Introduction of a Pediatric Neurology Hospitalist Service With Continuous Electroencephalography Monitoring at a Children's Hospital

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Philip J. Overby, MD¹, Jules C. Beal, MD¹,
Elissa G. Yozawitz, MD¹, and Solomon L. Moshé MD^{1,2,3}

Abstract

Hospitalists, specializing in inpatient medicine, are increasingly being utilized in the hospital setting to improve efficiency, decrease costs and length of stay, and potentially improve outcomes. With these goals in mind and with the purpose of addressing the specific needs of patients on the inpatient pediatric neurology service, we established a pediatric neurohospitalist service in 2009. The primary purpose of this article is to describe the structure and the rationale for a pediatric neurohospitalist service with continuous electroencephalography at a pediatric teaching hospital and to discuss the categories of disease seen by the inpatient neurology service.

Keywords

neurohospitalist, clinical specialty, pediatric neurology, outcomes, techniques

Introduction

In 2009, our hospital instituted a pediatric neurology hospitalist service. There were multiple reasons for initiating the service. First, the case mix of the inpatient service and outpatient services is quite distinct and while they overlap (particularly with the epilepsy cases) require a different skill set, for example, intensive care unit (ICU) care. Second, as part of their training, house staff spend approximately 50% of their time in the inpatient setting. Third, with increasing pressures to shorten length of stay, the hospitalist model in other specialties has been shown to make the evaluation, treatment, and discharge of patients from the hospital more efficient. Fourth, there is an emerging need for long-term electroencephalography (EEG) monitoring in the pediatric ICU (PICU), and part of the initiative for the service was to provide this service.

Purpose of the Article

The primary purpose of this article is to describe the rationale for and structure of a pediatric neurology hospitalist service at an urban pediatric teaching hospital. We discuss the categories of disease seen by the inpatient pediatric neurology team, categories which overlap with, but are distinct from, outpatient pediatric neurology. In addition, initial data on video EEG monitoring both in the ICU and on the pediatric floors are presented.

Methods

The structure of the pediatric neurology service consists of the neurology hospitalist, a rotating teaching attending, a pediatric neurology resident, 2 to 3 adult neurology residents, and 1 to 3 medical students. The service functions as a primary service for neurology patients as well as a consult service. There is no separate pediatric neurology service. Neonatal intensive care unit patients (NICU patients) are cared for on a separate campus and have not been part of the hospitalist service.

Currently, there is a single pediatric neurology hospitalist from 8 AM to 5 PM. Overnight call responsibilities during the week are shared with the teaching attending. Weekend call is assigned to the teaching attending for the month they are

¹ Saul R. Korey Department of Neurology, Albert Einstein College of Medicine and Montefiore Medical Center, Bronx, NY, USA

² Department of Pediatrics, Children's Hospital at Montefiore and Albert Einstein College of Medicine and Montefiore Medical Center, Bronx, NY, USA

³ Dominick P. Purpura Department of Neuroscience, Albert Einstein College of Medicine, Bronx, NY, USA

Corresponding Author:

Philip J. Overby, Department of Neurology, 111 E 210th St, Bronx, NY 10467, USA.

Email: poverby1@gmail.com

on service, with a variable portion of the weekend calls also taken by the hospitalist. Teaching attending responsibilities range from 1 to 3 months per year. When the neurohospitalist is away, the pediatric neurology service is covered by pediatric neurology faculty. Additional weekend and holiday coverage for long-term EEG monitoring is shared with adult neurology colleagues when needed.

Long-term EEG monitoring is reviewed by the neurology hospitalist prior to rounds, in the afternoon and overnight as needed. A 6-bed pediatric epilepsy monitoring unit (EMU) is present in the children's hospital, which is an independent service. Because nurses in the EMU are trained to recognize and respond to seizures and are familiar with EEG monitoring, preference is given to transferring stable patients from the pediatric floor or ICU to the EMU when clinically stable.

