, likeable, and willing worker.

After a gratifying seizure-free, neurologically stable postoperative course of nearly 10 years, he became lethargic, ataxic and increasingly spastic on both sides over a period of several weeks. Re-exploration showed the hemispherectomy cavity filled with dark, viscid fluid containing high levels of protein and iron. A subsequent Torkildsen shunt from the hemispherectomy cavity to the cisterna magna resulted in a prompt but partial recovery. Several months later, however, neurologic deterioration recurred, and he died 1⅓ years after the shunt and 12 years after the hemispherectomy.

He was the first patient in whom we recognized the late complication of anatomically complete hemispherectomy—superficial cerebral hemosiderosis (SCH)—that resulted in the virtual abandonment of the operation again during the late 1960s and the 1970s. The unfortunate lad was also the first patient in whom we identified the syndrome of "chronic encephalitis" and seizures, which has aroused considerable interest and discussion in recent years.[32,33]

LATE COMPLICATIONS OF ANATOMICALLY COMPLETE HEMISPHERECTOMY

Late complications like those sustained by W, appearing 4 or more years after anatomically complete cerebral hemispherectomy, in patients who previously had been doing well and were neurologically stable, were first reported in 1964 by the French team, Laine, Pruvet, and Osson.[34] Their report was followed in 1966 by Oppenheimer and Griffith's report of similar late complications in the Oxford series of hemispherectomy patients.[35] It soon became clear that this late and sometimes fatal complication developed in a quarter to a third of the patients in most of the reported hemispherectomy series of any size in which a significant proportion of the patients had been followed for long periods.[36–41]

In the MNI series of 29 patients with anatomically complete hemispherectomy, whose results were shown in *Figure 1*, two died in the first postoperative year of an encephalopathy not recognized preoperatively. Eleven of the remaining 27 patients have developed SCH, 5 to 24 years after surgery. Five of these 11 patients have died of this complication; three made partial recoveries but were left with significant increases in their previously stable neurologic deficits. The remaining three patients, who were diagnosed and treated early after onset of SCH, made good recoveries back to their precomplication neurologic status and have remained neurologically stable to date.

We have not encountered SCH in our series of 57 patients who have had a subtotal hemispherectomy (removal of ⅔ to ⅘ of the hemisphere) and have been followed for 4 to 34 years. It thus seems clear that the

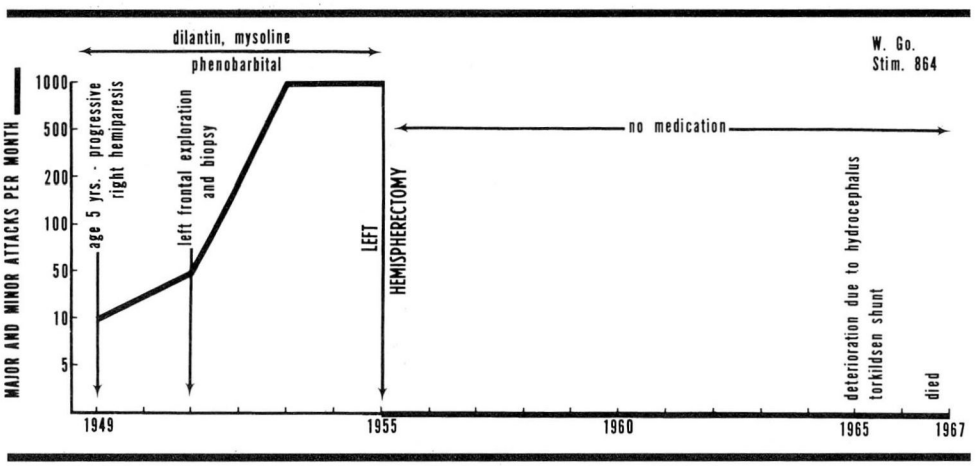

FIGURE 5. Patient W., seizure frequency diagram.

preservation of even a small segment of the damaged cerebral hemisphere protects the patient against the gradual seepage of red blood cells into the large removal cavity over the years that often results in the syndrome of SCH. This syndrome was originally described by the German pathologist Noetzel in 1940.[42] The pathology of the condition was reproduced experimentally in dogs by Iwanowski and Olszenski in Saskatoon in 1960.[43] They showed that 15 to 25 injections of the dogs' own blood, or hemolyzed red blood cells, reproduced the neuropathologic findings of SCH seen in man.[44–46] One or two injections, however, were not sufficient.

