Published in final edited form as:

Epilepsy Res. 2013 February ; 103(2-3): 270–278. doi:10.1016/j.epilepsyres.2012.07.016.

Temporal Trends in Pre-surgical Evaluations and Epilepsy Surgery in the U.S. From 1998 To 2009

Nicholas K. Schiltz, BS¹, Siran M. Koroukian, PhD¹, Samden D. Lhatoo, MD, FRCP², and Kitti Kaiboriboon, MD²

¹Department of Epidemiology & Biostatistics, Case Western Reserve University, Cleveland, Ohio

²Epilepsy Center, Department of Neurology, University Hospitals Case Medical Center, Cleveland, Ohio

Abstract

Objective—To analyze trends in utilization of pre-surgical evaluations including video-EEG (VEEG) monitoring, intracranial EEG (IEEG) monitoring, and epilepsy surgery from 1998 to 2009 in the U.S.

Methods—Data from the Nationwide Inpatient Sample were used to identify admissions for pre-surgical evaluations and surgery. Surgical treatment of epilepsy was identified by the presence of primary ICD-9-CM procedure codes 01.52 (hemispherectomy), 01.53 (lobectomy), or 01.59 (other excision of the brain, including amygdalohippocampectomy). We calculated annual rates of pre-surgical evaluations and surgery based on published estimates of prevalence of epilepsy in the U.S. In addition, we examined variations by region and hospital characteristics, and conducted multivariable analysis to detect temporal trends, adjusting for changes in the population. Sensitivity analysis was also conducted using different algorithms to identify the study population and outcomes.

Results—We detected an increase in the rate of hospitalizations related to intractable epilepsy. Similarly, we noted a significant increase in hospitalizations for VEEG monitoring, but not in IEEG monitoring or in surgery. Multivariable analysis and sensitivity analysis confirmed these results. In addition, there was a significant increase in the proportion of pre-surgical evaluations and surgery performed in non-teaching hospitals.

Conclusions—Despite the increase in VEEG monitoring, the availability of guideline and evidences demonstrating benefits of epilepsy surgery was not associated with a greater employment of surgery over time. Nevertheless, access to pre-surgical evaluations and epilepsy surgery is no longer limited to large medical centers.

Keywords

Temporal trends; Pre-surgical evaluation; EEG monitoring; Intracranial electrodes; Epilepsy surgery

© 2012 Elsevier B.V. All rights reserved.

Corresponding author: Kitti Kaiboriboon, MD. 11100 Euclid Avenue, Lakeside 3200, Cleveland, OH 44106. Phone: (216) 844-8799. Fax: (216) 844-3160. Kitti.Kaiboriboon@UHhospitals.org.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

INTRODUCTION

Epilepsy surgery remains a surprisingly under-utilized treatment option in persons with intractable epilepsy (Engel, 2011), despite accrual of positive outcome data (Wiebe et al., 2001; de Tisi et al., 2011; Engel et al., 2012), evidence-based guidelines (Engel et al., 2003), and the established safety of resective surgery (McClelland et al., 2011; Kaiboriboon et al., 2011). This under-utilization is reflected in studies that have either found no significant changes in referral patterns for surgery after the publications of Class I evidence and national recommendations (Haneef et al., 2010), or have in fact found a decrease in the trend for surgical treatment for epilepsy (Englot et al., 2012). The latter study (Englot et al., 2012) analyzed data from the Nationwide Inpatient Sample (NIS), which used hospitalizations as the unit of analysis. As the U.S. population grew from approximately 248 millions in 1990 to 307 millions in 2009 (U.S. Census Bureau, 2011), the number of hospitalizations for all conditions including epilepsy are expected to increase but whether the rate of increase in hospitalizations is proportionate to the rate of increase in the U.S. population is unknown. Without making the necessary adjustments that reflect population growth, the rate of epilepsy surgery might not be estimated accurately.

We sought to analyze nationwide trends in the utilization of epilepsy surgery over a period of 12 years. Since determination of candidacy for epilepsy surgery requires specific pre-surgical investigations, some of which are inpatient procedures including video-EEG (VEEG) monitoring and intracranial EEG (IEEG) monitoring, we also investigated temporal trends in these diagnostic evaluations. We used published prevalence rate of epilepsy (Hirtz et al., 2007) and U.S. census population estimates (U.S. Census Bureau, 2011) to examine temporal trends in hospitalizations for intractable epilepsy, for pre-surgical evaluations, as well as for surgery, across geographical regions, and by hospital characteristics.

