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ORIGINAL ARTICLE

Anatomical hemispherectomy revisited—outcome, blood loss, hydrocephalus, and absence of chronic hemosiderosis

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Abstract

Purpose To evaluate microsurgical trans-sylvian trans-ventricular anatomical hemispherectomy with regard to seizure outcome, risk of hydrocephalus, blood loss, and risk of chronic hemosiderosis in patients with intractable seizures selected for surgery using current preoperative assessment techniques.

Methods Out of 86 patients who underwent hemispherectomy between February 2000 and April 2019, by a single surgeon, at a tertiary care referral center, 77 patients (ages 0.2–20 years; 40 females) who had an anatomical hemispherectomy were analyzed. Five of these were 'palliative' surgeries. One-stage anatomical hemispherectomy was performed in 55 children, two-stage anatomical hemispherectomy after extraoperative intracranial monitoring in 16, and six hemispherectomies were done following failed previous resection. Mean follow-up duration was 5.7 years (range 1–16.84 years). Forty-six patients had postoperative MRI scans.

Results Ninety percent of children with non-palliative hemispherectomy achieved ILAE Class-1 outcome. Twenty-seven patients were no longer taking anticonvulsant medications. Surgical failures ($n = 4$) included one patient with previous meningoencephalitis, one with anti-GAD antibody encephalitis, one with idiopathic neonatal thalamic hemorrhage, and one with extensive tuberous sclerosis. There were no failures among patients with malformations of cortical development. Estimated average blood loss during surgery was 387 ml. Ten (21%) children developed hydrocephalus and required a shunt following one-stage hemispherectomy, whereas 10 (50%) patients developed hydrocephalus among those who had extraoperative intracranial monitoring. Only 20% of the shunts malfunctioned in the first year. Early malfunctions were related to the valve and later to fracture disconnection of the shunt. One patent had a traumatic subdural hematoma. None of the patients developed clinical signs of chronic 'superficial cerebral hemosiderosis' nor was there evidence of radiologically persistent chronic hemosiderosis in patients who had postoperative MRI imaging.

Conclusion Surgical results of anatomical hemispherectomy are excellent in carefully selected cases. Post-operative complications of hydrocephalus and intraoperative blood loss are comparable to those reported for hemispheric disconnective surgery (hemispherotomy). The rate of shunt malfunction was less than that reported for patients with hydrocephalus of other etiologies Absence of chronic 'superficial hemosiderosis', even on long-term follow-up, suggests that anatomical hemispherectomy should

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be revisited as a viable option in patients with intractable seizures and altered anatomy such as in malformations of cortical development, a group that has a reported high rate of seizure recurrence related to incomplete disconnection following hemispheric disconnective surgery.

Keywords Hemispherectomy · PET scan · Hydrocephalus · Hemosiderosis · Hemispherotomy · Seizures

Introduction

Anatomical hemispherectomy is the surgical gold standard for complete disconnection from the diseased hemisphere in intractable seizures of hemispheric origin. Yet, it has been abandoned as a procedure of choice for two reasons. First, deaths attributed to development of delayed chronic 'superficial cerebral hemosiderosis' in the pre-CT era [1–3]. Second, lower incidence of post-operative hydrocephalus and a reportedly comparable outcome of seizure control with subsequently developed hemispheric disconnective surgical procedures (functional, lateral, vertical, or peri-insular hemispherotomy) [4, 5]. In these publications, unfortunately, outcome with the hemispheric disconnective procedures was compared to the data from older anatomical hemispherectomy series, which lacked use of current preoperative evaluation and microsurgical techniques. Likewise, the more contemporary series of Di Rocco et al. and subsequent publication by O'Brien et al. have shown complete absence of chronic 'superifical cerebral hemosiderosis' even at long-term follow-up [6, 7]. In light of this, in this study, we evaluated the complication rate and seizure outcome with anatomical hemispherectomy in the current setting.

Methods

Data of 86 patients who had undergone hemispherectomy between 2000 and 2019 at the Children's Hospital of Michigan (Detroit, Michigan) were reviewed under an approved IRB protocol. Seventy-seven patients had anatomical hemispherectomy.

