Pediatric Intensive Care Outcomes: Development of New Morbidities During Pediatric Critical Care*

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Objective: To investigate significant new morbidities associated with pediatric critical care.

Design: Randomly selected, prospective cohort.

Setting: PICU patients from eight medical and cardiac PICUs.

Patients: This was a randomly selected, prospective cohort of PICU patients from eight medical and cardiac PICUs.

Measurements and Main Results: The main outcomes measures were hospital discharge functional status measured by Functional Status Scale scores and new morbidity defined as an increase in the Functional Status Scale of more than or equal to 3. Of the 5,017 patients, there were 242 new morbidities (4.8%), 99 PICU deaths (2.0%), and 120 hospital deaths (2.4%). Both morbidity and mortality rates differed ($p < 0.001$) among the sites. The worst functional status profile was on PICU discharge and improved on hospital discharge. On hospital discharge, the good category decreased from a baseline of 72% to 63%, mild abnormality increased from 10% to 15%, moderate abnormality status increased from 13% to 14%, severe status increased from 4% to 5%, and very severe was unchanged at 1%. The highest new morbidity rates were in the neurological diagnoses (7.3%), acquired cardiovascular disease (5.9%), cancer (5.3%), and congenital cardiovascular disease (4.9%). New morbidities occurred in all ages with more in those under 12 months. New morbidities involved all Functional Status Scale domains with the highest proportions involving respiratory, motor, and feeding dysfunction.

Conclusions: The prevalence of new morbidity was 4.8%, twice the mortality rate, and occurred in essentially all types of patients, in relatively equal proportions, and involved all aspects of function. Compared with historical data, it is possible that pediatric critical care has exchanged improved mortality rates for increased morbidity rates. (*Pediatr Crit Care Med* 2014; 15:821–827)

Key Words: critical care; functional status; functional status score; intensive care; morbidity; outcome prediction; pediatric critical care; pediatric intensive care; pediatrics

The development of new morbidities from pediatric intensive care illnesses and therapies is a fundamental yet relatively unexplored outcome measure of pediatric intensive care. It is generally believed that many illnesses requiring admission to the PICU and their therapies result in new morbidity. Although there is some condition-specific information on new morbidities associated with PICU illnesses (1–5), there is surprisingly little general PICU population information on the development of new morbidities and these data are over a decade old (6, 7). For example, little is known about the diagnoses, operative status, and ages at greatest risk for the development of new morbidities. Fiser et al (7) in the 1990s tabulated the disability status (Pediatric Overall Performance Category [POPC] and Pediatric Cerebral Performance Category [PCPC]) of admissions and discharges from the PICU. They found that there was a 7.7% increase of at least 2 POPC categories, including a 4.6% death rate, equating to a significant new morbidity rate of 3.1%.

The aims of this report are to investigate the baseline and hospital discharge functional status of children admitted to the PICU and to describe the general characteristics of patients who developed a new morbidity. Recently, the Collaborative Pediatric Critical Care Research Network (CPCCRN) developed and validated the Functional Status Scale (FSS) to measure the development of new morbidities (8). The FSS was developed to add objectivity, increase granularity, and improve quantification of morbidities and is particularly designed for use in large-scale studies (9).

METHODOLOGY

The current investigation was performed at the seven sites (eight PICUs) in the CPCCRN. These sites have approximately 17,000 PICU admissions per year (10). The details of patient selection and data collection have been published (9, 11). In brief, only the first PICU admission was included. Patients ranging in ages from newborn to less than 18 years were randomly selected from both the general/medical PICUs and cardiac/cardiovascular PICUs. There were no separate general surgical or neurological PICUs. This report includes the initial 5,017 patients from a larger data collection and included all enrolled patients from the first day of the study (December 4, 2011) to the day when the 5,000th patient was enrolled (August 2, 2012). The protocol was approved by the institutional review boards at all participating institutions.

Data for this analysis included diagnostic and demographic data and FSS scores determined at PICU admission to assess baseline (prehospital admission) status and status at PICU and hospital discharge. Baseline FSS status was determined from the medical records supplemented by caretaker knowledge as needed to reflect chronic functional status prior to the acute illness. Researchers, research coordinators, and research assistants were trained in data collection with in-person training on multiple occasions and conducted biweekly teleconference calls. Diagnoses were classified by the system of dysfunction accounting for the primary reason for PICU admission. Since a previous publication on this sample (9), we are able to better categorize some of the miscellaneous classifications resulting in small changes in the numbers of diagnoses. Operative status included both operating room and interventional catheterization procedures but not diagnostic catheterization procedures.