METHODS

The study protocol was approved by the Institutional Review Board at Case Western Reserve University.

Data source

This study is a retrospective cross-sectional study using data from the NIS. The NIS is part of the Healthcare Cost and Utilization Project (HCUP) and is maintained by the Agency for Healthcare Research and Quality (AHRQ). From states participating in the HCUP, nearly 20% of all non-Federal hospitals selected from a stratified sample contribute data to the NIS. The details of sampling and weighting strategies and their modifications to improve the representativeness of the NIS can be found on HCUP website. (Houchens and Elixhauser, 2006; Agency for Healthcare Research & Quality, 2011) As the data from 1998 onward better represent all hospitals in the U.S., we conducted the analysis using the NIS from 1998 to 2009.

Study population

We selected all discharges with an epilepsy-related primary International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis code with mention of intractability (ICD-9-CM: 345.x1 excluding 345.2 and 345.3). After a preliminary exploration of the data, we excluded discharges for patients over the age of 65 from the analysis due to very low number of surgeries performed in this subgroup (n = 10 admissions). No other exclusion criteria were applied.

Outcomes of interest

The primary outcome of interest was surgical treatment of epilepsy, identified by the presence of primary ICD-9-CM procedure codes 01.52 for hemispherectomy, 01.53 for brain lobectomy, or 01.59 for other excision of the brain, which includes partial brain lobectomy, and amygdalohippocampectomy.

The secondary outcomes of interest included pre-surgical diagnostic tests performed in an inpatient setting including VEEG monitoring (ICD-9-CM: 89.19) and IEEG monitoring (ICD-9-CM: 02.93).

These outcomes were independent from each other. For example, subjects who had surgery might or might not have VEEG and/or IEEG monitoring. Similarly, subjects who had IEEG monitoring might or might not undergo VEEG monitoring.

Independent variables

Our main independent variable was the year of discharge, which was grouped into 2 time periods: 1998 to 2003 and 2004 to 2009, representing 6-year periods before and after the AAN published practice parameters on anterior temporal lobectomy in 2003, respectively (Engel et al., 2003). For the regression model, the year of discharge was measured in single year increments. Other independent variables included sociodemographic factors that predispose persons to access of health services including age, race, and gender. Additionally, we accounted for hospital's characteristics including location/teaching status and geographic region.

Data analysis

Given that each record in the NIS represents a discharge rather than an individual, we used yearly data from the U.S. Census population estimates (U.S. Census Bureau, 2011) and the previously published prevalence rate of 7.1/1,000 persons to estimate the total number of persons with epilepsy in the U.S. in each year of our study period (Hirtz et al., 2007). This provided the denominator to calculate rates for comparison over time and across regions.

To account for potentially low specificity and accuracy in medical coding, we conducted sensitivity analysis using 4 different combinations of ICD-9-CM codes to define our population (intractable partial epilepsy, intractable epilepsy, all epilepsy, and all epilepsy and convulsions). We also considered 2 different algorithms to identify epilepsy surgery using ICD-9-CM procedure codes (01.53 alone, and 01.52, 01.53, and 01.59).

All statistical analysis was conducted using SAS/STAT software, version 9.2 of the SAS system for UNIX (SAS Institute Inc., Cary, NC, USA). Weighted frequencies of pre-surgical tests and surgery were computed using the SURVEYMEANS and SURVEYFREQ procedures (Houchens and Elixhauser, 2006). Comparison between time periods was made using the t-test for continuous variables, and Rao-Scott Chi-square test for categorical variables. Negative binomial regression with number of procedures as the outcome term, year as the predictor term and population as the offset term was used to test for temporal trends. Multiple negative binomial regression was used to adjust for age, race, gender, and hospital region. All P values were two-sided and values of <0.05 were considered statistically significant.

RESULTS

Examining the distribution of discharges for pre-surgical diagnostic evaluations and for surgery, we noted a greater representation of patients from older age groups, particularly

with epilepsy surgery (Table 1). In addition, there was an increase in epilepsy surgery in the 0–17 age group, and a decrease in the older age group over time. With respect to other covariates, we observed smaller proportions of African Americans in discharges for surgery, as well as variations by region. A significant increase in the proportion of pre-surgical evaluations and surgery performed in non-teaching hospitals was also observed, although the majority of pre-surgical evaluations and surgery was performed in a large medical center.

