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Advancing Neurologic Care in the Neonatal Intensive Care Unit with a Neonatal Neurologist

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Abstract

Neonatal neurology is a growing sub-specialty area. Given the considerable amount of neurologic problems present in the neonatal intensive care unit, a neurologist with expertise in neonates is becoming more important. We sought to evaluate the change in neurologic care in the neonatal intensive care unit at our tertiary care hospital by having a dedicated neonatal neurologist. The period post-neonatal neurologist showed a greater number of neurology consultations ($P<0.001$), number of neurology encounters per patient ($P<0.001$), a wider variety of diagnoses seen, and an increase in the use of video-electroencephalography ($P=0.022$), compared to the pre-neonatal neurologist period. The neonatologists expressed appreciation for having a dedicated neurologist available. Standardized protocols for treating hypoxic-ischemic encephalopathy and neonatal seizures were also developed. Overall, by having a neonatal neurologist, neurology became part of the multi-disciplinary team providing focused neurologic care to newborns.

Keywords

Newborns; neonatal neurology; quality improvement; neonatal intensive care unit

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Author Contribution (roles)

SB Mulkey is the neurologist dedicated to the care of the newborns with neurologic disease in the neonatal intensive care unit at Arkansas Children's Hospital. She designed this quality improvement project, collected the data, and wrote the manuscript. CJ Swearingen is a statistician who performed the statistical analysis, made the tables/figures, and edited the manuscript.

Conflict of Interest

The authors do not have any conflicts of interest.

Ethical Approval

A project summary was submitted to the Institutional Review Board, who decided the study met criteria for quality improvement and did not need Institutional Review Board approval.

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Introduction

Neonatal neurology is a growing subspecialty.^{1,2} The most commonly encountered neurologic diagnoses in the neonatal intensive care unit are brain injury relating to prematurity, hypoxic-ischemic encephalopathy, seizures, stroke, cerebral malformation, and abnormal tone. These problems are best addressed by the combined experience of pediatric neurologists with expertise in neonatal neurology and neonatologists with a special interest in the newborn brain, working closely within a multidisciplinary team whose goal is improving neurologic outcomes.

Neonatal neurology has evolved over time,³ and neuroprotection in the form of therapeutic hypothermia has become a standard of care for the asphyxiated term newborn.⁴⁻⁶ Preventing brain injury in premature newborns is now a main concern. Seizure treatment practices in the newborn are also being actively studied.⁷ Protection of the newborn brain and its treatment once injured are now possible making this an exciting time in neonatal neurology.⁸ Despite the widespread advancements in neurologic care, few centers have a neurologist devoted specifically to neonatal care. The objective of this study was to evaluate the impact of having a dedicated neurologist in the neonatal intensive care unit. We hypothesized that there would be an increase in neurology involvement by having a neonatal neurologist.

Methods

The Institutional Review Board ruled the proposed study met criteria for quality improvement. The retrospective study reviewed all neurology consultations in the neonatal intensive care unit at our tertiary care hospital from 9/1/2009 through 2/28/2012. A 10-week interval during 2011 was excluded due to a planned leave by the primary neurologist. Prior to employing a neurologist with a strong clinical interest in neonatal neurology in November 2010, the child neurologist covering the inpatient service conducted all neurology consultations. The study period from 9/1/2009 to 10/31/2010 was the 60-weeks pre-neonatal neurologist and the period 11/1/2010 to 4/11/2011 and 6/20/2011 to 2/28/2012 was the first 60-weeks post-neonatal neurologist. All neurologist consultations were included during both periods.

The inpatient billing records for neurology consultations in the unit were obtained and included the International Classification of Diseases diagnosis codes and the number of encounters for each patient.⁹ For each infant, birth date, gestational age at birth and Apgar scores, birth weight, admission date, consultation date and reason, if the patient had a head ultrasound, a head computed tomography scan, and/or brain magnetic resonance imaging with or without magnetic resonance spectroscopy, genetic testing, and any neurometabolic laboratory testing were recorded.

The time to neurology consultation was calculated as the difference in days between the consultation and the admission date. Routine electroencephalography was documented for patients who had electroencephalography that did not include video and was typically <1 hour long. Video-electroencephalography studies were prolonged and included continuous

monitoring. Patients who did not survive to the study time were noted. Each patient was categorized by reason for consultation into primary diagnosis groups of abnormal tone, seizures, hypoxic-ischemic encephalopathy, abnormal imaging, nerve problem, or brain malformation. The use of selective head-cooling for infants with hypoxic-ischemic encephalopathy was documented. Neurology follow-up rates were determined by whether a clinic appointment requested at discharge was attended.

