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Effects of temporal lobectomy on consciousness-impairing and consciousness-sparing seizures in children

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Abstract

Purpose Most children with medically refractory temporal lobe epilepsy (TLE) become seizure free after temporal lobectomy, but some individuals continue to seize. As studies of temporal lobectomy typically focus on seizure freedom, the effect of surgery on seizure type and frequency among children with persistent seizures is poorly understood. Seizures which impair consciousness are associated with increased morbidity compared to consciousness-sparing seizures.

Methods A retrospective cohort study was performed to evaluate the effects of temporal lobectomy on seizure type and frequency in children with intractable TLE.

Results Among 58 pediatric TLE patients with a mean (\pm SEM) age of 14.0 \pm 0.7 years who received temporal lobectomy, 46 (79.3 %) individuals achieved an Engel class I seizure outcome, including 38 (65.5 %) children who became completely seizure free (Engel IA). Mean follow-up was 2.7 \pm 0.4 years. While the number of patients experiencing simple partial seizures (SPSs) (consciousness sparing) decreased by only 23 % after surgery, the number of

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P. P. Sun · R. A. Kuperman · K. I. Auguste Pediatric Epilepsy Program, Children's Hospital and Research Center Oakland, Oakland, CA, USA children having complex partial seizures and generalized tonic–clonic seizures (consciousness impairing) diminished by 87 and 83 %, respectively (p < 0.01). SPS was the predominant seizure type in only 11.3 % of patients before resection, but in 42.1 % of patients with postoperative seizures (p < 0.01). Children with postoperative seizures experienced a 70 % reduction in overall seizure frequency compared to baseline (p < 0.05), having consciousness-impairing seizures 94 % *less* frequently (p < 0.05), but having consciousness-sparing seizures 35 % *more* frequently (p = 0.73).

Conclusions Seizure type and frequency are important considerations in the medical and surgical treatment of children with epilepsy, although complete seizure freedom remains the ultimate goal.

Keywords Children · Consciousness · Epilepsy surgery · Temporal lobectomy · Seizure type

Introduction

Temporal lobe epilepsy (TLE) is responsible for 15–20 % of epilepsy cases in children [1, 10]. Given that intractable seizures can lead to significant morbidity and increased risk of death, temporal lobectomy is an important treatment option for medically refractory TLE [11, 28]. Complete seizure freedom is the ultimate goal in pediatric TLE surgery, as it is the most important predictor of quality of life in epilepsy treatment [9, 31]. Unfortunately, 10–40 % of children continue to have seizures after temporal lobectomy [32, 35]. Factors which prognosticate seizure freedom in pediatric epilepsy surgery have been well studied, but seizure type and frequency in those children who do not achieve seizure freedom are less well understood. Patients with persistent seizures are often said to have "failed" therapy, but do some of them gain meaningful benefit from surgery?

Morbidity varies across the three main types of seizures in TLE, which include generalized tonic-clonic seizures (GTCSs), complex partial seizures (CPSs), and simple partial seizures (SPSs). GTCSs represent the most severe selflimited seizure type, during which seizure activity propagates to widespread distal brain regions, consciousness is lost, and convulsive motor activity ensues [13]. As in GTCSs, CPSs in TLE are also associated with impaired consciousness, but motor activity is less vigorous, often involving facial automatisms [14]. SPSs represent the least severe seizure type, during which consciousness is retained, and include self-limited auras [14]. Seizures which impair consciousness lead to significant morbidity, including motor vehicle accidents, drownings, poor school performance, and diminished quality of life [8, 16, 24, 27, 38, 41]. Consciousness-sparing and consciousness-impairing seizures also have differential effects on brain network activity, as shown in human intracranial electroencephalography (EEG) and functional neuroimaging studies [3, 4, 21] and also in animal models [17, 18]. Temporal lobectomy disrupts the networks underlying seizure generation, eliminating seizures in most cases, but what effect does surgery have on seizures among patients who do continue to have seizures?

The present study is a retrospective cohort study investigating pediatric patients undergoing temporal lobectomy for TLE. Seizure type and frequency are examined before and after surgery, with a particular focus on consciousnessimpairing (GTCSs and CPSs) versus consciousness-sparing (SPSs) seizure types, and predictors of seizure outcome are explored.