The FSS was developed to provide assessment of functional status suitable for large studies. It is composed of six domains (mental status, sensory, communication, motor function, feeding, and respiratory) with domain scores ranging from 1 (normal) to 5 (very severe dysfunction). Therefore, total scores may range from 6 to 30 with lower scores indicating better function. The operational definitions and manual for the classifications have been published (8). The FSS validation consisted of comparison to the Adaptive Behavior Assessment System II, a validated measure of pediatric adaptive behavior, and comparison to the pediatric performance scales, the PCPC/POPC (8, 9). For this analysis, we categorized FSS scores of 6–7 as good, 8–9 as mildly abnormal, 10–15 as moderately abnormal, 16–21 as severely abnormal, and more than 21 as very severely abnormal. These category ranges were chosen based on the dysfunction reflected in the score and to be the approximately equivalent FSS score range that corresponded to the POPC categories (9).

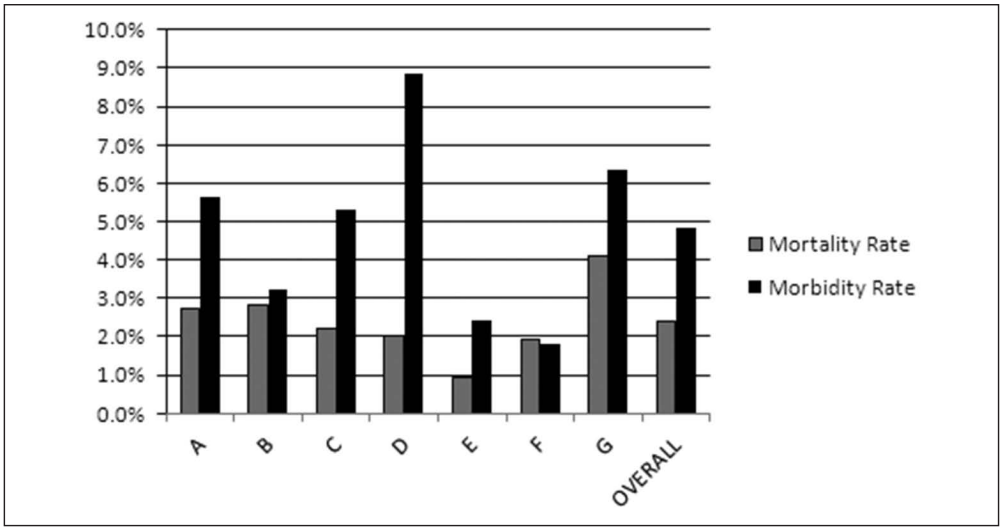

Figure 1. Morbidity and mortality rates by site. There was a significant difference among the sites for both morbidity ($p < 0.0001$) and mortality ($p = 0.009$) rates.

Newborns who had never achieved a stable baseline of function were assigned an FSS = 6; this was operationalized by assigning a baseline FSS score of 6 to all infant admissions from 0 to 2 days old and to transfers from another facility for infants from 3 to 6 days old. Significant, new morbidity was defined as worsening of FSS of 3 or greater from baseline to hospital discharge. This definition was based on a consensus perception of the importance of the change(s), and this was the change in mean FSS scores between the normal and moderate disability categories of the POPC (9). Since this was the initial use of the FSS to define new morbidities, we evaluated the change in individual FSS domains and the magnitude of that change for both patients with a worsening FSS of 3 or greater and 2 or less.

Data are expressed as mean ± SD. Comparison of data across categories used the Pearson chi-square test and the Mantel-Haenszel chi-square test. The assessment of association between morbidity and mortality rates used the Pearson correlation.

RESULTS

There were 5,017 patients and sites contributed from 619 (12%) to 808 (16%) of the sample. **Figure 1** shows the morbidity and mortality rates by site and overall. Significant new morbidity occurred in 242 patients (4.8%). There were 99 PICU deaths (2.0% PICU mortality rate) and 120 hospital deaths (2.4% hospital mortality rate). There was a significant difference in both morbidity ($p < 0.0001$) and mortality ($p = 0.009$) rates among the sites; these rates differed by over 300% between the lowest and the highest sites and did not significantly correlate ($r = 0.38$, $p = 0.40$). Overall, significant new morbidity occurred in all FSS baseline categories (**Fig. 2**). There was no significant difference among the rates of new morbidities for survivors admitted in the various baseline FSS categories ($p > 0.8$). Patients had a median age of 3.7 years (25th and 75th quartile, 0.8 and 10.9) and stayed in the PICU a median of 2.0 days (25th and 75th quartile, 1.0 and 4.8).