The hospital does not have delivery services so all patients were born elsewhere. Occasionally, a newborn presented through the emergency department or from a primary care provider. The neonatal intensive care unit provides care to newborns requiring a pediatric sub-specialist.

Statistical Analysis

Demographic, clinical features, and assessment differences between patients seen before and after the addition of the dedicated neonatal neurologist were estimated using the Wilcoxon-Mann-Whitney rank test for continuous variables, Chi-square test for categorical variables, and Poisson regression for count variables. A pre-planned subgroup analysis was performed estimating differences between dedicated neonatal neurologist eras for those patients with hypoxic-ischemic encephalopathy. For this subgroup, all comparisons were evaluated with a Bonferroni-corrected Type 1 error rate of 0.025. All analyses were completed using Stata version 12.1 (College Station, Texas).

Results

The baseline comparison of the period pre-neonatal neurologist to the period post-neonatal neurologist is shown in Table 1. Patients were similar regarding demographics despite the number who received neurology consultation in the neonatal intensive care unit showing a substantial increase, post-neonatal neurologist. Patients who received a consultation rose from 54 to 105 ($P<0.001$), patient encounters increased from 71 to 283 ($P<0.001$), and the average number of encounters per patient receiving consultation increased from 1.3 ± 0.7 (mean $\pm$ standard deviation) to 2.7 ± 2.6 ($P<0.001$). The primary diagnosis in each period is shown in Figure 1. A larger patient variety was seen post-neonatal neurologist compared to pre-neonatal neurologist.

The overall frequency of neurologic tests showed little difference between the two periods; however, a substantial change in the frequency of routine electroencephalography versus video-electroencephalography was recorded. The pre-neonatal neurologist era had more routine electroencephalography studies, and the period post-neonatal neurologist had more video-electroencephalography studies (Table 2).

When only infants with hypoxic-ischemic encephalopathy are considered, a similar trend was seen. While overall consultations did not differ significantly, the number of patient encounters, and the average number of encounters per patient receiving consultation increased (Table 3). Patients who received selective head-cooling increased as did the frequency of video-electroencephalography use post-neonatal neurologist ($P=0.006$). An increase was also seen for genetic and neurometabolic testing in this group; however, these

differences were not statistically significant due to decreased power of the subgroup analysis.

Discussion

A neurologist with dedicated time and interest in newborn neurologic disease increased neurologic specialty care input in the neonatal intensive care unit with a nearly 200% increase in the number of patients seen and an almost 400% increase in the number of patient encounters during the first 14 months the neonatal neurologist was available. We do not believe the overall patient population changed since admissions to the neonatal intensive care unit remained relatively stable, so this increase likely reflects the neonatologists accepting greater neurology involvement and a large number of newborns with neurologic disease.

Having a single neurologist following patients for the duration of their admission resulted in an increased number of encounters per patient. This continuity of care is important, as some newborns have complicated disease processes and may require a lengthy investigation. A neurologist involved in the initial workup and evaluation, while communicating with other specialists and neonatologists as part of a multidisciplinary team, helps with understanding the disease process and the steps needed to evaluate the neurologic condition.

There was some expansion in the types of patients who received neurology consultation; however, the patients in each period were similar regarding baseline status. Neurology involvement was probably requested earlier than it would have been previously, for some cases, leading to more encounters per patient. For example, problems such as a cerebral malformation, which previously was explained by the neonatologists and the patient later seen by neurology, now received consultation. A neurologist was then present at family meetings to answer questions about long-term outcome alongside the neonatologists. Seizures that quickly responded to treatment in the past were worked up often without neurology input. Patients received electroencephalograms sometimes without having consultations. After the start of a dedicated neonatal neurologist, patients with controlled seizures more often received neurology consultation. This helped in evaluating seizure etiology, management of anti-epileptic medications, family discussions, and interpretation of test results. Follow-up and the best timing were also determined.

Having a neurologist who is knowledgeable in current newborn treatments and neuroprotective therapies is essential. Standardized protocols can be developed. The neurologist is now notified about every electroencephalogram performed in the unit and is involved in deciding how long the test should be continued based on the history and the clinical reason for the test. Electroencephalography technicians provide continuous monitoring. Seizures are treated in a step-wise fashion typically first with loading doses of phenobarbital and progressing to levetiracetam for persistent seizures.¹⁰ Hypotonia evaluation is also performed with a similar work-up plan to focus the necessary testing (BT Darras, unpublished data, 2008).