All patients were evaluated with scalp inter-ictal and ictal video-EEG recordings, MRI scan, 2-^{18}F-fluoro-2-deoxy-D-glucose (FDG) positron emission tomography (PET) scan, and neuropsychological assessments where appropriate. Patients with significant contralateral PET abnormalities were excluded but with less severe involvement were offered a 'palliative' resection [8, 9].

Type of surgery A one-stage anatomical hemispherectomy procedure was performed in 55 patients. A two-stage procedure was performed in 16 patients, in whom multilobar resections were planned, but the results of extraoperative intracranial EEG monitoring led to the decision to proceed with hemispherectomy. Six patients underwent hemispherectomy following failed previous two-stage focal resection. Sixteen of the 77 (21%) patients younger than 1-year age.

Hemispherectomy procedure All hemispherectomies were performed by a single surgeon (SS) using a microsurgical trans-sylvian trans-ventricular approach that has evolved over time with minor changes. The general method is of arterial disconnection, followed by hemispheric disconnection, and lastly, venous disconnection. This is different from the sequence of arterial ligation, venous interruption, and lastly hemisphere disconnection described in the classical anatomic hemispherectomy [10]. In our method, the sylvian fissure is opened widely, the middle cerebral artery (MCA) is coagulated and cut lateral to the lenticulostriate vessel, and medial dissection is done to identify the carotid bifurcation. Cortisectomy is then done to follow the anterior cerebral artery (ACA) through the rectus gyrus. Distal to the anterior communicating artery, the first branch from A2 is identified as the recurrent artery of Huebner and distal to it, the ACA of the ipsilateral side is coagulated and cut after visualizing the opposite ACA. The ipsilateral ACA is then traced superiorly to enter the lateral ventricle and thence through the ventricle followed posteriorly cutting the corpus callosum, completing the anterior and medial disconnections. At this point, the temporal lobe is retracted laterally from the insula to define the circular sulcus. This is then opened to enter the temporal horn. The fimbria of the fornix is incised to locate the subiculum. A cortisectomy is made in the subiculum to reach the margin of the tentorium which is then followed posteriorly, cutting and coagulating the posterior cerebral artery (PCA) as it passes over the tentorium. This cortisectomy is connected to the one from the front isolating the hemisphere from the thalamus, basal ganglia, and insula. The bridging veins to the sagittal sinus and from the temporal lobe to the base are then coagulated and cut. The entire hemisphere is then removed in one piece (Fig. 1). The residual part of the insula and the subiculum is then removed, and the choroid plexus along the fissure is coagulated and removed. A drain is left in the cavity for 4–5 days to remove any blood and debris to minimize post-operative hyperpyrexia [11]. A sub-galeal drain is left for 2 days to reduce post-operative scalp swelling and reduce the chances of epidural collection.

Post-operative MRI Forty-six patients had initial post-operative MRI at a mean of 1.08 years (SD 1.6; range, 0.02–8.6 years). Seventeen had a subsequent MRI at a mean of 5.86 years (SD

