# Characteristics and Outcomes of Critical Illness in Children With Feeding and Respiratory Technology Dependence

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**Objectives:** Children with dependence on respiratory or feeding technologies are frequently admitted to the PICU, but little is known about their characteristics or outcomes. We hypothesized that they are at increased risk of critical illness–related morbidity and mortality compared with children without technology dependence.

**Design:** Secondary analysis of prospective, probability-sampled cohort study of children from birth to 18 years old. Demographic and clinical characteristics were assessed. Outcomes included death, survival with new morbidity, intact survival, and survival with functional status improvement.

**Setting:** General and cardiovascular PICUs at seven participating children's hospitals as part of the Trichotomous Outcome Prediction in Critical Care study.

**Subjects:** Children from birth to 18 years of age as part of the Trichotomous Outcome Prediction in Critical Care study.

**Interventions:** None.

**Measurements and Main Results:** Children with technology dependence composed 19.7% (1,989/10,078) of PICU admissions. Compared with those without these forms of technology dependence, these children were younger, received more ICU-specific therapeutics, and were more frequently readmitted to the ICU. Death occurred in 3.7% of technology-dependent patients ($n = 74$), and new morbidities developed in 4.5% ($n = 89$). Technology-dependent children who developed new morbidities had higher Pediatric Risk of Mortality scores and received more ICU therapies than those who did not. A total of 3.0% of technology-dependent survivors ($n = 57$) showed improved functional status at hospital discharge.

**Conclusions:** Children with feeding and respiratory technology dependence composed approximately 20% of PICU admissions. Their new morbidity rates are similar to those without technology dependence, which contradicts our hypothesis that children with technology dependence would demonstrate worse outcomes. These comparable outcomes, however, were achieved with additional resources, including the use of more ICU therapies and longer lengths of stay. Improvement in functional status was seen in some technology-dependent survivors of critical illness. (*Pediatr Crit Care Med* 2018; XX:00–00)

**Key Words:** critical care; gastrostomy; morbidity; outcomes; pediatrics; tracheostomy

Medically fragile children are frequently admitted to the PICU. Children who are dependent on technology are an important group of medically fragile children, but the definition of technology dependence is not well established. Past research has predominantly focused on children with "complex chronic conditions," a set of conditions defined by diagnostic coding that includes dependence on a medical device (1, 2). Feudtner et al (3) defined technology dependency as a situation in which "the failure or withdrawal of the technology would likely have adverse health consequences sufficient to require hospitalization" and included medication dependence as well as device dependence. An alternative definition of technology-dependent children includes only those who need a medical device to perform a necessary bodily function (4).

As a reflection of their underlying conditions, the inherent risks associated with their technology dependence, and their reduced physiologic reserve, these children may be at increased risk for critical illness, resulting in increased therapeutic needs, worsening dysfunction, and mortality. For example, chronic mechanical ventilation is associated with increased rates of medical resource utilization and longer hospital lengths of stay (5, 6). Little is known about the critical care course of technology-dependent children. Although some technology-dependent children are routinely triaged to the PICU regardless of their reason for admission due to resource constraints on the general care wards, others are admitted with significant critical illness (7).

Because technology-dependent children represent a distinct group of patients in the PICU, their clinical courses and outcomes may differ from the general population. The aim of this study was to describe the demographic, physiologic, and therapeutic characteristics, as well as outcomes, of children dependent on respiratory and feeding technologies and compare them to children without such technology dependence during episodes of critical illness. Our definition of technology dependence—reliance on respiratory or gastrointestinal devices—identifies a representative, although not comprehensive, group of technology-dependent children. We hypothesized that children reliant on feeding or respiratory devices would be characterized by higher mortality and incur more new morbidity than the general PICU population.

