Characteristics and Outcomes of Intrahospital Transfers from Neonatal Intensive Care to Pediatric Intensive Care Units

Lauren Mazur, BS[1] Ahmed Veten, MD[2] Gary Ceneviva, MD[2] Sandeep Pradhan, MBBS, MPH[3] Junjia Zhu, PhD[3] Neal J. Thomas, MD[2,3] Conrad Krawiec, MD[2]

[1] Department of Pediatrics, Penn State College of Medicine, Hershey, Pennsylvania
[2] Department of Pediatrics, Pediatric Critical Care Medicine, Penn State Hershey Children's Hospital, Hershey, Pennsylvania
[3] Department of Public Health Sciences, Pennsylvania State University College of Medicine, Hershey, Pennsylvania

Address for correspondence Conrad Krawiec, MD, Department of Pediatrics, Penn State Health Children's Hospital, 500 University Drive, P.O. Box, 850, Hershey, PA 17033-0850 (e-mail: ckrawiec@pennstatehealth.psu.edu).

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Abstract

Objective Critically ill children may be transferred from the neonatal intensive care unit (NICU) to the pediatric intensive care unit (PICU) for further critical care, but the frequency and outcomes of this patient population are unknown. The aims of this study are to describe the characteristics and outcomes in patients transferred from NICU to PICUs. We hypothesized that a higher-than-expected mortality would be present for patients with respiratory or cardiovascular diagnoses that underwent a NICU to PICU transition and that specific factors (timing of transfer, illness severity, and critical care interventions) are associated with a higher risk of mortality in the cardiovascular group.

Study Design Retrospective analysis of Virtual Pediatric Systems, LLC (2011–2019) deidentified cardiovascular and respiratory NICU to PICU subject data. We evaluated demographics, PICU length of stay, procedures, disposition, and mortality scores. Pediatric Index of Mortality 2 (PIM2) score was utilized to determine the standardized mortality ratio (SMR).

Results SMR of 4,547 included subjects (3,607 [79.3%] cardiovascular and 940 [20.7%] respiratory) was 1.795 (95% confidence interval: 1.62–1.97, $p < 0.0001$). Multivariable logistic regression analysis demonstrated transfer age (cardiovascular: odds ratio, 1.246 [1.10–1.41], $p = 0.0005$; respiratory: 1.254 [1.07–1.47], $p = 0.0046$) and PIM2 scores (cardiovascular: 1.404 [1.25–1.58], $p < 0.0001$; respiratory: 1.353 [1.08–1.70], $p = 0.0095$) were significantly associated with increased odds of mortality.

Conclusion In this present study, we found that NICU to PICU observed deaths were high and various factors, particularly transfer age, were associated with increased odds of mortality. While the type of patients evaluated in this study likely influenced mortality, further investigation is warranted to determine if transfer timing is also a factor.

Keywords

- critical care
- outcomes
- pediatrics
- transfer

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Key Points

- NICU patients may be transitioned to the PICU.
- NICU to PICU observed deaths were high.
- Transfer timing may be a factor.

Each year, infants with prematurity, critical heart disease, and infectious diseases require hospitalization.[1] These diseases are the leading causes of neonatal morbidity and mortality that can result in short-term and long-term complications.[2–5] Due to these risks, this patient population is hospitalized in the neonatal intensive care unit (NICU) to provide mechanical and medical therapies aimed to enhance survival and improve these morbidities.

Improvements in neonatal intensive care treatments and nursing care have resulted in an increased survival rate of infants.[6,7] Depending on the severity of the disease process, however, these patients continue to be at risk for the development of long-term comorbidities. This may include tracheostomy and long-term respiratory support in severe bronchopulmonary dysplasia (BPD, a form of chronic lung disease), development of necrotizing enterocolitis, nosocomial infections, and intraventricular hemorrhage resulting in a prolonged NICU stay and increased resource utilization.[8]

Occasionally, NICU patients may be transitioned to the pediatric intensive care unit (PICU). This may occur early on for perioperative care for critical congenital heart disease or for continued support for severe BPD.[9–11] Some patients may be transferred due to limited NICU beds or if the patient is of a certain age where neonatal resuscitation is no longer applicable.[12] Despite the large body of literature analyzing NICU outcomes, it is unknown how frequently NICU to PICU transitions occur or the outcomes of this patient population. An evaluation of the patient characteristics, timing of the transition, and outcomes may enable us to understand the long-term impact of a PICU transfer in this fragile patient population.

The objective of this present study is to evaluate the patient characteristics, age of NICU to PICU transition, length of stay, type of critical care support pre- and posttransfer to the PICU, disposition, and to calculate the standardized mortality ratio (SMR) upon NICU to PICU transition. Because the PICU is equipped to manage many conditions (including chromosomal abnormalities, intestinal failure, and neurologic conditions), we focused this study to evaluate the two most common reasons for transfer to a PICU (respiratory and cardiovascular diagnoses).[13] We hypothesized that overall risk of mortality would be higher-than-expected for patients with respiratory or cardiovascular diagnoses that underwent a NICU to PICU transition and that specific factors (timing of transfer, illness severity, and critical care interventions) are associated with a higher risk of mortality in the cardiovascular group.