Table 2 presents the weighted count of hospitalizations for each calendar year, as well as the rate per 100,000 persons with epilepsy (PWE) for total discharges for intractable epilepsy, presurgical evaluations, and epilepsy surgery. Over the study period, we noted a significant increase of intractable epilepsy-related discharges, as well as in discharges for VEEG monitoring. Conversely, we noted very little variation IEEG monitoring and epilepsy surgery over the study period.

Table 3 presents the results from our multivariable analysis, as well as the results obtained from the sensitivity analysis. Adjusting for changes in the distribution of the population over the years, we noted a significant increase in the number of VEEG monitoring, but no change in IEEG monitoring or epilepsy surgery. Our results continued to show no significant increase in epilepsy surgery over time in the sensitivity analysis.

DISCUSSION

That epilepsy surgery is an underutilized procedure despite its proven efficacy and safety, even in high income countries, is a widely held notion for which there is some evidence (Wiebe et al., 2001; Lhatoo et al., 2003; de Tisi et al., 2011; McClelland et al., 2011; Engel et al., 2012). Despite the impetus provided by national and international conferences, a burgeoning evidence-base and an expanding worldwide interest in epilepsy surgery, the relative plateauing of epilepsy surgery numbers in the U.S. is intriguing. The reasons for this are unclear, given that there has been no reticence in the timely issuing and publicizing of evidence-based guidelines. Whether this simply represents tardy translation into actual clinical practice for a variety of reasons or whether there are other as yet undetermined factors responsible is unknown. The former argument has been made in epilepsy surgery (Engel, 2011) as well as other disease domains (Shahi et al., 2001). Some patients and physicians unfamiliar with epilepsy surgery, or even patients who are well educated about the surgery by their physicians might perceive this option negatively and decline surgery entirely (Swarztrauber et al., 2003; Erba et al., 2012). For patients with a positive attitude toward surgery, the appropriate timing of surgical intervention is still debated (Cascino, 2009; Gomez-Alonso and Cascino, 2010). As the concept of pre-surgical evaluations has evolved and become more sophisticated, we are more selective in choosing patients for surgery resulting in stable rate of surgery. Moreover, it is quite possible that the pool of epilepsy surgery candidates, especially in metropolitan areas where the majority of level 3 and 4 epilepsy centers are located, is smaller than previously assumed or may be shrinking. The associated finding of a significant increase in pre-surgical evaluations and surgery in non-teaching hospitals, suggesting that these are no longer the exclusive remit of large teaching hospitals, lends some support to this view. This increase outside large, teaching centers is interesting although further conclusions on their impact is limited as the NIS does not provide finer detail on the kind of surgeries carried out and provides no outcomes data. One might argue that the pool of epilepsy surgery candidates probably remains unchanged. Instead, the number of subjects who have access to specialized epilepsy centers might be lowering. People with public insurance, especially Medicaid, might not have access to specialists (Bisgaier and Rhodes, 2011), and therefore might have never been worked up properly. Disparities in access to epilepsy care have been a major concern and are recently

reiterated in the Institute of Medicine report (Institute of Medicine, 2012). Barriers to accessing epilepsy specialists could be partially responsible for stagnant of epilepsy surgery, especially in the past few years during the economic downturn.

In general, the majority of VEEG monitoring is performed to characterize seizures or paroxysmal events, rather than for pre-surgical workup, even in people with intractable epilepsy (Cascino, 2002). The observed dichotomy of an increase in VEEG monitoring, as an indicator of the dissemination of epilepsy and/or EEG expertise throughout the U.S., in the presence of stagnant epilepsy surgery numbers is surprising. It may reflect a greater number of diagnostic evaluations for psychogenic and non-psychogenic, non-epileptic paroxysmal disorders, and/or a lowering of the threshold for consideration of epilepsy surgery in patients with complex extra-temporal or multi-focal epilepsies who are subsequently deemed inoperable. Since the NIS does not include the results of diagnostic and pre-surgical assessments, these remain speculative rather than established explanations. The (non-significant) trend towards an increase in IEEG monitoring during the study period lends partial support to the hypothesis of an increase in the complexity of the cases evaluated. It is undeniable that several other factors including the fear of litigation due to missed diagnosis, a widespread practice of defensive medicine, or monetary incentive could potentially drive up the number of high cost procedures like VEEG monitoring. This, however, is probably much less likely for most cases but without clinical data, we cannot judge whether VEEG monitoring is being used appropriately. Nonetheless, it appears very likely that an increase in VEEG monitoring reflects a trend where neurologists with epilepsy or EEG expertise are now widely dispersed to many hospitals outside of academic medical centers.