## MATERIALS AND METHODS

Children from newborn to up to 18 years old were probability sampled from general and cardiovascular PICUs at seven participating children's hospitals from December 4, 2011, to April 7, 2013, as part of the Trichotomous Outcome Prediction in Critical Care (TOPICC) study. Detailed methods for TOPICC have been previously described (8). Multiple other evaluations using this database have been published (9–12). As in the original TOPICC study, patients who were moribund at the time of admission were excluded, and only the first ICU admission during the study was eligible for inclusion. Preillness ("baseline") functional status was assessed via the Functional Status Scale (FSS) at admission to the ICU using information from the caregiver and medical record as needed to establish functional status before the acute illness. FSS was additionally collected at the time of transfer from ICU to floor and at hospital discharge. The FSS is a relatively granular and objective classification method that characterizes functional status in a variety of domains (13, 14). Each of the six domains is scored from 1 to 5 points, with lower numbers indicating better function. Overall FSS scores have previously been categorized as good (6, 7), mildly abnormal (8, 9), moderately abnormal (10–15), severely abnormal (16–21), and very severely abnormal (> 21) to reflect the patient's dysfunction and to correlate with Pediatric Overall Performance Category scores (13). The decision to define a new morbidity as an increase in the overall FSS score of greater than or equal to 3 points has been previously published (9). Similarly, we used a decrease of greater than or equal to 3 points in the overall FSS score on hospital discharge to indicate significant improvement in functional status.

Patients dependent on feeding or respiratory technology were identified as those with a FSS of greater than or equal to 3 in the feeding and/or respiratory domains (tube feedings and/or parenteral nutrition, and tracheostomy and/or chronic mechanical respiratory support, including continuous or bilevel positive airway pressure for part or all of the day, respectively) at baseline, as seen in **Figure 1** (14). There may have been other children with device dependence present in the patient sample, but use of other devices was not collected in the TOPICC dataset. Therefore, this group served as a major, but not complete, sample of technology-dependent children. Feeding or respiratory technology–dependent patients were compared with patients without these technology dependencies. The study was approved by the Institutional Review Board at all participating institutions.

Descriptive data included age, gender, race, insurance status, admission characteristics, and primary system of dysfunction prompting admission. Resource use outcomes included length of stay, readmission to the ICU during the same hospitalization, and selected therapeutics (e.g., mechanical ventilation, vasoactive infusions, provision of antibiotics and steroids, and renal replacement therapy). Analyses were not adjusted to account for chronic therapeutics, including mechanical ventilation or parenteral nutrition, given our lack of information about the specifics of a patient's baseline support. Severity of illness was measured with physiologic profiles from Pediatric Risk of Mortality (PRISM) 3 scoring (15). Outcomes included death, survival with new morbidity (total FSS increase of ≥ 3 points), intact survival (no significant change in functional status), and survival with functional status improvement (total FSS decrease of ≥ 3 points).

Counts and percentages are reported for categorical variables, whereas medians and interquartile ranges are reported for continuous variables. Associations with baseline technology dependence were assessed with Fisher exact test for categorical variables and the Wilcoxon rank-sum test for continuous variables (**Tables 1** and **2**). Although age was categorized for reporting, tests of association are based on the

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | NORMAL | MILD DYSFUNCTION | MODERATE DYSFUNCTION | SEVERE DYSFUNCTION | VERY SEVERE DYSFUNCTION |
| MENTAL STATUS | Normal sleep/wake; appropriate responsivity | Sleepy but arousable to noise/ touch/movement and/or periods of social nonresponsivity | lethargic and/or irritable | Minimal arousal to stimulus (stupor) | Unresponsive and/or Coma and/or Vegetative |
| SENSORY | Intact hearing and vision and responsive to touch | Suspected hearing or Suspected vision loss. | Not reactive to auditory stimuli or Not reactive to visional stimuli | Not reactive to auditory stimuli and Not reactive to visional stimuli | Abnormal response to pain or touch |
| COMMUNICATION | Appropriate non-crying vocalizations, interactive facial expressiveness, or gestures | Diminished Vocalization Diminished Facial Expression and/or social responsiveness | Absence of attention getting behavior | No demonstration of discomfort | Absence of communication |
| MOTOR FUNCTION | Coordinated body movements and Normal muscle control and Awareness of action and why it's being done | 1 limb functionally impaired | 2 or more limbs functionally impaired | Poor head control | Diffuse Spasticity, Paralysis, Decerebrate/Decorticate Posturing |
| FEEDING | All food taken by mouth with age appropriate help | NPO or need for age-inappropriate help with feeding | Oral and tube feedings | Parenteral Nutrition with oral or tube feedings | All parenteral nutrition |
| RESPIRATORY | Room air and no artificial support or aids | Oxygen and/or Suctioning | Tracheostomy | CPAP for all or part of the day and/or Mechanical ventilator support for part of the day | Mechanical ventilatory support for all of the day and night |

