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ORIGINAL ARTICLE

# Pediatric Neurocritical Care: A Short Survey of Current Perceptions and Practices

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**Abstract**
*Background* Although attention to neurologic injuries and illnesses in pediatric critical care is not new, a sub-specialized field of pediatric neurocritical care has only recently been recognized. Pediatric neurocritical care is an emerging area of clinical and investigative focus. Little is known about the prevalence of specialized pediatric neurocritical care services nor about perceptions regarding how it is impacting medical practice. This survey sought to capture perceptions about an emerging area of specialized pediatric neurocritical care among practitioners in intersecting disciplines, including pediatric intensivists, pediatric neurologits and pediatric neurosurgeons.
*Methods* A web-based survey was distributed via email to members of relevant professional societies and groups. Survey responses were analyzed using descriptive statistics. Differences in responses between groups of respondents were analyzed using Chi-squared analysis where appropriate.
*Main Results* Specialized clinical PNCC programs were not uncommon among the survey respondents with 20 % currently having a PNCC service at their institution. Despite familiarity with this area of sub-specialization among the survey respondents, the survey did not find consensus regarding its value. Overall, 46 % of respondents believed that a specialized clinical PNCC service improves the quality of care of critically ill children. Support for PNCC sub-specialization was more common among pediatric neurologists and pediatric neurosurgeons than pediatric intensivists. This survey found support across specialties for creating PNCC training pathways for both pediatric intensivists and pediatric neurologists with an interest in this specialized field.
*Conclusions* PNCC programs are not uncommon; however, there is not clear agreement on the optimal role or benefit of this area of practice sub-specialization. A broader dialog should be undertaken regarding the emerging practice of pediatric neurocritical care, the potential benefits and drawbacks of this partitioning of neurology and critical care medicine practice, economic and other practical factors, the organization of clinical support services, and the formalization of training and certification pathways for sub-specialization.

**Keywords** Pediatrics · Neurocritical care · Pediatric neurocritical care · Sub-specialization · Critical care fellowship · Practice patterns

## Introduction

Attention to neurological injuries and illnesses in pediatric critical care is not new [1, 2]. However, the recognition of a distinct, focused, neurological sub-specialization within pediatric critical care has only recently been described. In 2008, LaRovere et al. first described one model of such a sub-specialization—a dedicated pediatric neurology consult team for ICU patients at a busy tertiary care pediatric hospital [3]. This was followed shortly thereafter by the first reported experience of a multi-disciplinary model of pediatric neurocritical care. A team composed of pediatric neurologists, pediatric intensivists, and pediatric neurosurgeons was consulted on more than a quarter of all ICU admissions [4]. Diagnoses were variable, including both

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primary neurologic diagnoses (status epilepticus, traumatic brain injury (TBI), brain tumors, neurosurgical procedure, stroke) and secondary neurologic concerns in patients with a non-neurologic primary illness. More recently, Pineda and colleagues have described improved outcomes in children with severe TBI after the implementation of a PNCC program. The program created a clinical pathway for the monitoring and treatment of children with TBI with careful monitoring of patients for adherence to the care pathway [5].

Factors driving the increased attention on specialized pediatric neurocritical care (PNCC) may include a more global trend toward sub-specialization in medicine [6], the relatively recent development of guidelines and recommendations for the management of specific neurologic injuries and illnesses affecting children [7–10], and the establishment of the field of adult neurocritical care, including subspecialty board certification and fellowship training programs [11]. Also important may be increased attention on long-term morbidity from critical illness, particularly neurologic morbidity, as overall pediatric ICU mortality rates have improved [12–14]. As appears to often be the case with the movement toward sub-specialization in medical practice, the evolution of a sub-specialized field of clinical care (pediatric neurocritical care) has been accompanied by a burgeoning biomedical science literature. This growing body of knowledge covers increasingly more complex understandings of brain development, brain injury, and potential mechanisms of brain protection and recovery [15, 16].

