Published in final edited form as:
*J Clin Neurophysiol*. 2013 April ; 30(2): 156–160. doi:10.1097/WNP.0b013e31827eda27.

# Pediatric ICU EEG Monitoring: Current Resources and Practice in the United States and Canada

**Sarah M. Sanchez**[a], **Jessica Carpenter**[b], **Kevin E. Chapman**[c], **Dennis J. Dlugos**[a], **William Gallentine**[d], **Christopher C. Giza**[e], **Joshua L. Goldstein**[f], **Cecil D. Hahn**[g], **Sudha Kilaru Kessler**[a], **Tobias Loddenkemper**[h], **James J. Riviello Jr.**[i], and **Nicholas S. Abend**[a] **On behalf of the Pediatric Critical Care EEG Consortium**

Sarah M. Sanchez: sanchezs@email.chop.edu; Jessica Carpenter: JCarpent@childrensnational.org; Kevin E. Chapman: Kevin.Chapman@childrenscolorado.org; Dennis J. Dlugos: dlugos@email.chop.edu; William Gallentine: william.gallentine@duke.edu; Christopher C. Giza: CGiza@mednet.ucla.edu; Joshua L. Goldstein: JGoldstein@childrensmemorial.org; Cecil D. Hahn: cecil.hahn@sickkids.ca; Sudha Kilaru Kessler: kesslers@email.chop.edu; Tobias Loddenkemper: Tobias.Loddenkemper@childrens.harvard.edu; James J. Riviello: james.riviello@nyumc.org; Nicholas S. Abend: abend@email.chop.edu

[a]Division of Neurology, Departments of Pediatrics and Neurology, Children's Hospital of Philadelphia and University of Pennsylvania School of Medicine

[b]Department of Neurology, Children's National Medical Center

[c]Division of Neurology, Children's Hospital of Colorado and University of Colorado School of Medicine

[d]Division of Neurology, Duke Children's Hospital and Duke University School of Medicine

[e]Division of Neurology, Department of Pediatrics Mattel Children's Hospital and UCLA Brain Injury Research Center, Department of Neurosurgery, David Geffen School of Medicine at UCLA

[f]Division of Neurology, Children's Memorial Hospital and Northwestern University Feinberg School of Medicine

[g]Division of Neurology, The Hospital for Sick Children and University of Toronto

---

Financial Disclosures:

- Sarah M. Sanchez: None
- Jessica Carpenter: None
- Kevin E. Chapman: None
- Dennis J. Dlugos: None
- William Gallentine: Receives payment for Cyberonics speakers bureau, advisory board; Questcor advisory board.
- Christopher C. Giza: Medical Education Speakers Network, Book Royalties from Blackwell Publishing for Neurological Differential Diagnosis, occasional Medicolegal cases. None are related to this work.
- Cecil D. Hahn: None
- Sudha Kilaru Kessler: None
- Joshua L. Goldstein: None
- Tobias Loddenkemper: Serves on the Laboratory Accreditation Board for Long Term (Epilepsy and ICU) Monitoring (ABRET), performs Video EEG longterm monitoring, EEGs, and other electrophysiological studies at Children's Hospital Boston and bills for these procedures.
- James J. Riviello, Jr.: Spouse receives honorarium as section editor for Up-to-Date.
- Nicholas S. Abend: None

[h]Division of Epilepsy and Clinical Neurophysiology, Department of Neurology, Children's Hospital Boston and Harvard Medical School

[i]Division of Pediatric Neurology, New York University Langone Medical Center and New York University School of Medicine

## Abstract

**PURPOSE—**To describe current continuous EEG (cEEG) utilization in critically ill children.

**METHODS—**An online survey of pediatric neurologists from 50 United States (U.S.) and 11 Canadian institutions was conducted in August 2011.