**Figure 1.** Functional Status Scale scoring by subdomains. Reprinted with permission from Pollack et al (14).

**TABLE 1. Descriptive Characteristics of Children With and Without Feeding and Respiratory Technology Dependence.**

| Patient Characteristic | Technology Dependence (*n* = 1,989), *n* (%) | No Technology Dependence (*n* = 8,089), *n* (%) | *p* |
|---|---|---|---|
| Age at PICU admission (yr) | | | |
| < 1 | 470 (23.6) | 2,324 (28.7) | < 0.001 |
| 1–5 | 767 (38.6) | 2,100 (26.0) | |
| 5–12 | 473 (23.8) | 1,771 (21.9) | |
| 12–18 | 279 (14.0) | 1,894 (23.4) | |
| Gender | | | |
| Female | 859 (43.2) | 3,689 (45.6) | 0.053 |
| Male | 1,130 (56.8) | 4,400 (54.4) | |
| Race | | | |
| Black | 448 (22.5) | 1,848 (22.8) | [a] |
| White | 1,066 (53.6) | 4,096 (50.6) | |
| Unknown/other | 475 (23.9) | 2,145 (26.5) | |
| Primary payer type | | | |
| Government | 1,275 (64.1) | 4,145 (51.2) | <0.001 |
| Commercial | 660 (33.2) | 3,508 (43.4) | |
| Unknown | 54 (2.7) | 436 (5.4) | |

[a]Significance for race was not analyzed due to the large number of unknown classifications.

Wilcoxon rank-sum test in order to use the ordered nature of the categories. For those assessments which included more parameters than could be assessed in a standard 2×2 table, a Monte Carlo approximation was used to estimate the *p* value for Fisher exact test. The associations with development of new morbidity among technology-dependent survivors were analyzed analogously (**Table 3**). Summaries and analyses were performed using SAS 9.4 (SAS Institute, Cary, NC) under the direction of author R.W.R.

## RESULTS

Among 10,078 total admissions over approximately 16 months, 1,989 (19.7%) were technology dependent at baseline. Overall, children with feeding and respiratory technology dependence were younger ($p < 0.001$) and had a higher frequency of government insurance ($p < 0.001$) than those without technology dependence (Table 1).

The clinical characteristics of children with and without technology dependence are reported in **Table 2**. As expected, the baseline FSS scores of technology-dependent children were higher than for those without dependence ($p < 0.001$). Both groups had predominantly emergent admissions, were frequently admitted from an inpatient unit, and had similar severity of illness scores. The system of primary dysfunction prompting admission was predominantly respiratory for both groups. Compared with children without technology dependence, those with technology dependence stayed in the PICU longer (median duration, 7.1 vs 4.6 d; $p < 0.001$). The hospital discharge FSS scores were similar to the baseline scores for both groups. Although prehospital origin is not known, discharge outcomes differed between the groups with outcomes of mortality and discharge to chronic care or skilled nursing care