SCH, a late postoperative complication, is not to be confused with the *early* postoperative complication of persisting low-grade increase in intracranial pressure that sometimes follows removals of large portions of a cerebral hemisphere and is due to inadequate absorption of cerebrospinal fluid secondary to an extensive removal of the pia-arachnoidal membrane. This early pressure complication is particularly likely to occur in patients in whom the original brain insult has produced some chronic fibrosis of the leptomeninges, as often occurs after head injury with extensive subarachnoidal hemorrhage or after meningoencephalitis. This early postoperative increase in intracranial pressure usually resolves spontaneously, but if it persists beyond the third or fourth postoperative week, a cavity-peritoneal shunt should be carried out without delay. With prompt shunting, this early postoperative pressure complication does not have a deleterious long-term effect, in contrast to the devastating and insidious late complication, SCH.

FUNCTIONAL HEMISPHERECTOMY

Recognition of SCH ultimately led to the development of the modified operation we now call a functional hemispherectomy. This modified operation, consisting of an anatomically subtotal but functional complete hemispherectomy, has been carried out at the MNI since 1974.[47–49] The procedure consists of removing the central part of the hemisphere and the temporal lobe, leaving the anterior half of the frontal lobe and the posterior third of the hemisphere intact and vascularized (*Figure 6*).

These areas are then disconnected from the "good" hemisphere and from the upper brain stem by sectioning the white matter in front of the rostrum of the corpus callosum down to the medial leptomeningeal membrane on the falx and by similarly sectioning the white matter behind the splenium of the corpus callosum down to the leptomeningeal membrane on the falx and tentorium. The two persisting brain segments are thus functionally disconnected from the brain stem and from the "good" hemisphere.

Functional hemispherectomy has been carried out at the MNI in 21 patients between 1974 and the end of 1987. The resulting reduction of seizure tendency is presented in *Figure 7*.

The important point of comparison with anatomically complete hemispherectomy (*Figure 1*) is the 82% complete or nearly complete reduction of seizure tendency in this series compared to 86% in the anatomically complete hemispherectomy series. The 82% are all seizure-free at present, but with longer follow-up, some of the patients in these two seizure-free groups will undoubtedly be removed to the third and fourth follow-up groups; so we cannot claim that functional hemispherectomy produces a higher percentage of completely seizure-free patients than does anatomically complete hemispherectomy. It is worth noting that the three patients with the poorest results, as in the anatomically complete hemispherectomy series, did derive considerable benefit since the postoperative seizure rate and severity were approximately 1%, 10%,

and 20% of the preoperative status respectively. Four patients are recent and have less than 2 years follow-up data.

Preoperatively nearly two thirds of the patients in both the anatomically complete and the functional hemispherectomy series exhibited significant behavioral abnormalities. Postoperatively, all of these patients showed definite improvement in behavior, and in some of them improvement was marked. Patients with normal behavior preoperatively remained unchanged in this regard postoperatively.