Materials and Methods

Data Source

We conducted a retrospective cohort study evaluating subjects identified as admissions from the NICU to PICU data using the Virtual Pediatric Systems (VPS, LLC) database (VPS, LLC, Los Angeles, CA), a prospectively collected web-based research database developed by an online pediatric critical care network formed by the Children's Hospital Association and Children's Hospital Los Angeles.[14] The VPS is a clinical database dedicated to standardized data sharing among PICUs and is used to track outcomes, measure quality, and conduct research. VPS neither endorsed nor restricted our interpretation of these data. This study was reviewed by the Institutional Review Board of Penn State College of Medicine, determined to be nonhuman subject research, and consent was waived. Data were collected and entered by trained individuals. It currently consists of prospective observational cohort clinical data of consecutive PICU admissions from 200 hospitals caring for children across the United States.

Patient Population

Using this data source, deidentified data were obtained from subjects who were identified as admissions from the NICU to PICU in the VPS database from January 1, 2011 to January 31, 2019. The initial study population included 5,852 NICU to PICU admissions from 132 hospitals and were grouped based on diagnostic category. PICU admission subjects between the ages of 0 to 12 months whose diagnosis was categorized as respiratory or cardiovascular were included in this study. The primary diagnosis was determined through a standardized fashion under VPS written guidance based on International Classification of Diseases, 9th and 10th edition coding in the electronic health record, confirmed by discharge diagnosis listed on discharge summaries, and assigned to a diagnostic category by an organ system. Because the database was deidentified and ages above 6 months were included in NICU to PICU transfers within this database, 12 months was selected as the upper limit of age in the inclusion criteria as it is possible that unit policy and clinical practices allowed for clinicians to manage NICU patients up to this age. Cardiovascular and respiratory diagnostic categories were selected as these are common reasons for transfer to a PICU.[14]

The following patients were excluded from the study: (1) patients aged greater than 12 months of age; (2) encounter triggered an age or weight error (likely due to documentation error); (3) diagnosis was not categorized as respiratory or cardiovascular; (4) encounter was reported as a trauma.

Data Collection

Demographic data (age at time of PICU transfer, gender, weight, and ethnicity) and clinical data (diagnostic category, PICU mortality, Pediatric Index of Mortality 2 [PIM2] scores, PIM2 risk of mortality, procedure codes, the start and end time of each procedure code, presence of procedure code before [pretransfer] or after PICU admission [posttransfer], and PICU physical length of stay [PLOS]) were collected. PIM2 scores are calculated based on clinical data (type of admission, presence of underlying conditions, pupillary response, blood gas values, fraction of inspired oxygen, systolic blood pressure, need for mechanical ventilation, and outcome of PICU admission) collected at the time a patient is admitted to the PICU and face-to-face contact is initiated.[15] Procedure codes described as pretransfer were considered to be attained in the NICU or the operating room. Posttransfer procedure codes were considered to be acquired in the PICU. The procedure codes were used to determine the proportion of subjects requiring noninvasive respiratory support (NIV; high-flow nasal cannula, bilevel positive airway pressure/continuous positive airway pressure), endotracheal intubation (ETI), extracorporeal life support (ECLS), presence of tracheostomy, and cardiopulmonary resuscitation (CPR). Procedure duration was not present for all subjects; thus, this was not evaluated. The outcomes used for regression analyses were PICU mortality and PLOS.

Statistical Analysis

Data were analyzed using SAS 9.4 (SAS Institute Inc., Cary, NC). Categorical data are presented as count (percent), whereas continuous variables are presented as mean (standard deviation) and median (interquartile range [IQR]). Summarization were performed on all patient records first, then stratified by disease type (cardiovascular vs. respiratory). Comparisons between disease types were made using two-sample *t*-tests or chi-square tests when appropriate. Logistic regression models were used to analysis the associations between the mortality (a binary outcome) and selected predictors. Within each disease type, the factors that could affect mortality were examined initially using univariate logistic regression models. Then a multivariate logistic regression analysis was performed where each predictor was adjusted for other selected predictors (age, sex, weight, PIM2 score, noninvasive ventilation, ETI with mechanical ventilation, ECLS, tracheostomy, and CPR). The predictors included in the multivariate regression model were either marginally significant (with a p-value ≤ 0.15) in the univariate regression analysis or selected based on existing evidence from previous literature. Odds ratios (ORs) with 95% confidence intervals (95% CI) were calculated for each parameter in the model (in both univariate and multivariate models). Upon the PICU mortality multivariate analysis of the cardiovascular group, for comparison purposes and easier interpretation, we calculated the inverse OR for the body weight covariate. Linear regression models were used to analyze the PLOS data using similar research strategy. PLOS variable was log-transformed due to skewness in its distribution, to make sure the underlying statistical assumptions were satisfied. Subjects whose PLOS was truncated due to death were included in this analysis. SMR were calculated for each group based on the probability of death predicted by PIM2 as coded in VPS (SMR; the ratio of observed to predicted death by PIM2 risk of mortality). SMR greater than 1 was considered to be greater than expected, SMR of 1 was considered expected, and SMR was considered less than expected. All tests are two-sided and a p-value of 0.05 or less was considered statistically significant.