**TABLE 2. Hospitalization Characteristics of Children With and Without Feeding or Respiratory Technology Dependence**

| Patient Characteristic | Technology Dependence (*n* = 1,989) | No Technology Dependence (*n* = 8,089) | *p* |
|---|---|---|---|
| Admission Pediatric Risk of Mortality 3 score, median (IQR) | 2.0 (0.0–5.0) | 2.0 (0.0–5.0) | 0.969 |
| Baseline FSS score, median (IQR) | 12.0 (10.0–16.0) | 6.0 (6.0–6.0) | < 0.001 |
| Admission status, *n* (%) | | | |
| Elective | 713 (35.8) | 2,954 (36.5) | 0.585 |
| Emergent | 1,276 (64.2) | 5,135 (63.5) | |
| Admission source, *n* (%) | | | |
| Emergency department | 688 (34.6) | 2,599 (32.1) | 0.070 |
| Inpatient unit | 869 (43.7) | 3,740 (46.2) | |
| Direct admission from outside institution | 432 (21.7) | 1,750 (21.6) | |
| System of primary dysfunction, *n* (%) | | | |
| Low-risk diagnoses[a] | 145 (7.3) | 799 (9.9) | < 0.001 |
| Cardiac | 379 (19.1) | 2,051 (25.4) | |
| Respiratory | 992 (49.9) | 2,384 (29.5) | |
| Oncologic | 24 (1.2) | 346 (4.3) | |
| Neurologic | 225 (11.3) | 1,797 (22.2) | |
| Other | 224 (11.3) | 712 (8.8) | |
| PICU therapies, *n* (%) | | | |
| Mechanical ventilation | 1,142 (57.4) | 2,697 (33.3) | < 0.001 |
| Vasoactive infusions | 408 (20.5) | 1,977 (24.4) | < 0.001 |
| Antibiotic administration | 1,559 (78.4) | 5,292 (65.4) | < 0.001 |
| Steroid administration | 713 (35.8) | 2,585 (32.0) | 0.001 |
| Parenteral nutrition | 342 (17.2) | 993 (12.3) | < 0.001 |
| Nitric oxide | 87 (4.4) | 198 (2.4) | < 0.001 |
| High-frequency ventilation | 35 (1.8) | 71 (0.9) | 0.001 |
| Intracranial pressure monitoring | 16 (0.8) | 222 (2.7) | < 0.001 |
| Therapeutic hypothermia | 8 (0.4) | 46 (0.6) | 0.492 |
| Neuromuscular blockade | 282 (14.2) | 1,089 (13.5) | 0.401 |
| Renal replacement therapy | 41 (2.1) | 112 (1.4) | 0.031 |
| Extracorporeal support | 16 (0.8) | 94 (1.2) | 0.186 |
| PICU length of stay (d), median (IQR) | 3.0 (1.5–7.0) | 1.8 (1.0–4.1) | < 0.001 |
| PICU readmission during same admission, *n* (%) | 121 (6.1) | 358 (4.4) | 0.003 |
| Hospital discharge outcomes, *n* (%) | | | |
| Home or foster care | 1,679 (84.4) | 7,448 (95.8) | < 0.001 |
| Another acute care hospital | 63 (3.2) | 111 (1.4) | |
| Acute inpatient rehabilitation | 50 (2.5) | 217 (2.7) | |
| Chronic care or skilled nursing facility | 122 (6.1) | 43 (0.5) | |
| Death | 74 (3.7) | 201 (2.5) | |
| Hospital discharge FSS score, median (IQR)[b] | 12.0 (10.0–16.0) | 6.0 (6.0–7.0) | < 0.001 |

FSS = Functional Status Scale, IQR = interquartile range.

[a]Low-risk diagnoses included diabetic ketoacidosis, and hematologic, musculoskeletal, and renal dysfunction.

[b]Discharge FSS score was analyzed only for survivors.

**TABLE 3. Comparison of Survivors With Feeding or Respiratory Technology Dependence With and Without New Morbidities**

| Patient Characteristic | New Morbidity ($n = 89$) | No New Morbidity ($n = 1,826$) | $p$ |
|---|---|---|---|
| Admission Pediatric Risk of Mortality 3 score, median (IQR) | 3.0 (0.0–8.0) | 2.0 (0.0–5.0) | 0.006 |
| Baseline FSS score, median (IQR) | 13.0 (9.0–16.0) | 12.0 (10.0–16.0) | 0.993 |
| Admission status, *n* (%) | | | |
| Elective | 16 (18.0) | 681 (37.3) | < 0.001 |
| Emergent | 73 (82.0) | 1,145 (62.7) | |
| Admission source, *n* (%) | | | |
| Emergency department | 24 (27.0) | 644 (35.3) | < 0.001 |
| Inpatient unit | 29 (32.6) | 804 (44.0) | |
| Direct admission from outside institution | 36 (40.4) | 378 (20.7) | |
| System of primary dysfunction, *n* (%) | | | |
| Low-risk diagnoses[a] | 2 (2.2) | 141 (7.7) | 0.020 |
| Cardiac | 12 (13.5) | 343 (18.8) | |
| Respiratory | 59 (66.3) | 897 (49.1) | |
| Oncologic | 2 (2.2) | 21 (1.2) | |
| Neurologic | 7 (7.9) | 213 (11.7) | |
| Other | 7 (7.9) | 211 (11.6) | |
| PICU therapies, *n* (%) | | | |
| Mechanical ventilation | 70 (78.7) | 1,011 (55.4) | < 0.001 |
| Vasoactive infusions | 29 (32.6) | 329 (18.0) | 0.001 |
| Antibiotic administration | 77 (86.5) | 1,416 (77.5) | 0.049 |
| Steroid administration | 44 (49.4) | 627 (34.3) | 0.004 |
| Parenteral nutrition | 26 (29.2) | 281 (15.4) | 0.002 |
| Nitric oxide | 8 (9.0) | 60 (3.3) | 0.012 |
| High-frequency ventilation | 5 (5.6) | 24 (1.3) | 0.009 |
| Intracranial pressure monitoring | 2 (2.2) | 11 (0.6) | 0.120 |
| Therapeutic hypothermia | 2 (2.2) | 4 (0.2) | 0.028 |
| Neuromuscular blockade | 36 (40.4) | 212 (11.6) | < 0.001 |
| Renal replacement therapy | 6 (6.7) | 22 (1.2) | 0.001 |
| Extracorporeal support | 3 (3.4) | 8 (0.4) | 0.012 |
| PICU length of stay (d), median (IQR) | 10.0 (3.0–31.7) | 2.9 (1.4–6.6) | < 0.001 |
| PICU readmission, *n* (%) | 20 (22.5) | 87 (4.8) | < 0.001 |
| Discharge location, *n* (%) | | | |
| Home or foster care | 56 (62.9) | 1,623 (88.9) | < 0.001 |
| Another acute care hospital | 10 (11.2) | 53 (2.9) | |
| Acute inpatient rehabilitation | 5 (5.6) | 45 (2.5) | |
| Chronic care or skilled nursing facility | 18 (20.2) | 104 (5.7) | |
| Hospital discharge FSS score, median (IQR) | 17.0 (14.0–21.0) | 12.0 (9.0–16.0) | < 0.001 |