The day begins for the pediatric neurology hospitalist in the 18-bed PICU. Typically, the pediatric neurology hospitalist and the pediatric neurology resident review overnight events and prioritize goals for the day. Together, they examine the most urgent patients and review imaging and EEG studies prior to rounds and visit the PICU team to communicate about overnight events and new consultations. During this prerounding, there is coaching of the resident with the aim that he or she will lead rounds, which run from 9:00 to 10:30 AM. The goals of rounds are pragmatic and goal directed. Priority is given to sick patients, new patients, patients who need decisions made regarding studies to be ordered for the day, and patients needing clearance to be discharged. After rounds are finished and the pediatricians are notified of plans for the day, the team meets for 45 minutes of a didactic session with the teaching attending 3 days per week. The pediatric neurology hospitalist typically returns to the ICU to complete notes or finish EEG reports at this time. At 11:30 AM, the team meets again to review pertinent imaging with the neuroradiologist.

Discussion about optimal management of patients between the neurology hospitalist, teaching attending, and house staff is central to daily rounds. The pediatric neurology resident is expected to lead rounds and arbitrate decisions. However, as the attending of record final decisions are made by the pediatric neurology hospitalist. The availability of the hospitalist to the house staff facilitates both teaching and management of patients, allowing both activities to occur in real time.

To follow up on the hospital admission, we have arranged for the neurology hospitalist to see patients after discharge once. One afternoon per week is allocated to hospital follow-up visits. If the patient will require ongoing neurological care, the goal is for hospitalized patients ultimately to be followed by other faculty in the outpatient neurology offices. Those patients seen in follow-up are typically the patients with pending laboratory results or following a complicated hospital course. This has proved helpful for continuity of care and transition to outpatient care.

Table 1. Total Consults Seen, by Year.

	2009-2010	2010-2011	Total
Total consults	528	527	1055
ICU	101	101	202
Non-ICU	427	426	853
Repeats	55 (473 unique)	59 (468 unique)	

Abbreviation: ICU, intensive care unit.

Table 2. Consults seen, by category.

Category	Number of consults (% of total)
Epilepsy/seizures	266 (25.2)
Headaches/migraine	101 (9.6)
Spells, including syncope and GERD	81 (7.7)
Disorders of intracranial pressure	63 (6.0)
Febrile seizures	61 (5.8)
Immune mediated	54 (5.1)
Psychiatric	52 (5.1)
Infections	47 (4.5)
Ingestion/toxicity/medication	47 (4.5)
Genetic/malformative	40 (4.5)
Trauma	34 (3.6)
Stroke/vascular	33 (3.1)
Neoplastic diseases	31 (2.9)
Neuromuscular, including neuropathy	31 (2.9)
Hypoxic-ischemic encephalopathy	20 (1.9)
Pain	20 (1.9)
Delirium	15 (1.4)
Metabolic disorders	13 (1.2)
Degenerative diseases	9 (0.9)
Undiagnosed	7 (0.7)
Brain death	6 (0.6)
Medical (nonneurologic)	5 (0.5)
Movement disorders	5 (0.5)
Autonomic dysfunction	4 (0.3)
Vestibular	4 (0.3)
Sleep disorders	3 (0.2)
Normal, no pathology	3 (0.2)

Abbreviation: gastroesophageal reflux disease.

Results

Over the 2-year period from July 2009 to June 2011, there were 16 203 total admissions to the 106-bed children's hospital, 2003 of which were admitted to the PICU. A total of 1055 neurology consultations were performed during this period. Of these, 202 consultations were for ICU patients. Therefore, 6.5% of all admissions to the hospital and 10.1% of patients in the ICU were evaluated by the inpatient neurology service.

The total number of consultations is listed in Table 1. They are divided by category in Table 2. The most common reasons for consultation were seizures and headaches. Febrile and nonfebrile seizures represented 5.8% and 25% of the

Table 3. Long-Term EEG Monitoring in the Pediatric ICU: July 2009-June 2011.