Functional status categories at baseline and hospital discharge are shown in **Figure 3**. The worst functional status profile was on discharge from the PICU but improved on hospital discharge. On hospital discharge, the good category decreased from a baseline of 72% to 63%, mild abnormality increased from a baseline of 10% to 15%, moderate abnormality status increased from 13% to 14%, severe status increased from 4% to 5%, and very severe was unchanged at 1%.

Of the patients classified with new morbidities, 109 patients (45.0%) had a worsening of 3 levels or more FSS levels in at least one FSS domain, 122 patients (50.4%) had a worsening of 2 FSS levels in one or more FSS domains but no change of three or more, and only 11 patients (4.5%) had a worsening of only 1 level in three or more FSS domains. **Table 1** shows the new morbidities by diagnoses classified by the physiological system of primary dysfunction. Overall, 31% of patients were admitted with respiratory disease, 21% with neurological disease, and 25% with acquired and congenital heart disease. There were significantly different morbidity rates among the diagnoses ($p = 0.0005$) with the highest new morbidity rates in the neurological diagnoses (7.3%), acquired

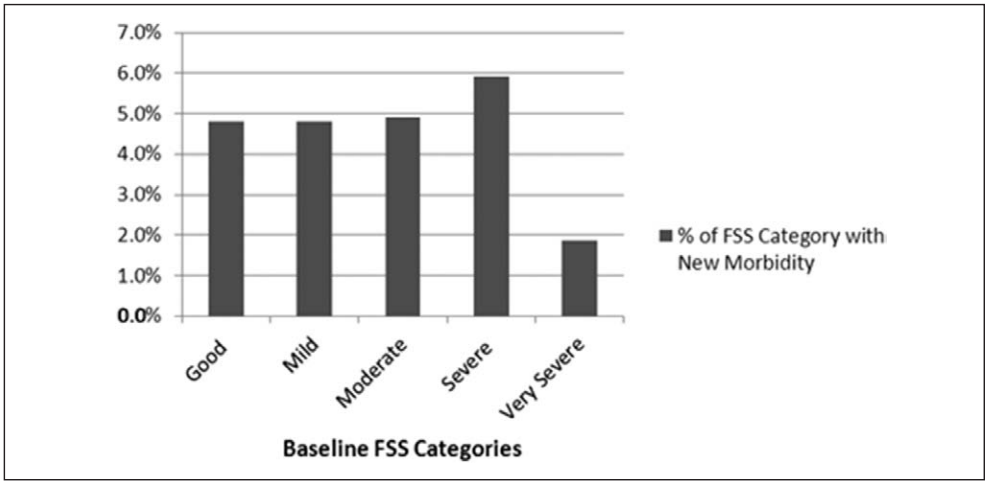

Figure 2. New morbidities (Functional Status Scale [FSS] ≥ 3) as a percentage of baseline FSS categories. There was no significant difference among the rates of new morbidities for survivors admitted in the baseline FSS categories ($p > 0.8$).

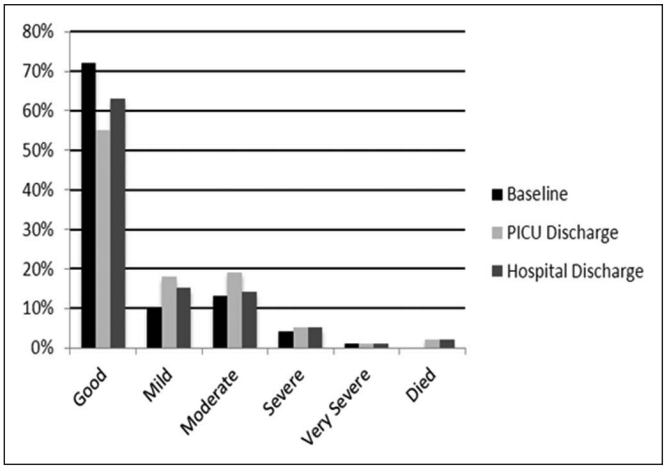

Figure 3. Functional Status Scale categories at baseline, PICU discharge, and hospital discharge. See text for details.

cardiovascular disease (5.9%), cancer (5.3%), and congenital cardiovascular disease (4.9%).