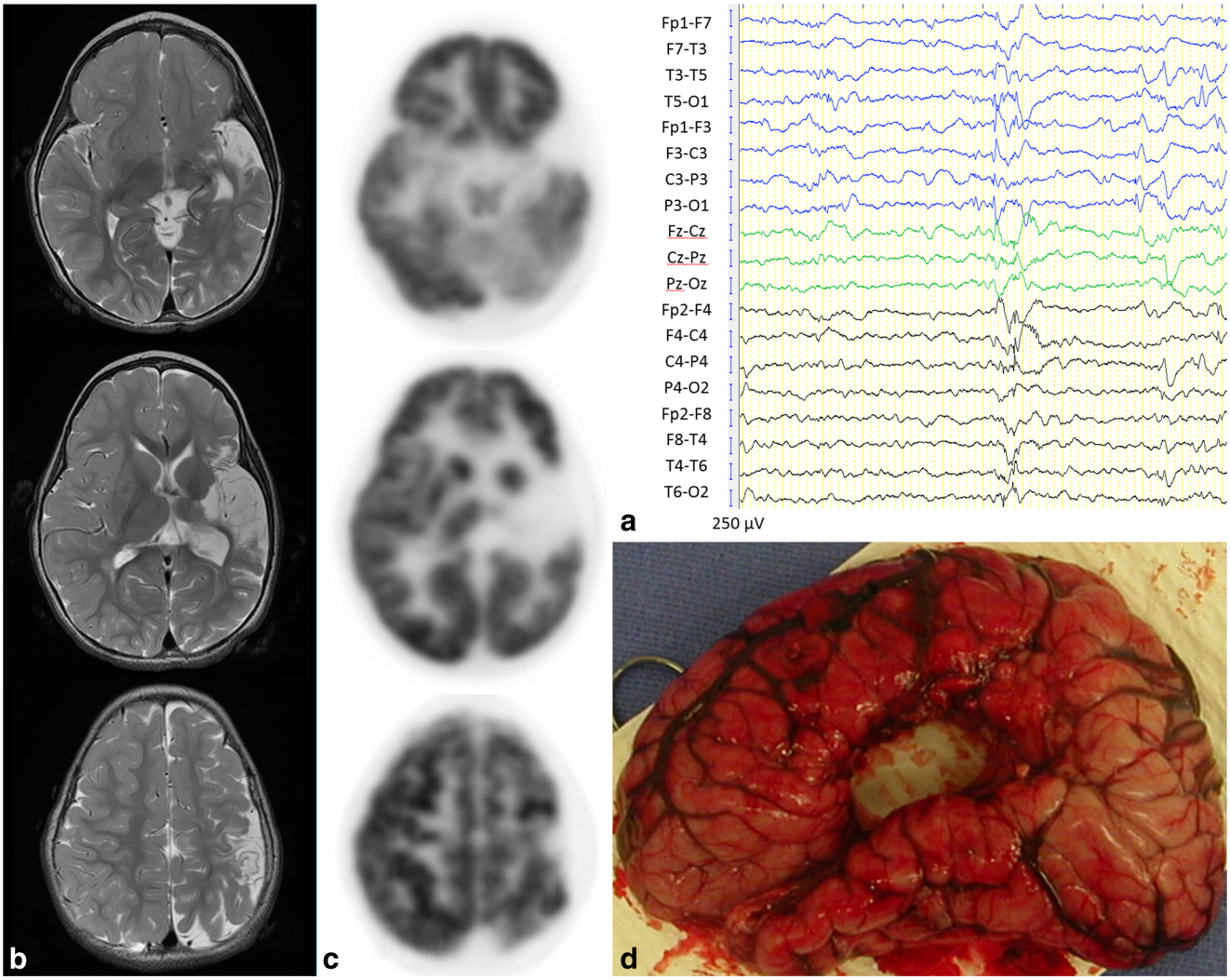

Fig. 1 A 24-month-old girl underwent left hemispherectomy. **a** Preoperative EEG showed frequent interictal spike-wave discharges in the left hemisphere with and without secondary bilateral synchrony. **b** Preoperative axial T2 MRI showed extensive encephalomalacia in the left middle cerebral artery territory. **c** Preoperative axial FDG PET also showed widespread hypometabolism in the left hemisphere. **d** The entire left cerebral cortex was removed en-bloc

4.3; range, 1.7–16.7 years) after the hemispherectomy. Thirty-three patients had blood product sensitive sequences as Gradient Recalled echo (GRE; 13 patients) or Susceptibility Weighted Angiography (SWAN; 20 patients).

Analysis of outcome Average period of follow-up was 5.66 years (±4.2 years). Surgical outcome was reported according to the 6-point scale of the International League Against Epilepsy (ILAE) classification system [12].

Figure 2 shows the number of patients who were analyzed for operative and peri-operative complications, seizure outcome, and long-term complications.

Results

There were 40 females and 37 males. Age at seizure onset ranged from 0.1 to 12 years, and age at surgery from 0.2 to 20 years. Ethnicity included 53 Caucasian, 14 African-American, 5 Hispanic, and 3 Middle-Eastern, and 2 Asians. The mean number of anticonvulsants prior to surgery was 3.75 (range 2–7) and 0.7 (range 0–3) at time of evaluation.

Etiology Table 1 shows the pathology in the resected hemisphere.