Methods

Patients and data collection

The medical records were reviewed for 61 consecutive temporal lobectomies in pediatric patients (age 0–19 years) with TLE. Surgeries were performed between January 1995 and December 2011 at the University of California, San Francisco (UCSF), and between January 2009 and December 2011 at Children's Hospital Oakland (CHO). A minimum of 1 year postoperative follow-up was required. Three children without adequate follow-up were excluded from the study, leaving 58 patients for whom data were analyzed. Study aspects were in compliance with UCSF and CHO clinical research policies, and research protocols were approved by the UCSF Committee on Human Research.

Decisions to offer surgery were made by a comprehensive team of pediatric epileptologists, neurosurgeons, neuropsychologists, neuroradiologists, and other practitioners. Standard preoperative workup included structural magnetic resonance imaging (MRI) and electroencephalography (EEG), and often also included neuropsychology evaluation. magnetoencephalography, positron emission tomography (PET), Wada testing of language and memory lateralization, and long-term video/EEG monitoring with or without electrocorticography (ECoG) via surgically implanted subdural and depth electrodes. Anterior temporal lobectomy was performed by one of five neurosurgeons, with over half of the procedures performed by the senior author of the present study (KIA). Resection included the anterior middle and inferior temporal gyri, anterior hippocampus, and amygdala, and was customized to incorporate regions of identified epileptogenic zones and/or cerebral lesions and to preserve eloquent cortex, where applicable. Intraoperative ECoG was utilized in approximately 70 % of surgeries to further guide resection. Awake intraoperative language mapping using direct cortical stimulation was used for six surgeries when the resection involved the dominant hemisphere and where patient maturity allowed. Surgical specimens were analyzed by neuropathologists.

All inpatient and outpatient provider notes, lab and diagnostic reports, and operative records were reviewed. Patient age, gender, handedness, duration of epilepsy, medication history, surgical history, MRI results, PET results, EEG results, use of implanted intracranial electrodes for long-term recording, details of resection extent, side of surgery, use of intraoperative ECoG or mapping, and pathological findings were recorded. Details regarding patients' epilepsy history and seizure semiology, including seizure type and frequency, were obtained from preoperative and postoperative charting entered by epileptologists. Specific seizure types tracked included GTCSs (bilateral convulsive activity with impaired consciousness and postictal confusion), CPSs (partial seizures with impairment of consciousness, awareness, or ability to interact during the event, but without convulsion), and SPSs (partial seizures with preserved consciousness, including isolated auras). Patients of age <5 years, in whom impaired consciousness may be more difficult to discern, were excluded from analyses involving seizure types. Epilepsy risk factors were recorded and tallied, including history of: (1) cerebral palsy or birth injury, (2) developmental delay or static encephalopathy, (3) febrile seizures, (4) head trauma, (5) central nervous system infection, (6) family history of epilepsy, (7) alcohol or drug abuse, (8) status epilepticus, and/or (9) cerebral ischemia. Seizure outcome as of latest follow-up with the epileptologist was determined using a modified Engel classification system [15].

Statistical analysis

To investigate factors associated with seizure outcome (Engel I versus II–IV), chi-square (χ^2) test was used for categorical variables (e.g., gender), and an unpaired Student's *t* test was utilized for continuous variables (e.g.,

age). Prior to utilizing parametric tests, normality of data was verified and Levene's test for equality of variances was used. For multivariate analysis, variables were dichotomized where applicable and entered into a multivariate logistic regression in a backwards fashion. Individual seizure types and the predominant seizure type (defined as the seizure type most commonly experienced for each patient) among patients before versus after resection were compared using χ^2 tests. *T* tests were used to compare preoperative and postoperative seizure frequencies among individuals with continued postoperative seizures. Odds ratios (ORs) were calculated with a 95 % confidence interval. Statistical significance was assessed at *p*<0.05, and statistical analyses were performed using SPSS version 20 (IBM, Somers, NY).

Results

Fifty eight of the 61 pediatric patients (95.1 %) who received temporal lobectomy for TLE during the study period had \geq 1 year of postoperative follow-up and were included in the study. Mean (±SEM) follow-up was 2.7±0.4 years. The mean (±SEM) patient age was 14.0±0.7 at the time of surgery, with an age range of 0–19 years, and 53.4 % of the children were male. Other patient characteristics are summarized in Table 1.

After surgery, 46 (79.3 %) patients achieved a favorable Engel class I seizure outcome, including 38 (65.5 %) children who were completely seizure free (Engel IA). Seizure outcome was Engel class II in nine patients (15.5 %), while two (3.4 %) individuals had an Engel III outcome, and one (1.7 %) child had an Engel IV outcome. Of those patients who achieved seizure freedom, 11 (28.9 %) had discontinued all seizure medications at the last follow-up, 17 (44.7 %) individuals remained on one agent, and ten (26.3 %) children were taking two medications.