Indication for Monitoring	Number of Studies	Mean Age (Age Range)	Mean Days of Monitoring (Range)	Studies Showing Clinical Seizures	Studies Showing Electrographic Seizures
Capture and characterize frequent events	22	5.75 years (1 week-17 years)	2.27 days (1-5 days)	1 (5%)	2 (9%)
Persistent encephalopathy	18	9.3 years (5 weeks-17 years)	2.17 days (1-4 days)	6 (33%)	3 (17%)
Monitoring of status epilepticus	17	4.95 years (1 week-8 years)	4.24 days (1-18 days)	0 (0%)	3 (18%)
Screen for nonconvulsive status epilepticus	14	8.9 years (1 week-20 years)	2.64 days (1-5 days)	3 (21%)	12
	Total 71			Total 10 (14%)	Total 20 (28%)

Abbreviations: EEG, electroencephalography; ICU, intensive care unit.

consultations, respectively, or nearly one-third of the total. Headaches or migraines represented nearly 10% of the referrals. “Spells” or paroxysmal events represented 7.7% of the consults, one-third of which were gastroesophageal reflux or syncope. These diagnoses are also common reasons for outpatient referral to a pediatric neurology practice.¹

Unlike most outpatient referrals, elevated intracranial pressure (ICP; 6%), immune-mediated disorders (5.1%), and infections (4.5%) together made up more than 15% of the patients. Consultations for medication toxicity, adjustments, or ingestions made up additional 4.4% of the patients.

Intensive care unit patients represented nearly 20% of the consultations. Half of these patients had seizures, vascular events, or trauma. The next third of ICU patients represented a broad range of categories including (in descending order of frequency) delirium, neoplasia, infection, medication/toxicity, elevated ICP, genetic conditions, spells, brain death, immune-mediated conditions, neuromuscular disease, and febrile seizures. Interestingly, delirium was the next most common ICU diagnosis (5%). This finding warrants further consideration, as a diagnosis that has received limited attention in the current pediatric literature.²

Chronic encephalopathies, movement disorders, or neuromuscular disorders—common diagnoses in the outpatient setting—taken together represented only 7% of the reasons for inpatient consultation. This underestimates the total number of patients with chronic encephalopathy seen by the service, since many of the patients with epilepsy, for example, had an underlying encephalopathy. Predictably, however, the cause for a chronic encephalopathy was not a common reason for inpatient consultation. Finally, psychiatric disorders made up 4.9% of the consultations.

Central to the service was continuous EEG (cEEG) monitoring. In total, 99 studies were performed, 71 of which were ICU studies. In total, 54 individual ICU patients (27% of all ICU patients consulted by pediatric neurology) were monitored (see Table 3). The studies were collected in a prospective database maintained for all adult and pediatric patients undergoing cEEG. The database provides 4 clinical indications for cEEG

monitoring: monitoring of status epilepticus; screen for nonconvulsive status epilepticus; persistent encephalopathy; and capture and characterize frequent events. These indications reflect the decision that the indication for cEEG monitoring should typically be driven by the patient’s underlying diagnosis, more than by bedside suspicion for seizures.

Of the 54 ICU patients monitored, 5 (9%) had electroclinical seizures exclusively, 4 (7.4%) had electroclinical seizures and electrographic seizures, and 10 (18.5%) had electrographic seizures exclusively, that is, 35% of the 54 ICU patients monitored had seizures and in 19% of these patients the seizures were exclusively electrographic. Of the 35% of patients in whom seizures of any type were identified, 74% had electrographic seizures. Of the 13 patients with epilepsy monitored, only 15% (2 patients) had seizures (1 electroclinical and 1 electrographic). In contrast, in patients with encephalitis (bacterial, viral, or immune mediated) 44% (4 of 9 patients) had seizures and 75% had electrographic seizures exclusively. In 10 patients with stroke (9 hemorrhagic and 1 ischemic), 60% had seizures. Of the patients with stroke, 33% of patients had exclusively clinical seizures and 66% of patients had exclusively electrographic seizures. Finally, of 10 patients monitored for status epilepticus, 50% (5 patients) had seizures, including 30% (3 of 10 patients) with exclusively electrographic seizures. Of these 10 patients, 3 had a prior diagnosis of epilepsy.