As the proportion of IEEG monitoring, compared to surgery, is high, it is possible that the rate of epilepsy surgery could have been underestimated. However, an elevated rate of IEEG monitoring might be explained by an inclusion of intraoperative electrocorticography (ECoG), which carries similar ICD-9-CM procedure code as IEEG monitoring. The lack of clinical information and unique patient identifiers in the NIS makes it impossible to distinguish between these procedures. In addition, the number of surgeries in our study is at least double that reported previously using similar dataset (for comparison see Figure 1A in Englot et al., 2012). This is simply because we have included all epilepsy-related surgical procedures that are hemispherectomy, lobectomy, partial lobectomy, and amygdalohippocampectomy in this study. Our findings are further corroborated through a parallel study by our group, in which we analyzed data from the California State Inpatient Sample that includes 100% of hospital discharges and contains unique patient identifiers. We found that there were 5,059 admissions for VEEG monitoring, and 540 admissions for epilepsy surgery between 2005 and 2009, which represented about 14% of VEEG monitoring and 9% of surgery in the NIS during the same time period. It, therefore, is highly unlikely that the number of pre-surgical evaluations and epilepsy surgery in the NIS is underestimated.

The high proportion of IEEG monitoring in urban non-teaching and rural hospitals is also noteworthy. It appears to confirm the dissemination of epileptologists to hospitals outside large academic medical centers. Based on our findings, complex epilepsy cases who live outside large metropolitan areas seem to have access to pre-surgical evaluations and epilepsy surgery locally, which could in part contribute to a slight drop in IEEG monitoring in teaching hospitals. One might speculate that limited availability of neuroimaging technology such as a high resolution MRI in the non-teaching hospital setting might be partially responsible for high numbers of IEEG monitoring, as most lesional cases do not usually require IEEG monitoring. In addition, it is possible that financial incentives could

potentially play a role in increasing numbers of IEEG monitoring in non-teaching and rural hospitals but probably only in a very small fraction of cases.

We observed several significant demographic trends. Interestingly, there was a statistically significant increase in epilepsy surgery in children over time. This may reflect an expansion in pediatric epilepsy and pediatric epilepsy surgery expertise. Also, that older patients with epilepsy are not referred for specialist management as often as their younger counterparts, as shown in previous studies (Reuber et al., 2010) is also evidenced in our study where only a very small number of surgeries were performed in the elderly, forcing us to exclude this important segment of the population from our analysis. Racial disparity in the provision of epilepsy surgery has been reported (Burneo et al., 2005; McClelland et al., 2010). NIS data in this regard requires cautious interpretation since approximately 20% of the data on race and ethnicity are non-randomly missing (Santry et al., 2005; George et al., 2011). Nevertheless, a hopeful exception is one of an apparent increase in the utilization of epilepsy surgery among minorities, especially in Hispanics over time.

Use of NIS data for epilepsy surgery has several limitations, reflected in our study, although this is in part offset by the large number of subjects across diverse geographic regions that can be studied using such data. Firstly, the annual rates of pre-surgical evaluations and surgery were derived from a random sample of approximately 20% of all hospitalizations in the U.S. (Agency for Healthcare Research & Quality, 2011). In addition, over time there are several modifications to the NIS including additions of states to the sampling frame, changes in sampling methods to better reflect hospital representation, revision of hospital stratification variables, or changes in data element names and values (Houchens and Elixhauser, 2006). To adjust for these changes, HCUP has developed and provided supplementary files, called NIS-Trends (Agency for Healthcare Research & Quality, 2008), to be specifically used for trend analysis, as we did in this study. Nonetheless, sampling errors, despite weighting, may overestimate or underestimate rates of pre-surgical evaluations and surgery and important information could have been missed in our study. The spikes in epilepsy-related hospitalizations, pre-surgical evaluations, and epilepsy surgeries in 2005 might reflect the over-representation of level 3 and 4 epilepsy centers in the dataset. Moreover, the data from hospitals operated by the Department of Veteran Affairs, the Department of Defense, or the Indian Health Service are not included in the NIS. However, most of these hospitals did not perform epilepsy surgery routinely prior to 2009. Exclusion of these hospitals, therefore, is unlikely to affect our findings.