Several factors were examined as potential predictors of Engel class I seizure outcome, as summarized in Table 2. While all 20 (100 %) patients with mesial temporal sclerosis (MTS) had an Engel class I outcome, only 68.4 % of children with other etiologies achieved this outcome (p<0.01). Similarly, MTS was the only significant prognosticator revealed by multivariate analysis, predicting seizure freedom with an odds ratio of 12.7 (1.35–125) over other epilepsy pathologies. Improved seizure outcomes were also observed among patients with well-localized preoperative EEG findings over those with a poorly localized EEG, although this factor did not reach statistical significance after multivariate analysis (p=0.06).

Pre- and postoperative seizure type and frequency were then investigated (Figs. 1, 2). Five (8.6 %) patients of age <5 years were excluded from this analysis, as impairment of consciousness may be more difficult to classify in young children. While the number of patients experiencing SPSs (consciousness sparing) decreased by only 23 % after surgery, the number of children having CPSs and GTCSs (consciousness impairing) diminished by 87 and 83 %, respectively (χ^2 =11.3, p<0.01) (Fig. 1a). Also, while SPS was the predominant (i.e., most common) seizure type in only 11.3 % of all patients before resection, it was more frequently (42.1 %) the predominant seizure type among patients still having seizures after resection (χ^2 =9.3, p<0.01) (Fig. 1b). These findings suggest temporal lobectomy has a greater impact on the number of patients having consciousness-impairing seizures than those having consciousness-sparing seizures.

Next, seizure frequencies were examined among the 19 patients with persistent postoperative seizures (Fig. 2a) and 34 patients who achieved complete seizure freedom after surgery (Fig. 2b). Children with continued seizures after temporal lobectomy experienced consciousness-sparing seizures 35 % more frequently than their preoperative baseline (t=0.3, p=0.73), but had consciousness-impairing seizures 94 % less frequently (t=2.0, p<0.05). The frequency of all seizures combined was decreased by 70 % after surgery in these patients (t=2.0, p<0.05). Notably, baseline seizure rates were somewhat lower in patients who ultimately became seizure free (Fig. 2b) compared to those with persistent seizures (Fig. 2a), but these differences were not significant (p>0.10 for each comparison). These results suggest that children who continue to have seizures after temporal lobectomy have significantly fewer seizures than before surgery, with a large decrease in the number of consciousnessimpairing seizures.

There were no cases of perioperative mortality in this series and no wound infections or hematomas requiring reoperation. There were four (6.9%) cases of notable transient neurological deficits seen in the postoperative period, all of which resolved completely within weeks to months. Among these, two children had mild contralateral hemiparesis, one of which was associated with a small infarct seen on MRI. Also, one child had a transient expressive aphasia, and one patient had a self-limited short-term memory deficit.

Discussion

The present study is a retrospective cohort study examining seizure outcomes after temporal lobectomy in pediatric TLE patients, with a focus on consciousness-sparing and consciousness-impairing seizures. After resection, 79 % of patients achieved a favorable Engel class I seizure outcome, including 66 % of children who were completely seizure free (Engel IA). MTS was significantly predictive of Engel class I outcome over other pathological diagnoses. Interestingly, the number of patients experiencing consciousness-sparing SPSs

Table 1 Patient characteristics	Age at surgery	Years	14±0.7
	Follow-up duration	Years	2.7±0.4
	Gender	Male	31 (53.4)
		Female	26 (46.6)
	Handedness	Right	35 (60.3)
		Left	4 (6.9)
		Not lateralized/unknown	19 (32.8)
	Duration epilepsy	Years	8.0±0.7
	Epilepsy etiology/final pathology	MTS	20 (34.5)
		Tumor	15 (25.9)
		Cortical dysplasia	11 (19.0)
		Unknown/gliosis only	6 (10.3)
		Vascular malformation	2 (3.4)
		Tuberous sclerosis	2 (3.4)
		Infection	1 (1.7)
		Stroke	1 (1.7)
	Epilepsy risk factors	0	20 (34.5)
		1	25 (43.1)
		≥2	13 (22.4)
	History of generalized seizures	Yes	31 (53.4)
		No	27 (46.6)
	Epilepsy surgery history	None	55 (91.4)
		VNS	3 (5.2)
		Previous resection	2 (3.4)
	Preoperative MRI	Abnormal	51 (87.9)
		Normal	7 (12.1)
	Preoperative EEG	Localized	26 (44.8)
		Lateralized	14 (24.1)
		Not lateralized	12 (20.7)
		Not done	6 (10.3)
	Preoperative PET	Abnormal	13 (22.4)
		Normal	4 (6.9)
		Not done	41 (70.7)
	Implanted ECoG	Used	15 (25.9)
		Not used	43 (74.1)
	Side of surgery	Right	34 (58.6)
		Left	24 (41.4)
	Intraoperative ECoG	Used	39 (68.4)
		Not used	18 (31.6)
Data are N (percent) for cate- gorical variables or mean \pm SEM for continuous variables	Language mapping	Done	6 (10.3)
		Not done	52 (89.7)