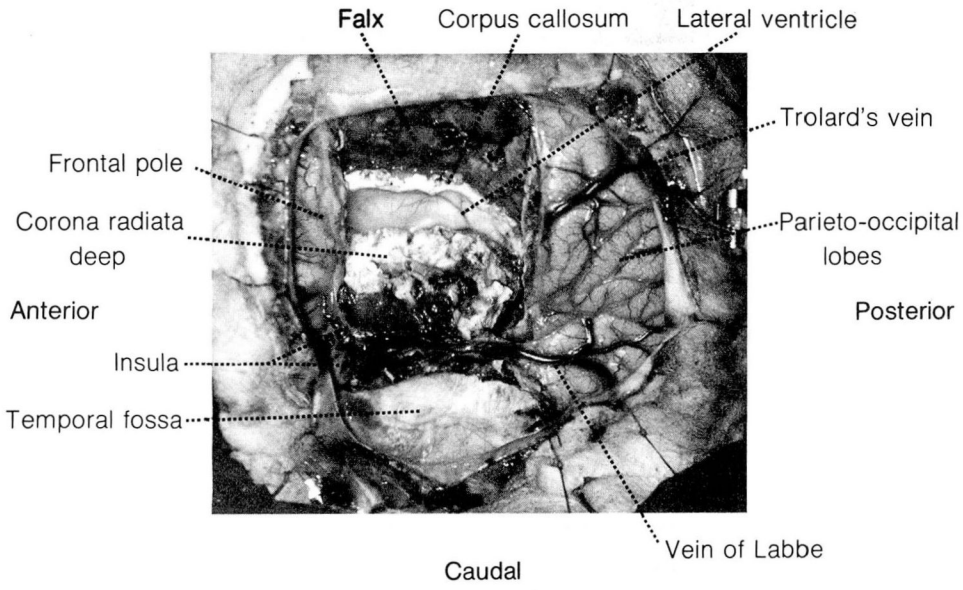

FIGURE 6. Functional hemispherectomy, operative photo.[49] Reproduced with permission.

Results with regard to intellectual functions are also similar in both the anatomically complete and the functional hemispherectomy groups. A rise of 6 to 20 points of the full scale IQ between the preoperative and the latest postoperative testing occurred in nine patients in the anatomically complete hemispherectomy group, and in nine patients in the functional hemispherectomy group. The full-scale IQ was unchanged (+5 to −5) in seven and five patients, respectively. There was a fall of 6 to 12 points in four patients of the former and one of the latter group. In each of these five patients, however, only the early, 2 to 3 week postoperative, neuropsychology tests were available. Both early postoperative and late postoperative psychology tests, 1 or more years after operation, were available in 18 patients of the two groups. In 13 of these 18 patients, the full-scale IQ had risen 6 to 19 points between the early and the late postoperative tests. In four patients, the full-scale IQ tests were unchanged (+5 points). A fall of 13 points was noted in the remaining patient, probably the result of late development of SCH, for which she required three shunting procedures. Either the pre- or the postoperative IQ test was not carried out in ten patients of the two groups; therefore, no pre- and postoperative comparisons could be made in these ten. Five patients of the two groups were untestable because of frequency and severity of seizures, or severe behavioral problems.

Results of Functional Hemispherectomy for Seizures
operated 1974 through 1987

Seizure free since discharge	12 pts.	14 pts. (82%)	14 pts. (82%)	17 pts. with follow-up data of 2-11 yrs. (median 5 yrs.)
Became seizure free after some early attacks	2 pts.			
Seizure free 3 or more years then rare or occasional attacks	0	0 pts.		
Marked reduction of seizure tendency	0			
Moderate or less reduction of seizure tendency	3 pts. (18%)			
Less than 2 years follow-up	4 pts.			
Total	**21 pts.**			

FIGURE 7. Results of functional hemispherectomy for seizures (operations 1974 through 1987).

Nearly all of the patients in each series had significant improvement in socioeconomic status. Preoperatively the patients' socioeconomic status was determined by three factors: (1) level of mental retardation, (2) frequency and severity of seizures, and (3) presence or absence of significant behavioral abnormalities. Postoperatively, the main determinant of socioeconomic status was the level of intellectual capacity.

SUMMARY

The risk-benefit ratio of this functionally complete but anatomically subtotal hemispherectomy is strongly in favor of its more widespread and early use for the small group of unfortunate seizure patients who have maximal or near maximal hemiplegia and a complete or high-grade hemianopsia, and whose seizures constitute a significant handicap in regard to schooling and psychosocial development despite an adequate trial of appropriate antiepileptic medication. The earlier the "good" hemisphere and the upper brain are spared the nociferous effect of continual bombardment by widespread high-amplitude epileptiform discharges, the more effectively motor, sensory, intellectual, and psychosocial development can take place in the remainder of the nervous system.

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