**RESULTS—**Responses were received from 58 of 61 (95%) surveyed institutions. Common cEEG indications are altered mental status after a seizure or status epilepticus (97%), altered mental status of unknown etiology (88%), or altered mental status with an acute primary neurological condition (88%). The median number of patients undergoing cEEG per month per center increased from August 2010 to August 2011 (6 to 10 per month in U.S., 2 to 3 per month in Canada). Few institutions have clinical pathways addressing cEEG use (31%). Physicians most commonly review cEEG twice per day (37%). There is variability regarding which services can order cEEG, the degree of neurology involvement, technologist availability, and whether technologists perform cEEG screening.

**CONCLUSIONS—**Among the surveyed institutions, which included primarily large academic centers, cEEG use in pediatric intensive care units is increasing and is often considered indicated for children with altered mental status at risk for non-convulsive seizures. However, there remains substantial variability in cEEG access and utilization among institutions.

### Keywords

Critical Care; EEG; Pediatric; Survey; EEG monitoring

## Introduction

Continuous electroencephalographic monitoring (cEEG) is a noninvasive neuromonitoring technique that detects non-convulsive seizures (NCS) and non-convulsive status epilepticus (NCSE), determines whether clinical events of concern are epileptic, and can identify meaningful background changes. When used in a pediatric intensive care unit (PICU), the most common clinical impact is identification of NCS or NCSE(Abend, Topjian, Gutierrez-Colina et al. 2011), which have been reported in 7–47% of critically ill children with acute encephalopathy.(Alehan, Morton and Pellock 2001; Hosain, Solomon and Kobylarz 2005; Jette, Claassen, Emerson et al. 2006; Saengpattrachai, Sharma, Hunjan et al. 2006; Tay, Hirsch, Leary et al. 2006; Abend and Dlugos 2007; Hyllienmark and Amark 2007; Abend, Topjian, Ichord et al. 2009; Shahwan, Bailey, Shekerdemian et al.; Abend, Gutierrez-Colina, Topjian et al. 2011; McCoy, Sharma, Ochi et al. 2011; Williams, Jarrar and Buchhalter 2011) NCS and NCSE are associated with worse outcome in critically ill children.(Greiner, Holland, Leach et al. 2012; Kirkham, Wade, McElduff et al. 2012; Topjian, Gutierrez-Colina, Sanchez et al. In press.) However, use of cEEG to identify NCS and NCSE is resource intense because it requires encephalographers, EEG technologists, EEG equipment, and a network infrastructure.

A prior survey of adult and pediatric neurologists indicated that respondents often used cEEG, but that substantial variability existed in cEEG indications and NCS management. (Abend, Dlugos, Hahn et al. 2010) Limited pediatric data were available at the time, so pediatric neurologists likely based their practice on available adult data. In the intervening

two years, there has been improved consensus for the use of cEEG in critically ill patients(Guerit, Amantini, Amodio et al. 2009), development of cEEG technical guidelines, (2008) and publication of additional pediatric data.(Shahwan, Bailey et al. 2010; Stewart, Otsubo, Ochi et al. 2010; Abend, Gutierrez-Colina, Topjian et al. 2011; Akman, Micic, Thompson et al. 2011; McCoy, Sharma et al. 2011; Williams, Jarrar et al. 2011) Consequently, we aimed to describe available cEEG resources and practice related to cEEG of critically ill children. These data may be useful in developing clinical pathways that take into account available resources and in designing ethical and feasible clinical trials focused on NCS management and outcome assessment. We report data acquired from a survey of primarily large academic pediatric neurology programs in the United States (U.S.) and Canada.

## Methods

The survey was developed by the Pediatric Critical Care EEG Group, a subgroup of the American Clinical Neurophysiology Society's ICU EEG Interest Group and the Critical Care EEG Monitoring Research Consortium. It was conducted in August 2011 using SurveyMonkey (www.surveymonkey.com). This study was deemed exempt from review by the Institutional Review Board of the Children's Hospital of Philadelphia.