FSS = Functional Status Scale, IQR = interquartile range.

[a]Low-risk diagnoses included diabetic ketoacidosis, and hematologic, musculoskeletal, and renal dysfunction.

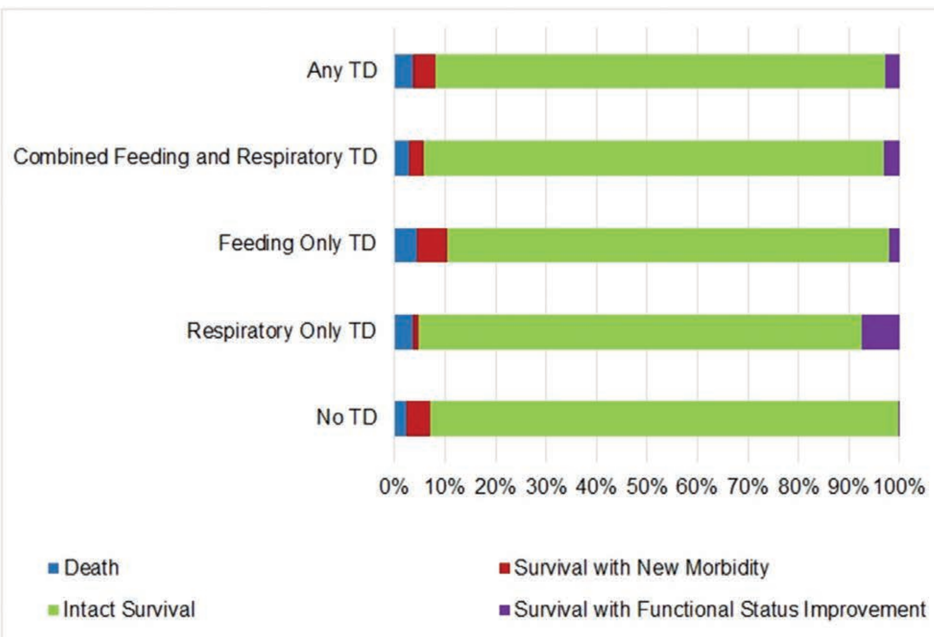
facilities and other acute care facilities being more common among technology-dependent patients than those without technology dependence ($p < 0.001$). Discharge to acute inpatient rehabilitation was similar between groups.

Use of critical care therapeutics (Table 2) differed between the two group of patients. Technology-dependent patients were more likely to receive mechanical ventilation ($p < 0.001$), antibiotics ($p < 0.001$), steroids ($p < 0.001$), total parenteral nutrition ($p < 0.001$), inhaled nitric oxide ($p < 0.001$), high-frequency ventilation ($p = 0.001$), and renal replacement therapy ($p = 0.031$). They were less likely to receive vasoactive medications ($p < 0.001$) and were less likely to have intracranial pressure monitoring ($p < 0.001$). They were readmitted to the PICU during that same hospitalization at a significantly higher rate than children without technology dependence (6.1% vs 4.4%; $p = 0.003$).

The distribution of mortality and new morbidity for children with and without various types of feeding and respiratory technology dependence is shown in **Figure 2**. Technology-dependent children died more frequently than did those without dependence (3.7% vs 2.5%; $p = 0.003$), whereas new morbidities developed in similar percentages of both groups (4.5% vs 4.6%). Within the technology-dependent group, both mortality and new morbidity were highest in the subgroup of patients with only feeding technology dependence (4.4% and 6.1%, respectively). Improvement in functional status during the hospitalization was observed in 57 technology-dependent survivors (3.0%), and only 19 survivors (0.2%) without technology dependence demonstrated survival with improvement ($p < 0.001$).

