Seizure incidence in the acute postneurosurgical period diagnosed using continuous electroencephalography

Brin Freund, MD, John C. Probasco, MD, and Eva K. Ritzl, MD

Department of Neurology, Johns Hopkins Hospital, Baltimore, Maryland

OBJECTIVE Delay in diagnosis and subsequent treatment of nonconvulsive seizures can lead to worsened outcomes. The gold standard in detecting nonconvulsive seizures is continuous video-electroencephalography (cEEG). Compared to routine, 30-minute EEG, the use of cEEG increases the likelihood of capturing intermittent nonconvulsive seizures. Studies of critically ill patients in intensive care units demonstrate a particularly high rate of nonconvulsive seizures. Some of these studies included postsurgical patients, but often subanalyses of specific populations were not done. In particular, few studies have specifically evaluated postsurgical patients by using cEEG in the acute postoperative setting. Therefore, the incidence and predictors of acute postsurgical seizures are unclear.

METHODS In this study, the authors focused on patients who were admitted to the neurological critical care unit following neurosurgery and who underwent cEEG monitoring within 72 hours of surgery.

RESULTS A total of 105 cEEG studies were performed in 102 patients. Twenty-nine patients demonstrated electrographic (subclinical) seizures, of whom 10 had clinical seizures clearly documented either before or during cEEG monitoring. Twenty-two patients had subclinical seizures only detected on cEEG, 19 of whom did not have clinical seizure activity at any point during hospitalization. Those with seizures were more likely to have had a history of epilepsy (p = 0.006). The EEG studies of patients with seizures were more likely to show lateralized periodic discharges (p = 0.012) and lateralized rhythmic delta activity (p = 0.012). The underlying neuropathological disorders most associated with seizure risk were lobar tumor on presentation (p = 0.048), subdural hematoma (SDH) requiring craniotomy for evacuation (p = 0.002), subarachnoid hemorrhage (SAH) (p = 0.028), and perioperative SAH (p = 0.019). In those undergoing craniotomy, the presence of SDH (p = 0.032), particularly if requiring evacuation (p = 0.003), increased the risk of seizures. In those without preoperative intracranial bleeding, perioperative SAH after craniotomy was associated with a higher incidence of seizures (p = 0.014). There was an additive effect on seizure incidence when perioperative SAH as well as concomitant intraparenchymal hemorrhage and/or stroke were present. The clinical examination of the patient, including the presence or absence of altered mental status and the presence or absence of repetitive movements, was not predictive of subclinical seizures.

CONCLUSIONS In postneurosurgical patients referred for cEEG monitoring, there is a high rate of both clinical and subclinical seizures in the early postoperative period. Seizures are particularly common in patients with SDH or lobar tumor and perioperative SAH. There was an additive effect on seizure incidence when more extensive brain injury was present. As expected, those with a history of epilepsy also demonstrated higher seizure rates. Further studies are needed to evaluate the time period of maximum seizure incidence after surgery, and the effects acute postsurgical seizures have on long-term outcomes.

https://thejns.org/doi/abs/10.3171/2018.1.JNS171466

KEYWORDS continuous electroencephalography; neurosurgery; seizure; status epilepticus; craniotomy; epilepsy

CONTINUOUS video-electroencephalography (cEEG) monitoring is an important tool to evaluate acute alteration of mental state in critically ill patients for possible nonconvulsive seizures or nonconvulsive status epilepticus. In the neurological critical care unit, studies using cEEG have demonstrated subclinical seizures in up to 35% of patients. Typically, these studies listed the underlying conditions that were associated with seizures, but they did not specifically analyze different subgroups. The association of postsurgical seizures with worsened outcomes has been described previously, and

ABBREVIATIONS cEEG = continuous video-electroencephalography; GCS = Glasgow Coma Scale; ICH = intracranial hemorrhage; LPD = lateralized periodic discharge; LRDA = lateralized rhythmic delta activity; SAH = subarachnoid hemorrhage; SDH = subdural hematoma.