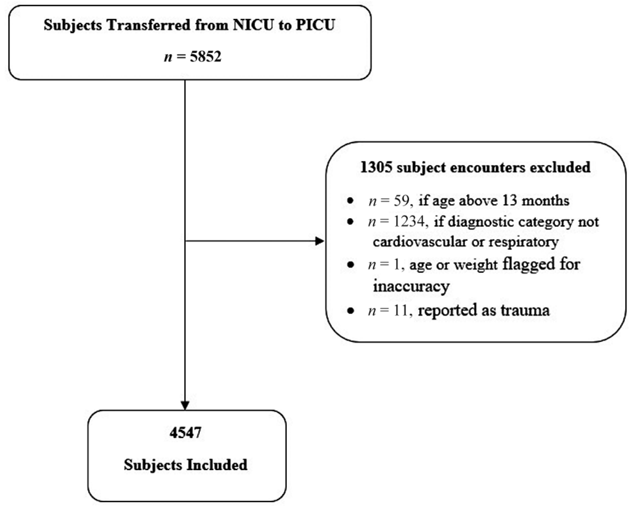

Fig. 1 Inclusion and exclusion criteria of cardiovascular and respiratory subjects transferred from the neonatal intensive care unit (NICU) to the pediatric intensive care unit (PICU).

Results

Overview

A total of 4,547 patient encounters were included in the study (►Fig. 1).

Subject Demographics

The cardiovascular and respiratory group consisted of 3,607 (79.3%) and 940 (20.7%) subjects, respectively. Both the mean age (3.9 ± 2.99 mo) and the median PLOS (20.8 ± 46.8 d) were higher in the respiratory group. Between the cardiac and respiratory group, there was no significant difference in mortality rate (9.2 vs. 8.7%, $p = 0.6279$). Subject demographics are summarized in ►Table 1. Specific diagnostic codes were summarized in ►Supplementary Tables S1 and S2 (available in the online version).

Critical Care Support

Respiratory subjects had a significantly higher proportion of tracheostomies present pretransfer (405 [43.1%] vs. 64 [1.8%], $p < 0.0001$) and tracheostomies-acquired posttransfer to the PICU (81 [8.6%] vs. 90 [2.5%], $p < 0.0001$) compared with cardiac subjects. ECLS was present pretransfer more often in respiratory subjects (22 [2.3%] vs. 26 [0.7%], $p < 0.0001$), whereas it was acquired posttransfer more often in cardiac subjects (360 [10.0%] vs. 63 [6.7%], $p < 0.0001$).

There was no difference in CPR requirements between the two groups (7.7 vs. 6.5%, $p = 0.1960$). More cardiovascular subjects acquired ETI (2,156 [59.9%] vs. 61 [6.5%], $p < 0.0001$) and NIV (1,290 [35.8%] vs. 78 [8.3%], $p < 0.0001$) posttransfer compared with respiratory subjects (►Table 2).

Pediatric Intensive Care Unit Mortality

The overall study population showed an elevated risk of mortality upon transfer to the PICU, with a SMR as

Table 1 Patient demographics by disease (cardiovascular vs. respiratory)

	Total ($N = 4,547$)	Cardiovascular ($N = 3,607$)	Respiratory ($N = 940$)	*p*-Value
Age (mo)				<0.0001[a]
Mean (SD)	1.1 (2.29)	0.4 (1.33)	3.9 (2.99)	
Gender, *n* (%)				0.0434[b]
Male	2,651 (58.3%)	2,076 (57.6%)	575 (61.2%)	
Female	1,893 (41.7%)	1,529 (42.4%)	364 (38.8%)	
Race, *n* (%)				<0.0001[b]
White	2,023 (52.6%)	1,680 (55.6%)	343 (41.4%)	
Black or African American	692 (18.0%)	473 (15.7%)	219 (26.4%)	
Hispanic or Latino	433 (11.2%)	321 (10.6%)	112 (13.5%)	
Asian/Native/Pacific Islander	193 (5.0%)	146 (4.8%)	47 (5.7%)	
Others	508 (13.2%)	400 (13.2%)	108 (13.0%)	
PIM2 score				0.0026[a]
Mean (SD)	−3.8 (1.33)	−3.7 (1.35)	−3.9 (1.25)	
Median (IQR)	−4.0 (1.8)	−4.0 (2.1)	−4.1 (1.3)	
PLOS (d)				<0.0001[a]
Mean (SD	32.7 (53.20)	28.9 (44.40)	47.3 (76.56)	
Median (IQR)	14.9 (27.8)	14.0 (23.6)	20.8 (46.8)	
Outcome, *n* (%)				0.6279[b]
Died	415 (9.1%)	333 (9.2%)	82 (8.7%)	
Survived	4,131 (90.9%)	3,273 (90.8%)	858 (91.3%)	
Disposition, *n* (%)				<0.0001[b]
Dedicated technology dependent unit (transitional/progressive care unit)	92 (2.0%)	15 (0.4%)	77 (8.2%)	
Home	1,042 (22.9%)	853 (23.6%)	189 (20.1%)	
NICU (in this hospital)	638 (14.0%)	517 (14.3%)	121 (12.9%)	
Other	2,712 (59.6%)	2,194 (60.8%)	518 (55.1%)	
Transitional care/skilled nursing facility/chronic care facility	63 (1.4%)	28 (0.8%)	35 (3.7%)	