The clinical characteristics of the 89 technology-dependent survivors (4.6%) who developed new morbidities compared with the 1,826 who did not are shown in Table 3. Children with feeding and respiratory technology dependence who developed new morbidities had similar baseline FSS scores to those who did not. However, they had higher PRISM scores at admission ($p = 0.006$) and were more likely to be admitted on an emergency basis ($p < 0.001$) or from an outside facility ($p < 0.001$). Children with technology dependence who developed new morbidities differed from those who did not develop new morbidities with regard to primary systems of dysfunction, with higher rates of respiratory dysfunction and lower rates of neurologic dysfunction ($p = 0.02$).

Children with baseline feeding and respiratory technology dependence were most likely to have worsening in their respiratory ($n = 53$ [59.6%]) and motor ($n = 30$ [33.7%]) FSS domains. PICU length of stay was markedly longer in technology-dependent children who developed new morbidities ($p < 0.001$), and they used significantly more high-intensity




| | Baseline Feeding or Respiratory Technology Dependence | | P-value |
|---|---|---|---|
| | Yes (n=1989) | No (n=8089) | |
| Death | 74 (3.7%) | 201 (2.5%) | 0.003 |
| Survival with New Morbidity | 89 (4.5%) | 374 (4.6%) | 0.811 |
| Intact Survival | 1769 (88.9%) | 7495 (92.7%) | <0.001 |
| Survival with Functional Status Improvement | 57 (2.9%) | 19 (0.2%) | <0.001 |

| | Baseline Feeding or Respiratory Technology Dependence | | | P-value |
|---|---|---|---|---|
| | Respiratory Only (n=131) | Feeding Only (n=1070) | Combined Feeding and Respiratory (n=788) | |
| Death | 5 (3.8%) | 47 (4.4%) | 22 (2.8%) | 0.201 |
| Survival with New Morbidity | 1 (0.8%) | 65 (6.1%) | 23 (2.9%) | <0.001 |
| Intact Survival | 115 (87.8%) | 936 (87.5%) | 718 (91.1%) | 0.039 |
| Survival with Functional Status Improvement | 10 (7.6%) | 22 (2.1%) | 25 (3.2%) | 0.003 |

**Figure 2.** Outcomes of children with and without feeding and respiratory technology dependence (TD).

ICU therapies including mechanical ventilation ($p < 0.001$), vasoactive infusions ($p = 0.001$), neuromuscular blockade ($p < 0.001$), and extracorporeal support (0.012). Those who developed new morbidities were readmitted to the PICU at nearly five times the rate as those who did not ($p < 0.001$). Those with new morbidities were more likely to be transferred to another hospital or discharged to rehabilitation and chronic care facilities than those without new morbidities ($p < 0.001$).

## DISCUSSION

Children with respiratory and feeding technology dependence composed approximately 20% of PICU admissions, which is fewer than in previous studies focusing on the broader definitions of medically fragile or complex children (16, 17). Some of this difference may be in the methodology and focus of the studies because this study is the first to define technology dependence using the FSS. Our definition, which uses only the respiratory and feeding domains in the FSS, is more narrowly tailored than many other definitions of medical complexity, and it will not include some children with device dependence, such as those with ventriculoperitoneal shunts, or those who receive dialysis or subcutaneous pulmonary hypertension medications.

Compared with those without feeding or respiratory technology dependence, technology-dependent children admitted to the PICU were younger, were more frequently insured by governmental health insurance, and most importantly, received more ICU-specific therapeutics, and were more frequently readmitted to the critical care service following care on the general ward. Children dependent on feeding or respiratory technology had higher mortality rates than children without technology dependence. Although morbidity rates were similar between the two groups, technology-dependent children required longer lengths of stay. Both mortality and morbidity were highest in the subgroup of patients with only feeding technology dependence. Improvement in functional status during the hospitalization was noted in 3.0% of technology-dependent survivors. These functional status improvements presumably occurred because these patients were admitted for a procedure, such as tracheostomy decannulation, which improved their FSS classification or a corrective procedure which improved their underlying physiologic reserve. We did not assess how different baseline degrees of dysfunction among technology-dependent children were related to outcomes because our aim was to provide a global description of critically ill technology-dependent children.