decreased by only 23 % after surgery, while the number of children having CPSs and GTCSs (consciousness impairing) diminished by 87 and 83 %, respectively. Patients with continued postoperative seizures experienced a 70 % decrease in overall seizure frequency, driven by a dramatic 94 % decrease in consciousness-impairing seizures, while consciousnesssparing seizures actually increased slightly in frequency. Thus, some children who "fail" temporal lobectomy and continue to have seizures may nonetheless receive incremental clinical benefit in the form of decreased incidence and frequency of consciousness-impairing seizures.

In TLE, all seizure types are not created equal, and morbidity can vary by semiology. It is well known that GTCSs are the most severe [13], but important differences also exist between partial seizures which impair (CPSs) or spare (SPSs) consciousness [16]. Patient quality of life can be dramatically impacted by consciousness-impairing seizures, which are associated with motor vehicle accidents,

Table 2 Seizure outcomes

		Engel I seizure outcome	Engel II–IV seizure outcome	χ^2 or Student's t test	p value
Patient demographics					
Age at surgery	Years	$14.0 {\pm} 0.8$	13.9 ± 1.4	0.1	0.96
Gender	Male	24 (77.4)	7 (22.6)	0.7	0.76
	Female	22 (81.5)	5 (18.5)		
Handedness	Right	30 (85.7)	5 (14.3)	0.32	0.50
	Left	3 (75.0)	1 (25.0)		
Epilepsy characteristics					
Duration epilepsy	Years	$7.9 {\pm} 0.8$	8.3 ± 1.6	-0.22	0.83
Pathology	MTS	20 (100.0)	0 (0.0)	8.0	< 0.01*
	Other	26 (68.4)	12 (31.6)		
Epilepsy risk factors	0	16 (80.0)	4 (20.0)	0.06	0.97
	1	20 (80.0)	5 (20.0)		
	≥2	10 (76.9)	3 (23.1)		
History of generalized seizures	Yes	24 (77.4)	7 (22.6)	0.15	0.76
	No	22 (81.5)	5 (18.5)		
Preoperative diagnostics					
MRI	Abnormal	41 (80.4)	10 (19.6)	0.3	0.58
	Normal	5 (71.4)	2 (28.6)		
EEG	Localized	23 (88.5)	3 (11.5)		
	Lateralized	11 (78.6)	3 (21.4)		
	Not lateralized	7 (58.3)	5 (41.7)		
Implanted ECoG	Used	12 (80.0)	3 (20.0)	0.0	1.0
	Not used	34 (79.1)	9 (20.9)		
Operative factors					
Side of surgery	Right	28 (82.4)	6 (17.6)	0.46	0.53
	Left	18 (75.0)	6 (25.0)		
Intraoperative ECoG	Used	30 (76.9)	9 (23.1)	0.3	0.73
	Not used	15 (83.3)	3 (16.7)		
Total		46 (79.3)	12 (20.7)		

Data are N (percent) for categorical variables or mean \pm SEM for continuous variables

*p<0.05, statistically significant value from χ^2 test (categorical) or t test (continuous) comparing patients with Engel I versus II–IV seizure outcomes

drownings, diminished school performance, and social stigmatization [8, 24, 27, 38, 41]. Prior work has helped delineate the neurobiological network differences between partial seizures which do or do not cause loss of consciousness. During CPSs in TLE, intracranial EEG studies have shown that fast seizure activity often propagates to the contralateral temporal lobe and also leads to abnormal frontoparietal neocortical slow activity that resembles sleep or coma [4, 21]. In contrast, during SPSs, seizure activity typically does not propagate contralaterally, and widespread neocortical slow activity is also absent. Ictal single photon emission computed tomography recordings have revealed that while seizure activity leads to an *increase* in temporal lobe cerebral blood flow, ictal neocortical slow activity is associated with *decreased* blood flow in the association cortices [3]. Recurrent negative effects of seizures on the association neocortex may lead to hypometabolism and gray matter atrophy [5, 7] and may be related to neuropsychological and cognitive deficits frequently seen in TLE patients [22, 23, 29].