Abbreviations: IQR, interquartile range; NICU, neonatal intensive care unit; SD, standard deviation.
[a]Two-sample *t*-test *p*-value.
[b]Chi-square test *p*-value.

predicted by PIM2 score of 1.795 (95% CI: 1.62–1.97, $p < 0.0001$; ►**Table 3**).

Upon the multivariate analysis of the cardiovascular group, higher age (OR: 1.246 [95% CI: 1.10–1.41], $p = 0.0005$), lower weight (1.367 [1.15–1.63], $p = 0.0004$), higher PIM2 scores (1.404 [1.25–1.58], $p < 0.0001$), ECLS present pretransfer (3.448 [1.32–9.02], $p = 0.0116$), ECLS-acquired posttransfer (10.222 [7.47–13.98], $p < 0.0001$), ETI present pretransfer (2.107 [1.08–4.10], $p = 0.0284$), need for tracheostomy posttransfer (2.235 [1.26–4.30], $p = 0.0071$), and need for CPR (5.519 [3.87–7.88], $p < 0.0001$) were all significantly associated with increased OR of PICU mortality. NIV posttransfer (0.193 [0.13–0.28], $p < 0.0001$) was significantly associated with reduced OR of PICU mortality (►**Table 4**).

In the respiratory group, upon multivariable analysis, age (1.254 [1.07–1.47], $p = 0.0046$), PIM2 scores (1.353 [1.08–1.70], $p = 0.0095$), ETI pretransfer (8.897 [2.58–30.71], $p = 0.0005$), ETI posttransfer (11.195 [3.14–39.93], $p = 0.0002$), need for CPR (2.613 [1.22–5.59], $p = 0.0134$) were associated with increased mortality for respiratory patients. Tracheostomy present upon transfer did not influence mortality (1.235 [0.37–4.08], $p = 0.7292$), but patients who had a tracheostomy-placed posttransfer had significantly reduced OR of PICU mortality (OR: 0.215 [95% CI: 0.07–0.65], $p = 0.0062$). NIV-acquired posttransfer was associated with significant reduced mortality odd ratio (OR: 0.218 [0.06–0.80], $p = 0.0222$).

Physical Length of Stay

Median PLOS in the PICU was higher in the respiratory group (median [IQR] 20.8 [46.8] d) when compared with the cardiovascular group (median [IQR] 14.0 [23.6] d, $p < 0.0001$).

Table 2 Critical care support on pediatric intensive care unit admission and acquired during pediatric intensive care unit hospitalization

	Total	Cardiovascular	Respiratory	*p*-Value
Number of subjects	4,547	3,607	940	
Tracheostomy, *n* (%)				<0.0001[a]
No tracheostomy	3,907 (85.9%)	3,453 (95.7%)	454 (48.3%)	
Tracheostomy pretransfer	469 (10.3%)	64 (1.8%)	405 (43.1%)	
Tracheostomy posttransfer	171 (3.8%)	90 (2.5%)	81 (8.6%)	
Extracorporeal life support, *n* (%)				<0.0001[a]
No extracorporeal life support	4,071 (89.6%)	3,218 (89.3%)	853 (90.9%)	
Extracorporeal life support pretransfer	48 (1.1%)	26 (0.7%)	22 (2.3%)	
Extracorporeal life support posttransfer	423 (9.3%)	360 (10.0%)	63 (6.7%)	
Cardiopulmonary resuscitation, *n* (%)				0.1960[a]
Cardiopulmonary resuscitation	340 (7.5%)	279 (7.7%)	61 (6.5%)	
No cardiopulmonary resuscitation	4,207 (92.5%)	3,328 (92.3%)	879 (93.5%)	
Endotracheal intubation, *n* (%)				<0.0001[a]
Endotracheal intubation pretransfer	1,182 (26.1%)	942 (26.2%)	240 (25.6%)	
Endotracheal intubation posttransfer	2,217 (48.9%)	2,156 (59.9%)	61 (6.5%)	
No endotracheal intubation	1,138 (25.1%)	500 (13.9%)	638 (67.9%)	
Noninvasive ventilation, *n* (%)				<0.0001[a]
Noninvasive ventilation pretransfer	590 (13.0%)	458 (12.7%)	132 (14.1%)	
Noninvasive ventilation posttransfer	1,368 (30.1%)	1,290 (35.8%)	78 (8.3%)	
No noninvasive ventilation	2,587 (56.9%)	1,858 (51.5%)	729 (77.6%)	

[a]Chi-square test *p*-value.