Surgical results One patient, who underwent a two-stage procedure, died on day 2 from Pseudomonas urosepsis. Of the 69 patients from the non-palliative group, 62 achieved a class 1 (seizure free) outcome (90%; 88% for patients who had one-stage and 95% for those who had two or three-stage surgery), 2 patients had class 2, 2 patients had class 3, and 1 each of class 4 and class 5 outcomes. Twenty-seven patients were off anticonvulsants medication. Four patients with class 3 or poorer outcome

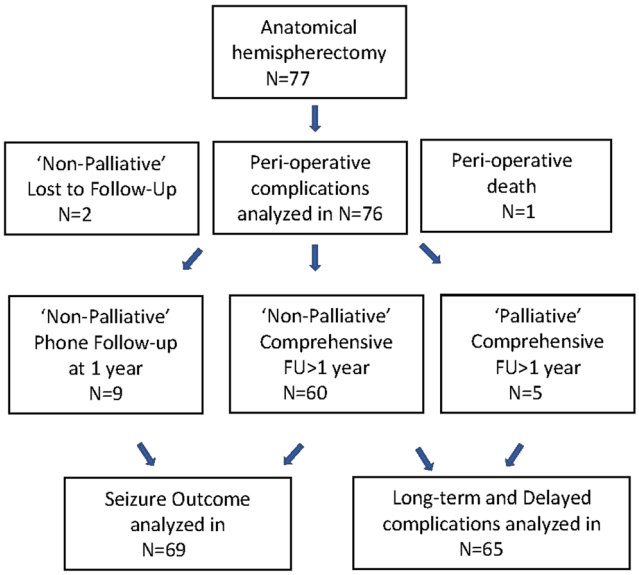

Fig. 2 Flow chart showing the number of patients in each category of analysis

are described in Table 2. Data of five patients who underwent palliative hemispherectomy is summarized separately in Table 3.

Intraoperative blood loss The mean intra-operative blood loss was 387 ± 383 ml (28% of blood volume). There was no significant difference in blood loss between patients who underwent one-stage versus two-stage surgery ($p = 0.45$).

Post-operative complications Among 77 patients, in 1 of the 6 patients, who had a pre-existing shunt, the shunt was removed after surgery. Excluding 1 death and 2 patients lost to follow-up, in the remaining 68 patients, a new shunt was required in 10 patients (21%; 10/47), who had one-stage hemispherectomy and in 10 patients (50%; 10/21) who had two- or three-stage surgery. The decision to place a shunt was based on enlarging ventricles and symptoms of increased pressure. Ten shunts were done in the first 2 months, 5 in 1st year, 1 each in 2nd, 5th, 7th, and 10th year after surgery. The shunted patients had a mean follow-up of 8.9 ± 4 years. Eight patients had a malfunction, 4 of which were in the first 5 months, 1 each in 2nd, 3rd, 4th, and 5th year. Early revisions were related to valve upgrading for over-drainage and later to fracture/disconnection of the shunt ($n = 1$). Two patients required multiple revisions: one for recurrent over drainage concerns in the 1st year and has been free of revisions since then and another following an event of falling 7 years after surgery resulting in a subdural hematoma. Overall, the first-year shunt survival rate was 79%. Neither age at surgery, blood loss, nor duration of surgery was significantly associated with the requirement of a shunt. Thirty-five percent patient with malformation of cortical development (MCD; 10/29) and 15% (3/19) with seizures secondary to stroke required a shunt.

Three patients developed other postoperative complications; 1 developed a hematoma while still in the operating room and was re-explored; 1 patient developed a postoperative epidural hematoma (both of these patients had one-stage surgery); and one patient, who had two-stage surgery, had an infection, requiring cranioplasty. The rate of operative and peri-operative complications among 77 patients was 3.8%. One peri-operative death (1.2% mortality; 1/77) on day 2 was due to urosepsis, in a patient who underwent two-stage surgery.

Table 1 Etiology of seizures in 77 patients who underwent hemispherectomy

Etiology	No:
Malformation of cortical development	29
Hemimegelencephaly (8)	
Cortical dysplasia (5),	
Hemispheric (2)	
Hypothalamic hamartoma with cortical dysplasia (1)	
Polygyria (4), Uregyria (3; 1 had *E. coli* meningitis),	
Schizencephaly (3),	
Hypomelanosis of Ito (1)	
Peri-sylvian syndrome (1)	
Heterotopia (1)	
Stroke/Sturge Weber syndrome	19/13
Rasmussen encephalitis	8
Tuberous sclerosis	3
Non-specific gliosis	5

Post-operative MRI MRI did not show any evidence of hemosiderin deposition on the surface of the good hemisphere on the T2, GRE, or SWAN sequences.