A limited cohort of institutions was surveyed. U.S. centers ranked from number 1 to 50 in pediatric neurology/neurosurgery by the 2011–2012 U.S. News and World Report (U.S. News and World Report, 2011) were surveyed. All eleven major tertiary care Canadian institutions were surveyed. This cohort represented mostly large academic medical centers and hospitals. One response per institution was obtained. We targeted physicians designated as neurophysiology or epilepsy program directors, and if unavailable, then faculty with a special interest or training in epilepsy and neurophysiology.

The survey defined cEEG as an EEG recording lasting at least three hours. The survey consisted of thirty-one multiple-choice, closed-ended questions some of which permitted multiple responses, required about ten minutes to complete, and was composed of three sections. The first section addressed the institution's resources, cEEG practice, cEEG indications, and the number of patients who underwent cEEG in August 2011 as compared to August 2010. The second section addressed cEEG interpretation, report generation, and the means by which results are conveyed to the care team. The third section addressed EEG technologist availability and equipment.

For survey questions with yes/no answers, frequency data are presented as percentages of total respondents. For questions with ordinal categories, the central tendency is reported as a median and interquartile range (IQR). Data are reported for U.S. and Canadian institutions. Comparisons of the distributions of answers between respondents from the U.S. and Canada and between respondents from larger (≥26 PICU beds) and smaller (≤25 PICU beds) PICUs in the U.S. were made using Fisher's exact test for dichotomous variables (yes/no questions) and the Wilcoxon rank sum test for ordinal categories, with a significance level of 0.05. The differences in the median number of children undergoing cEEG in August 2010 and August 2011 were compared using the Wilcoxon signed-rank test for comparison of paired non-parametric distributions.

## Results

Responses were received from 58 of 61 (95%) surveyed institutions (47/50 U.S. and 11/11 Canada), which were primarily large academic medical centers. In the U.S., PICUs tend to be larger (p=0.0006) and hospitals tend to have independent cardiac ICUs (p=0.0008) (Table

1). General neurology consultation services provide care for PICU patients in 85% of institutions (81% U.S., 100% Canada). Nineteen percent of U.S. institutions report having a dedicated neuro-ICU consultation service.

Among surveyed institutions, the use of cEEG increased from August 2010 to August 2011. In the U.S., a median of ten patients per month underwent cEEG (IQR 6.3–15), an increase from a median of six patients per month (IQR 5–15) in the prior year ($p<0.0001$). Institutions with larger and smaller PICUs in the U.S. reported a similar median number of patients per month who underwent cEEG (larger PICUs 11 patients with IQR 7.5–17.5, smaller PICUs 8 patients with IQR 5–12, $p=0.12$). At Canadian hospitals a median of three patients per month underwent cEEG (IQR 2–4.5), an increase from a median of two patients per month (IQR 1–2.5) in the prior year ($p<0.0063$).

Only 31% of surveyed institutions (34% U.S., 18% Canada) reported having an institutional ICU EEG clinical pathway or guideline. Routine EEGs were required prior to cEEG at 39% of institutions (37% U.S., 46% Canada). Neurology services could order cEEG at 100% of institutions. Critical care and neurosurgical services could order cEEG at 59% and 57% of institutions, respectively. A formal neurology consult with recommendation for cEEG was required at 36% of institutions. Phone discussion prior to cEEG initiation, sometimes with formal consultation during the cEEG, was required by 53% of institutions (62% U.S., 18% Canada). No neurology involvement was needed at 10% of institutions (11% U.S., 9% Canada).

Respondents were asked to select their indications for EEG monitoring in current practice (Table 2). The initial twenty minutes of EEG was generally reviewed within one hour by EEG technologists in 65% of institutions (70% U.S., 46% Canada), and by a physician EEG reader in 79% of institutions (80% U.S., 73% Canada). The frequency of EEG review while screening for seizures and the frequency of written reports are shown in Table 3. The ability to remotely view EEG and the percentage of PICU beds that can be viewed remotely are shown in Table 4. Quantitative trend analysis was used by the EEG reader in 39% of institutions (42% U.S., 27% Canada) and at bedside in 14% of institutions (13% U.S., 18% Canada).

