



Original Article

Pediatric Neurocritical Care: A Neurology Consultation Model and Implication for Education and Training

Kerri L. LaRovere MD^{a,*}, Robert J. Graham MD^b, Robert C. Tasker MBBS, MD^{a,b} and The Pediatric Critical Nervous System Program (pCNSp)^{a,b}

^a Department of Neurology, Boston Children's Hospital and Harvard Medical School, Boston, Massachusetts

^b Department of Anesthesiology, Perioperative and Pain Medicine, Division of Critical Care Medicine, Boston Children's Hospital and Harvard Medical School, Boston, Massachusetts

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ABSTRACT

Pediatric neurocritical care is developing specialization within pediatric intensive care and pediatric neurology practice, and the evolving clinical expertise has relevance to training and education in both fields. We describe a model of service using a Neurology Consulting Team in the intensive care unit setting. Medical records were reviewed from a 32-month cohort of Neurology Consulting Team referrals. Six hundred eighty-nine (19%) of 3719 patients admitted to the intensive care unit were assessed by the team. The most common diagnostic categories were seizures, neurosurgical, cerebrovascular, or central nervous system infection. Fifty-seven percent (350 of 615 patients) required mechanical ventilation. Cohort mortality was 7% vs 2% for the general intensive care population ($P < 0.01$). The team provided 4592 initial and subsequent consultations; on average there were five to six new consultations per week. Each patient had a median of two (interquartile range, 1 to 6) consultations during admission. Three quarters of the cohort required neurodiagnostic investigation (1625 tests), with each patient undergoing a median of two (range, 0 to 3) studies. Taken together, the subset of pediatric intensive care unit patients undergoing neurology consultation, investigation, and management represents a significant practice experience for trainees, which has implications for future curriculum development in both pediatric critical care medicine and pediatric neurology.

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Introduction

Acute, severe neurological and neurosurgical diseases are significant causes of death in the pediatric intensive care unit [1–4]. The range of such critical pathology includes brain tissue herniation, hypoxic-ischemic, hemorrhage, trauma, tumor, epilepsy, and peripheral neuromuscular disorders [2,5–7]. There are three potential models for providing specialist neurocritical care for such children. First, the adult model of a neurointensivist-led distinct neuroscience intensive care unit may be reproduced in

centers with a large neurosurgical practice [8,9]. Second, a special interest group led by the critical care medicine faculty may be developed in centers with significant neurotrauma practice [6,7]. Third, a combination of the above models into an operational policy that suits the resources, service, and educational needs of local pediatric intensive care unit and hospital practice [10] may be used. Each model, however, has to overcome the problems of patient volume, need for multiorgan-system support, and a critical mass of clinical expertise. Also, each model has to be applicable to the educational needs of specialists in training and their future practice.

Therefore, one purpose of this study is to describe a model of pediatric neurocritical care service delivery that uses a Neurology Consulting Team to support intensive care management and care in the continuum starting at admission to the pediatric intensive care unit through

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* Communications should be addressed to: Dr. LaRovere; Department of Neurology; Boston Children's Hospital; 300 Longwood Avenue; Boston, Massachusetts 02115.

E-mail address: kerri.larovere@childrens.harvard.edu

hospital discharge and follow-up. A second aim of the study is to describe the scale of referrals and to characterize consultations by diagnoses, illness severity, investigations, and gross outcomes, because this information will inform educational needs and curriculum development.

Materials and Methods

The Institutional Review Board granted ethical approval with a waiver for study of retrospective, electronic data.

Setting and patients

During the study period, 689 cases were reviewed, and we have complete data on 615 patients (90%). This study was restricted to the practice in a 29-bed noncardiac, general medical, and surgical pediatric intensive care unit in the 350-bed Boston Children's Hospital that accepts regional, national, and international referrals. The unit is staffed by critical care medicine attending physicians who are present in the intensive care unit 24 hours per day, 7 days per week. The daytime attending physicians are on service for 1 week, with nights covered in house by rotating critical care medicine attending physicians. The intensive care unit team also includes fellows, residents, and nurse practitioners. All consultations for the Neurology Consulting Team originated from the pediatric intensive care unit. The Neurology Consulting Team is also available to conduct consults in the cardiac and neonatal intensive care units; however, we did not have complete data on these populations, and they were excluded from this study.