Among patients who had GRE/SWAN sequences, in three who had a scan done within 2 weeks of the surgery, no hemosiderin staining was seen.

In 20 patients, who had an initial scan done in the first year after anatomical hemispherectomy (mean 0.5 years), six patients had hemosiderin staining in the posterior fossa that had resolved on the follow-up scan done at a mean of 4.03 years (range, 0.5–5.9 years) (Fig. 3). One patient, who had mild staining, did not have follow-up scans and has remained asymptomatic. Only one of these seven patients (14%) required a new shunt after hemispherectomy compared to five of the 13 who had no staining (38%; $p = 0.53$).

Seven patients had MRI between 1 and 3 years (mean 1.5 years) after the anatomical hemispherectomy. One patient, with faint hemosiderin staining at 1.8 years after surgery had no further follow-up scan and has remained asymptomatic. This patient had a shunt placed 1 month after hemispherectomy compared to 2 of the 6 (25%), without hemosiderin staining, who required a shunt.

Ten patients had a scan more than 3 years postoperatively (mean 7.7 years; range, 3.4–16.7 years). Only one patient, who had a traumatic subdural hematoma from a fall event

Table 2 Data on patients who continued to have persistent seizures after hemispherectomy

Sex	Age onset	Surgery age years	Pre-op AEDs	Post-op AEDs	Seizure semiology	Seizure frequency	Seizure free interval	ILAE	Pathology	Co-existing condition
F	10 years	11 years	7	3	absence seizure	Multiple daily	1 m	5	Encephalitis (anti-GAD)	Mosaic chromosome 7
F	5 years	6 years	3	2	generalized seizure	Weekly	4 m	4	Stroke of unknown etiology-	listeria meningitis, hydrocephalus VP shunt,
M	6 month	4 years	5	1	spasm	Multiple daily	22 m	4	Thalamic infarction	
M	2 years	16 years	2	3	Tonic/GTC	Multiple daily	–	3	Tuberous sclerosis	Prior corpus callosotomy

7 years after surgery, showed hemosiderin staining. This patient had a shunt placed within 2 months after hemispherectomy, and it was removed following resection of subdural hematoma years' later. She has remained shunt free since.

Discussion

Seizure outcome

Seizure control following hemispheric disconnection surgery is suggested to be not as good as after anatomical hemispherectomy, particularly in patients with MCD [13]. This may relate to a high incidence of incomplete disconnection reported to be from 6.8 to 54% [1, 14–18]. However, review of 1161 patients, from 29 studies and of 1528 patients from 56 studies, found no statistically significant difference in seizure outcome (73%) between the types of hemispherectomy procedures, but reported more complications with anatomical hemispherectomy [4, 5]. These results should be interpreted with caution as the analysis included older anatomical hemispherectomy series that lacked comprehensive preoperative evaluation with current imaging, or use of modern microsurgical techniques.

In the present series, 90% patients achieved a class 1 surgical outcome after anatomical hemispherectomy. These results are better than the published reports and meta-analyses [4, 5]. We attribute these results to stringent selection criteria use of FDG PET imaging, high volume of cases, experience of the surgeon, and exclusion of patients with significant contralateral hemisphere PET abnormality. In addition, FDG PET scan helped determine the functional integrity of the contralateral hemisphere that corelates with better developmental outcome and language re-organization [8, 19, 20].

All patients with MCDs had a good outcome. While this could be function of patient selection, however, the following literature suggests that the use of anatomic hemispherectomy rather than disconnection may have contributed to it. For example, in a series of 35 patients who underwent a vertical hemispherotomy, Traub-Weidinger et al. [21] had a 91.5% seizure-free outcome but 20% of their patients with MCD continued to have seizures. Likewise, Iwasaki et al. [22] had a poor outcome in 28% of patients with MCD after vertical hemispherotomy. Seven of the 8 failures, after lateral hemispherotomy, among 88 patients in Kiehna et al. [23] series, and, the majority of the 36 failures described by Vadera et al. [24], were in patients with MCD. Two-thirds of these