Secondly, similar to other administrative databases, the NIS does not contain detailed clinical information or patient unique identifiers. Specific data on epilepsy syndromes and/or procedures cannot be identified by ICD-9-CM codes (Kaiboriboon et al., 2011) and specific indications for all procedures performed cannot be determined, as previously mentioned in the case of IEEG and ECoG monitoring. In addition, there is some likelihood of coding errors, which could potentially affect the number of pre-surgical evaluations and epilepsy surgeries. However, these types of errors are randomly distributed, probably diluted in a large sample size, and therefore less likely to significantly bias the overall results. As administrative data are derived from claims submitted by physicians or hospitals to receive payment, it is therefore possible that reimbursement policies have significant impact on the diagnoses and procedures reported (Sarrazin and Rosenthal, 2012). Policy-influenced changes might also have an impact on clinical decisions and ultimately affect the frequency of some procedures over time. In addition, changes in coding practices and importantly, the dynamics of the ICD-9-CM coding system itself could complicate the findings. Without clinical information, some of these issues cannot be tested. Nonetheless, previous research using claims data suggests that reimbursement plays only a minor role in volume or type of surgeries performed (Escarce, 1993). In addition, medical advances rather than changes in

reimbursement appear to be the major drivers for decreasing or increasing in the number of surgical procedures (Paikal et al., 2002). In fact, a recent study showed that procedures with substantial decrease of payments are performed more often than those with higher payment (Schmier et al., 2009). In our study, all common and uncommon, high and low reimbursement, epilepsy-related surgical procedures are included to represent the total number of surgeries. Moreover, our findings remained unchanged after robust sensitivity analyses for all reasonable combinations of ICD-9-CM procedures codes.

A third limitation is the unavailability of epilepsy prevalence rates that are age-, race-, or sex-specific. This forced us to apply the same prevalence rate of 7.1/1,000 uniformly across the different subgroups of our population, even though its prevalence likely varied across these groups and over the study period. Given inherent limitations of the NIS, it is crucial that information obtained from NIS dataset is interpreted with caution.

Acknowledgments

Mr. Schiltz is supported by the Agency for Healthcare Research and Quality (AHRQ) T32 Institutional Training Grant, #5T32HS000059-18. Dr. Kaiboriboon is supported by the Epilepsy Foundation. This study was also supported in part by the Case Western Reserve University/Cleveland Clinic CTSA Grant Number UL1 RR024989 from the National Center for Research Resources (NCRR), a component of the National Institutes of Health and NIH roadmap for Medical Research. Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NCRR or NIH.

References

1. Agency for Healthcare Research and Quality. HCUP NIS trends supplemental files. 2008. Available at www.hcup-us.ahrq.gov/db/nation/nis/nistrends.jsp
2. Agency for Healthcare Research & Quality. Introduction to the HCUP Nationwide Inpatient Sample (NIS) 2009. 2011. Available at www.hcup-us.ahrq.gov/db/nation/nis/NIS_2009_INTRODUCTION.pdf
3. Bisgaier J, Rhodes KV. Auditing access to specialty care for children with public insurance. *N Engl J Med*. 2011; 364:2324–2333. [PubMed: 21675891]
4. Burneo JG, Black L, Knowlton RC, Faught E, Morawetz R, Kuzniecky RI. Racial disparities in the use of surgical treatment for intractable temporal lobe epilepsy. *Neurology*. 2005; 64:50–54. [PubMed: 15642903]
5. Cascino GD. Clinical indications and diagnostic yield of video-electroencephalographic monitoring in patients with seizures and spells. *Mayo Clin Proc*. 2002; 77:1111–1120. [PubMed: 12374255]
6. Cascino GD. Temporal lobe epilepsy is a progressive neurologic disorder: Time means neurons! *Neurology*. 2009; 72:1718–1719. [PubMed: 19321843]
7. de Tisi J, Bell GS, Peacock JL, McEvoy AW, Harkness WF, Sander JW, Duncan JS. The long-term outcome of adult epilepsy surgery, patterns of seizure remission, and relapse: a cohort study. *Lancet*. 2011; 378:1388–1395. [PubMed: 22000136]
8. Engel JJ. Another good reason to consider surgical treatment for epilepsy more often and sooner. *Arch Neurol*. 2011; 68:707–708. [PubMed: 21670394]
9. Engel JJ, McDermott MP, Wiebe S, Langfitt JT, Stern JM, Dewar S, Sperling MR, Gardiner I, Erba G, Fried I, Jacobs M, Vinters HV, Mintzer S, Kieburtz K. Early surgical therapy for drug-resistant temporal lobe epilepsy: a randomized trial. *JAMA*. 2012; 307:922–930. [PubMed: 22396514]
10. Engel JJ, Wiebe S, French J, Sperling M, Williamson P, Spencer D, Gumnit R, Zahn C, Westbrook E, Enos B. 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*. 2003; 60:538–547. [PubMed: 12601090]
11. Englot DJ, Ouyang D, Garcia PA, Barbaro NM, Chang EF. Epilepsy surgery trends in the United States, 1990–2008. *Neurology*. 2012; 78:1200–1206. [PubMed: 22442428]