The mechanistic underpinnings of ictal neocortical slow activity in CPSs have been investigated using functional MRI, blood flow measurements, behavioral assessments, and electrophysiology in rodents [17, 18]. These studies suggest that when seizures recruit subcortical structures involved in normal neocortical activation, a depressed cortical state and behavioral arrest ensue. It was also observed that a surgical lesion in the rat fornix did not halt hippocampal seizure activity but did prevent ictal neocortical slow activity and related behavioral changes, thus making a CPS



Fig. 1 Seizure types across pediatric patients before and after temporal lobectomy. **a** The number of patients experiencing SPSs decreased by only 23 % after surgery, while the number of individuals having CPSs and GTCSs diminished by 87 and 83 %, respectively (χ^2 =11.3, p< 0.01). With resection, the overall number of patients having any seizures decreased by 64 % from 53 to 19. As certain patients had more than one seizure type, the number of patients with "any" seizures does not equal the sum of various seizure types. **b** While SPS was the predominant (i.e., most common) seizure type in only 11.3 % of all patients before resection, it was more frequently (42.1 %) the predominant seizure type among patients of age \geq 5 years are included. *CPS* complex partial seizures, *GTCS* generalized tonic–clonic seizures, *SPS* simple partial seizures

look more like an SPS [18]. The idea that diminished neocortical activity may underlie loss of consciousness in CPSs has been termed the "network inhibition hypothesis" [16]. Therefore, it is possible that in some instances of "failed" temporal lobectomy for TLE, epilepsy networks are nonetheless affected by the resection, and distal neocortical effects of limbic seizure activity become less prominent.

The present results suggest that certain pediatric patients with seizures after temporal lobectomy may nonetheless receive some benefit from surgery, but it is critical to maintain the clinical emphasis on seizure freedom. Seizure freedom in children leads to improved intellectual and cognitive ability [36], better memory function [30], fewer behavioral problems [33], decreased medication use and side effects [25, 34], and is the most important predictor of quality of life [9, 31]. Survey data have also suggested that Engel class I outcome is associated with higher levels of education, employment status, independence, and overall satisfaction compared to less favorable seizure outcomes [25, 26]. Furthermore, while resective epilepsy surgery is typically safe, it is nevertheless associated with risks that are



Fig. 2 Seizure frequencies before and after temporal lobectomy in pediatric patients. Seizure frequencies are shown for 19 patients who did have seizures after surgery (a) and 34 patients who achieved complete seizure freedom after surgery (b). a Compared to preoperative baseline, patients with continued seizures after resection experienced consciousness-sparing seizures 35 % more frequently (t=0.3, p=0.73), but had consciousness-impairing seizures 94 % less frequently (t=2.0, p<0.05). Total seizure frequency was diminished by 70 % in this group after resection (t=2.0, p<0.05). **b** Among patients who achieved postoperative seizure freedom, preoperative baseline seizure rates were somewhat lower than baseline rates in individuals with persistent seizures (a), but these differences were not significant (p > p)0.10 for each comparison). Data are mean \pm SEM number of seizures per week. Only patients of age ≥ 5 years are included. CPS complex partial seizures, GTCS generalized tonic-clonic seizures, SPS simple partial seizures

important to consider [37, 39, 40]. Thus, the ultimate goal in resective epilepsy remains complete seizure freedom without associated surgical morbidity.

While there is still significant room for improvement, overall clinical results in the present series are encouraging, with 79 % of children achieving Engel class I outcome after surgery. Similarly, a recent meta-analysis of seizure outcomes after temporal lobectomy for pediatric TLE revealed that across the literature, approximately 72 % of children achieve an Engel I outcome postoperatively [20]. Despite these successes, as well as class I evidence supporting the efficacy of temporal lobectomy, resective epilepsy surgery remains underutilized [19]. International League Against Epilepsy guidelines regarding pediatric epilepsy surgery recommend that children with localizable medically refractory epilepsy be referred for surgical evaluation [6], as individuals who have failed multiple seizure medications are unlikely to achieve seizure control with further medication changes [12, 28]. Thus, our recommendation is that children with intractable seizures be referred to a comprehensive epilepsy center for multidisciplinary evaluation by epileptologists, neuropsychologists, neurosurgeons, neuroradiologists, and other experienced practitioners.