Policies regarding how information was conveyed from the EEG reader to critical care physicians were utilized at 49% of institutions (52% U.S., 36% Canada). Most institutions used a combination of methods to convey information including immediate written reports in 71% (67% U.S., 91% Canada), verbal discussion with the neurology team in 93% (91% U.S., 100% Canada), and verbal discussion with the PICU team in 67% (65% U.S., 73% Canada) of institutions. If an EEG finding indicated a change in management, a multi-step system of conveying information, in which the EEG reader speaks with a neurology consultant who then speaks with an intensivist, was used in 65% of institutions (70% U.S., 46% Canada). The EEG reader contacted the PICU physician directly at 18% of institutions (15% U.S., 27% Canada).

Technologist availability and work type are shown in Table 5. Electrodes were applied by EEG technologists for all recordings at 89% of institutions (91% U.S., 80% Canada). Non-EEG technologists applied electrodes at night in 11% of institutions (9% U.S., 20% Canada). Computerized tomography compatible electrodes were used by 26% (24% U.S., 36% Canada) and magnetic resonance imaging compatible electrodes were used at 28% of institutions (26% U.S., 36% Canada). Reduced montages were used for some patients at 9% of institutions (9% U.S., 9% Canada). A technologist protocol to assess reactivity was used in 81% of institutions (79% U.S., 91% Canada).

Among the cohort of institutions surveyed, there were no differences between larger and smaller PICUs in the U.S. Several differences were noted between responses from the U.S. and Canada. A formal neurology consultation with recommendation for cEEG was required more often at Canadian institutions (28% in U.S., 75% in Canada, p=0.0382). EEG monitoring could be ordered by non-neurology services more commonly in the U.S. than in Canada, including the PICU service (68% in U.S., 18% in Canada, p=0.0005) and the neurosurgical service (66% in U.S., 18% in Canada, p=0.0052). Technologists were more widely available at all times in the U.S. than in Canada (p=0.0034). The ability to remotely review EEG, especially from home, was available more often at U.S. institutions (p=0.0024) and for a greater percentage of PICU beds at U.S. institutions (p=0.0023).

## Discussion

Among surveyed centers which included primarily large academic institutions, cEEG use increased by about 30% over one year. A majority of surveyed institutions monitor critically ill children with altered mental status of unknown etiology, altered mental status and a primary acute neurologic disorder, and altered mental status persisting after a clinically evident convulsion or status epilepticus.

Many aspects of clinical practice vary between surveyed institutions, and most institutions do not have a clinical pathway guiding use of cEEG, suggesting that clinical practice may vary even within institutions. Prior studies have indicated that seemingly small variations in cEEG indications and monitoring duration have a substantial impact on resource utilization(Gutierrez-Colina, Topjian, Dlugos et al. 2012) indicating that the demonstrated variability may have important consequences for the healthcare system. While studies have indicated that electrographic seizures are associated with worse outcome in critically ill children(Greiner, Holland et al. 2012; Kirkham, Wade et al. 2012; Topjian, Gutierrez-Colina et al. In press.) and that clinical management is often impacted by cEEG data(Abend, Topjian et al. 2011), studies have not investigated whether seizure identification and management improves neurodevelopmental outcome. In the absence of definitive data regarding outcome, it is understandable that cEEG use is variable. Characterizing this variability in the context of outcomes assessment may yield useful data regarding the impact of cEEG on outcome.(Loddenkemper, Nichol, Allred et al. 2010)