12. Erba G, Moja L, Beghi E, Messina P, Pupillo E. Barriers toward epilepsy surgery. A survey among practicing neurologists. *Epilepsia*. 2012; 53:35–43. [PubMed: 21973118]
13. Escarce JJ. Effects of lower surgical fees on the use of physician services under Medicare. *JAMA*. 1993; 269:2513–2518. [PubMed: 8487414]
14. George MG, Tong X, Kuklina EV, Labarthe DR. Trends in stroke hospitalizations and associated risk factors among children and young adults, 1995–2008. *Ann Neurol*. 2011; 70:713–721. [PubMed: 21898534]
15. Gomez-Alonso J, Cascino G. Temporal lobe epilepsy is a progressive neurologic disorder: time means neurons! *Neurology*. 2010; 74:347. author reply 347. [PubMed: 20101044]
16. Haneef Z, Stern J, Dewar S, Engel JJ. Referral pattern for epilepsy surgery after evidence-based recommendations: a retrospective study. *Neurology*. 2010; 75:699–704. [PubMed: 20733145]
17. Hirtz D, Thurman DJ, Gwinn-Hardy K, Mohamed M, Chaudhuri AR, Zalutsky R. How common are the “common” neurologic disorders? *Neurology*. 2007; 68:326–337. [PubMed: 17261678]
18. Houchens, RL.; Elixhauser, A. Using the HCUP Nationwide Inpatient Sample to estimate trends. 2006. (Updated for 1988–2004). Available at www.hcup-us.ahrq.gov/reports/methods/2006_05_NISTrendsReport_1988-2004.pdf
19. Institute of Medicine. Epilepsy across the spectrum: promoting health and understanding. The National Academic Press; Washington, DC: 2012. Available at books.nap.edu/openbook.php?record_id=13379
20. Kaiboriboon K, Schiltz N, Koroukian SM, Lhatoo SD, Koubeissi MZ. Limitations of NIS Database in Evaluation of Epilepsy Surgery Morbidity and Mortality. *Arch Neurol*. 2011; 68:1483. [PubMed: 22084137]
21. Lhatoo SD, Solomon JK, McEvoy AW, Kitchen ND, Shorvon SD, Sander JW. A prospective study of the requirement for and the provision of epilepsy surgery in the United Kingdom. *Epilepsia*. 2003; 44:673–676. [PubMed: 12752466]
22. McClelland, Sr; Guo, H.; Okuyemi, KS. Racial disparities in the surgical management of intractable temporal lobe epilepsy in the United States: a population-based analysis. *Arch Neurol*. 2010; 67:577–583. [PubMed: 20457957]
23. McClelland, Sr; Guo, H.; Okuyemi, KS. Population-based analysis of morbidity and mortality following surgery for intractable temporal lobe epilepsy in the United States. *Arch Neurol*. 2011; 68:725–729. [PubMed: 21320984]
24. Paikal D, Yu F, Coleman AL. Trends in glaucoma surgery incidence and reimbursement for physician services in the Medicare population from 1995 to 1998. *Ophthalmology*. 2002; 109:1372–1376. [PubMed: 12093665]
25. Reuber M, Torane P, Mack C. Do older adults have equitable access to specialist epilepsy services? *Epilepsia*. 2010; 51:2341–2343. [PubMed: 20662895]
26. Santry HP, Gillen DL, Lauderdale DS. Trends in bariatric surgical procedures. *JAMA*. 2005; 294:1909–1917. [PubMed: 16234497]
27. Sarrazin MSV, Rosenthal GE. Finding Pure and Simple Truths With Administrative Data. *JAMA*. 2012; 307:1433–1435. [PubMed: 22474208]
28. Schmier JK, Covert DW, Lau EC, Robin AL. Trends in annual medicare expenditures for glaucoma surgical procedures from 1997 to 2006. *Arch Ophthalmol*. 2009; 127:900–905. [PubMed: 19597112]
29. Shahi CN, Rathore SS, Wang Y, Thakur R, Wu WC, Lewis JM, Petrillo MK, Radford MJ, Krumholz HM. Quality of care among elderly patients hospitalized with unstable angina. *Am Heart J*. 2001; 142:263–270. [PubMed: 11479465]
30. Swartztrauber K, Dewar S, Engel JJ. Patient attitudes about treatments for intractable epilepsy. *Epilepsy Behav*. 2003; 4:19–25. [PubMed: 12609224]
31. U.S. Census Bureau. Population estimates. 2011. Available at www.census.gov/popest/data/historical/index.html
32. Wiebe S, Blume WT, Girvin JP, Eliasziw M. A randomized, controlled trial of surgery for temporal-lobe epilepsy. *N Engl J Med*. 2001; 345:311–318. [PubMed: 11484687]