INCLUDE WHEN CITING Published online June 1, 2018, DOI: 10.3171/2018.1.JNS171466.
seizures in this setting require prompt diagnosis and treatment.\textsuperscript{6,16,21,37} Importantly though, the incidence of postneurosurgical seizures may be greatest in the acute postoperative period.\textsuperscript{47} In those undergoing craniotomy, the acute period is thought to be within 48–72 hours of surgery.\textsuperscript{42,43} Although some studies have focused on the acute phase after surgery,\textsuperscript{2,3,9,11,12,19,22–24,28,29,31,35,37–39,50} they did not use cEEG monitoring, similar to others in which postneurosurgical seizures were studied in the subacute to chronic postoperative period.\textsuperscript{1,4,5,15,20,25,30,33,41,52} cEEG is particularly vital in patients who undergo anesthetic or sedative treatment that can mask the neurological examination findings,\textsuperscript{22} and make abnormal, nonseizure-related rhythmic movements difficult to differentiate from clinical seizures. Although some studies evaluating seizures in neurosurgical patients did use cEEG,\textsuperscript{7,10,18,26,40,45,46,48} they were narrow in their focus, did not differentiate the acute time period, included a small cohort, or omitted significant details regarding the type of surgery or underlying neuropathology. Therefore, further analysis of this subgroup of patients with respect to seizure incidence is needed.

In this study we analyzed cEEG performed in the acute postneurosurgical period, primarily after intracranial procedures. Our goal was to better describe the incidence of seizures—including nonconvulsive seizures and nonconvulsive status epilepticus—in this population and to define those at most risk, to guide further study and use of cEEG in these patients.

\textbf{Methods}

Our study design was approved by the institutional review board at Johns Hopkins University. We retrospectively identified patients consecutively admitted to the neurological critical care unit at the Johns Hopkins Hospital between January 1, 2013, and December 31, 2015, who underwent neurosurgery and were subsequently monitored using cEEG within 72 hours of the surgical procedure, with concern for seizures. All patients were 18 years of age or older. Patients with any neurosurgical procedure were included.

Demographics and clinical data were obtained by detailed chart review, including medical history, laboratory studies, medications, and imaging interpretations by board-certified radiologists. Perioperative subarachnoid hemorrhage (SAH) was defined by the presence of subarachnoid blood products or hemorrhage noted in the radiologist’s interpretation on either CT or MRI studies. Glasgow Coma Scale (GCS) score was calculated based on the documented examination. Scalp EEG recordings were performed using electrodes placed in accordance with the 10–20 international system (Nihon Kohden system; Nihon Kohden Corp.). cEEG interpretations were performed by expert encephalographers as part of clinical care. These reports were retrieved from the medical record system and, if seizures or status epilepticus were noted, the EEG study was re-reviewed by an expert encephalographer (E.K.R.) to confirm these findings and the timing of onset in the recording.

Periodic discharges detected on cEEG were defined as repetitive sharp waves, spikes, or sharply contoured waves occurring at nearly regular intervals and without evolution into seizures (evolution in frequency or spread to adjacent regions). Subclinical seizures were defined as events consisting of rhythmic spiking showing intrinsic evolution, often but not necessarily with a defined onset and resolution. Seizures were considered clinical if recorded as facial or extremity “rhythmic movements,” “switching,” “jerking,” or “tonic activity,” and intermittent or acute “gaze deviation” or “head turning,” “grand mal” or “generalized tonic-clonic” activity. If clinical seizure activity was not well described, or if it was only mentioned when listed as the reason for ordering cEEG, it was not counted in the overall clinical seizure incidence. We recorded the presence of a clinical seizure correlate, as noted above, when electrographic (subclinical) seizures were detected on cEEG.

Statistical analyses were performed using SPSS, version 22 (IBM Corp.). Continuous data were analyzed using the Mann-Whitney U-test, and categorical data were analyzed using Fisher’s exact t-test. All tests were 2-sided, and \( p < 0.05 \) was considered statistically significant. Post hoc Bonferroni testing was performed given the number of variables compared between groups regarding clinical features and EEG findings, with significance corrections to \( p < 0.005 \) for neuropathology, procedures, clinical examination, and EEG findings. We also performed linear regression for collinearity on data from those who underwent a craniotomy or craniectomy with \( p \) values \( < 0.15 \), and also included demographic information (age, sex). We then performed a logistic regression analysis to create a model predicting the likelihood of seizures.