In 2009, the Leapfrog Initiative funded a survey to evaluate perceptions regarding adult neurocritical care, finding broad support for the new discipline and for the establishment of adult neurocritical care units [17]. This current survey sought to pose similar questions to practitioners in pediatric critical care medicine, pediatric neurology, and pediatric neurosurgery, where both similarities and dissimilarities with the adult experience might be found. Perceptions about the potential benefits, drawbacks, and obstacles to PNCC sub-specialization have yet to be introduced into the literature. The field of PNCC, as it is evolving, remains ill-defined. A need for specialized clinical PNCC services has not been clearly articulated, nor a benefit to such a specialty proven. There are currently no standardized training programs, certification processes, or regulatory boards in PNCC. Questions about how PNCC might advance as a discipline, its potential significance, and what should be its appropriate focus are germane. This survey was conducted to gain insight into current perceptions regarding PNCC, and in that context, it also sought to describe current practice patterns among survey respondents.

## Methods

An online survey about PNCC was developed, consisting of between 16 and 25 questions focusing on three areas: (1) demographics of the health care provider completing the survey (2), current PNCC practices, and (3) perceptions about strengths, weaknesses, and appropriate goals for the field of PNCC (Table 1). Questions were posed in a multiple choice format. For questions in which more than one answer was possible, participants were able to select all answers that apply. In all cases, an "other" option was provided with the ability to enter free text. Experts and sample participants were distributed early drafts to assess and advise for face and content validity. After obtaining waiver for approval by the local Institutional Review Board (Partners Human Research Committee at Massachusetts General Hospital), physicians and health care practitioners in related fields were contacted via email in the fall of 2013.

An introductory email was sent that included an overview of the content of the online survey as well as a direct link to the survey tool. The introductory email explained that participation was completely voluntary and confidential, and that no personal identifying data were being collected. Participants were also informed that no IP addresses would be collected. The following groups were contacted: Society of Critical Care Medicine (SCCM), Neurocritical Care Society (NCS), American Academy of Pediatrics (AAP), Pediatric Neurocritical Care Research Group (Pittsburgh), American Board of Pediatric Neurological Surgeons, and the Child Neurology Society (CNS). The SCCM, NCS, and AAP reviewed and approved the survey and subsequently distributed it to their pediatric critical care members. The group members of the

**Table 1** Core survey questions

| |
|---|
| 1. Do you have a specialized PNC or a separate PNC unit at your institution? |
| 2. Are pediatric stroke teams and PNC teams combined or separate? |
| 3. Would or does a PNC team improve the quality of care of critically ill pediatric neurological/neurosurgical patients? |
| 4. What are the reasons why a PNC subspecialty *does or would* improve quality of care? |
| 5. What are the reasons why a PNC subspecialty *does not or would not* improve quality of care? |
| 6. What should be the goals of PNC? |
| 7. Should Pediatric Critical Care programs or Pediatric Neurology programs make training programs available for physicians interested in PNC? |

American Board of Pediatric Neurological Surgeons were emailed directly after obtaining permission and addresses from the Chairman of the Board. The American Academy of Neurology and Child Neurology Society were contacted but had no system in place for approval and distribution of an electronic survey or email request. A list of 87 Pediatric Neurology Program Directors was publicly available. A separate email correspondence was sent to this group with a link to the survey and a request that the survey be distributed by the program directors to their faculty members.

The initial email invitation was followed by a reminder 2 weeks later. Participants were asked to participate in the survey only once and to disregard the reminder if they had already completed the survey. The survey was open to respondents for a period of three months, from September through November 2013.

### Statistical Analysis

Survey responses were analyzed using descriptive statistics. Where appropriate 95 % confidence intervals for percentages reported were calculated using normal approximation. Differences in responses between categories of respondents were analyzed using Chi-squared analysis (with two group comparisons).

**Table 2** Demographics of respondents

| Respondent characteristics | Number of respondents (%) |
|---|---|
| Practice in US | 459 (94.6) |
| University/teaching hospital | 397 (81.5) |
| Primary specialty | |
| Pediatric critical care | 362 (74.3) |
| Pediatric neurology | 60 (12.3) |
| Pediatric neurosurgery | 45 (9.2) |
| Other | 12 (2.5) |
| Neonatology | 3 (0.6) |
| Neurosurgery (not pediatric) | 2 (0.4) |
| General pediatrics | 2 (0.4) |
| Adult pulmonary/critical care | 1 (0.2) |
| Current position | |
| Physician out of training >5 years | 225 (46.2) |
| Director/division chief | 167 (34.3) |
| Physician out of training for less than 5 years | 62 (12.7) |
| Physician in-training (resident, fellow, or equivalent) | 16 (3.3) |
| Other | 10 (2.1) |
| Advanced nursing care practitioner | 5 (1) |
| Retired | 2 (0.4) |

## Survey Results

A total of 2787 email requests were distributed with 487 respondents ultimately completing the survey. Ninety-three percent of those who started the survey completed it. Table 2 summarizes the demographics of participants. A large majority of respondents (74.3 %) were critical care physicians. Overall 77 % of survey respondents had heard of PNCC as an area of sub-specialization and 20.2 % of all respondents had a PNCC service (consult service or specialized care unit) at their institution. Among PCCM physicians 14 % reported having a PNCC program and among those respondents working in an academic hospital 22.3 % reported having PNCC services.