Limitations of the present study should be discussed. This is a retrospective cohort study, without prospective control, and is thus biased in selection or outcome reporting is a concern. Also, seizure types were subjectively assigned based on epileptologist classification and description. Impairment of consciousness during seizures can often be challenging to assess historically, particularly in young children. For this reason, children of age <5 years were excluded from analysis of seizure types. While prior work has suggested increased morbidity associated with more severe seizure types, the present study did not examine neuropsychological, cognitive, or quality of life outcomes. Prospective investigation of the effects of epilepsy surgery on seizure types, and their relationship to multifaceted outcome measures, will be important looking forward. Finally, it should be noted that the International League Against Epilepsy Commission on Classification and Terminology recently suggested avoiding the descriptors "complex partial" and "simple partial" in classifying seizures and recommends the terminology "focal seizures with (or without) the impairment of consciousness or awareness" [2]. Regardless of the terminology used, however, important clinical differences exist between seizures which spare or impair consciousness, and these should continue to be appreciated.

Conclusions

Most pediatric patients with medically refractory TLE who undergo temporal lobectomy achieve seizure freedom postoperatively, but some continue to have seizures. The number of patients experiencing consciousness-impairing seizures after surgery is disproportionately lower than the number of children with consciousness-sparing seizures. Also, patients with continued postoperative seizures have an overall lower seizure frequency compared to their preoperative baseline, with a specific and large decrease in the number of consciousness-impairing seizures. Seizure type and frequency are important considerations in the medical and surgical treatment of children with epilepsy, although complete seizure freedom remains the ultimate goal.

Conflict of interest The authors have no conflicts of interest to disclose.

References

 Benifla M, Otsubo H, Ochi A, Weiss SK, Donner EJ, Shroff M, Chuang S, Hawkins C, Drake JM, Elliott I, Smith ML, Snead OC III, Rutka JT (2006) Temporal lobe surgery for intractable epilepsy in children: an analysis of outcomes in 126 children. Neurosurgery 59(6):1203–1213. doi:10.1227/01.NEU.0000245615.32226.83, discussion 1213–1204

- Berg AT, Berkovic SF, Brodie MJ, Buchhalter J, Cross JH, van Emde BW, Engel J, French J, Glauser TA, Mathern GW, Moshe SL, Nordli D, Plouin P, Scheffer IE (2010) Revised terminology and concepts for organization of seizures and epilepsies: report of the ILAE Commission on Classification and Terminology, 2005–2009. Epilepsia 51(4):676–685. doi:10.1111/j.1528-1167.2010.02522.x
- Blumenfeld H, McNally KA, Vanderhill SD, Paige AL, Chung R, Davis K, Norden AD, Stokking R, Studholme C, Novotny EJ Jr, Zubal IG, Spencer SS (2004) Positive and negative network correlations in temporal lobe epilepsy. Cereb Cortex 14(8):892–902. doi:10.1093/cercor/bhh048
- Blumenfeld H, Rivera M, McNally KA, Davis K, Spencer DD, Spencer SS (2004) Ictal neocortical slowing in temporal lobe epilepsy. Neurology 63(6):1015–1021
- Bonilha L, Rorden C, Appenzeller S, Coan AC, Cendes F, Li LM (2006) Gray matter atrophy associated with duration of temporal lobe epilepsy. NeuroImage 32(3):1070–1079. doi:10.1016/ j.neuroimage.2006.05.038
- Cross JH, Jayakar P, Nordli D, Delalande O, Duchowny M, Wieser HG, Guerrini R, Mathern GW, International League against Epilepsy SfPES, Commissions of N, Paediatrics (2006) Proposed criteria for referral and evaluation of children for epilepsy surgery: recommendations of the Subcommission for Pediatric Epilepsy Surgery. Epilepsia 47(6):952–959. doi:10.1111/j.1528-1167.2006.00569.x
- Diehl B, LaPresto E, Najm I, Raja S, Rona S, Babb T, Ying Z, Bingaman W, Luders HO, Ruggieri P (2003) Neocortical temporal FDG-PET hypometabolism correlates with temporal lobe atrophy in hippocampal sclerosis associated with microscopic cortical dysplasia. Epilepsia 44(4):559–564
- Drazkowski J (2007) An overview of epilepsy and driving. Epilepsia 48(Suppl 9):10–12. doi:10.1111/j.1528-1167.2007.01392.x
- Elliott I, Kadis DS, Lach L, Olds J, McCleary L, Whiting S, Snyder T, Smith ML (2012) Quality of life in young adults who underwent resective surgery for epilepsy in childhood. Epilepsia 53(9):1577–1586. doi:10.1111/j.1528-1167.2012.03594.x
- Engel J Jr (1987) Outcome with respect to epileptic seizures. In: Engel J Jr (ed) Surgical treatment of the epilepsies. Raven, New York, pp 553–571
- Engel J Jr (2008) Surgical treatment for epilepsy: too little, too late? JAMA: J Am Med Assoc 300(21):2548–2550. doi:10.1001/ jama.2008.756
- 12. Engel J Jr, Wiebe S, French J, Sperling M, Williamson P, Spencer D, Gumnit R, Zahn C, Westbrook E, Enos B (2003) Practice parameter: temporal lobe and localized neocortical resections for epilepsy: report of the Quality Standards Subcommittee of the American Academy of Neurology, in association with the American Epilepsy Society and the American Association of Neurological Surgeons. Neurology 60(4):538–547
- Engel J Jr, Williamson PD et al (2007) Generalized tonic-clonic seizures. In: Engel J Jr, Pedley TA, Aicardi J (eds) Epilepsy: a comprehensive textbook, 2nd edn. Lippincott, Williams, and Wilkins, Philadelphia, pp 554–562
- Engel J Jr, Williamson PD et al (2007) Limbic seizures. In: Engel J Jr, Pedley TA, Aicardi J (eds) Epilepsy: a comprehensive textbook, 2nd edn. Lippincott, Williams, and Wilkins, Philadelphia, pp 541–552
- Engel J Jr, Van Ness P, Rasmussen T, Ojemann L (1993) Outcome with respect to epileptic seizures. In: Engel J Jr (ed) Surgical treatment of the epilepsies, ed 2. Raven, New York, pp 609–621
- Englot DJ, Blumenfeld H (2009) Consciousness and epilepsy: why are complex-partial seizures complex? Prog Brain Res 177:147– 170. doi:10.1016/S0079-6123(09)17711-7
- Englot DJ, Mishra AM, Mansuripur PK, Herman P, Hyder F, Blumenfeld H (2008) Remote effects of focal hippocampal seizures on the rat neocortex. J Neurosci 28(36):9066–9081. doi:10.1523/ JNEUROSCI.2014-08.2008