\textbf{Results}

Overall, 105 cEEG sessions were performed in 102 patients. Three patients had 2 cEEG recordings begun within the first 72 hours after surgery, 1 of whom had seizures detected only on the second cEEG. All but 7 cEEG sessions were recorded for at least 12 hours, the briefest being 4 hours because the patient went for a procedure and needed to be disconnected. This being a retrospective study, the cEEG recordings were ended at the discretion of the clinician taking care of the patient at the time. However, none of those recorded for less than 12 hours demonstrated seizure activity on cEEG, nor were they referred for a second cEEG or described as having clinical seizures later in their hospitalization.

Thirty (29.4\%) patients had either clinical or subclinical seizures; 29 of these patients demonstrated electrographic seizures during cEEG monitoring, with 15 diagnosed as status epilepticus. One patient had a generalized tonic-clonic seizure that was well documented prior to cEEG, without any electrographic seizures detected while monitored. No other patient had well-documented clinical seizures without EEG correlation of epileptic activity. 22 (21.6\%) patients had subclinical electrographic seizures on cEEG, and 19 of these patients had no reported clinical motor seizures in the postoperative period, with their only clinical correlate being depressed mental state or unresponsiveness.

Table 1 describes demographic data and timing of
cEEG. Only 1 patient’s first seizure was detected more than 24 hours (52 hours) after cEEG was begun, and 26/29 with electrographic seizures had seizures recorded within than 24 hours (52 hours) after cEEG was begun, and 26/29 with electrographic seizures had seizures recorded within the first hour.

Data regarding history of seizures, underlying neuro-pathology, surgical procedure, and associated incidence of seizures are described in Table 2. A majority of patients (79) underwent craniotomy or craniectomy, of which 4 were suboccipital craniectomies and the rest were supratentorial surgeries. Other procedures included angiography, extraventricular drain placement, and placement of burr holes. In those undergoing craniotomy or craniectomy, when excluding those with preoperative intracranial bleeding on CT or MRI, perioperative SAH was a risk factor for clinical and subclinical seizures (p = 0.014). There was a trend toward a further increase in seizure risk when perioperative SAH occurred concurrent with stroke and/or lobar intracranial hemorrhage (ICH); this can be concluded based on the fact that there was a nonsignificant difference in seizure incidence when SAH patients with coexisting stroke and/or ICH were excluded from the subanalysis (p = 0.054). Other conditions that significantly increased the risk of seizure in those undergoing craniotomy or craniectomy were a preexisting history of seizures disorder (p = 0.004) and subdural hematoma (SDH) (p = 0.032), particularly if requiring craniotomy for evacuation (p = 0.003).

Indications for cEEG and neurological examination findings are noted in Table 3, which demonstrates that these factors had no association with the presence of electrographic seizures.

Table 4 lists EEG patterns other than seizures found in our patients. Of these the only EEG findings that predicted seizure incidence were lateralized periodic discharges (LPDs) (p = 0.012) and lateralized rhythmic delta activity (LRDA) (p = 0.012).

With respect to outcomes, 4/30 patients with clinical or subclinical seizures and 11/75 without seizures died prior to discharge (p > 0.05). There was no difference in mortality at discharge between those who had status epilepticus and the rest of the cohort (3/15 vs 12/90, p > 0.05) for all surgical procedures taken together. In those undergoing craniotomy or craniectomy, mortality at discharge was greater in those with status epilepticus (p = 0.052). Long-term follow-up was not documented for the majority of patients. Direct logistic regression performed using data from those in the craniotomy or craniectomy group produced a model containing the following factors: continuous variables including GCS score and age; and categorical variables including sex (0 = male, 1 = female); history of seizures (0 = no, 1 = yes); lobar tumor (0 = no, 1 = yes); SAH (0 = no, 1 = yes); and craniotomy or craniectomy for SDH evacuation (0 = no, 1 = yes). The model was statistically significant, with $\chi^2 = 34.23$ (7 variables, n = 79; p < 0.001), indicating that it was able to distinguish between those with and without seizures. The model as a whole explained between 35.2% and 49.3% of the variance in seizure incidence, and correctly classified 85% of cases. As shown in Table 5, 4/7 independent variables (history of seizures, lobar tumor, SAH, and craniotomy for SDH evacuation) made a unique statistically significant contribution to the model. The strongest predictors of seizure incidence were a history of seizures and undergoing a craniotomy for SDH evacuation. SAH and lobar tumor were moderately strong predictors of seizure incidence, whereas sex, age, and GCS score did not significantly factor into the model.