Table 3 Standardized mortality ratio

	Total number of observations	Number of deaths	Observed probability of death	Expected probability of death	SMR	95% CI
Overall cohort	4,547	415	0.091269	0.050842	1.7951	1.62–1.97
Cardiovascular	3,607	333	0.092320	0.053103	1.7385	1.5518–1.92
Respiratory	940	82	0.087234	0.042169	2.0687	1.6209–2.5164

Abbreviations: CI, confidence interval; SMR, standardized mortality ratio.

In the respiratory group, the age at transfer, weight, PIM2 scores, ETI posttransfer, tracheostomy pre- and posttransfer, and CPR during the PICU stay were associated with a prolonged PLOS in the univariate analysis. Female sex, ECLS pretransfer, ECLS posttransfer, and NIV pretransfer was associated with a shortened PLOS. Upon multivariate analysis, the findings were consistent, with the exception that ECLS posttransfer was no longer significantly associated with a shortened PLOS and weight was significantly associated with a shortened PLOS.

In the cardiovascular group age, PIM2, ECLS-acquired posttransfer, ETI pre- and posttransfer, noninvasive ventilation pre- and posttransfer, tracheostomy pre- and posttransfer, and CPR were associated with prolonged PLOS in the univariate analysis. The findings were consistent in the multivariate analysis, with the exception of age (►**Table 5**).

Discussion

In this present study, we aimed to evaluate the clinical characteristics and outcomes of NICU to PICU transfers. Our main findings were that even while controlling for severity of illness, observed deaths were high than expected. In addition, mortality was associated with age and both the type and timing of critical care support provided. Overall PLOS was higher among respiratory patients. These findings may have significant implications in planning for these transfers in the future and understanding the outcomes of future NICU to PICU transfers.

Recent technologic advancements in NICU clinical management have improved survival. This patient population, however, continues to have significant comorbidities that require intensive care. These can include recovery from

Table 4 Univariate and multivariate analysis of clinical characteristics and its association with mortality

	Univariate analysis				Multivariate analysis			
	Cardiovascular		Respiratory		Cardiovascular		Respiratory	
	Odds ratio (95% CI)	*p*-Value	Odds ratio (95% CI)	*p*-Value	Odds ratio (95% CI)	*p*-Value	Odds ratio (95% CI)	*p*-Value
Age (mo)	1.062 (0.99–1.14)	0.1094	0.932 (0.86–1.01)	0.0810	1.246 (1.10–1.41)	0.0005[a]	1.254 (1.07–1.47)	0.0046[a]
Sex								
Female	1.150 (0.90–1.48)	0.2726	1.361 (0.82–2.25)	0.2302	0.882 (0.67–1.16)	0.3744	1.176 (0.70–1.98)	0.5396
Male	Reference		Reference		Reference		Reference	
Race								
Asian/Native/Pacific Islander	1.662 (1.00–2.77)	0.0521	0.440 (0.10–1.90)	0.2719	–		–	–
Black or African American	1.319 (0.94–1.86)	0.1112	0.767 (0.41–1.43)	0.4068	–		–	–
Hispanic or Latino	0.945 (0.61–1.47)	0.8014	0.554 (0.23–1.36)	0.1976	–		–	–
Others	1.349 (0.94–1.94)	0.1041	1.099 (0.53–2.26)	0.7985	–		–	–
White	Reference		Reference					
Weight (kg)	0.900 (0.79–1.03)	0.1189	0.820 (0.71–0.95)	0.0070[a]	0.731 (0.62–0.87)	0.0004[a]	0.822 (0.64–1.05)	0.1178
Pediatric Index of Mortality (PIM) 2 score	1.628 (1.51–1.76)	<0.0001[a]	1.836 (1.54–2.19)	<0.001[a]	1.404 (1.25–1.58)	<0.0001[a]	1.353 (1.08–1.70)	0.0095[a]
Extracorporeal life support (ECLS)								
Pretransfer	9.011 (3.64–22.30)	<0.0001[a]	11.495 (4.61–28.68)	<0.001[a]	3.448 (1.32–9.02)	0.0116[a]	2.675 (0.92–7.79)	0.0712
Posttransfer	18.654 (13.98–24.90)	<0.0001[a]	4.486 (2.21–9.12)	<0.001[a]	10.222 (7.47–13.98)	<0.0001[a]	1.332 (0.56–3.15)	0.5138
No ECLS	Reference		Reference		Reference		Reference	
Endotracheal intubation								
Pretransfer	3.773 (2.23–6.38)	<0.0001[a]	5.021 (2.91–8.66)	<0.001[a]	2.107 (1.08–4.10)	0.0284[a]	8.897 (2.58–30.71)	0.0005[a]
Posttransfer	1.883 (1.13–3.15)	<0.0160[a]	3.558 (1.45–8.71)	0.0054[a]	1.827 (0.98–3.41)	0.0585	11.195 (3.14–39.93)	0.0002[a]
No endotracheal intubation	Reference		Reference		Reference		Reference	
Noninvasive ventilation								
Pretransfer	0.645 (0.43–0.96)	0.0308[a]	0.439 (0.17–1.12)	0.0843	0.658 (0.42–1.03)	0.0695	0.820 (0.24–2.80)	0.7509
Posttransfer	0.331 (0.24–0.46)	<0.0001[a]	0.447 (0.14–1.47)	0.1837	0.193 (0.13–0.28)	<0.0001[a]	0.218 (0.06–0.80)	0.0222[a]
No noninvasive ventilation	Reference		Reference		Reference		Reference	
Tracheostomy								
Pretransfer	1.674 (0.75–3.75)	0.8105	0.452 (0.26–0.79)	0.0953	2.080 (0.59–7.33)	0.2546	1.235 (0.37–4.08)	0.7292
Posttransfer	3.443 (1.99–5.95)	0.0041[a]	0.629 (0.24–1.65)	0.8899	2.325 (1.26–4.30)	0.0071[a]	0.215 (0.07–0.65)	0.0062[a]
No tracheostomy	Reference		Reference		Reference		Reference	
Cardiopulmonary resuscitation (CPR)								
CPR	10.983 (8.10–14.89)	<0.0001[a]	3.719 (1.85–7.47)	0.0002[a]	5.519 (3.87–7.88)	<0.0001[a]	2.613 (1.22–5.59)	0.0134[a]
No CPR	Reference		Reference		Reference		Reference	