- Englot DJ, Modi B, Mishra AM, DeSalvo M, Hyder F, Blumenfeld H (2009) Cortical deactivation induced by subcortical network dysfunction in limbic seizures. J Neurosci 29(41):13006–13018. doi:10.1523/JNEUROSCI.3846-09.2009
- Englot DJ, Ouyang D, Garcia P, Barbaro NM, Chang EF (2012) Epilepsy surgery trends in the United States, 1990–2008. Neurology 78:1200–1206. doi:10.1212/WNL.0b013e318250d7ea
- Englot DJ, Rolston JD, Wang DD, Sun PP, Chang EF, Auguste KI (2013) Seizure outcomes after temporal lobectomy in pediatric patients. J Neurosurg: Pediatrics (in press)
- 21. Englot DJ, Yang L, Hamid H, Danielson N, Bai X, Marfeo A, Yu L, Gordon A, Purcaro MJ, Motelow JE, Agarwal R, Ellens DJ, Golomb JD, Shamy MC, Zhang H, Carlson C, Doyle W, Devinsky O, Vives K, Spencer DD, Spencer SS, Schevon C, Zaveri HP, Blumenfeld H (2010) Impaired consciousness in temporal lobe seizures: role of cortical slow activity. Brain 133(Pt 12):3764–3777. doi:10.1093/brain/awq316
- Helmstaedter C, Kockelmann E (2006) Cognitive outcomes in patients with chronic temporal lobe epilepsy. Epilepsia 47(Suppl 2):96–98. doi:10.1111/j.1528-1167.2006.00702.x
- Hermann BP, Seidenberg M, Schoenfeld J, Davies K (1997) Neuropsychological characteristics of the syndrome of mesial temporal lobe epilepsy. Arch Neurol 54(4):369–376
- 24. Jacoby A, Snape D, Baker GA (2005) Epilepsy and social identity: the stigma of a chronic neurological disorder. Lancet Neurol 4(3):171–178. doi:10.1016/S1474-4422(05)01014-8
- 25. Keene DL, Loy-English I, Ventureyra EC (1998) Long-term socioeconomic outcome following surgical intervention in the treatment of refractory epilepsy in childhood and adolescence. Childs Nerv Syst 14(8):362–365
- Keene DL, Loy-English I, Ventureyra EC (1998) Patient satisfaction with surgical treatment of refractory epilepsy done in childhood and early adolescence. Childs Nerv Syst 14(1–2):30–32
- Kobau R, Zahran H, Thurman DJ, Zack MM, Henry TR, Schachter SC, Price PH (2008) Epilepsy surveillance among adults—19 states, Behavioral Risk Factor Surveillance System, 2005. MMWR Surveill Summ 57(6):1–20
- Kwan P, Sperling MR (2009) Refractory seizures: try additional antiepileptic drugs (after two have failed) or go directly to early surgery evaluation? Epilepsia 50(Suppl 8):57–62. doi:10.1111/ j.1528-1167.2009.02237.x
- Laurent A, Arzimanoglou A (2006) Cognitive impairments in children with nonidiopathic temporal lobe epilepsy. Epilepsia 47(Suppl 2):99–102. doi:10.1111/j.1528-1167.2006.00703.x
- Liang S, Wang S, Zhang J, Ding C, Zhang Z, Fu X, Hu X, Meng X, Jiang H, Zhang S (2012) Long-term outcomes of epilepsy