Most of the surveyed institutions do not truly provide cEEG “monitoring,” but rather continuously acquire EEG data and review it intermittently. Based on our data, reviewing cEEG twice per day is well within the scope of current clinical practice. While time may elapse between seizure onset and cEEG review, it is likely that identifying seizures at some point, even after a delay, is better than never identifying them. The majority of surveyed institutions report that the initial portion of cEEG is reviewed within about an hour of cEEG initiation by either a technologist and/or physician, which likely avoids long delays in the diagnosis of NCSE if it is present from the start of the recording. Use of quantitative EEG at bedside might allow caregivers to identify seizures, thereby improving the speed of seizure identification without requiring continuous interpretation by neurophysiologists. Initial studies have indicated that quantitative EEG trends are useful for seizure identification (Stewart, Otsubo et al. 2010; Akman, Micic et al. 2011), yet our data indicate they are rarely used in clinical practice. Further development and implementation of quantitative EEG trends may allow for more rapid identification of seizures. Most of the surveyed institutions have multiple methods for conveying cEEG data to bedside physicians, and when management changes may be indicated, a phone-chain involving multiple people is activated. A pathway guiding distribution of cEEG data could make management more efficient and consistent. Even if not entirely evidence-based, institutional cEEG pathways could still standardize care, and such standardization has been shown to improve

management of related conditions such as status epilepticus.(Tirupathi, McMenamin and Webb 2009)

If future studies find that management changes related to cEEG findings improve outcome, then our data indicate that many institutions will need both personnel and technical infrastructure development before cEEG can be used more widely, even among a surveyed cohort that included primarily large academic institutions. Many of the surveyed institutions do not have in-house EEG technologists available at all times and rely on a call-back system. Additionally, EEG technologists only screen EEG at about half of the centers, and many PICU beds cannot be monitored remotely. Increasing cEEG use at many of these institutions would require updated networks to permit remote reading, additional technologists available to apply and remove electrodes, additional technologists capable of screening EEG, and additional neurophysiologists to review and interpret EEG. Interestingly, there were no differences in resource availability when comparing PICUs with greater or fewer than 25 beds in the U.S., indicating that institutional choices regarding cEEG importance and not PICU size may be the primary determinant of resource availability. However, we did not assess PICU volume which may not have correlated with size as measured by the number of beds. EEG screening costs might be lower when spread across a larger number of patients, so multi-institution neuro-telemetry services could be considered. The costs associated with implementing cEEG more widely should motivate further investigation of the epidemiology and neurodevelopmental impact of NCS to ensure that limited healthcare resources are optimally allocated.

Several interesting differences are noted between surveyed U.S. and Canadian institutions. Canadian institutions report that neurologists have more involvement in making decisions related to cEEG utilization. For example, Canadian institutions more often report that formal neurologic consultation with recommendation for cEEG is required. Continuous EEG may not be as readily available and this may lead to greater involvement by neurologists in order to best allocate this limited resource. Alternatively, direct neurologist involvement might help to prevent unnecessary cEEG use, and this could lead to a lower need for cEEG resources. Further study is needed to determine whether cEEG should be viewed as a test that can be ordered by all physicians within an institution or as a specialized procedure approved for use by a limited number of physicians.

This study has several important limitations. First and foremost, this study did not survey every pediatric institution in the U.S. or Canada. The fifty U.S. institutions surveyed were derived from the 2011–2012 U.S. News and World Report rankings (2011) of pediatric neurology/neurosurgery centers. While this list provided a replicable and describable cohort, it is comprised of primarily large academic institutions and is unlikely to reflect practice at all institutions providing critical care to children. Larger institutions may be more likely to have epilepsy monitoring units and therefore may be more easily capable of implementing critical care cEEG. Second, this study utilized primarily closed-ended questions that could not capture the full complexity of neuromonitoring in critically ill patients. When asked for “other comments” at the end of the survey, many respondents elaborated on additional situation dependent considerations, indicating that even carefully crafted and evidence-based pathways may have difficulties capturing the important intricacies of clinical practice. Third, there may be differences in reported and actual use of cEEG.