**Discussion**

Our study elucidates the incidence of early clinical and subclinical seizures after neurosurgical procedures.

---

**Table 1. Demographic data and timing of cEEG**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Szs</th>
<th>No Szs</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in yrs, mean</td>
<td>61.6</td>
<td>59.7</td>
<td>0.610</td>
</tr>
<tr>
<td>Sex</td>
<td>10 M, 20 F</td>
<td>38 M, 37 F</td>
<td>0.131</td>
</tr>
<tr>
<td>Length of time on cEEG, mean hrs</td>
<td>104.1</td>
<td>25.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Time after op at which cEEG was begun, mean hrs (range)</td>
<td>35.3 (6–72)</td>
<td>32.5 (5–72)</td>
<td>0.749</td>
</tr>
<tr>
<td>Time to onset of Szs after cEEG was begun, mean hrs</td>
<td>2.8</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

NA = not applicable; Szs = seizures.

**Table 2. Seizure incidence and neuropathology or procedure**

<table>
<thead>
<tr>
<th>Neuraphathy or History</th>
<th>Szs in Those w/ Variable</th>
<th>Szs in the Rest of the Cohort</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>History of Szs</td>
<td>12/22</td>
<td>18/83</td>
<td>0.006</td>
</tr>
<tr>
<td>Lobar ICH</td>
<td>7/17</td>
<td>23/88</td>
<td>0.245</td>
</tr>
<tr>
<td>Lobar tumor</td>
<td>12/27</td>
<td>18/78</td>
<td>0.048</td>
</tr>
<tr>
<td>Herniation (uncal or subfalcine)</td>
<td>1/7</td>
<td>29/98</td>
<td>0.670</td>
</tr>
<tr>
<td>Midline shift</td>
<td>7/20</td>
<td>23/85</td>
<td>0.583</td>
</tr>
<tr>
<td>Lobar stroke</td>
<td>12/27</td>
<td>21/78</td>
<td>0.622</td>
</tr>
<tr>
<td>SDH</td>
<td>10/20</td>
<td>20/85</td>
<td>0.056</td>
</tr>
<tr>
<td>SAH</td>
<td>14/63</td>
<td>16/42</td>
<td>0.026</td>
</tr>
<tr>
<td>SAH on presentation</td>
<td>4/14</td>
<td>26/91</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>IVH</td>
<td>10/29</td>
<td>20/76</td>
<td>0.339</td>
</tr>
<tr>
<td>Hydrocephalus</td>
<td>7/22</td>
<td>23/83</td>
<td>0.792</td>
</tr>
<tr>
<td>Periop SAH</td>
<td>13/28</td>
<td>17/77</td>
<td>0.019</td>
</tr>
<tr>
<td>Periop SDH</td>
<td>2/8</td>
<td>28/97</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Periop IVH</td>
<td>5/15</td>
<td>25/90</td>
<td>0.536</td>
</tr>
<tr>
<td>Procedure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aneurysm clipping</td>
<td>3/8</td>
<td>27/97</td>
<td>0.686</td>
</tr>
<tr>
<td>Aneurysm coiling</td>
<td>5/25</td>
<td>25/80</td>
<td>0.321</td>
</tr>
<tr>
<td>Tumor resection</td>
<td>12/35</td>
<td>18/70</td>
<td>0.369</td>
</tr>
<tr>
<td>(craniotomy or endoscopy)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Craniotomy for SDH evacuation</td>
<td>8/11</td>
<td>22/94</td>
<td>0.002</td>
</tr>
<tr>
<td>IVC or EVD</td>
<td>6/20</td>
<td>24/85</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Craniotomy or craniectomy</td>
<td>25/79</td>
<td>5/26</td>
<td>0.318</td>
</tr>
</tbody>
</table>

EVD = extraventricular drain; IVC = intraventricular catheter; IVH = intraventricular hemorrhage.