Abbreviation: CI, confidence interval.
[a] $p < 0.05$

Table 5 Univariate and multivariate linear regression model of clinical characteristics and its association with physical length of stay

	Cardiovascular		Respiratory		Cardiovascular		Respiratory	
	(Log-transformed) PLOS estimate (95% CI)	*p*-Value	(Log-transformed) PLOS estimate (95% CI)	*p*-Value	(Log-transformed) PLOS estimate (95% CI)	*p*-Value	(Log-transformed) PLOS estimate (95% CI)	*p*-Value
Age (mo)	0.049 (0.02–0.07)	0.0006[a]	0.183 (0.15–0.21)	<0.0001[a]	0.02 (−0.01 to 0.05)	0.1826	0.14 (0.09–0.18)	<0.0001[a]
Sex								
Female	0.012 (−0.07 to 0.09)	0.7695	−0.241 (−0.45 to −0.04)	0.0200[a]	0.04 (−0.02 to 0.11)	0.1592	−0.20 (−0.35 to −0.06)	0.0067[a]
Male	Reference		Reference		Reference		Reference	
Race					–			
Asian/Native/Pacific Islander	0.127 (−0.06 to 0.32)	0.1947	−0.105 (−0.55 to 0.34)	0.6492	–			
Black or African American	0.076 (−0.04 to 0.19)	0.1952	0.038 (−0.21 to 0.28)	0.7558	–			
Hispanic or Latino	0.031 (−0.10 to 0.16)	0.6500	−0.480 (−0.79 to −0.17)	0.0024[a]	–			
Others	−0.015 (−0.14 to 0.11)	0.8051	0.022 (−0.29 to 0.34)	0.8871	–			
White	Reference		Reference					
Weight (kg)	0.036 (−0.00 to 0.08)	0.0771	0.177 (0.13 to 0.23)	<0.0001[a]	0.01 (−0.03 to 0.05)	0.6021	−0.08 (−0.14 to 0.02)	0.0123[a]
Pediatric Index of Mortality (PIM) 2 score	0.152 (0.12–0.18)	<0.0001[a]	0.172 (0.10–0.24)	<0.0001[a]	0.14 (0.11–0.17)	<0.0001[a]	0.12 (0.05–0.19)	0.0012[a]
Extracorporeal life support (ECLS)								
Pretransfer	−0.275 (−0.72 to 0.17)	0.2320	−1.009 (−1.63 to −0.38)	0.0016[a]	−0.19 (−0.57 to 0.19)	0.3236	−0.68 (−1.20 to 0.17)	0.0093[a]
Posttransfer	0.959 (0.82–1.09)	<0.0001[a]	−0.434 (−0.84 to −0.03)	0.0341[a]	0.58 (0.47–0.69)	<0.0001[a]	−0.09 (−0.45 to 0.26)	0.6060
No ECLS	Reference		Reference		Reference		Reference	
Endotracheal intubation								
Pretransfer	1.012 (0.88–1.14)	<0.0001[a]	−0.167 (−0.40 to 0.06)	0.1566	0.59 (0.47–0.71)	<0.0001[a]	0.23 (−0.05 to 0.51)	0.1088
Posttransfer	1.100 (0.98–1.22)	<0.0001[a]	0.580 (0.177–0.99)	0.0056[a]	0.98 (0.88–1.08)	<0.0001[a]	1.22 (0.89–1.54)	<0.0001[a]
No endotracheal intubation	Reference		Reference		Reference		Reference	
Noninvasive ventilation								
Pretransfer	0.383 (0.26–0.51)	<0.0001[a]	−1.003 (−1.30 to −0.73)	<0.0001[a]	0.30 (0.20–0.40)	<0.0001[a]	−0.40 (−0.67 to −0.13)	0.0032[a]
Posttransfer	0.822 (0.74–0.91)	<0.0001[a]	−0.227 (−0.58 to 0.12)	0.2023	0.70 (0.63–0.77)	<0.0001[a]	0.24 (−0.04 to 0.53)	0.0950
No noninvasive ventilation	Reference		Reference		Reference		Reference	
Tracheostomy								
Pretransfer	0.792 (0.49–1.09)	<0.0001[a]	1.332 (1.16–1.51)	<0.0001[a]	1.70 (1.38–2.02)	<0.0001[a]	1.01 (0.78–1.25)	<0.0001[a]
Posttransfer	1.979 (1.73–2.23)	<0.0001[a]	2.186 (1.87–2.50)	<0.0001[a]	1.73 (1.53–1.93)	<0.0001[a]	1.57 (1.28–1.86)	<0.0001[a]
No tracheostomy	Reference		Reference		Reference		Reference	
Cardiopulmonary resuscitation (CPR)								
CPR	0.963 (0.81–1.11)	<0.0001[a]	1.442 (1.05–1.83)	<0.0001[a]	0.31 (0.19–0.43)	<0.0001[a]	0.85 (0.54–1.15)	<0.0001[a]
No CPR	Reference		Reference		Reference		Reference	