Table 1
Patient and hospital characteristics of epilepsy-related discharges and procedures, 1998–2009

	Epilepsy-related hospitalizations			Video-EEG monitoring			Invasive EEG monitoring			Epilepsy surgery		
	1998 – 2003	2004 – 2009		1998 – 2003	2004 – 2009		1998 – 2003	2004 – 2009		1998 – 2003	2004 – 2009	
Weighted N	n=13805	n=20355		n=4683	n=8171		n=1094	n=1285		n=1209	n=1433	
95% CI	69196 ±9530	101123 b ±15811		23684 ±6244	40942 b ±12346		5607 ±1291	6422 ±1455		6071 ±1123	7094 ±1398	
Age (years), N (%)												
0 – 17	24747 (36)	37772 (37)		8361 (35)	15629 (39)		1584 (28)	1878 (29)		1306 (22)	1962 (28)	
18 – 34	19659 (28)	26984 (27)		7140 (30)	11669 (30)		2137 (38)	2368 (37)		2073 (34)	2238 (32)	
35 – 64	24570 (36)	35147 (35)		8123 (34)	13060 (32)		1881 (34)	2157 (34)		2676 (44)	2782 (40)	
Female sex, N (%)	35025 (51)	50081 (51)		11961 (51)	20544 (52)		2836 (51)	3055 (48)		3343 (55)	3491 (51) ^a	
Race, N (%)												
White	36835 (53)	49499 (49)		11453 (48)	18545 (45)		3295 (59)	3871 (60)		3432 (57)	3965 (55)	
Black	5532 (8)	7831 (8)		1565 (7)	2518 (6)		359 (6)	248 (4)		251 (4)	285 (4)	
Hispanic	5304 (8)	8862 (9)		2011 (8)	3152 (8)		413 (7)	506 (8)		372 (6)	633 (9)	
Other	3195 (5)	6175 (6)		1474 (6)	3281 (8)		204 (4)	318 (5)		211 (3)	331 (5)	
Missing	18323 (26)	28733 (28)		7181 (30)	13446 (33)		1337 (24)	1480 (23)		1805 (30)	1944 (27)	
Hospital region, N (%)												
Northeast	17421 (25)	25066 (25)		7409 (31)	14997 (37)		1449 (26)	2052 (32)		995 (17)	1536 (22)	
Midwest	16849 (24)	25029 (25)		4220 (18)	9368 (23)		1657 (29)	1494 (23)		1466 (24)	1818 (26)	
South	19381 (28)	28553 (28)		6012 (25)	7702 (19)		1128 (20)	1287 (20)		1604 (26)	1772 (25)	
West	15545 (22)	22476 (22)		6043 (26)	8874 (22)		1374 (25)	1589 (24)		2005 (33)	1968 (28)	
Hospital status, N (%)												
Rural	2180 (3)	4822 (5) ^a		15 (0)	1984 (5) ^b		57 (1)	374 (6) ^b		73 (1)	304 (4) ^b	
Urban non-teaching	5868 (8)	12571 (12)		393 (2)	1062 (3)		44 (1)	309 (5)		40 (1)	369 (5)	
Urban teaching	61147 (88)	83578 (83)		23276 (98)	37859 (93)		5506 (98)	5739 (89)		5958 (98)	6610 (90)	

Cells display estimated national counts after weighting with percentages in parenthesis, except where otherwise noted.