Discussion

In this retrospective review, we describe our neurohospitalist service, list the reasons for consultation for the service, and provide preliminary data on our continuous EEG monitoring.

A recent review¹ of a large cohort of outpatient pediatric patients found the majority (62%) of referrals were for paroxysmal events, 52% of which were for epilepsy. The second most common reason for consultation was headache, followed by congenital anomalies or developmental delay. These results suggest that inpatient pediatric neurology overlaps with, but is distinct from, outpatient pediatric neurology.

Predictably, inpatient pediatric neurology is distinguished from outpatient by a shift in emphasis toward disorders requiring more urgent attention: infection, immune-mediated disorders, intoxications, acute encephalopathy, and so on. Moreover, the frequency of seizures reinforces the importance of expertise in this subset of patients on the inpatient service. In contrast to adult neurology hospitalists, the majority of whom have fellowship training in vascular neurology, pediatric neurology hospitalists will need to be well trained in epilepsy.

Critical Care

It has been argued that the first critical care patient was not only a child but a child with a neurological disease, namely, polio.³ However, at this time the optimal model for provision of neurological care to critically ill patients remains a matter of discussion. Different models, from a dedicated neurocritical care service to neurologists trained in PICU, have been proposed. A full review of the subject is beyond the scope of this article, and interested readers are directed to recent discussions of the topic.⁴⁻⁷ The use of a neurohospitalist service to provide neurocritical care is another model. The virtues of the neurohospitalist model include the ability to adapt to fluctuating volumes of ICU patients, provision of continuous EEG monitoring from the team caring for the patient, availability throughout the day to respond quickly to urgent consultations and changes in clinical status, and longitudinal care over the course of a hospitalization to discharge.

Adult neurocritical care units provide care to a broad constellation of neurological and neurosurgical disorders, but their original justification was for the acute management of subarachnoid hemorrhage. In pediatric neurology, the most common ICU diagnoses are seizures and status epilepticus. It is not clear that a separate training in pediatric critical care, or independent management of the sort provided in an adult neurocritical care unit, would be superior to the more common model of shared management between neurology and intensivists. However, we have found that having a neurohospitalist trained in EEG to provide long-term monitoring is central to the provision of neurological services in the ICU. We have also found that having the physician caring for the patient also review the EEG increases the value of the EEG considerably. For example, patterns on the EEG of uncertain significance can be assessed in the context of the patient's diagnosis and current clinical status.

Most likely is that the optimal model for pediatric neurocritical care, just like the optimal model for inpatient neurology, will vary based on the institution and population being served.

Continuous EEG Monitoring in the ICU

In this retrospective review, we found that 35% of all patients monitored with continuous EEG in the PICU had seizures, 19% of which were exclusively electrographic. In recent reviews of the incidence of seizures with EEG monitoring in

adult and PICU patients, the incidence appears to vary based on the cohort and indications for monitoring. Generally, the overall incidence of seizures in these studies in the pediatric population is similar to our results, although the incidence of purely electrographic seizures may vary. In a recent retrospective study of pediatric and neonatal ICU patients, 138 studies from 122 patients, 38% of the cohort experienced seizures.⁷ In this cohort, patients <2 months were included. Similar to our cohort, monitoring was based on risk of seizures based on clinical diagnosis rather than coma or clinical suspicion at the bedside. In the largest study of its kind, a multicenter retrospective review of 550 PICU patients found that 30% had seizures, 36% of which were exclusively electrographic.⁸

The Case for Hospitalists

The original justifications for hospitalists remain relevant today⁹ and are manifold. They were developed for pediatricians and internists specializing in inpatient care but could equally be applied to a pediatric neurology hospitalist service. Having a physician close to sick patients who is able to quickly and judiciously order studies and implement therapy facilitates efficient inpatient care. Moreover, there continues to be initiatives for quality and safety for hospitalized patients.¹⁰ A recent meta-analysis demonstrated a decrease in costs and length of stay, both by approximately 70%.¹¹