Overall, children dependent on respiratory or feeding technology had a similar pattern of primary admission reasons and illness severity as children without dependence on these technologies. Their resource use, however, was greater than that of patients without technology dependence, particularly as measured by ICU length of stay and need for discharge to a location other than home. This is consistent with previous studies demonstrating higher medical resource utilization in children with complex medical conditions (4, 16, 18). Previous studies additionally demonstrated that children dependent on long-term mechanical ventilation have prolonged hospital lengths of stay, mortality, and discharges to long-term care facilities than other children with complex conditions (5), findings which are mirrored in our population of ICU patients. These disparities suggest that there may be important barriers to discharge in technology-dependent patients, including care requirements after hospital discharge. But because the TOPICC dataset was collected for other purposes, it did not collect data regarding specific issues in the care of technology-dependent children that may be important to questions raised in this study. Specifically, a patient's primary residence was not noted, so the proportion of children discharged to a location other than home may not represent a change from baseline.

As medical care is increasingly able to support children through potentially life-ending conditions, the proportion of patients who are dependent on technology is growing (19, 20). Simultaneously, the focus of critical care has evolved from saving lives to preserving function. General PICU mortality rates are approximately 2.5–5.0%, whereas new morbidity rates are approximately twice as high (8, 9). It has been suggested that a portion of the improving mortality rate over time has been in exchange for a higher morbidity rate (21). Therefore, the provision of intensive care is changing the population of our ICUs, leading to the significant representation of technology-dependent patients in today's PICUs. ICU populations routinely evolve as medical care changes and improves. For example, when neonatal care improved the survival of premature infants, the impact on PICUs was notable (22). Additionally, increasing numbers of cardiac ICUs now provide subspecialized care for children with congenital and acquired heart disease (23).

Previous studies of children following critical illness demonstrate an unclear trajectory of functional status (9, 24–26). Children across a range of ages, diagnostic categories, and surgical statuses acquire new morbidities with critical illness (9, 23, 27). Many children with medical complexity return to their baseline level of function following an episode of critical illness (25). Typpo et al (25) determined that the vast majority of children with chronic disease returned to their functional baseline by discharge from the ICU, but their assessment of baseline and discharge outcomes was limited to the Pediatric Performance Categories, subjective assessments that do not specifically identify technology dependence. A recent 3-year follow-up study also using the FSS observed that new morbidities continued to accrue in many critically ill children even after hospital discharge, regardless of preillness functional status, and children infrequently exhibited improvement in functional status (26). Because our study does not investigate these longer term outcomes, similar outcomes at the time of hospital discharge does not preclude disparate long-term changes in functional status between children with and without technology dependence.

## CONCLUSIONS

Children dependent on feeding and respiratory technology as defined by the FSS compose a significant proportion of

PICU admissions. Although they had a higher mortality rate, their new morbidity rates were similar to those without technology dependence, and they had similar risk factors for these outcomes as children without technology dependence. These patterns contradict our hypothesis (and challenge the conventional wisdom) that children with technology dependence would demonstrate an additional burden of new morbidities from critical illness when compared with children without baseline physiologic dysfunction. However, these comparable outcomes were achieved only with a greater expenditure of resources, including the use of more ICU therapies and longer lengths of stay. Outcomes following critical illness are related to the patient's admission physiologic instability and the need for ICU therapeutics. Notably, approximately 3% of technology-dependent patients significantly improved their functional status during PICU admission.