Northeast region included Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. Midwest region included Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. South region included Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia. West region included Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

^a indicates $p < 0.05$, and

^b indicates $p < 0.01$ for Rao-Scott chi-square test for within group differences between time periods for categorical variables, and Student's t-test for continuous variables. All other comparisons were not significant at $p < 0.05$.

Table 2

National estimates of the annual rates of pre-surgical evaluations and epilepsy surgery, 1998 – 2009.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	p-value
Weighted count													
Epilepsy-related hospitalizations	10518	13496	9794	12373	10117	12898	13721	19414	15362	17021	17800	17805	<.0001
Video-EEG monitoring	3779	3800	2872	4644	3712	4877	5017	7905	5508	8922	5865	7725	<.0001
Intracranial EEG monitoring	950	1207	782	826	894	947	805	1555	1085	1048	984	945	.5069
Epilepsy surgery	945	1464	934	862	818	1032	1085	1705	1075	883	1155	1078	.7013
Population ^a (x100,000)	2412.3	2442.4	2471.0	2497.6	2522.3	2544.0	2567.8	2590.5	2613.9	2637.1	2655.7	2674.4	
Persons with epilepsy (PWE) ^b (x100,000)	17.13	17.34	17.54	17.73	17.91	18.06	18.23	18.39	18.56	18.72	18.86	18.99	
Observed Rate per 100,000 PWE													
Epilepsy-related hospitalizations	614.1	778.3	558.3	697.7	564.9	714.1	752.6	1055.5	827.8	909.1	944.0	937.7	<.0001
Video-EEG monitoring	220.6	219.1	163.7	261.9	207.3	270.0	275.2	429.8	296.8	476.5	311.0	406.8	<.0001
Intracranial EEG monitoring	55.5	69.6	44.6	46.6	49.9	52.4	44.2	84.5	58.5	56.0	52.2	49.8	.6873
Epilepsy surgery	56.4	86.6	53.2	48.6	45.7	57.2	59.6	92.8	58.0	47.2	61.3	56.8	.8772

National count estimate is the estimated number of procedures performed annually after weighting.

P-value test for trend based on negative binomial regression model with year as the predictor and population as the offset variable.

^aPopulation is the total U.S. population of persons age <65 based on data from the U.S. Census Bureau (2011).

^bPWE calculation based on 7.1/1000 prevalence rate for general U.S. population (Hirtz et al., 2007).

Observed rate per 100,000 PWE is calculated as the national count estimate divided by PWE * 100,000.

Table 3

Test for trend and sensitivity analysis

	N cases 1998–2003	SD	N cases 2004–2009	SD	Slope coefficient	P-value for trend
Baseline Analysis						
Video-EEG monitoring	23,684	3294	40,942	6405	.0683	<.0001
Intracranial EEG monitoring	5,607	689	6,422	765	.0097	.5510
Surgery	6,071	616	7,094	731	.0227	.1446
Sensitivity Analysis for Surgery						
345.X1 (all intractable) *	69,196	5,286	101,123	8,447	.0566	<.0001
01.53	2,927	327	2,648	317	-.0176	.3850
01.52, 01.53, 01.59	6,071	616	7,094	731	.0227	.1446
345.41, 345.51 (focal intractable)	28,617	2685	40,428	4744	.0609	<.0001
01.53	1,758	225	1,577	247	-.0173	.4810
01.52, 01.53, 01.59	3,498	405	3,913	478	-.0362	.0532
345.XX (all epilepsy) *	183,576	10,488	472,346	18,325	.1425	<.0001
01.53	3,162	347	2,920	336	-.0079	.6858
01.52, 01.53, 01.59	6,566	663	7,742	773	.0246	.1026
345.XX and 780.39 (all seizures) *	937,161	23,242	1,134,232	30,143	.0260	<.0001
01.53	3,325	360	3,010	339	-.0138	.4714
01.52, 01.53, 01.59	7,063	695	8,086	789	-.0192	.1950

Slope coefficient of year as a predictor of annual procedures and p-value were derived from a negative binomial regression model adjusting for age, race, sex, and region and using population as an offset term. Sensitivity analysis is shown for epilepsy surgery only. ICD-9-CM procedure codes are as follows: 01.52 (hemispherectomy), 01.53 (lobectomy), 01.59 (partial lobectomy including amygdalohippocampectomy).

* excludes 345.2, 345.3 (petit mal and grand mal status epilepticus). SD, Standard deviation.