The large number of patients undergoing cEEG and the extensive infrastructure being developed to perform cEEG should motivate further study addressing whether cEEG use improves neurodevelopmental outcome and guiding efficient and appropriate resource utilization. Identifying and managing electrographic seizures might improve outcome, but studies are needed to determine which patients or types of acute brain injury may benefit

from seizure identification and treatment and to establish the optimal management approach. In addition to identifying seizures, cEEG data may serve as a useful biomarker of cerebral function. If EEG permits early recognition of acute brain changes then it may provide a treatment window in which intervention improves outcome. Additionally, it may allow for the assessment of the impact of interventions on brain function. While cEEG may benefit critically ill children, decisions regarding cEEG practice have a substantial impact on resource utilization.(Gutierrez-Colina, Topjian et al. 2012) Thus, further study is needed to ensure cEEG implementation is evidence-based and truly improves patient care.

## Acknowledgments

Dr. Abend is supported by NIH/NINDS grant K23NS076550-01 and Institutional Development Funds from the Department of Pediatrics at the Children's Hospital of Philadelphia. Dr. Giza is supported by Thrasher Research Foundation, Today's and Tomorrow's Children Fund, UCLA Brain Injury Research Center, Winokur Family Foundation/Child Neurology Foundation. Dr. Loddenkemper is supported by NIH/NINDS 1R21NS076859-01 (2011–2013), a Career Development Fellowship Award from Harvard Medical School and Children's Hospital Boston, the Program for Quality and Safety at Children's Hospital Boston, the Division of Epilepsy and Clinical Neurophysiology in the Department of Neurology at Children's Hospital Boston, the Epilepsy Foundation of America (EF-213583 & EF-213882), and the Center for Integration of Medicine and Innovative Technology (CIMIT), and received investigator initiated research support from Eisai Inc. Dr. Hahn is supported by the SickKids Foundation. The Pediatric Critical Care EEG Consortium has been supported by funding from the American Epilepsy Society's Infrastructure Award, the Children's Hospital of Philadelphia, and the SickKids Foundation.

## References

Abend NS, Dlugos DJ. Nonconvulsive status epilepticus in a pediatric intensive care unit. Pediatr Neurol. 2007; 37:165–70. [PubMed: 17765803]

Abend NS, Dlugos DJ, Hahn CD, Hirsch LJ, Herman ST. Use of EEG Monitoring and Management of Non-Convulsive Seizures in Critically Ill Patients: A Survey of Neurologists. Neurocritical Care. 2010; 12:382–389. [PubMed: 20198513]

Abend NS, Gutierrez-Colina AM, Topjian AA, Zhao H, Guo R, Donnelly M, Clancy RR, Dlugos DJ. Non-convulsive seizures are common in critically ill children. Neurology. 2011; 76:1071–1077. [PubMed: 21307352]

Abend NS, Gutierrez-Colina AM, Topjian AA, Zhao H, Guo R, Donnelly M, Clancy RR, Dlugos DJ. Nonconvulsive seizures are common in critically ill children. Neurology. 2011; 76:1071–7. [PubMed: 21307352]

Abend NS, Topjian A, Ichord R, Herman ST, Helfaer M, Donnelly M, Nadkarni V, Dlugos DJ, Clancy RR. Electroencephalographic monitoring during hypothermia after pediatric cardiac arrest. Neurology. 2009; 72:1931–1940. [PubMed: 19487651]

Abend NS, Topjian AA, Gutierrez-Colina AM, Donnelly M, Clancy RR, Dlugos DJ. Impact of continuous EEG monitoring on clinical management in critically ill children. Neurocrit Care. 2011; 15:70–5. [PubMed: 20499208]

Akman CI, Micic V, Thompson A, Riviello JJ Jr. Seizure detection using digital trend analysis: Factors affecting utility. Epilepsy Res. 2011; 93:66–72. [PubMed: 21146370]

Alehan FK, Morton LD, Pellock JM. Utility of electroencephalography in the pediatric emergency department. J Child Neurol. 2001; 16:484–7. [PubMed: 11453443]

American-Society-of-Electroneurodiagnostic-Technologists. National competency skill standards for ICU/cEEG monitoring. Am J Electroneurodiagnostic Technol. 2008; 48:258–64. [PubMed: 19203079]