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## REFERENCES

1. Ralston SL, Harrison W, Wasserman J, et al: Hospital variation in health care utilization by children with medical complexity. *Pediatrics* 2015; 136:860–867
2. Simon TD, Cawthon ML, Stanford S, et al: Pediatric medical complexity algorithm: A new method to stratify children by medical complexity. *Pediatrics* 2014; 133:e1647–e1654
3. Feudtner C, Villareale NL, Morray B, et al: Technology-dependency among patients discharged from a children's hospital: A retrospective cohort study. *BMC Pediatr* 2005; 5:8
4. Dosa N, Boeing N, Kanter R: Excess risk of severe acute illness in children with chronic health conditions. *Pediatrics* 2001; 107:499–504
5. Benneyworth BD, Gebremariam A, Clark SJ, et al: Inpatient health care utilization for children dependent on long-term mechanical ventilation. *Pediatrics* 2011; 127:e1533–e1541
6. Berry JG, Graham RJ, Roberson DW, et al: Patient characteristics associated with in-hospital mortality in children following tracheotomy. *Arch Dis Child* 2010; 95:703–710
7. Russ CM, Agus M: Triage of intermediate-care patients in pediatric hospitals. *Hosp Pediatr* 2015; 5:542–547
8. Pollack MM, Holubkov R, Funai T, et al; Eunice Kennedy Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network: Simultaneous prediction of new morbidity, mortality, and survival without new morbidity from pediatric intensive care: A new paradigm for outcomes assessment. *Crit Care Med* 2015; 43:1699–1709
9. Pollack MM, Holubkov R, Funai T, et al; Eunice Kennedy Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network: Pediatric intensive care outcomes: Development of new morbidities during pediatric critical care. *Pediatr Crit Care Med* 2014; 15:821–827
10. Keele L, Meert KL, Berg RA, et al; Eunice Kennedy Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network: Limiting and withdrawing life support in the PICU: For whom are these options discussed? *Pediatr Crit Care Med* 2016; 17:110–120
11. Meert KL, Keele L, Morrison W, et al; Eunice Kennedy Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network: End-of-life practices among tertiary care PICUs in the United States: A multicenter study. *Pediatr Crit Care Med* 2015; 16:e231–e238
12. Zinter MS, Holubkov R, Steurer MA, et al: Pediatric hematopoietic cell transplant patients who survive critical illness frequently have significant but recoverable decline in functional status. *Biol Blood Marrow Transplant* 2018; 24:330–336
13. Pollack MM, Holubkov R, Funai T, et al: Relationship between the Functional Status Scale and the Pediatric Overall Performance Category and Pediatric Cerebral Performance Category scales. *JAMA Pediatr* 2014; 168:671–676
14. Pollack MM, Holubkov R, Glass P, et al; Eunice Kennedy Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network: Functional Status Scale: New pediatric outcome measure. *Pediatrics* 2009; 124:e18–e28
15. Pollack MM, Holubkov R, Funai T, et al; Eunice Kennedy Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network: The Pediatric Risk of Mortality score: Update 2015. *Pediatr Crit Care Med* 2016; 17:2–9

16. Chan T, Rodean J, Richardson T, et al: Pediatric critical care resource use by children with medical complexity. *J Pediatr* 2016; 177:197–203.e1
17. Edwards JD, Houtrow AJ, Vasilevskis EE, et al: Chronic conditions among children admitted to U.S. pediatric intensive care units: Their prevalence and impact on risk for mortality and prolonged length of stay. *Crit Care Med* 2012; 40:2196–2203
18. Marcus KL, Henderson CM, Boss RD: Chronic critical illness in infants and children: A speculative synthesis on adapting ICU care to meet the needs of long-stay patients. *Pediatr Crit Care Med* 2016; 17:743–752
19. Simon TD, Berry J, Feudtner C, et al: Children with complex chronic conditions in inpatient hospital settings in the United States. *Pediatrics* 2010; 126:647–655
20. Burns KH, Casey PH, Lyle RE, et al: Increasing prevalence of medically complex children in US hospitals. *Pediatrics* 2010; 126:638–646
21. Dominguez TE: Are we exchanging morbidity for mortality in pediatric intensive care? *Pediatr Crit Care Med* 2014; 15:898–899
22. Slonim AD, Patel KM, Ruttimann UE, et al: The impact of prematurity: A perspective of pediatric intensive care units. *Crit Care Med* 2000; 28:848–853
23. Burstein DS, Jacobs JP, Li JS, et al: Care models and associated outcomes in congenital heart surgery. *Pediatrics* 2011; 127:e1482–e1489
24. Bone MF, Feinglass JM, Goodman DM: Risk factors for acquiring functional and cognitive disabilities during admission to a PICU. *Pediatr Crit Care Med* 2014; 15:640–648
25. Typpo KV, Petersen NJ, Petersen LA, et al: Children with chronic illness return to their baseline functional status after organ dysfunction on the first day of admission in the pediatric intensive care unit. *J Pediatr* 2010; 157:108–113.e1
26. Pinto NP, Rhinesmith EW, Kim TY, et al: Long-term function after pediatric critical illness: Results from the Survivor Outcomes Study. *Pediatr Crit Care Med* 2017; 18:e122–e130
27. Fiser DH, Tilford JM, Roberson PK: Relationship of illness severity and length of stay to functional outcomes in the pediatric intensive care unit: A multi-institutional study. *Crit Care Med* 2000; 28:1173–1179