By having a dedicated neonatal neurologist, a formal practice plan to standardize care was developed in 2010 for newborns with hypoxic-ischemic encephalopathy treated with selective head-cooling. Previously, neurology consultation was only requested if seizures were present following cooling. The practice plan includes a neurology consultation, video-electroencephalography for at least 24 hours following removal of the Cool-Cap® (Natus Medical Inc., San Carlos, CA), brain magnetic resonance imaging and magnetic resonance spectroscopy following cooling at around day of life 5, follow-up in high-risk-newborn clinic and hypoxic-ischemic encephalopathy clinic with follow-up brain magnetic resonance imaging at age 1 year, and developmental testing at age 18 months and 3 years. The neurologist performing most of the consultations is the one who follows the infants in the clinic, so this provides additional continuity of care. Prior to this, follow-up for newborns treated with therapeutic hypothermia was sporadic, so this has been an important improvement.

Education for child neurology and pediatric residents and neonatology fellows was also enhanced. Residents typically perform initial consultations and attend weekly neuroradiology conferences during which neuroimaging and case presentations are discussed. The neonatal neurologist also presents lectures to residents and fellows.

This model of care may lead to some cost increase, but the additional benefits outweigh the expense. Patients may have received similar amounts of neurologic diagnostic testing in each period; however, this study did not focus on the total number of tests, but on the total for patients who received neurology consultations. The main difference is the neurologists' involvement with the results, bedside presence with the neonatologists to provide focused neurologic care, and more neurology communication with the family. Perhaps, prior to this change, there was not adequate coverage by neurology, so this change reflects improved multi-disciplinary care for newborns with neurologic disease. Overall, video-electroencephalography was likely increased post-neonatal neurologist as this was when the practice plan for head-cooled patients with hypoxic-ischemic encephalopathy was started and because the neurologist began helping with the decision on the electroencephalogram type to best address the clinical concern. The neurologist was also more involved in patients with hypotonia and cerebral malformation who often require genetic and neurometabolic testing, reflecting a higher frequency of these types of tests post-neonatal neurologist.

A similar service can be established at hospitals that have a neonatal intensive care unit and a child neurologist with a special interest in neonatal neurology. Time involved to cover the neurology patients can be variable. Our neonatal intensive care unit has about 850 admissions per year, with about 12% needing a neurology consultation. This resulted in a need for about 20% time of a full-time neurologist. Prior to initiation, the neonatology and pediatric neurology section and the Department of Pediatrics Chairman approved the plan as a way to provide excellent, up-to-date, standardized neurologic care to newborns. The neonatal neurologist sees all consultations during the week. Most new and follow-up consultations are seen on Monday, Wednesday, and Friday, leaving Tuesday and Thursday for more urgent consultations. When not available, the service is covered by the inpatient neurologist. Patients requiring close follow-up during off hours are discussed with the child neurology resident and inpatient attending. The neonatologists were welcoming of having

this dedicated neurology service. An improvement that could be made would be the addition of another neurologist with a similar interest sharing the service responsibility and improving discharge continuity of care.

There are several limitations to this retrospective study. This analysis cannot conclude that having a dedicated neonatal neurologist improves care or outcomes. The inclusion of a survey prior to initiation would have enabled a measure of improved satisfaction in neurologic care among providers and parents. Regardless, the positive feedback received indicated that this role is important.

Including a dedicated neurologist in a neonatal intensive care unit may represent an improved model of care. The neurologist can play an integral part in evaluating known or suspected neurologic processes, the daily management regarding these conditions, and in communicating with the family about test results, brain imaging, and their newborns' neurodevelopmental prognosis. Therefore, the neonatal neurologist should be a welcomed addition, as an increased focus on the brain at this early age hopefully will lead to improved outcomes for the youngest neurology patients. Further studies aimed at quantifying improved neurologic outcomes with a model of care that incorporates a neurologist as part of a multi-disciplinary team in the neonatal intensive care unit need to be performed to understand the full benefit this care provides.