The operative categories are shown in **Table 2**. A total of 40% of the sample were operative patients with a rate of new morbidities of 3.5%. The new morbidities rates were significantly different ($p \leq 0.003$) with the highest rates of new morbidities occurring in the nonoperative patients (5.7%) and general surgery patients (5.7%) followed by cardiac surgery (4.5%). Neurosurgical patients had a prevalence of new morbidities of only 3.1%. New morbidities occurred in all age categories with more in those under 12 months than in those over 12 months of age (**Table 3**), and these rates were also significantly different among the age categories ($p < 0.0001$).

New morbidities occurred in all of the FSS domains. **Table 4** shows the domains and numbers of patients where there was a worsening in domain scores of 3 levels or more, 2 and 1 for those patients with new morbidities, and those patients whose FSS scores worsened by 2 but were not classified with new morbidities. For the patients with new morbidities and an increase of 3 or more in the domain scores, the largest numbers occurred in the respiratory (21.1%) and motor (14.5%) domains. For patients with new morbidities and domain increases of 2, the largest numbers occurred in the feeding (47.9%) and motor (34.3%) domains. Only six patients (0.1%) had increases in domain scores of 3 or more but were not classified with new morbidities because of improvements in another domain. Of the patients who had worsening of 2 levels in their domain score but were not classified with a new morbidity, most occurred in the feeding and motor domains. A total of 106 patients improved their FSS by 2 or more and improved in a single domain by 2 or more. Most improvement occurred in the feeding, motor, and respiratory domains.

DISCUSSION

New, significant morbidities resulting from the illnesses and therapies in the PICU are common and occur in essentially all types of patients in relatively equal proportions. The prevalence of new morbidity was 4.8%, twice the mortality rate. The rate of new morbidity was 4.5–6% in patients with good, mildly abnormal, moderately abnormal, and severely abnormal baseline status. Although the prevalence of new morbidity was only 1.9% in very severely abnormal children at baseline, this lower prevalence likely was observed because these patients already had very severe dysfunction. New morbidities developed in all common diagnostic groups with the highest rates in neurological and acquired cardiovascular disease. Although new morbidities developed in nonoperative patients more than operative patients (5.7% vs 3.5%), they also occurred in almost all operative groups with the highest rates in cardiac surgery and general surgery and in only 3.1% of neurosurgical patients. Finally, although new morbidities occurred more often in infants, they occurred in all age groups.

Both morbidity and mortality rates differed by more than 300% among the sites. Mortality rate differences among sites are well known and can be adjusted for by physiological status and

TABLE 1. New Morbidities by Admission Diagnosis

System of Primary Dysfunction	*n* (% of Sample)	New Morbidity (*n*)	New Morbidity (% of Diagnosis)
Respiratory	1,563 (31)	67	4.3
Neurologic	1,031 (21)	75	7.3
Cardiovascular disease, congenital	955 (19)	47	4.9
Cardiovascular disease, acquired	323 (6)	19	5.9
Cancer	247 (5)	13	5.3
Musculoskeletal condition	219 (4)	7	3.2
Gastrointestinal disorder	183 (4)	6	3.3
Endocrine	146 (3)	0	0
Renal	52 (1)	1	1.9
Miscellaneous	298 (6)	7	2.3

Admission diagnoses are classified by system of primary dysfunction. The new morbidity rates among the diagnoses were significantly different ($p < 0.0001$).

TABLE 2. New Morbidities by Operative Category

Operative System	*n* (%)	New Morbidities (*n* [% of Category])
No operation	3,025 (60)	173 (5.7)
Cardiac	755 (15)	34 (4.5)
Neurosurgery	353 (7)	11 (3.1)
Otolaryngology	285 (6)	3 (1.1)
Orthopedic	181 (4)	5 (2.8)
General surgery	176 (4)	10 (5.7)
Interventional catheterization	72 (1)	2 (2.8)
Other	170 (3)	4 (2.4)

The new morbidity rates among the operative systems were significantly different ($p < 0.005$).

TABLE 3. New Morbidities by Age Categories

Age at PICU Admission	*n* (%)	New Morbidities (*n* [% of Category])
0 d to < 7 d	167 (3)	15 (9.0)
7 d to <14 d	92 (2)	10 (10.9)
14 d to < 1 mo	71 (1)	4 (5.6)
1 mo to < 12 mo	1,060 (21)	68 (6.4)
12 mo to < 60 mo	1,429 (28)	62 (4.3)
60 mo to < 144 mo	1,094 (22)	42 (3.8)
≥ 144 mo	1,104 (22)	41 (3.7)

The new morbidity rates among the age categories were significantly different ($p < 0.0001$).

other patient descriptors (12, 13). Such adjustment has formed the foundation for many comparative and quality studies in critical care. It is not yet known whether morbidity rate differences can be accounted for with similar or different independent variables that will enable us to incorporate morbidity into studies investigating the importance of care factors in patient outcomes or quality studies. In this small sample of sites, morbidity and mortality rates were not strongly correlated, indicating that incorporating morbidity into outcome models may uncover new associations and expand our understanding of factors associated with the best outcomes from pediatric critical care.