For most of the respondents (83.2 %) who have PNCC services at their institution PNCC is delivered as a consult service for the PICU and/or cardiac ICU. Fifty-nine percent of respondents chose "consult service to the NICU" in addition to "consult service to the PICU/CICU" from the multiple choice options. Other models of PNCC included dedicated beds in the PICU for neurocritically ill patients (chosen by 35 %), a pediatric neurological step down unit (12 %), a separate PNCC unit (10 %), dedicated beds in the NICU (9 %), and a separate PNCC team that serves as the primary team for neurological patients within the PICU (4 %). PNCC team composition varied (Table 3).

### Do the Respondents Believe that Having a PNCC Service Improves (or Would Improve) the Quality of Care of Critically Ill Pediatric Patients?

Forty-six percent of all survey respondents thought that specialized PNCC services either do or would improve the quality of care of critically ill children (Table 4). Eighty-two percent of all respondents who have a PNCC service believe it *does* improve care. This is compared with only 38 % of those who do not have a PNCC service who think that having such a service *would* improve care. Overall, 17.2 % reported that PNCC services did not improve quality of care and 34.5 % of respondents were uncertain about its benefit. More pediatric neurologists (67.4 %) and pediatric neurosurgeons (74.0 %) than pediatric critical care practitioners (38.8 %) thought that PNCC services improve quality of care. There was no association between the model of PNCC delivery and overall satisfaction with a PNCC service, but fewer respondents favored the creation of a separate PNCC unit when asked (26.7 % of overall group).

**Table 3** Pediatric Neurocritical Care team composition

| | |
|---|---|
| Staff pediatric neurologist | 79.3 % |
| Pediatric neurology resident/fellow | 77.2 % |
| Staff pediatric intensivist | 67.4 % |
| Staff pediatric neurosurgeon | 41.3 % |
| Pediatric critical care fellow | 33.7 % |
| Nurse practitioner | 23.9 % |
| Neurocritical care fellow | 16.3 % |

### What are the Reasons Given for Why a Specialized PNCC Service Improves Quality of Care?

The reasons most commonly chosen for thinking that a PNCC service improves quality of care were improved knowledge, more consistently available expertise, and better coordination of care. The ability to carry out research to advance the field was also chosen by half of the respondents in favor of the subspecialty (Table 5). Survey respondents were asked for which patients PNCC services would be of the most potential benefit. Patients with stroke, TBI, and status epilepticus were the most commonly selected patient groups (Table 6).

### What are the Reasons Given for Why Specialized PNCC Does not Improve Quality of Care?

The most common reasons chosen included that the PICU attending can adequately provide this care with appropriate neurology and neurosurgery input and that there is not a sufficient volume of patients to justify this service (Table 7). Several survey respondents wrote comments expressing concern that a PNCC service would result in unnecessary fragmentation of care.

### How are Pediatric Stroke Teams and Pediatric Neurocritical Care Teams Related?

Overall, 38.1 % of respondents reported having a pediatric stroke team at their institution and 44 % of those respondents who practice at an academic center reported having a pediatric stroke team (Table 8). In a majority of cases where both exist, the PNCC team and the pediatric stroke team were separate.

### What Should be the Goals of PNCC?

A majority of respondents thought the goals of PNCC should include the care of pediatric stroke patients (90 %),