Table 3 Data on patients who underwent palliative surgery

Sex	Age of onset	Age at Surgery	Pre-op AEDs	Post-op AEDs	Seizure semiology	Seizure frequency	Seizure free interval	ILAE	Pathology
F	9 month	5 years	4	3	Febrile seizures; Myoclonic Sz; spasms	Multiple daily	6 m; myoclonic seizure free	5	Patchy gliosis
F	5 month	2 years	3	2	Spasms; generalized seizures; focal seizures	Multiple daily	10 m; focal seizure free	5	Schizencephaly; polymicrogyria
F	3 month	9 month	2	0	Extensor spasms	Multiple daily	No seizures	1	MCA Stroke from MRSA meningitis
M	6 month	2.5 years	5	1	Severe myoclonic epilepsy	Multiple daily	–	5	Bilateral hippocampal sclerosis
M	4 month	5 month	3	3	Generalized; focal; spasms	Multiple daily	–	5	Cortical Dysplasia; Hypomelanosis of Ito

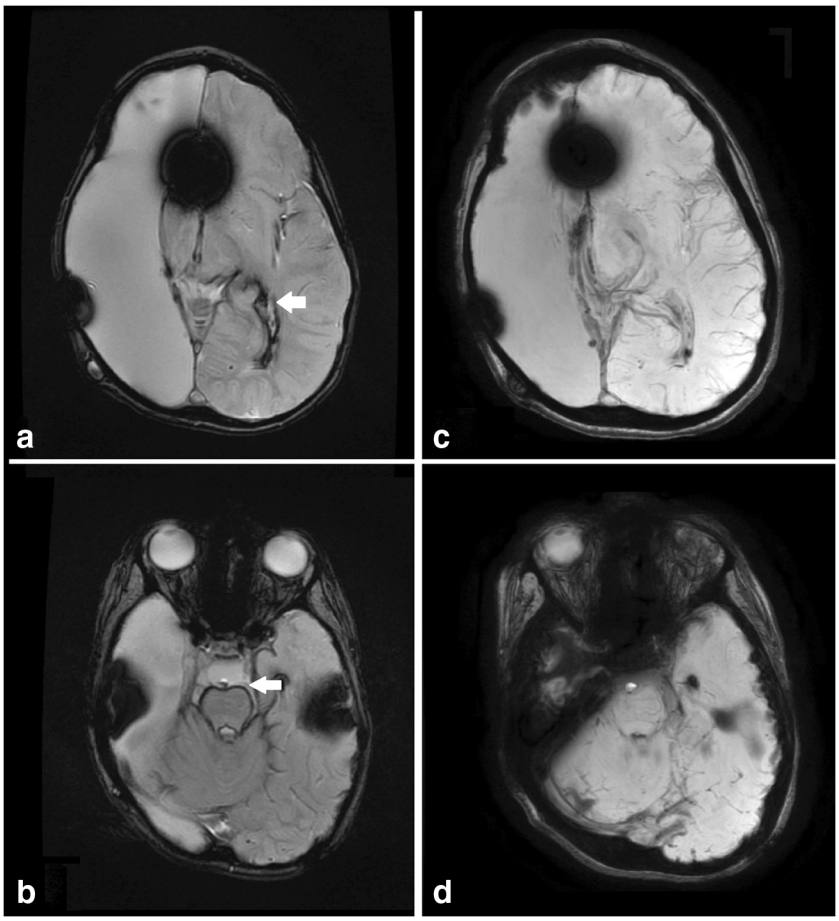

Fig. 3 **a**, **b** Postoperative *Gradient Recalled Echo T2 weighted (GRE)* MRI sequences at 6 months after hemispherectomy showing hemosiderin staining in the ventricles and over the brainstem and cerebellar surface (*white arrow*). Note that there is no staining over the convexity of the normal hemisphere. **c**, **d** Susceptibility-weighted angiography (SWAN) MRI images from the same patient 5.8 years after hemispherectomy. *SWAN* is 6 times more sensitive than GRE for hemosiderin staining. Note marked resolution of the hemosiderin with no staining of the brainstem, cerebellar, or ventricular lining

patients became seizure free after subsequent anatomic hemispherotomy [23, 24]. It is for this reason, we feel that the difference in outcomes in anatomical versus disconnective surgery is related to incomplete disconnection in latter. It may be reasonable to consider anatomical hemispherectomy as a viable option in patients with MCD, as it confirms that all white matter connections have been removed.

Inability to achieve seizure control in four patients suggests that even stringent evaluation may miss a more diffuse involvement (Table 2).