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Figure 1.
Total Number of Patients Seen Pre- and Post-Neonatal Neurologist by Diagnosis Category

Table 1
Demographic and Clinical Outcomes of Patients seen Pre- and Post-Neonatal Neurologist

	Pre			Post			P
	N	Mean (SD)	Median [Min, Max]	N	Mean (SD)	Median [Min, Max]	
Gestational Age (weeks)	53	36.6 (3.7)	37.0 [25.0, 41.0]	105	36.8 (3.8)	38.0 [23.0, 42.0]	0.759
Birth Weight (kilograms)	52	2.8 (0.9)	3.1 [0.8, 4.4]	103	2.8 (1.0)	2.8 [0.5, 6.1]	0.49
APGAR at 1 minute	50	4.5 (3.1)	4.0 [0.0, 9.0]	97	4.6 (2.9)	4.0 [0.0, 9.0]	0.898
APGAR at 5 minute	50	5.8 (3.0)	7.0 [0.0, 9.0]	97	6.4 (2.5)	7.0 [0.0, 9.0]	0.331
Age at Admission (days)	54	7.1 (20.0)	1.0 [0.0, 118.0]	105	6.9 (14.8)	1.0 [0.0, 96.0]	0.264
Time to Consult (days)	54	19.4 (56.0)	2.0 [0.0, 283.0]	105	12.4 (26.0)	3.0 [0.0, 149.0]	0.916
Consultations per Patient	54	1.3 (0.7)	1.0 [1.0, 4.0]	105	2.7 (2.6)	2.0 [1.0, 21.0]	<0.001
Total Patients Seen (N)		54			105		<0.001 *
Total Patient Encounters		71			283		<0.001 *
Requested Neurology Follow-up	54	33 (61.1%)		105	56 (53.3%)		0.349 [†]
Attended First Neurology Follow-up	54	25 (46.3%)		105	45 (42.9%)		0.679 [†]
Survival to Date	54	46 (85.2%)		105	88 (83.8%)		0.821 [†]

* Total count and Poisson regression reported.

[†] Frequency (Percentage) and Chi-square test reported.

Table 2
Neurologic Diagnostic Testing of Patients during Pre- and Post-Neonatal Neurologist Eras

	Pre			Post		
	N	Frequency (%)		N	Frequency (%)	P*
Head Ultrasound	54	49 (90.7%)	105	82 (78.1%)	0.047	
Head Computed Tomography	54	6 (11.1%)	105	21 (20.0%)	0.157	
Brain Magnetic Resonance Imaging	54	50 (92.6%)	105	90 (85.7%)	0.205	
Brain Magnetic Resonance Spectroscopy	54	25 (46.3%)	105	42 (40.0%)	0.446	
Routine Electroencephalography	54	25 (46.3%)	105	28 (26.7%)	0.013	
Video-Electroencephalography	54	21 (38.9%)	105	61 (58.1%)	0.022	
Genetic Testing	54	15 (27.8%)	105	44 (41.9%)	0.081	
Neuro-Metabolic Testing	54	10 (18.5%)	105	29 (27.6%)	0.207	

* Frequency (Percentage) and Chi-square test reported.

Neurologic Diagnostic Testing and Selected Clinical Outcomes of Patients with Hypoxic-Ischemic Encephalopathy during Pre- and Post-Neonatal Neurologist Eras

Table 3

	Pre		Post		P
	N	Frequency (%)	N	Frequency (%)	
Selective Head-Cooling	12	12 (100.0%)	16	14 (87.5%)	0.204
Head Ultrasound	12	12 (100.0%)	16	13 (81.3%)	0.112
Head Computed Tomography	12	0 (0.0%)	16	0 (0.0%)	.
Brain Magnetic Resonance Imaging	12	11 (91.7%)	16	15 (93.8%)	0.832
Brain Magnetic Resonance Spectroscopy	12	11 (91.7%)	16	13 (81.3%)	0.436
Routine Electroencephalography	12	9 (75.0%)	16	7 (43.8%)	0.098
Video Electroencephalography	12	2 (16.7%)	16	12 (75.0%)	0.006*
Genetic Testing	12	0 (0.0%)	16	4 (25.0%)	0.113*
Neuro-Metabolic Testing	12	0 (0.0%)	16	5 (31.3%)	0.053*
Consultations per Patient	12	1 [1, 1]	16	3 [1, 9]	<0.001[‡]
Total Patients Seen (N)		12		16	0.449
Total Patient Encounters (N)		12		51	<0.001
Requested Neurology Follow-up	12	9 (75.0%)	16	14 (87.5%)	0.393
Attended First Neurology Follow-up	12	6 (50.0%)	16	12 (75.0%)	0.172
Survival to Date	12	10 (83.3%)	16	14 (87.5%)	0.755

* Frequency (Percentage) and Fisher's Exact test reported. Otherwise, Chi-square test reported.

[‡] Median [Min, Max] and Wilcoxon-Mann-Whitney rank test reported.

[‡] Poisson regression reported.