**Table 4** Do the respondents believe that having a PNC service improves (or would improve) the quality of care?

| | Number/total (%) |
|---|---|
| Yes | 221/478 (46.2) |
| No | 82/478 (17.2) |
| Uncertain | 165/478 (34.5) |

| | Number/total (%) | *p* value* |
|---|---|---|
| Percent of respondents by specialty who believe having a PNC service improves the quality of care: | | |
| Pediatric critical care medicine | 139/358 (38.8) | – |
| Pediatric neurosurgery | 29/43 (74) | <0.001 |
| Pediatric neurology | 43/58 (67.4) | <0.001 |
| Percent of respondents who believe having a PNC service improves the quality of care: | | |
| Among those who *have* PNCC service at their institution | 76/93 (81.7) | – |
| PCCM | 38/49 (77.6) | |
| Pediatric neurosurgery | 13/18 (72.2) | |
| Pediatric neurology | 18/22 (81.8) | |
| Among those who *do not have* PNCC service at their institution | 145/385 (37.7) | <0.0001 |
| PCCM | 80/310 (25.8) | |
| Pediatric neurosurgery | 14/25 (56.0) | |
| Pediatric neurology | 21/37 (56.8) | |

* *p* value calculated by Chi-squared analysis comparing proportions between two groups: pediatric critical care medicine physicians and pediatric neurologists, and pediatric critical care medicine physicians and pediatric neurosurgeons, and among all respondents who have and do not have PNCC services at their institution. The difference in response between pediatric neurosurgery and pediatric neurology respondents was not significant ($p = 0.62$)

**Table 5** What are the reasons a specialized PNC consult service improves quality of care?

| Reason | Number/total positive responses (%) |
|---|---|
| Improved knowledge about the needs of patients | 240/352 (68.2) |
| Respondents with PNCC | 75/94 (79.8) |
| Respondents without PNCC | 165/258 (64.0) [$p = 0.007$] |
| More consistently available expertise | 237/352 (67.0) |
| Respondents with PNCC | 75/94 (79.8) |
| Respondents without PNCC | 162/258 (62.8) [$p = 0.004$] |
| Better coordination of care | 195/352 (55) |
| Respondents with PNCC | 68/94 (72.3) |
| Respondents without PNCC | 127/258 (49.2) [$p = 0.0002$] |
| Able to carry out research to advance the field | 172/352 (48.9) |
| Respondents with PNCC | 53/94 (56.4) |
| Respondents without PNCC | 119/258 (46.1) [$p = 0.11$] |
| Increased satisfaction among physicians | 100/352 (28.4) |
| Respondents with PNCC | 41/94 (43.6) |
| Respondents without PNCC | 59/258 (22.9) [$p = 0.0002$] |
| Increased satisfaction of patients and families | 99/352 (28.1) |
| Respondents with PNCC | 36/94 (38.3) |
| Respondents without PNCC | 63/258 (24.4) [$p = 0.01$] |

$p$ value calculated by Chi-squared analysis comparing response between two groups: respondents with and respondents without PNCC

**Table 6** For which patients did respondents say specialized PNC services would "often" be beneficial?

| | Number (%) total = 172 |
|---|---|
| Stroke | 155 (90) |
| Traumatic brain injury | 145 (84) |
| Status epilepticus | 103 (60) |
| Hypoxic-ischemic injury | 90 (52) |
| Post-operative neurosurgical patients | 79 (46) |

the care of patients with TBI (88 %), neuromonitoring in the critically ill (85 %), and the care of any PICU patients with a primary neurological critical illness (84 %). Sixty-seven percent of respondents thought PNCC should include the care of post-operative neurosurgical patients.

### Should Critical Care Medicine Programs or Pediatric Neurology Programs Make Specialized Training Available for Physicians Interested in PNCC?

The majority of survey respondents, 82.3 %, supported the concept of pediatric critical care programs making specialized training tracks in PNCC available to trainees (Table 9). A smaller majority, 66.8 %, supported the idea that pediatric neurology programs should make such training available. There was greater support among pediatric neurologists and pediatric neurosurgeons for the creation of specialized training tracks in both pediatric critical care medicine and pediatric neurology than there was among pediatric critical care medicine physicians for specific training tracks being created in either of these disciplines.

Sixty-one survey respondents (12.5 %) indicated that they personally provide specialized PNCC at their institution (Table 10). The median number of new consults seen each week by these practitioners was 10 (range 1–40). These practitioners were asked what obstacles they had encountered in building a PNCC service. The most frequently chosen obstacles included a demanding or unsustainable workload for the size of the PNCC staff (28.9 %), inadequate reimbursement for services provided (24.4 %), and too low patient volume for the PNCC service (24.4 %).