Risk of hydrocephalus

The high risk of postoperative hydrocephalus is cited as the major complications of anatomical hemispherectomy [1]. This may be skewed, in most analysis, by the inclusion of series of Peacock et al. [10], who did prophylactic shunt and had a shunt rate of 78% following anatomic hemispherectomy. Alternatives as functional, lateral, and vertical hemispheric disconnection surgery have a reported 2% to 30% rate of shunting depending upon the surgical technique and follow-up duration [2, 15, 25–29]. However, Lew et al. [2] showed that the risk of hydrocephalus is significantly higher following anatomical hemispherectomy (30% versus 20% for disconnective surgery, $p < 0.001$). Their analysis did not stratify the results to a one-stage or two-stage procedure. In our series, with one-stage anatomical hemispherectomy, the rate of hydrocephalus (21%; 10/47) was comparable to that reported in literature for hemispheric disconnective surgery [2] and to 22–26% for patients who had one-stage modified lateral hemispherotomy [1, 30] (Table 4).

In this series, the rate of hydrocephalus following anatomical hemispherectomy was similar to that of hemispheric disconnective surgery. Hence, long-term implications of a shunt and its attendant issues of malfunction and infection become an important consideration, if a choice of the surgical procedure is to be made, knowing that hemispheric disconnection surgery has a lower rate of seizure freedom. The 20% shunt failure rate, in this series, in the first year is lower than the 40% reported in shunt for hydrocephalus from other causes [31]. This may relate to the proximal catheter being in the cavity rather than the ventricle. For patients who require a shunt following hemispheric disconnection surgery, since the shunt is in the ventricle, a higher rate of malfunction may be expected.

Blood loss

The operative blood loss and the need for blood transfusion is an important complication of hemispherectomy [32]. As seen in Table 4, the blood loss does not appear to be very different among different procedures [1, 15, 22, 26, 27, 30]. Our approach of preserving the draining veins, till after the hemisphere has been completely disconnected, may have contributed to a lower blood loss compared to older series on anatomical hemispherectomy by Cook et al. [1]. Blood loss, however, appears to be least in open and endoscopic vertical hemispherotomy [22, 26, 27, 33, 34].

Cerebral Hemosiderosis

Oppenheimer et al. [3] in 1966 described 3 deaths in a series of 17 anatomical hemispherectomies. It was felt that this was a 'result of gradual seepage of red blood cells into the hemispherectomy cavity over a period of several years, perhaps as a result of trivial jolts to the head or of abrupt normal changes in the intracranial pressure due to sneezing or coughing, etc.' [35] resulted in chronic 'superficial cerebral hemosiderosis'. The reported incidence of 30% in the pre-CT era and the notion that chronic 'superficial cerebral hemosiderosis' leads to inevitable death brought about a bias against anatomical hemispherectomy [36, 37]. To minimize 'cerebral hemosiderosis', techniques to isolate the ventricular system using a muscle plug [38], dural patch [6], glue to seal the foramen Monro [39], prophylactic shunting [10, 40], and operations with preservation of disconnected brain tissue (functional hemispherotomy) to prevent movement-related hemorrhage were devised [35, 41]. Many of these developments happened in the post-CT era, even though reports concerning hemosiderosis have been practically absent since the seventies [42].

Interestingly, Davies et al. [43] in 1993 published a report on 17 patients, who had classic hemispherectomy between 1950 and 1971, about the same time as Oppenheimer's cases and had a mean follow-up of 28 years. This Minnesota series recorded only one patient who had developed a chronic subdural hematoma 6 years after surgery on the side opposite the hemispherectomy. They concluded that incidence and severity of late hemorrhagic complications of classic hemispherectomy are overestimated. Interestingly, there was a major difference in technique in the two series. In the series reported by Davies et al. [43], a single piece resection of the hemisphere was done after performing a vertical disconnection similar to description of Delalande [27] and Dorfer [26], whereas Oppenheimer et al. [3] removed the hemisphere in 'three or four blocks leaving behind gyrus rectus, hippocampus and hippocampal gyrus, part of the cingulate gyrus, thalamus, hypothalamus and most of the basal nuclei.' Perhaps, the latter approach may have contributed to a higher incidence of complications recorded by them.