---

B. Freund et al.

J Neurosurg June 1, 2018 3
In prior studies focusing on seizure incidence within the first 1–2 weeks after neurosurgery the incidence has been reported as ranging widely, from 1% to 42%, depending on the underlying neuropathology and surgical procedure.1–5, 9, 11, 12, 19, 22–24, 28–31, 33, 35, 37–39, 41, 49, 50, 52 Notably, however, cEEG was not universally obtained. Some investigators used brief EEG recordings in an attempt to correlate clinical signs with seizure activity, but most relied on clinical manifestations of seizures alone. We have shown that a significant proportion of postneurosurgical patients referred for EEG monitoring have subclinical seizures, and without cEEG most if not all of these seizures would have eluded detection due to their intermittent nature. Therefore, studies reporting the seizure incidence in the postneurosurgical patient population as much below 30% may underestimate this important surgical complication.

In our study, patients undergoing craniotomy who developed SAH as noted on neuroimaging after surgery had a higher rate of seizures compared to the rest of the cohort, including those with SAH on admission. This was particularly true and statistically significant in the presence of stroke or intraparenchymal blood products. In general, SAH with or without surgical intervention is a risk factor for seizures.10 Stroke after SAH due to vasospasm has been noted to increase this risk further, and vasospasm can occur up to 2 weeks after SAH.15 We monitored our patients for a relatively short period of time, and so those presenting with SAH may have had seizures later in their course from subsequent vasospasm and parenchymal injury not yet present in the study period. This may explain the lack of increased seizure risk in those with SAH on presentation.

Other mechanisms suggested in the literature for early postneurosurgical seizures after craniotomy or craniectomy are manipulation and traction of brain tissue; formation of edema; hematoma; and pneumocephalus— with subsequent brain injury due to ischemia or hypoxia. These mechanical changes can, in turn, lead to free-radical generation, with an ensuing lack of cell membrane stability.13–27, 32–36 All of these changes may contribute to the association of seizure incidence with the extent of brain injury that we observed in our study.

Those patients with lobar tumors who underwent resection demonstrated a higher rate of postoperative seizures when compared to the rest of the cohort in this study. Patients with supratentorial brain tumors are known to have an increased risk of seizure postcraniotomy.12,25 However, studies have shown mixed results with respect to using antiseizure drug prophylaxis perioperatively to prevent seizures early after surgery.1, 9, 12, 19, 28, 36, 39, 41, 50, 52 Furthermore, most studies in those undergoing tumor resection focused more on subacute or chronic seizure incidence. This study is unique in the characterization of seizure incidence acutely after tumor resection using cEEG.

The presence of SDH as the indication for undergoing craniotomy was associated with increased risk of seizures following surgery in our study. A high rate of seizures following acute SDH evacuation has been described, particularly in patients who remain less responsive after sedatives are wearing off.37 Interestingly, undergoing craniotomy for SDH evacuation was one of the largest contributors to seizure risk in our model.

Not surprisingly, those with a prior seizure disorder were very likely to have postoperative seizures. This has been noted previously regarding postneurosurgical patients and others in critical care settings.8 This is consistent with the strong influence a history of seizures had on the likelihood of seizures in our model.

Preoperative neurological deficits found on examination have been described as a risk factor for postneurosurgical seizures.23 We were unable to find a correlation...
between neurological examination or clinical seizure-like movements—occurring both during and before video-EEG recording—and the incidence of seizures. The observation that reported clinical seizure activity may not predict subsequent detection of electrographic seizures on EEG has not been described previously. Yet, it highlights the fact that attempting to diagnose seizures clinically and without an EEG, particularly in critically ill postneurosurgical patients, is unreliable and potentially harmful. This may be especially true if the reliability of the clinical neurological examination is confounded by the use of anesthetics in the operating room and postoperative sedatives to permit ventilator support. The lack of EEG correlation with reported seizure-like movements may also be muddled by aggressive antiseizure treatment on an empirical basis in a vulnerable patient population prior to EEG.

In this cohort there was no association between early postoperative seizures and death by the time of discharge. There was a trend toward an increased risk of death in those who underwent craniotomy and subsequently developed acute-onset electrographic status epilepticus. Although most patients were not followed past discharge, it has been noted previously that the effects of postoperative seizures may impact outcomes prior to discharge more than in the long term. Some have questioned the utility of aggressive antiseizure treatment in critically ill patients who develop seizures. The difficulty in determining outcomes is that critical-care patients who develop seizures tend to be sicker, and therefore worsened outcomes may be due to the underlying disease itself rather than being related to seizures. Based on this, aggressive antiseizure treatment may not provide much benefit, and it may prolong admission and leave patients prone to complications of hospitalization and intensive care. On the other hand, an independent effect of seizures on outcomes in some critically ill populations has been described. Whether or not acute postneurosurgical seizures independently contribute to an unfavorable outcome has not been addressed specifically and should be evaluated in future studies.