This service was started in 1996 by Drs. Joseph Volpe and Adr e DuPlessis. By 2005 its standard operating procedure (Table 1) had reached a state of stability such that we could report our practice for a recent 32-month cohort (May 1, 2005, to January 31, 2008). The Neurology Consulting Team is staffed during the day by rotating pediatric neurology attending physicians who were exempted from other clinical activities during a 2-week period of continuous service. Following daily intensive care unit rounds, the Neurology Consulting Team rounds with the inpatient neurology ward teams to discuss transfers out of the intensive care unit. The Neurology Consulting Team is supported by in-house training of fellows and residents in neurology 24 hours per day, 7 days per week.

Table 1. Operating procedure for neurology consulting team model of neurocritical care at Boston Children's Hospital

Structure	Service
Members	Rotating pediatric neurology attendings and adult or pediatric neurology residents
Coverage	Dedicated to consultations in intensive care units only Daytime: attendings and residents; rotating attendings have protected clinical time for 2-week period on service Nights and weekends: residents in house 24 hours per day, 7 days per week
Reason for consultation	<i>Evaluation and medical management of:</i> <ul style="list-style-type: none"> • Altered consciousness • New neurological symptom or focal deficit • Acute on chronic neurological disease • Status epilepticus, first seizure or increased seizure activity • Postoperative epilepsy surgery • Continuous electroencephalogram monitoring • Prognostication • Brain death examination
Continuity	<i>Core group of neurologists with:</i> Clinical and research interests in neurocritical care Routine attendance at weekly critical care conferences Consistent presence in the intensive care unit

Design and data extraction

Two electronic databases were searched for information. One database contained data about investigations and outcomes of patients admitted to the intensive care unit and seen by the Neurology Consulting Team (Neurology Billing Database, Boston, MA). The other database contained detailed physiologic, severity of illness, and critical care data about the intensive care unit admission (Virtual PICU Systems, Alexandria, VA).

The data extracted included source of admission (e.g., transfer from the operating room, emergency department, inpatient ward, outside hospital, or high-dependency unit), patient type (e.g., nonoperative or perioperative within 24 hours of admission), date and total number of neurology consultations, use of mechanical ventilation via an endotracheal tube, Pediatric Index of Mortality (PIM2) [11,12], and Pediatric Risk of Mortality-III (PRISM3) scores [13]. PRISM3 and PIM2 scores assess risk of mortality in the pediatric intensive care unit. The PRISM3 score is derived from measurement of physiological variables during the first 24 hours of intensive care unit admission, whereas the PIM2 score is based on physiological variables measured from the time of first contact to 1 hour after intensive care unit admission. Gross outcomes of interest were hospital and intensive care unit length of stay, death during admission, disposition, and outpatient follow-up.

Other information extracted about individual cases included diagnoses (*International Statistical Classification of Diseases and Related Health Problems, Ninth Revision, ICD-9* codes) and neurodiagnostic investigations and procedures performed (number and type). Diagnoses were categorized as neurological, neurosurgical, and general medical or surgical conditions. Neurological diagnoses recorded by the Neurology Consulting Team's attending physician at the time of assessment were grouped into the following four broad categories: epilepsy, seizures, and status epilepticus; neurosurgical conditions including tumor, hydrocephalus, and trauma; cerebrovascular conditions, including arterial ischemic stroke, cerebral sinovenous thrombosis, cerebrovascular malformation, intracranial hemorrhage, and moyamoya; and central nervous system infection. General medical or surgical diagnoses recorded by the critical care medicine specialists were grouped into the following four broad categories: respiratory insufficiency; surgical; cardiac arrest and hypoxic-ischemic; and shock or sepsis. Finally, the neurodiagnostic investigations of interest were head computed tomography (CT), brain magnetic resonance imaging, and electroencephalogram (EEG) studies. Final reports of neurodiagnostic studies were used to categorize the study as normal, abnormal, or showing no change in pathology.

Data analysis

The Statistical Package for Social Sciences (SPSS version 19.0 for Windows, IBM, Armonk, NY) was used for descriptive statistics. All data are presented as number and percentages unless otherwise indicated. Continuous data were summarized with measures of central tendency (median) and variability (interquartile range, IQR). Subgroup data for the rate of mechanical ventilation and intensive care unit mortality were compared with an analysis of means for proportions by comparing the individual subgroup proportion to the overall mean proportion. In the analysis of investigations undertaken by diagnostic category, patients were assigned to a category based on their primary ICD-9 code. Patients who had a neurosurgical intervention were placed in the neurosurgical diagnostic category, regardless of the assigned ICD-9 code.

Results

In 32 months, 3719 patients were admitted to the pediatric intensive care unit; 689 (19%) of these patients were referred to the Neurology Consulting Team for advice concerning neurocritical care management and investigation. We have complete data on 615 patients (90%). The median age of patients was 7 years (IQR, 1 to 14 years) and 377 (55%) were male.

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