There is a national shortage of pediatric neurologists,¹² which commonly results in long waiting lists for outpatients. Also, financial pressures make coverage of hospitalized patients by pediatric neurologists a common struggle for hospitals.⁴ In academic medical centers, faculties have the additional competing demands on their time for research and teaching. There is also a trend toward more outpatient training for pediatric neurology residents, which further strains hospital coverage. In short, the hospitalist model was introduced to respond to trends seen throughout medicine, providing timely inpatient care, decreasing length of stay while improving quality of care, and providing education despite decreased resident work hours on the inpatient service and overall. The hospitalist model has been shown to reduce costs while preserving outcomes as well as patient and resident satisfaction.^{13,14}

Neurohospitalists and Pediatric Neurology Hospitalists

A PubMed of the search terms neurology hospitalist yielded 32 articles, all but 2 of which pertained to adult neurology hospitalists.^{15,16} To our knowledge, this is the first article to describe a pediatric neurology hospitalist service, although pediatric neurocritical care services have been described (see previously). Potential advantages of an adult neurohospitalist service were recently described and include improved emergency coverage, improved logistical care of inpatients, improved patient outcomes, improved hospital-based neurological education, improved inpatient neurology research, and reduced length of stay.^{17,18} To this list, we would add

improved provision of pediatric neurological critical care services, the integrated use of continuous EEG, and the coordination of care for neurologically impaired children.

Nationally, neurology patients represent a significant source of hospital resource utilization. A recent study evaluated the costs associated with the care of medically complex children.¹⁹ Among the population defined as medically complex were children with neurological diagnoses, such as brain and spinal cord malformations, mental retardation, central nervous system degeneration and disease, infantile cerebral palsy, epilepsy, muscular dystrophies, and myopathies. The study found that medically complex children composed 10% of hospital admissions, 25% of hospital days, and 40% of hospital charges.

It is more common for children with disabilities to be hospitalized. In comparison to other children, they have 8 times the number of hospital days. Indeed, the majority of hospital days and expenditures in children's hospitals result from children with chronic medical conditions. In the United States, 20% of children account for 80% of all medical expenditures.²⁰

This retrospective review has significant limitations, not least of which is the diagnoses are presented in broad categories that lack precision. In addition, there is no information on outcomes or length of stay to assess the clinical impact of the neurohospitalist service.

Conclusion

The overall goal of this article was to describe the structure and functioning of the service, to assess the categories of neurological disorders seen by an inpatient pediatric neurohospitalist service, and to illustrate the potential means by which such a service augments PICU care, particularly with video EEG monitoring. In our experience over 2 years, 6.5% of all hospitalized patients required neurological consultation. Although this is a small number, since neurological cases represent a large percentage of medically complex cases, it is likely that a pediatric neurology hospitalist could have a significant effect on overall hospital costs. Whether or not having a pediatric neurology hospitalist affects measures of efficiency or quality requires further study. The presence of a neurohospitalist offers the opportunity to impact care and length of stay. A dedicated neurohospitalist who knows hospital procedures can provide the coordination of timely and appropriate care upon admission, which requires ongoing discussion with families, other physicians, and frequently social workers to be done effectively.²¹

One concern about hospitalists generally in a teaching institution is that the presence of the hospitalist will interfere with resident learning. It is our policy that all patients be seen first by residents. Also, to increase the number of pediatric neurologist who teach the residents, we have a "teaching attending" whose role is to delve daily and more deeply into specific cases after the acute care is provided. The hospitalist

model itself has also been shown to be effective in teaching residents, encouraging evidence-based medicine and promoting cohesive, real-time care.²²⁻²⁴

Opportunities for research include a focus on quality improvement as well as improved efficiencies in care.¹⁹ In addition, outcomes of medical interventions are available to be studied. Measures of quality are increasingly utilized in medicine generally. The quality measures most relevant to adult neurologists typically pertain to vascular neurology—evaluation and treatment of stroke and discharge on appropriate medications to the appropriate rehabilitation facility.¹⁸

We have found that having a dedicated pediatric neurohospitalist is helpful in the provision of neurocritical care, supervision and teaching of house staff, allocation of faculty clinical responsibilities, and coordination of care with other specialties.

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