## Discussion

This survey captured pediatric intensivists, neurologists, and neurosurgeons primarily from academic centers in North America. Among the group of respondents, one-fifth (20.2 %) are at an institution that currently provides specialized clinical PNCC services in some form. The majority of these services, 83 %, are a consult service to the pediatric and/or cardiac ICU. In 59 % of cases the PNCC consult service also consults in the NICU. Although PNCC services are not rare, the survey did not find consensus around its perceived advantages or its shortcomings. There was more support for PNCC among surveyed

**Table 7** What are the reasons chosen for why a specialized PNC consult service does not or would not improve quality of care?

| Reason | Number/total negative responses (%) |
|---|---|
| Primary attending can provide this care/adequate care with neurosurgery or neurology consult | 213/281 (75.8) |
| Respondents with PNCC | 10/23 (43.5) |
| Respondents without PNCC | 203/258 (78.7) [$p = 0.0004$] |
| Not enough patients/volume to justify service | 165/281 (58.7) |
| Respondents with PNCC | 5/23 (21.7) |
| Respondents without PNCC | 160/258 (62.0) [$p = 0.0004$] |
| Not enough neuro-specific therapies to warrant a specialized service | 105/281 (37.4) |
| Respondents with PNCC | 7/23 (30.4) |
| Respondents without PNCC | 98/258 (38.0) [$p = 0.68$] |
| Not shown to improve outcomes | 91/281 (32.4) |
| Respondents with PNCC | 7/23 (30.4) |
| Respondents without PNCC | 85/258 (32.9) [$p = 0.98$] |
| Decreased physician satisfaction | 67/281 (23.8) |
| Respondents with PNCC | 6/23 (26.1) |
| Respondents without PNCC | 61/258 (23.6) [$p = 0.98$] |
| Too costly to justify | 49/281 (17.4) |
| Respondents with PNCC | 4/23 (17.4) |
| Respondents without PNCC | 46/258 (17.8) [$p = 0.81$] |
| Decreased satisfaction of patient and family members from fragmentation of care | 48/281 (17.1) |
| Respondents with PNCC | 1/23 (4.3) |
| Respondents without PNCC | 48/258 (18.6) [$p = 0.15$] |
| Examples of specific comments: | |
| "Often too many individuals directing patient care, confusing the staff and patient/families" | |
| "The benefit of PCCM is to coordinate care, not fragment it even more" | |
| "Too many critical care sub-specialists" | |
| "Unnecessary fragmentation" | |
| "Involving another service may just complicate things" | |
| "Fragmentation of critical care" | |
| "Concern over fragmentation of care" | |

*p* value calculated by Chi-squared analysis comparing response between two groups: respondents with and respondents without PNCC

**Table 8** Pediatric stroke teams

| | Number/total (%) |
|---|---|
| Do you have a pediatric stroke team? | |
| Yes | 186/487 (38.1) |
| No | 275/487 (58.1) |
| Are PNC and pediatric stroke teams the same or different? | Total number of respondents with both PNC and pediatric stroke team: 66 |
| The same | 13/66 (19.7) |
| Separate | 49/66 (74.2) |
| If you do not have a pediatric stroke team, are pediatric stroke patients seen by an adult stroke team? | Total number of respondents without pediatric stroke team: 275 |
| Yes | 194/275 (70.5) |
| No | 63/275 (24.4) |
| Uncertain | 14/275 (5.1) |

**Table 9** Percent of respondents who support Pediatric Neurocritical Care training

| | Number/total (%) | *p* value |
|---|---|---|
| Pediatric Critical Care Medicine programs should make training in pediatric neurocritical care available to trainees | 377/458 (82.3) | |
| Response by specialty: | | |
| PCCM | 274/346 (79.2) | – |
| Pediatric neurology | 49/53 (92.5) | 0.035 |
| Pediatric neurosurgery | 38/42 (90.5) | 0.124 |
| Pediatric neurology programs should make training in pediatric neurocritcal care available to trainees | 304/455 (66.8) | |
| Response by specialty | | |
| PCCM | 306/344 (59.9) | – |
| Pediatric neurology | 53/53 (100) | $<0.0001$ |
| Pediatric neurosurgery | 33/41 (80.5) | 0.016 |

*p* value calculated by Chi-squared analysis comparing support found between two groups: pediatric critical care medicine physicians and pediatric neurologists, and pediatric critical care medicine physicians and pediatric neurosurgeons. The difference in support found between pediatric neurology and pediatric neurosurgery was not significant when asked about Pediatric Critical Care Medicine programs. The difference in percent support between pediatric neurologists and pediatric neurosurgeons for the idea of Pediatric Neurology programs making such training tracks available was significant ($p = 0.003$)