It is unclear how long eEEG monitoring should be performed before the presence of subclinical seizures can be ruled out with appropriate certainty, and it may depend on the population being evaluated. Studies have shown that in comatose patients 87% of seizures are detected within the first 48 hours of monitoring, and in noncomatose patients 95% of seizures are captured within the first 24 hours. In our study 90% of patients demonstrating seizures on eEEG had their first event within 24 hours of the start of eEEG monitoring, and a significant proportion had their first seizure within the first hour. However, this may be confounded by the fact that monitoring was begun on average more than 30 hours after surgery. Therefore, it is unclear at what point patients are most susceptible to the onset of subclinical seizures postneurosurgery. It is quite possible that monitoring patients earlier after neurosurgery may lead to improved outcomes. Our study is unable to assess this. Future studies are necessary to determine whether earlier seizure monitoring and treatment is warranted.

Previous studies have noted LRDA and epileptiform activity or LPDs as predictive of seizure activity during prolonged monitoring in critically ill patients, where as generalized slowing forecasts lower seizure incidence. Our results confirm these findings for our study population.

Our model for predicting seizure incidence in those undergoing craniotomy or craniectomy who are referred for cEEG due to concern for seizures showed very high specificity and high negative and positive predictive values. Therefore, in patients with any of the 4 variables showing significant contribution to the model, cEEG should not be delayed. In those undergoing craniotomy without these clinical factors present, liberal use of cEEG monitoring is still warranted. This model should be evaluated prospectively in patients undergoing craniotomy acutely after surgery to validate its use. It is also important to keep in mind the fact that the model was developed for a selected patient population and may therefore not be applicable to all postneurosurgical patients.

Our study had certain limitations. We included only patients in whom cEEG was requested due to concern for seizures (based on poor mental status and/or abnormal movements), and we did not monitor all postoperative patients. We were also limited by the retrospective nature of our review of medical records, which described clinical seizure activity, medical history, and examinations. It should also be noted that for those patients we categorized as “without seizures,” seizures might simply have been missed if they occurred outside of the monitoring period. Furthermore, we were unable to collect detailed long-term outcome data. Although our sample size is comparable to others in this field of study, larger-sized analyses could yield additional information.

Conclusions

In this study we found a high rate of seizures in the acute postneurosurgical period, most of which were subclinical and would have gone undetected without cEEG. A history of seizures and the presence of SAH, perioperative SAH, undergoing craniotomy for SDH evacuation, or the presence of lobar tumor heralded an increased risk of seizures when evaluating the cohort as a whole. Although the surgical procedure itself did not predict the likelihood of seizures, the following variables were associated with a higher incidence of seizures: those undergoing craniotomy, history of seizures, SAH, lobar tumor, and SDH.
requiring evacuation. Nearly all of those who had seizures did not require more than 24 hours of monitoring to detect them, and seizures often occurred within the first hour. However, cEEG monitoring was begun on average more than 30 hours after surgery, and so seizure activity prior to cEEG monitoring may have gone undetected. No clinical examination features were helpful in determining those at greater risk of seizures. The presence of LPDs and LRDA on EEG were predictive of the subsequent presence of seizures. Our study demonstrates that cEEG monitoring is indispensable in the diagnosis of seizures in patients following neurosurgical procedures, given the high rates of subclinical events. The duration and timing of monitoring in the acute postneurosurgical period remains unclear. Further study is needed, given that prompt detection and treatment of seizures may have a significant impact on outcomes in neurosurgical patients.

References


Disclosures
The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions
Conception and design: Freund, Ritzl. Acquisition of data: Freund, Ritzl. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Freund. Statistical analysis: all authors. Administrative/technical/material support: Freund, Ritzl. Study supervision: Freund, Ritzl.

Correspondence
Brin Freund: Johns Hopkins School of Medicine, Baltimore, MD. bfreund3@jhmi.edu.