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# Mortality and PICU Hospitalization Among Pediatric Gunshot Wound Victims in Chicago

**IMPORTANCE:** Firearm injury accounts for significant morbidity with high mortality among children admitted to the PICU. Understanding risk factors for PICU admission is an important step toward developing prevention and intervention strategies to minimize the burden of pediatric gunshot wound (GSW) injury.

**OBJECTIVES:** The primary objective of this study was to characterize outcomes and the likelihood of PICU admission among children with GSWs.

**DESIGN, SETTING, AND PARTICIPANTS:** Retrospective cohort study of GSW patients 0–18 years old evaluated at the University of Chicago Comer Children's Hospital Pediatric Trauma Center from 2010 to 2017.

**MAIN OUTCOMES AND MEASURES:** Demographic and injury severity measures were acquired from an institutional database. We describe mortality and hospitalization characteristics for the cohort. We used logistic regression models to test the association between PICU admission and patient characteristics.

**RESULTS:** During the 8-year study period, 294 children experienced GSWs. We did not observe trends in overall mortality over time, but mortality for children with GSWs was higher than all-cause PICU mortality. