

Brief Report

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The 2022–2023 Pediatric Respiratory Illness Surge: Survey of Acute and Critical Care Resource Use

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Abstract

Objective: A surge of pediatric respiratory illnesses beset the United States in late 2022 and early 2023. This study evaluated within-surge hospital acute and critical care resource availability and utilization. The study aimed to determine pediatric hospital acute and critical care resource use during a respiratory illness surge.

Methods: Between January and February 2023, an online survey was sent to the sections of hospital medicine and critical care of the American Academy of Pediatrics, community discussion forums of the Children's Hospital Association, and PedSCCM—a pediatric critical care website. Data were summarized with median values and interquartile range.

Results: Across 35 hospitals with pediatric intensive care units (PICU), increase in critical care resource use was significant. In the month preceding the survey, 26 (74%) hospitals diverted patients away from their emergency department (ED) to other hospitals, with 46% diverting 1–5 patients, 23% diverting 6–10 patients, and 31% diverting more than 10 patients. One in 5 hospitals reported moving patients on mechanical ventilation from the PICU to other settings, including the ED (n = 2), intermediate care unit (n = 2), cardiac ICU (n = 1), ward converted to an ICU (n = 1), and a ward (n = 1). Utilization of human critical care resources was high, with PICU faculty, nurses, and respiratory therapists working at 100% capacity.

Conclusions: The respiratory illness surge triggered significant hospital resource use and diversion of patients away from hospitals. Pediatric public health emergency-preparedness should innovate around resource capacity.

Beginning in fall of 2022, a surge in pediatric hospitalizations for viral respiratory illness in the United States led to significant consumption of hospital resources. Unlike prior years, the respiratory illness season started 2 months earlier, in September, heralded by a rise in the incidence of infection with respiratory syncytial virus (RSV).¹ This early uptick in RSV infections, coupled with projected coalescence with infections caused by influenza and severe acute respiratory syndrome coronavirus 2, raised concern for overwhelming consumption of pediatric hospital resources over the ensuing months.

While a shortage of pediatric hospital beds across the country during the 2022–2023 respiratory season has been reported,^{2,3} utilization of acute and critical care resources is unknown. Knowledge of critical care resource capacity is paramount at times of critical illness surges, and prior inventories of critical care have been reported.^{4–6} However, to be used for planning during a public health emergency such as that experienced in late 2022, contemporaneous data on the capacity of acute and critical care resources are needed.

The current study was a rapid turnaround inventory of human and material acute and critical care resource availability and utilization at a sample of US pediatric hospitals during the viral respiratory illness surge from fall 2022 through winter 2023.

Methods

A cross-sectional study was conducted of physicians in pediatric acute and critical care medicine, and senior hospital administrators, to ascertain resource utilization during the ongoing patient surge. Participants were recruited as a convenience sample by invitations posted to electronic listservs maintained by the American Academy of Pediatrics (AAP) sections of critical care and hospital medicine, 2 Children's Hospital Association (CHA) community discussion forums, and to the [PedSCCM.org](https://www.pedsccm.org) website.

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Participants

Eligible study participants were physicians in acute and critical care medicine, and senior hospital administrators, who were:

- Members of the AAP sections of critical care and hospital medicine.
- Members of 2 community discussion forums within CHA: the *quality and patient safety* and *capacity management* communities. These are predominantly senior hospital administrators, physicians, and nurses with critical roles in hospital disaster preparedness, quality of care, capacity management, and patient safety.
- Pediatric intensive care unit (PICU) clinicians with access to [PedSCCM.org](https://www.pedsccm.org), a pediatric critical care website.

Study participation was voluntary and uncompensated, and respondents from hospitals without PICUs were excluded. The study was deemed not regulated (HUM00228469) by the institutional review board of the study institution. To mitigate recall bias and enhance data veracity, respondents had the option to save their responses, verify reported data, and return to the survey repeatedly until final submission.

Survey Design and Administration

A cross-sectional survey was conducted of the resource capacity at hospitals that employed the study participants. The survey instrument was a 1-page document to inventory key hospital acute and critical care human and material resources (see [Appendix](#)). Invitations to participate were sent in 3 weekly waves between January 5, 2023, and February 10, 2023, to electronic listservs maintained by the AAP sections of critical care and hospital medicine, respectively. Two messages were sent to 2 CHA community discussion forums and

1 posting was made to the [PedSCCM.org](https://www.pedsccm.org) website. The survey was fielded to capture the real-time dynamics of patient flow, resource capacity, and the extent of resource redeployment and redistribution that occurred during a surge in the incidence of respiratory viral illness.

Data Management and Analysis

Data were collected and managed using REDCap (Research Electronic Data Capture) tools hosted at the study institution.⁷ All analyses were conducted using Stata 17 for Windows (Stata Corp, College Station, TX, USA). The unit of analysis for the study was the hospital. This approach was taken given that the denominator population of hospitals with membership in the organizations that served as sources of data for the study was unknown. Respondents indicated the name of their hospital and the associated zip code on the submitted survey instrument. This information was used to ensure only 1 respondent was counted per hospital. Descriptive analyses characterized responses regarding the distribution of acute and critical care resources with summary data presented as median values and interquartile range (25th, 75th percentiles). Resource utilization, expressed as a percentage, was calculated as the ratio of the *count of resources currently in use* to the *count of resources available at baseline before the surge*. For technology not available at all hospitals, counts included only hospitals with the specific technology.

Results

Hospital Characteristics

Thirty-five hospitals with a PICU were included in the analysis. The hospitals were from all 4 major census regions: Northeast (6),

Table 1. Utilization of pediatric hospital acute and critical care resources at the time of the survey

Resources	Count at baseline (before the surge) Median (25th,75th percentiles)	Count of current use (during the surge) Median (25th,75th percentiles)	Percent utilization Median (25th,75th percentiles)
PICU human resources			
Faculty	5 (3, 12)	5 (3, 10)	100 (100, 100)
Nurses	20 (10, 50)	12 (6, 42)	100 (25, 100)
Respiratory therapists	6 (4, 20)	4 (2, 20)	100 (50, 100)
Pediatric hospital technology			
ECMO machines (n = 13)	3 (3, 5)	1 (1, 3)	33 (10, 60)
CRRT/hemodialysis machines (n = 18)	3 (2, 5)	1 (0, 1)	6 (0, 50)
Full-feature PICU ventilators	14 (6, 37)	3 (1, 10)	18 (0, 40)
High flow nasal cannula machines	20 (10, 28)	5 (3, 10)	33 (17, 50)
Non-invasive ventilators	9 (5, 20)	2 (0, 5)	18 (0, 50)
Pediatric hospital beds			Bed occupancy
Total hospital beds	119 (36, 271)	109 (20, 200)	74 (50, 85)
PICU beds	11 (6, 22)	10 (4, 18)	69 (50, 100)
Emergency department beds (n = 28)	25 (13, 40)	21 (10, 35)	86 (57, 100)
CICU beds (n = 10)	12 (11, 20)	12 (12, 14)	93 (67, 109)
Intermediate/step-down care unit beds	6 (4, 22)	2 (1, 18)	61 (17, 91)
General care ward beds	26 (18, 78)	24 (15, 63)	75 (52, 89)

Percent utilization is the ratio of the count of resources currently in use to the count of resources available at baseline before the surge; CICU, cardiac intensive care unit; CRRT, continuous renalreplacement therapy; ECMO, extracorporeal membrane oxygenation; PICU, pediatric intensive care unit.

Midwest (8), South (12), and West (9). Among the 35 hospitals, 25 (71%) were not freestanding children's hospitals, and 28 (80%) had a designated pediatric emergency department (ED). The ED staffing pool comprised a median of 10 (IQR: 5, 19) faculty physicians and 39 (14, 56) nurses. The PICU staffing pool included a median of 5 (3, 12) attending faculty physicians, and 20 (10, 50) nurses who provided a nurse-to-patient ratio of 1:2 (86%), 1:1 (9%), or 1:3 (6%).

Resource Use During the Surge

In the month preceding the survey, 26 (74%) hospitals diverted patients away from their ED to other hospitals, with 46% diverting 1-5 patients, 23% diverting 6-10 patients, and 31% diverting more than 10 patients. During that same month, respondents from 7 (20%) hospitals reported moving some mechanically ventilated patients from the PICU to other care settings, including the ED (2), intermediate care unit (2), cardiac ICU (1), ward space converted to an ICU (1), and a ward (1).

The utilization of human critical care resources was high, with PICU physicians, nurses, and respiratory therapists working at 100% capacity (Table 1). Hospital beds were in high use across all care settings, with cardiac intensive care unit (CICU) beds exceeding 100% use at 25% of 10 respondent hospitals that had a CICU (see Table 1) and full (100%) utilization of beds in the PICU and the ED at 1 of 4 respondent hospitals (see Table 1). Hospital technology, such as ventilators and dialysis machines, remained available at all institutions.

Discussion

This study provides data on the availability and utilization of acute and critical care resources at a geographically widespread sample of US pediatric hospitals during the recent viral respiratory illness surge. The findings highlight high utilization of human critical care resources and pediatric hospital beds, and variability in the utilization of pediatric hospital technology. Given that hospitals with PICUs have been associated with beneficial outcomes for critically ill children,^{8,9} real-time information about acute and critical care resource capacity at these hospitals is important during periods of surges in demand for resources to ensure optimal health care delivery to critically ill children.

With US pediatric hospitals just emerging from the multi-year coronavirus disease (COVID-19) pandemic that impacted human and material hospital resource use for an extended period, the recent widespread surge in pediatric respiratory viral illness across the United States raised concern for an overwhelming impact on pediatric hospital resource use. The surge was unexpected both in terms of its early occurrence and the high volume of hospitalizations. Many hospitals were taken by surprise, prompting leaders at the AAP and CHA to ask for federal declaration of a public health emergency.¹⁰

Respondent hospitals reported that physicians, nurses, and respiratory therapists were working at 100% capacity, raising the specter of overwork for PICU health care workers, amongst whom burnout is already quite prevalent.¹¹⁻¹³ Although the duration of such heavy utilization of PICU staff could not be determined given the study's cross-sectional nature, the multiple-month duration of the surge suggests the high likelihood of persistent burden. Given the known association of cumulative heavy workload with increased risk of infection,¹⁴ health-care-acquired complications,¹⁵⁻¹⁸ and mortality,¹⁹ this persistent burden has the potential to affect the quality of

care. Notably, beyond the PICU setting, 1 out of every 4 hospitals was operating at very high (85%) overall bed occupancy at the time of the survey, the threshold beyond which quality of care is impacted adversely.²⁰ Similarly, the top quartile of PICUs for occupancy was at 100% capacity, and the median ED and CICU bed occupancy exceeded the concerning threshold of 85%. Importantly, with lower average daily cardiac ICU occupancy being associated with better cardiac arrest prevention,²¹ the beyond-maximum bed occupancy in the CICU observed in the top quartile hospitals for bed occupancy is a source of concern regarding patient safety and the high potential for staff burnout. Patient-centered outcomes, resulting from the relocation of some mechanically ventilated patients to non-ICU or newly created ICU settings, are also unknown and require further research.

High ED bed occupancy (86%) led to the diversion of patients away from most respondent hospitals. Although patient outcomes were not captured in the study, diversion from the closest or most suitable hospital causes concern for potential adverse patient outcomes, including death.^{22,23} Importantly, the threshold of ED or hospital occupancy that prompts diversion of patients from the ED is unknown and is likely to be institution specific. Further research on patient diversion from the ED is warranted, with a robust collection of data on the frequency of patient diversion accompanied by capture of contemporaneous data on ED and hospital bed occupancy. Such work will be highly instructive to policy-makers and health care decision-makers at the hospital, local, and regional levels. It also has the potential to enhance optimal transfer of children to the next hospital with resource capacity to provide pediatric acute care during periods of high hospital census, including pediatric public health emergencies.

Recent reports of progressive decline in pediatric bed supply nationally²⁴ have generated discourse on the preparedness of pediatric hospitals for future pediatric public health emergencies. The current study captured real-time data on the availability of resources for hospitalized children during what was described by pediatricians nationwide as the pediatric version of the peak of wave 1 of the outgoing COVID-19 pandemic. The 2022-2023 pediatric respiratory illness surge was a test case of emergency preparedness for children, and the study findings suggest significant overburdening of a fragile system.

Limitations

The study findings need to be interpreted considering certain limitations. The absence of a centralized repository of pediatric hospitals limited the ability to conduct a national inventory of pediatric critical care resource use. While the study sample was a convenience sample of hospitals not meant to be epidemiologically or statistically representative of the entire United States, the respondents were physicians in acute and critical care medicine, and senior hospital administrators who could provide reliable data to enable a rapid turnaround snapshot of events at a variety of hospitals that provided care to ill children during a rapidly evolving crisis. This pragmatic rapid turnaround survey captured data across the 4 major US census regions, from a mix of hospitals with varying structure and resource capacity. Although limited by the sample size and sampling methods, the findings' generalizability was supported by the geographical and structural diversity of the study hospitals.

The study findings were also limited by the inability to capture the downstream patient and family-centered outcomes at the hospitals operating at such high capacity. Such outcomes would likely have supported reports of parental anxiety regarding the inability to

have their children hospitalized due to lack of beds or having to travel a long distance to access needed pediatric care.²⁵

Conclusions

The fall 2022 to winter 2023 pediatric respiratory illness surge triggered significant hospital resource use—often to maximum capacity, and diversion of patients away from hospitals. Preparedness for future pediatric public health emergencies should innovate around resource capacity. The preparation for pediatric public health emergencies will be enhanced by detailed inventory of baseline resource capacity at pediatric hospitals, real-time capture of resource use during illness surges, and the evaluation of ongoing resource constraints, including pediatric bed supply, across the United States. Improved understanding of these resource constraints will likely provide opportunities to optimize health care delivery, address health care worker workload and well-being, and improve patient care.

Abbreviations

AAP	American Academy of Pediatrics
CHA	Children's Hospital Association
ED	emergency department
ICU	intensive care unit
PICU	pediatric intensive care unit
RSV	respiratory syncytial virus

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Author contribution. Drs Christner, Carlton, and Gorga participated in the study conception and design, interpretation of the data, and critical revision of the manuscript for important intellectual content. Ms Whittington participated in the study conception and design, acquisition and interpretation of the data, and critical revision of the manuscript for important intellectual content. Dr Odetola had full access to the data and takes responsibility for the integrity of the data and the accuracy of the data analysis. He participated in the study conception and design, data acquisition and interpretation, drafting of the manuscript, and critical revision of the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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References

1. Hamid S, Winn A, Parikh R, et al. Seasonality of respiratory syncytial virus—United States, 2017–2023. *Morb Mortal Wkly Rep.* 2023;72(14):355–361.
2. Wu KJ. The worst pediatric-care crisis in decades. *The Atlantic.* Published October 31, 2022. Accessed November 1, 2022. <https://www.theatlantic.com/health/archive/2022/10/rise-of-rsv-flu-covid-infections-kids/671947/>
3. RSV Surge Puts Youngest Children at Risk. Northwestern University. Published November 10, 2022. Accessed November 10, 2022. <https://news.northwestern.edu/stories/2022/11/rsv-surge-puts-youngest-children-at-risk/?fj=1>
4. Horak RV, Griffin JF, Brown AM, et al; Pediatric Acute Lung Injury and Sepsis Investigator's (PALISI) Network. Growth and changing characteristics of pediatric intensive care 2001–2016. *Crit Care Med.* 2019;47(8):1135–1142.
5. Rubinson L, Vaughn F, Nelson S, et al. Mechanical ventilators in US acute care hospitals. *Disaster Med Public Health Prep.* 2010;4(3):199–206.
6. Odetola FO, Clark SJ, Freed GL, et al. A national survey of pediatric critical care resources in the United States. *Pediatrics.* 2005;115(4):e382–e386.
7. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* 2009;42(2):377–381.
8. Odetola FO, Miller WC, Davis MM, Bratton SL. The relationship between the location of pediatric intensive care unit facilities and child death from trauma: a county-level ecologic study. *J Pediatr.* 2005;147(1):74–77.
9. Kanter RK. Regional variation in child mortality at hospitals lacking a pediatric intensive care unit. *Crit Care Med.* 2002;30(1):94–99.
10. Jenco M. AAP, CHA call for emergency declaration to address surge of pediatric illnesses. Published November 15, 2022. Accessed November 22, 2022. <https://publications.aap.org/aapnews/news/22619/>
11. Dalal NN, Gaydos LM, Gillespie SE, et al. Environment and culture, a cross-sectional survey on drivers of burnout in pediatric intensive care. *J Pediatr Intensive Care.* 2021;12(1):44–54.
12. Crowe L, Young J, Turner MJ. What is the prevalence and risk factors of burnout among pediatric intensive care staff (PICU)? A review. *Transl Pediatr.* 2021;10(10):2825–2835.
13. Rodríguez-Rey R, Palacios A, Alonso-Tapia J, et al. Burnout and post-traumatic stress in paediatric critical care personnel: prediction from resilience and coping styles. *Aust Crit Care.* 2019;32(1):46–53.
14. Zingg W, Holmes A, Dettenkofer M, et al.; The Systematic Review and Evidence-based Guidance on Organization of Hospital Infection Control Programmes (SIGHT) study group. Hospital organisation, management, and structure for prevention of health-care-associated infection: a systematic review and expert consensus. *Lancet Infect Dis.* 2015;15(2):212–224. Erratum in: *Lancet Infect Dis.* 2015;15(3):263.
15. Chang LY, Yu HH, Chao YC. The relationship between nursing workload, quality of care, and nursing payment in intensive care units. *J Nurs Res.* 2019;27(1):1–9.
16. Weissman JS, Rothschild JM, Bendavid E, et al. Hospital workload and adverse events. *Med Care.* 2007;45(5):448–455.
17. Montgomery VL. Effect of fatigue, workload, and environment on patient safety in the pediatric intensive care unit. *Pediatr Crit Care Med.* 2007;8(2 Suppl): S11–S16.
18. Boyle J, Zeitz K, Hoffman R, et al. Probability of severe adverse events as a function of hospital occupancy. *IEEE J Biomed Health Inform.* 2014;18(1):15–20.
19. Madsen F, Ladelund S, Linneberg A. High levels of bed occupancy associated with increased inpatient and thirty-day hospital mortality in Denmark. *Health Aff (Millwood).* 2014;33(7):1236–1244.
20. Mateen BA, Wilde H, Dennis JM, et al. Hospital bed capacity and usage across secondary healthcare providers in England during the first wave of the COVID-19 pandemic: a descriptive analysis. *BMJ Open.* 2021;11(1):e042945.
21. Lasa JJ, Banerjee M, Zhang W, et al. Critical care unit organizational and personnel factors impact cardiac arrest prevention and rescue in the pediatric cardiac population. *Pediatr Crit Care Med.* 2022;23(4):255–267.
22. Shen YC, Hsia RY. Ambulance diversion associated with reduced access to cardiac technology and increased one-year mortality. *Health Aff (Millwood).* 2015;34(8):1273–1280.
23. Shen YC, Hsia RY. Association between ambulance diversion and survival among patients with acute myocardial infarction. *JAMA.* 2011;305(23):2440–2447.
24. Cushing AM, Buchholz EM, Chien AT, et al. Availability of pediatric inpatient services in the United States. *Pediatrics.* 2021;148(1):e2020041723.
25. Zdanowicz C. Pediatric hospital beds are in high demand for ailing children. Here's why. CNN Health. Updated March 17, 2023. Accessed March 25, 2023. <https://www.cnn.com/2023/03/16/health/pediatric-hospital-bed-shortage-ctrp>

Appendix

Survey of Pediatric (Non-Neonatal) Critical Care Resources

Please **circle** the most appropriate answer for each question, unless directed otherwise.

The following questions refer only to pediatric NOT NEONATAL critical care resources CURRENTLY in your hospital.

1. Do you have a pediatric intensive care unit (PICU) within your hospital?
 Yes → please go to Question 2 No → Please stop and submit the survey
2. Is your hospital a freestanding* children’s hospital? **Yes No**

3. What is the PICU average Nurse: Patient ratio? a. 1:1 b. 1:2 c. 1:3 d. Other ____
4. Do you have a pediatric emergency department (ED) within your hospital?
Yes No
5. How many Attending physicians work in the pediatric ED? ____
6. How many nurses are in your ED nursing pool? ____
7. In the past month:
 - 7a. How many times has your hospital ED diverted patients away?
 a. 0 b. 1-5 c. 6-10 d. >10
 - 7b. Have PICU patients on ventilators been housed in overflow units?
Yes - Cardiac ICU PACU Step-down ICU Other ____ No

Please fill in the information in the table below to determine the availability of critical care resources.

	Number available	Number currently in use	Leave blank
Pediatric intensive care unit human resources			
Faculty			
Nurses			
Respiratory therapists			
Pediatric hospital technology			
Extracorporeal membrane oxygenation machines			
Continuous renal replacement therapy/hemodialysis machines			
Full-feature (intensive care unit-level) mechanical ventilators			
High flow nasal cannula machines			
Non-invasive ventilators			
Pediatric hospital beds			
Total hospital beds			
Pediatric ICU beds			
Emergency department beds			
Cardiac ICU beds			
Intermediate (step-down) care unit beds			
General care ward beds			

*Freestanding is defined as not affiliated with a larger health care system already getting federal support for training medical residents. Thank you for your time. Please submit the survey.