Abbreviations: CI, confidence interval; PLOS, physical length of stay.
[a]$p < 0.05$

surgical procedures such as a tracheostomy, the need for long-term respiratory support, and time for growth.[16] Some of these circumstances may require prolonged critical care that can result in some patients "aging" out of the NICU and being transferred to another unit. This can also be due to a lack of resources, expertise or credentialing, and space in the NICU.[17] When this occurs, patients are often transferred to the PICU, where patients can receive more appropriate care for their age. Even though these transfers are known to occur, data describing the outcomes of transfers from the NICU to the PICU are lacking. Due to the high vulnerability of this patient population, as well as the potential strain on PICU resources, it is important to understand the characteristics of these transfers to determine if the most optimal care is being provided.

In our study, we sought to determine whether patients transferred to the PICU from the NICU were at increased risk of mortality. Adult studies have demonstrated that transfers from other ICUs are associated with higher odds of mortality compared with transfers from other units (i.e., wards, emergency department, and the operating room).[18–20] Pediatric studies (particularly PICU to PICU transfers), however, have demonstrated that despite longer mean length of stays and duration of mechanical ventilation, there was no observed increase in mortality, independent of diagnosis.[21,22] In our study, we found that even after controlling for severity of illness, NICU patients are at higher risk for mortality in the PICU posttransfer. The observed number of deaths within our study cohort was higher than expected and presents new findings compared with previously published pediatric data.[21,22] These findings could be due to an increased severity of disease experienced by this patient population compared with PICU admissions from other sources. Additionally, time spent in the NICU increases patient susceptibility to iatrogenic complications and nosocomial infections, putting patients at a potentially higher mortality risk than those admitted to the PICU from other settings.[23,24] PIM2 score is one the most commonly used mortality prediction models in PICUs.[25] It compiles various physiologic and laboratory variables upon arrival at the PICU up to 1 hour after arrival, can determine the risk of mortality, and is used in PICU settings as a metric to determine areas where patient care can be improved.[25] Of note, the PIM2 and other pediatric scoring systems do not include the duration of care received before admission to the PICU as a metric, which could explain the unexpected increase in mortality seen in our study.[26] This phenomenon, called lead-time bias, is a known risk factor for mortality among adult critically ill patients who have been treated for extended periods of time on the floor before being admitted to the intensive care unit.[27] In our study population, it is possible that interventions performed in the NICU before transfer may alter physiologic variables used in the PIM2 scoring system (e.g., fluid resuscitation and sodium bicarb administration prior to transfer could elevate the systolic blood pressure and the base excess), limiting its ability to accurately predict mortality in this population. Future scoring systems should account for the NICU to PICU transfer factor, as the increased mortality in the transferred patients could negatively impact performance metrics at tertiary and quaternary centers that serve as receiving hospitals for transferred patients.