Morbidity assessments are appropriately becoming a more important aspect of pediatric outcomes research (14–19). We defined morbidity broadly because the effects of acute conditions and their therapies can affect many different organ systems. We chose functional status because it is conceptually similar to adaptive behavior, which corresponds to activities of daily living, a commonly used and practical measure in adults (20). Other investigators may focus on different definitions of morbidity depending on their research needs. Recently, the use of health-related quality-of-life instruments have become more common place; these methods are often based in large part on the health burden of functional disabilities, so the FSS represents a more proximate measure of a similar outcome (21–23). Notably, there are hurdles to overcome when classifying children. First, functional status assessments that are reliable at the level of the individual are time consuming and require considerable training; therefore, they are not practical for most large sample-size studies (24–27). Second, pediatric functional status assessment methods must incorporate the rapidly changing norms of growth and development, making them difficult to design and complex to develop (28, 29). The FSS, designed to be used in large sample-size studies, performed well with regard to both adaptive behavior methods and the pediatric scales based on the Glasgow Outcome Scale and was successfully implemented in this multicenter study (8, 9, 30). We chose the FSS categories to be approximately equivalent to the POPC categories which have been used in other large pediatric studies (31, 32).

The FSS definition of significant morbidity of an increase of 3 or more worked well. A total of 95% of diagnoses had a worsening of at least two levels in at least one FSS domain (good to moderate, mild to severe, and moderate to very severe). These changes occurred in all of the FSS domains with a predominance of respiratory and motor for the domains that changed 3 or more levels and feeding and motor for those changing 2 levels.

Our data compared with the historical data suggest that pediatric critical care may have exchanged mortality for morbidity over the last several decades. Although it is not possible to precisely compare the rates over time because of the different research methods, data from the 1990s (31) demonstrated a PICU mortality rate of 4.6% and a PICU morbidity rate of 3.1% (based on a 2 or greater POPC change), whereas our data had a reversal of these percentages with a hospital mortality rate of 2.4% and morbidity rate of 4.8%. Thus, the "morbidity and mortality rate" decreased only from 7.7% to 7.2%. Since these rates are not severity or risk adjusted, the changes in admission criteria as well as other factors which have occurred in the last several decades could also significantly influence this comparison.

CONCLUSION

New, significant morbidities associated with pediatric critical care are common (4.8%) and occur in essentially all types of patients. Since reducing morbidity and mortality is a focus of medical initiatives, this rate is an important benchmark. There was significant inter-site variability in the unadjusted morbidity rates. It is possible that further investigation of the differences in morbidity rates could result in advances in the structure and process of pediatric critical care in a manner similar to the advances based on mortality rate differences. Our data compared with the historical data suggest that pediatric critical care may have exchanged mortality for morbidity over the last several decades.

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TABLE 4. Functional Status Scale Domain Changes in Patients With Increasing Functional Status Scale Scores

Variable	Domain Change, ≥ 3 Levels (%)	Domain Change, 2 Levels (%)	Domain Change, 1 Level (%)
Patients with new morbidities (FSS ≥ 3, $n = 242$)			
FSS domain mental status	19 (7.9)	21 (8.7)	59 (24.4)
FSS domain motor	35 (14.5)	83 (34.3)	23 (9.5)
FSS domain sensory	16 (6.6)	14 (5.8)	34 (14.1)
FSS domain respiratory	51 (21.1)	14 (5.8)	45 (18.6)
FSS domain feeding	22 (9.1)	116 (47.9)	18 (7.4)
FSS domain communication	16 (6.6)	21 (8.7)	72 (29.8)
Patients without new morbidities but FSS increase of 2 ($n = 660$)			
FSS domain mental status	0	5 (0.8)	55 (8.3)
FSS domain motor	0	92 (13.9)	106 (16.1)
FSS domain sensory	0	5 (0.8)	41 (6.2)
FSS domain respiratory	3 (0.5)	19 (2.9)	88 (13.3)
FSS domain feeding	2 (0.3)	188 (28.5)	63 (9.6)
FSS domain communication	1 (0.2)	4 (0.6)	46 (7.0)

FSS = Functional Status Scale.

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