Di Rocco et al. reported, in the discussion of their paper, absence of chronic hemosiderosis in 26 anatomical

Table 4 Blood loss and hydrocephalus with different techniques of hemispherectomy as reported in literature

Procedure Author (case series years)	Number	Age (years)	(% loss of estimated blood vol)/average blood loss (ml)/transfusion rate (%)	Post-operative hydrocephalus (FU)
Anatomical				
Cook et al. (1986–1997)	37	5.4	688 ml	78% (2 years)
Sood et al. (2000–2019)	77	6.0	(28%)/387 ml	21% (5.6 years) for one-stage hemispherectomy
Functional				
Cook et al. (1990–1997)	32	–	547 ml	9% (2 years)
Limbrick et al. (1995–2003)	14	7.2	(29%)/386 ml[a]	10% (2.3 years)
Peri Insular				
Limbrick et al. (2003–2008)	35	5	(23%) 391 ml[b]	10% (2.3 years)
Modified lateral				
Cook et al.[1] (1997–2002)	46		238 ml	22% (2 years)
Lew et al. (2004–2012)	50	9.1	340 ml	26% (3.5 years)
Villemure et al (–2006)	43	8	–	2.3%
Vertical				
Para-sagittal Delalande et al. (1990–2000)	83	8	/8%	15% (4.4 years)
Peri-thalamic Dorfer et al. (1998–2013)	40	5.5	/5%	2.5% (3.7 years)
Interhemispheric Iwasaki et al. (2001–2012)	8	1	44 ml/75%	0 (6.2 years)

[a] Blood loss was reported as 29% of estimated blood volume

[b] Blood loss was reported as 23% of estimated blood volume. Estimated blood Vol = 2*(age + 4)*75 ml

hemispherectomies, 18 of which had a follow-up of more than 8.5 years [6]. They felt that the late mortality reported in pre-CT era was more likely due to undiagnosed hydrocephalus rather than effects of Fe^{++} on brain parenchyma or recurrent hemorrahage [6]. Obrien et al. reported a similar absence of chronic hemosiderosis, at mean 7-year follow-up, in 19 patients who underwent anatomical hemispherectomy [7]. In the present series, at a mean follow-up of 5.7 years (range, 1 to 16 years; 25 patients with a follow-up of > 5 years), no patient developed symptoms of chronic 'superficial cerebral hemosiderosis' as described by Oppenheimer et al. [3].

There are no reports that show radiological hemosiderosis on MRI in the remaining hemisphere of patients who underwent anatomical hemispherectomy. Among 20 patients, who had a scan done within 1 year, 6 patients showed evidence of hemosiderin deposition, in the posterior fossa, that resolved on follow up scan at an average of 4 years, suggesting that the initial staining was post-operative, and, not from chronic recurrent micro-hemorrhaging. Further, except one patient who had a traumatic subdural hematoma, none of the other nine patients scanned at a mean of 7.7 years (3.4–16.7 years) after hemispherectomy showed hemosiderin staining that would suggest recurrent micro hemorrhaging. Finally, the rate of shunting was not related to transient early hemosiderin staining seen in some of the patients.

These series supports the view that in literature, the "reputation of anatomical hemispherectomy as an epilepsy tool has been unfairly blemished by the label of cerebral hemosiderosis as a delayed complication" [6, 7].

The complication rate in this series was low with no operative mortality. The 1.2% (1/77 patients) 30-day mortality compares favorably with the rates of 1.4% (4/285 patients) for hemispherotomy and 2.0% for functional hemispherotomy (2/96 patients) reported in the meta-analysis [4]. The operative and peri-operative complication rate of 3.8% for infections, epidural, subdural, and distant hemorrhages was lower than the 4.5% reported for hemispherotomy in the meta-analysis [4].

Conclusion

The present series shows that with the stringent preoperative evaluation, anatomical hemispherectomy can achieve seizure freedom in 90% of patients. The risk of postoperative hydrocephalus for one-stage anatomical hemispherectomy and intraoperative blood loss is comparable to that reported for other hemispheric disconnective surgeries. There is a lower rate of shunt malfunction should a shunt be needed. Absence of chronic 'superficial cerebral hemosiderosis' on long-term follow-up suggests that the term is misleading and overrated as a complication.

Anatomical hemispherectomy should be revisited as a viable option in patients with intractable seizure and altered anatomy as in MCD.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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