**Table 10** Pediatric neurocritical care providers

| | |
|---|---|
| What is the average number of NEW patients seen by the PNC service each week? | 10 (range 1–40) |
| What obstacles have you encountered in building a PNC service at your hospital? | Percent |
| Demanding or unsustainable workload for size of pediatric neurocritical care staff | 13 (28.9) |
| Inadequate reimbursement for services provided | 11 (24.4) |
| Too low patient volume | 11 (24.4) |
| Lack of institutional support | 10 (22.2) |
| Workforce recruitment—physician | 10 (22.2) |
| Difficulty with reimbursement | 9 (20.0) |
| Workforce recruitment—middle level practitioners | 8 (17.8) |
| Lack of support from pediatric critical care department | 7 (15.6) |
| Lack of support from pediatric neurology department | 6 (13.3) |
| Lack of support from pediatric neurosurgery department | 2 (4.4) |
| Too high patient volume | 2 (4.4) |
| Examples of other responses provided: | |
| "None" | |
| "Turf issues" | |
| "Variable patient load" | |
| "Coordination of care and assuring optimal follow-up for patients receiving care from multiple subspecialties" | |

pediatric neurologists and pediatric neurosurgeons than among pediatric intensivists. Not surprisingly, there was significantly more support for PNCC services among practitioners who have PNCC services already in place at their institution. PCCM practitioners who currently practice in an institution without a PNCC service were the least likely to think that PNCC improves quality of care.

This was a web-based survey targeting a large population (practicing pediatric intensivists, pediatric neurosurgeons, academic pediatric neurologists). Our estimated response rate (17.5 %), though in keeping with other web-based survey results [17, 18], is low and our results have a high risk of selection bias [19]. The greater number of pediatric intensivists in practice may have biased the data to represent the view of intensivists. In addition it is likely that those contacted who felt most strongly about PNCC, either for or against, were most attuned to the survey request and also most motivated to respond. It is also likely that many of the members of the societies contacted overlap. Any overlap between society

members would underestimate our true response rate which is therefore likely greater than that calculated. In addition, this was a survey of individual practitioners, as such it is likely that multiple people from the same institutions were sampled. The true prevalence of specialized PNCC programs cannot be inferred.

Potential benefits to PNCC specialization that were identified in this survey included improved knowledge, more consistently available expertise, and better coordination of care. In addition, half of all respondents in favor of PNCC cited the ability to carry out research related to the field as an important potential benefit. These potential advantages were counter balanced, particularly among intensivists, by concern that the same level of care can be adequately provided by the pediatric intensivist. Many worried that further subspecialization may lead to unnecessary fragmentation of patient care. For many respondents, the lack of neuro-specific therapies (37 %) and the lack of a demonstrable benefit to specialized PNCC (32 %) were significant obstacles to its adoption.

Interestingly, there was little overlap found among our survey respondents between existing PNCC teams and the pediatric stroke teams at their institutions. In spite of this, stroke was the illness most commonly chosen by survey respondents as a condition or disease for which a specialized PNCC service would "often" be helpful. Assistance with neuromonitoring was another commonly identified need. This is in keeping with a growing recognition of neurologic morbidity as an important outcome of critical illness, an increased focus on neuroprotection and an expanding role for EEG and other neuromonitoring techniques in the ICU. All of these require close collaboration between PICU and neurology teams [20, 21].

Despite "a lack of" agreement about the potential benefits of PNCC services, the majority of respondents expressed support for creating training pathways for trainees from either PCCM or pediatric neurology who are interested in PNCC. This raises important follow-up questions: should accreditation for formal fellowship training in PNCC or sub-specialized board certification be pursued? What prior training would best prepare someone who wants to specialize in PNCC? What would be the mandate for such training in terms of desired clinical skills and expertise?

Comparisons about the evolution of PNCC might be made with pediatric cardiac critical care. In 2005, a pathway for advanced training in pediatric cardiac critical care was laid out by a special Task Force on Clinical Competence made up of members from the American College of Cardiology Foundation, American Heart Association, and the American College of Physicians [22]. The creation of a subspecialty of pediatric cardiac critical care, however, was also bridled with controversy [23, 24]. Subspecialty board certification in this area has not been established.