Greiner HM, Holland K, Leach JL, Horn PS, Hershey AD, Rose DF. Nonconvulsive status epilepticus: the encephalopathic pediatric patient. Pediatrics. 2012; 129:e748–55. [PubMed: 22331332]

Guerit JM, Amantini A, Amodio P, Andersen KV, Butler S, de Weerd A, Facco E, Fischer C, Hantson P, Jantti V, Lamblin MD, Litscher G, Pereon Y. Consensus on the use of neurophysiological tests in the intensive care unit (ICU): electroencephalogram (EEG), evoked potentials (EP), and electroneuromyography (ENMG). Neurophysiol Clin. 2009; 39:71–83. [PubMed: 19467437]

Gutierrez-Colina AM, Topjian AA, Dlugos DJ, Abend NS. EEG Monitoring in Critically Ill Children: Indications and Strategies. Pediatric Neurology. 2012; 46:158–161. [PubMed: 22353290]

Hosain SA, Solomon GE, Kobylarz EJ. Electroencephalographic patterns in unresponsive pediatric patients. Pediatr Neurol. 2005; 32:162–5. [PubMed: 15730895]

Hyllienmark L, Amark P. Continuous EEG monitoring in a paediatric intensive care unit. Eur J Paediatr Neurol. 2007; 11:70–5. [PubMed: 17188917]

Jette N, Claassen J, Emerson RG, Hirsch LJ. Frequency and predictors of nonconvulsive seizures during continuous electroencephalographic monitoring in critically ill children. Arch Neurol. 2006; 63:1750–5. [PubMed: 17172615]

Kirkham FJ, Wade AM, McElduff F, Boyd SG, Tasker RC, Edwards M, Neville BG, Peshu N, Newton CR. Seizures in 204 comatose children: incidence and outcome. Intensive Care Med. 2012; 38:853–62. [PubMed: 22491938]

Loddenkemper T, Nichol SM, Allred EN, Leviton A. Fears and promises of comparative effectiveness research. Acta Paediatr. 2010; 99:1311–3. [PubMed: 20659075]

McCoy B, Sharma R, Ochi A, Go C, Otsubo H, Hutchison JS, Atenafu EG, Hahn CD. Predictors of nonconvulsive seizures among critically ill children. Epilepsia. 2011; 52:1973–8. [PubMed: 22003955]

Saengpattrachai M, Sharma R, Hunjan A, Shroff M, Ochi A, Otsubo H, Cortez MA, Carter Snead O 3rd. Nonconvulsive seizures in the pediatric intensive care unit: etiology, EEG, and brain imaging findings. Epilepsia. 2006; 47:1510–8. [PubMed: 16981868]

Shahwan A, Bailey C, Shekerdemian L, Harvey AS. The prevalence of seizures in comatose children in the pediatric intensive care unit: A prospective video-EEG study. Epilepsia. 2010; 51:1198–1204. [PubMed: 20163439]

Stewart CP, Otsubo H, Ochi A, Sharma R, Hutchison JS, Hahn CD. Seizure identification in the ICU using quantitative EEG displays. Neurology. 2010; 75:1501–8. [PubMed: 20861452]

Tay SK, Hirsch LJ, Leary L, Jette N, Wittman J, Akman CI. Nonconvulsive status epilepticus in children: clinical and EEG characteristics. Epilepsia. 2006; 47:1504–9. [PubMed: 16981867]

Tirupathi S, McMenamin JB, Webb DW. Analysis of factors influencing admission to intensive care following convulsive status epilepticus in children. Seizure. 2009; 18:630–3. [PubMed: 19699662]

Topjian AA, Gutierrez-Colina AM, Sanchez SM, Berg RA, Friess SH, Dlugos DJ, Abend NS. Electrographic Status Epilepticus is Associated with Mortality and Worse Short-Term Outcome in Critically Ill Children. Critical Care Medicine. In press.