In both cardiac and respiratory patients, we found that older age upon transfer was associated with higher mortality. There are several reasons for these findings. Acutely ill neonatal patients may require a long period of time to attain stabilization and even so, this may not be completely achieved. Patients in this state who may be transferred to the PICU (with different nursing, training, and expertise) may be at higher risk of death due to potentially different nursing care, physician expertise, and a delay in providing definitive care during the evaluation period. NICU patients may have complex conditions that often require a longer period of care due to the presence of comorbidities. A longer length of stay in the NICU secondary to delayed discharge may occur if complications related to hospital-acquired infections develop. Another potential explanation for our findings is that some patients may have needed to be transferred out of the NICU to prepare beds and resources for new NICU admissions. Older patients who are eligible for transfer to the PICU could be transferred in haste without ample time for preparation if inadequate resources are available, potentially affecting the care of the child. NICU and PICU need to establish triage strategies in advance to communicate when these transfers may need to happen as units fill, so that transfer of care can be planned appropriately. Additionally, NICU and PICU staff should work together to educate both units on the clinical issues unique to their unit and focus on a multidisciplinary approach to understanding the wider breadth of cases seen by both units.[27] This would facilitate safer transfers when they must occur quickly under the pressure of limited resources. Nevertheless, because older age is associated with worse outcomes, further research may be necessary to determine whether early transfer to the PICU should be considered for particular types of aging NICU subjects.

In this analysis, it was observed that certain procedures, when initiated at specific times in relation to transfer from the NICU to the PICU, were associated with mortality and PLOS. Our data showed that a significant number of respiratory patients arrived at the PICU with a tracheostomy, and this was not associated with mortality. Tracheostomy care is complex and is associated with significant long-term morbidity and potential physical complications.[28] Specialized coordinated care is necessary to prevent bleeding, air trapping in the mediastinum, esophageal damage, and blockage of the tube by blood, mucus, or pressure, infection, or accidental decannulation.[28] Despite this risk, the lack of association with mortality for these patients may show the benefit of tracheostomy as an early intervention for respiratory patients. The relationship between tracheostomy and mortality for cardiovascular patients is less clear but may be an associated with survival when performed during the PICU stay after cardiac stabilization, as our multivariable analysis showed significantly lower mortality for patients who had a tracheostomy-placed posttransfer to the PICU. Therefore, if no contraindications are present for a cardiac patient, such as mediastinitis risk, tracheostomy placement should be considered early for patients in this group who require prolonged mechanical ventilation to improve the chances of survival.[28]

In cardiac patients, ECLS initiation was associated with higher mortality both pre- and posttransfer and was associated with longer PLOS in patients when acquired after transfer to the PICU. Subjects who require ECLS may be more ill than other patients, contributing to their increased risk of mortality, regardless of time of intervention. However, longer PLOS for these patients can be associated with the potential to develop nosocomial infections contributing to worse outcomes, regardless of disease severity. Longer PLOS was only associated with ECLS initiation in cardiac patients when initiation occurred after transfer to the PICU. Future studies should be considered to evaluate if there is any benefit to initiating ECLS in these patients prior to transfer to the PICU.

The PLOS was longer for respiratory patients compared with cardiovascular patients, despite cardiac patients having a higher severity of illness. It remained high for this group despite evidence of early respiratory intervention in the PICU. There are a variety of potential causes for the observed prolonged PLOS for respiratory patients. It could be attributed to the higher incidence of tracheostomy among those patients, or that noninvasive ventilation was present more often upon admission in respiratory patients versus cardiovascular patients. It is possible that NIV is not assisting in recovery of these patients and perhaps a more aggressive (possibly sooner) respiratory intervention is necessary for these patients prior to transfer. However, it is also important to consider the goals for care for these patients and families, and the impact more aggressive respiratory interventions such as tracheostomy can have on quality of life. Understanding what interventions contribute to longer length of stay in these patients is important, as this could have a large impact on PICU resources. More research is necessary to fully understand these implications, particularly in how interventions in the NICU impact the trajectory of care for patients in the PICU.

Limitations

This study has several limitations. First, we were limited to the clinical data available within the VPS database. Due to the retrospective, multi-institutional nature of this study, typical NICU and PICU practices (including how interunit communication) and policies were unable to be assessed. The circumstances of the transfer (i.e., clinical vs. bed space), birthweight, gestational age, the exact timing of interventions (particularly tracheostomy), the cause of the death, and if the subject underwent withdrawal of care was unable to be determined. Because the hospital data were also deidentified, the NICU care level was unknown.

Conclusion

In our study, the observed deaths from NICU to PICU transfers were high. Transfer age, illness severity, and critical care interventions may place patients at higher risk for mortality. While the type of patients evaluated in this study likely influenced mortality, these data suggest that the timing and type of care for children with certain conditions who are transferred to the PICU from the NICU can also potentially be a modifiable factor that can result in more favorable outcomes. Further research is needed to determine if the care of patients transferred from the NICU to the PICU can be optimized

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Conflict of Interest
None declared.

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