surgery in school-aged children with partial epilepsy. Pediatr Neurol 47(4):284-290. doi:10.1016/j.pediatrneurol.2012.06.014

- Macrodimitris S, Sherman EM, Williams TS, Bigras C, Wiebe S (2011) Measuring patient satisfaction following epilepsy surgery. Epilepsia 52(8):1409–1417. doi:10.1111/j.1528-1167.2011. 03160.x
- 32. McClelland S 3rd, Curran CC, Davey CS, Okuyemi KS (2007) Intractable pediatric temporal lobe epilepsy in the United States: examination of race, age, sex, and insurance status as factors predicting receipt of resective treatment. J Neurosurg 107(6 Suppl):469–473. doi:10.3171/PED-07/12/469
- 33. Mikati MA, Ataya N, Ferzli J, Kurdi R, El-Banna D, Rahi A, Shamseddine A, Sinno D, Comair Y (2010) Quality of life after surgery for intractable partial epilepsy in children: a cohort study with controls. Epilepsy Res 90(3):207–213. doi:10.1016/ j.eplepsyres.2010.05.002
- 34. Mikati MA, Rahi AC, Shamseddine A, Mroueh S, Shoeib H, Comair Y (2008) Marked benefits in physical activity and wellbeing, but not in functioning domains, 2 years after successful epilepsy surgery in children. Epilepsy Behav 12(1):145–149. doi:10.1016/j.yebeh.2007.08.010
- 35. Sinclair DB, Jurasek L, Wheatley M, Datta A, Gross D, Ahmed N, Quigley D, Snyder T, Aronyk K, McKean J (2007) Discontinuation of antiepileptic drugs after pediatric epilepsy surgery. Pediatr Neurol 37(3):200–202. doi:10.1016/j.pediatrneurol.2007.05.004
- Souza-Oliveira C, Escorsi-Rosset S, Terra VC, Muxfeldt-Bianchin M, Machado HR, Sakamoto AC (2012) Impact of pediatric epilepsy surgery on intellectual efficiency. Rev Neurol 54(4):214–220
- Spencer S, Huh L (2008) Outcomes of epilepsy surgery in adults and children. Lancet Neurol 7(6):525–537. doi:10.1016/S1474-4422(08)70109-1
- Sperling MR (2004) The consequences of uncontrolled epilepsy. CNS Spectr 9(2):98–101, 106–109
- Thom M, Mathern GW, Cross JH, Bertram EH (2010) Mesial temporal lobe epilepsy: how do we improve surgical outcome? Ann Neurol 68(4):424–434. doi:10.1002/ana.22142
- 40. Wiebe S (2004) Effectiveness and safety of epilepsy surgery: what is the evidence? CNS Spectr 9(2):120–122, 126–132
- 41. Yang L, Morland TB, Schmits K, Rawson E, Narasimhan P, Motelow JE, Purcaro MJ, Peng K, Raouf S, Desalvo MN, Oh T, Wilkerson J, Bod J, Srinivasan A, Kurashvili P, Anaya J, Manza P, Danielson N, Ransom CB, Huh L, Elrich S, Padin-Rosado J, Naidu Y, Detyniecki K, Hamid H, Farooque P, Astur R, Xiao B, Duckrow RB, Blumenfeld H (2010) A prospective study of loss of consciousness in epilepsy using virtual reality driving simulation and other video games. Epilepsy Behav 18(3):238–246. doi:10.1016/j.yebeh.2010.04.011