U.S.-News-and-World-Report. US News Best Children's Hospitals: Neurology & Neurosurgery. 2011. Retrieved July 2, 2011, Available at: http://health.usnews.com/best-hospitals/pediatric-rankings/neurology-and-neurosurgery

Williams K, Jarrar R, Buchhalter J. Continuous video-EEG monitoring in pediatric intensive care units. Epilepsia. 2011; 52:1130–6. [PubMed: 21671924]

## Table 1

Size of Pediatric (PICU) and Cardiac (CICU) Intensive Care Units among respondent hospitals in the United States and Canada

| Number of Beds | Number of ICUs (Percent) | | | |
|---|---|---|---|---|
| | United States PICU | Canada PICU | United States CICU | Canada CICU |
| **<10** | 0 (0%) | 1 (9%) | 9 (19%) | 0 (0%) |
| **11–25** | 17 (36%) | 10 (91%) | 16 (34%) | 1 (100%) |
| **26–50** | 28 (60%) | 0 (0%) | 8 (17%) | 0 (0%) |
| **>51** | 2 (4%) | 0 (0%) | 0 (0%) | 0 (0%) |

## Table 2

Indications for EEG monitoring.

| cEEG Indication | All | U.S. | Canada |
|---|---|---|---|
| ΔMS with acute primary neurologic disorder | 88% | 89% | 82% |
| ΔMS after clinically evident seizure or status epilepticus | 97% | 96% | 100% |
| ΔMS of unknown etiology | 88% | 89% | 82% |
| ΔMS and systemic disorder (but no acute neurologic disorder) | 72% | 75% | 64% |
| Event Characterization (movement or vital sign fluctuations) | 95% | 100% | 73% |
| Resuscitation from cardiac arrest | 62% | 68% | 36% |
| Extra corporal membrane oxygenation | 34% | 36% | 27% |
| Traumatic brain injury | 53% | 60% | 27% |
| Sepsis | 9% | 11% | 0% |

ΔMS = altered mental status

## Table 3

Frequency of technologist review, physician review, and written report generation.

| EEG Review and Reporting | Frequency | All | U.S. | Canada |
|---|---|---|---|---|
| **Technologist Review** | Never | 27% | 28% | 20% |
| | 1 per day | 16% | 13% | 30% |
| | 2 per day | 27% | 22% | 50% |
| | 3 per day | 4% | 4% | 0% |
| | 4 per day | 5% | 7% | 0% |
| | >4 per day | 7% | 9% | 0% |
| | Continuously | 14% | 17% | 0% |
| **Physician Review** | 1 per day | 19% | 15% | 36% |
| | 2 per day | 37% | 37% | 36% |
| | 3 per day | 19% | 24% | 0% |
| | 4 per day | 7% | 2% | 27% |
| | >4 per day | 17% | 20% | 0% |
| | Continuously | 2% | 2% | 0% |
| **Written Report** | <1 per day | 21% | 22% | 18% |
| | 1 per day | 70% | 72% | 64% |
| | >1 per day | 9% | 7% | 18% |

## Table 4

Remote access by EEG reader location and percent of PICU beds.

| Remote Access | | All | U.S. | Canada |
|---|---|---|---|---|
| **Remote Access by Reader Location** | Remote in hospital and home | 82% | 93% | 37% |
| | Remote in hospital | 11% | 7% | 27% |
| | No remote | 7% | 0% | 36% |
| **% PICU Beds that can be Accessed Remotely** | 0% | 9% | 0% | 46% |
| | 1–49% | 23% | 22% | 27% |
| | ≥50% | 68% | 78% | 27% |

## Table 5

Technologist availability and type of work.

| Technologist Availability and Work | | All | U.S. | Canada |
|---|---|---|---|---|
| **Availability** | Always available in-hospital | 28% | 35% | 0% |
| | Always available but sometimes by call-back | 51% | 52% | 46% |
| | Not always available | 21% | 13% | 54% |
| **Technologist Work** | Technical Only | 51% | 50% | 55% |
| | Technical and EEG Screening | 49% | 50% | 45% |