There may also be some similarity with the evolution of adult neurocritical care. Adult neurocritical care ICUs were first established by providing post-operative care of neurosurgical patients, with the scope later expanding to include other diagnoses typically managed by neurosurgeons such as TBI and subarachnoid hemorrhage. In some centers, medical patients with neurological illness began to be cohorted with neurosurgical patients in specialized ICUs with the advantage of providing neuroscience-focused nursing care [11]. The advent of advanced neuromonitoring techniques has enabled a focus on the prevention or limitation of secondary brain injury that is the cornerstone of adult neurocritical care. Adult NCC fellowships and board certification followed with standards established for the skills, experience, and knowledge expected of an adult neurointensivist [11]. Several studies suggest that adult patients with neurological injury or illness may benefit from care in a neurocritical care unit, although which aspect of that care (neurointensivist-led care, nursing expertise, adoption, and adherence to care protocols) is responsible for these measurements of improved care is not clear [25].

There are similarities and dissimilarities with both of these specialties to the maturing field of pediatric neurocritical care. Neurological injuries, illnesses, and concerns may affect 20–25 % of all PICU patients in a tertiary care pediatric hospital [4, 26]. Pediatric neurocritical care diagnoses are heterogeneous including seizures, TBI, post-neurosurgical, tumor, stroke, coma, brain death, CNS infection, and demyelinating diseases. A single, large volume disease, such as stroke in the adult population with its targeted and proven beneficial therapies (e.g., tPA), is missing. Amongst critically ill pediatric patients, there is a great deal of overlap between neurological and systemic disease and many critically ill pediatric patients have pre-existing neurologic illness [4]. The smaller volume of PICU patients may render the creation of specialized clinical services unsustainable or just impractical for many institutions.

Taken more globally, questions regarding "the" optimal training and certification "processes" and discussions about how best to organize "critical care" sub-specialization are coming to the fore in an era of ever more specialized care with increasingly sick and complicated critical care patients [1, 27]. As previous publications have suggested, for the time being PNCC seems likely to continue to evolve locally in response to the needs of a particular institution and out of the resources available [3, 26, 28]. However, survey participants identified benefits and challenges to establishing and expanding the field. PNCC providers also signified some additional challenges with demanding workloads and issues with service reimbursement, as well as a lack of institutional support and

difficulty with recruiting staff. Many of these identified issues would likely be impacted by formal recognition of a subspecialty, supported by either accredited fellowship training programs and/or subspecialty board certification.

There are several important limitations to our findings. One thousand six hundred and forty-five physician members of the SCCM identified themselves as pediatric practitioners. In contrast, there were only 163 members of the American Board of Pediatric Neurosurgeons. There may be fewer than 200 pediatric neurosurgeons in practice in the US [29] and a 2005 study of the pediatric neurology workforce estimated there to be approximately 300 pediatric neurologists in academic practice in the US [30]. Although the response rate for pediatric neurosurgeons (27.6 %) exceeds the overall response rate, the total number of both pediatric neurologists (60) and pediatric neurosurgeons (45) represented is small. Neonatologists, an important stakeholder group, were not included in this survey. We found that 16 % of PNCC teams included a neonatologist and more than half of all PNCC teams consulted in the PICU and NICU. The perspective of neonatologists will be important to illicit in further discussions about the development of the field.

The findings reported here are also limited by the inherent design of this email survey, including the assessments of instrument validity and specific restrictions on brevity of the survey imposed by the participating societies. The response format (multiple choice with open text option) was logistically necessary but inherently limited in regards to the ability to survey opinions on this topic. Although this survey provides data about current perceptions regarding pediatric neurocritical practice and a snapshot of current practices in that context, a more qualitative survey focused on the current practice of PNCC would also add to the dialog.

## Conclusions

This study is the first to capture perceptions about the evolving practice of PNCC among practitioners in closely-related fields. It also provides a snapshot of existing PNCC practice patterns among the surveyed practitioners. Pediatric critical care medicine physicians, pediatric neurologists, pediatric neurosurgeons, and neonatologists across institutions will be important stakeholders in the advancement of the field. Even if PNCC is a sub-specialization that exists largely in the busiest academic and tertiary care children's hospitals, the clinical experience and, importantly, the research opportunities grounded in these endeavors will stand to benefit all critically ill children. A broader national and international dialog should be pursued concerning the role and scope of pediatric neurocritical care, how it can be best organized, supported, and advanced, and how its potential to benefit our patients harnessed.

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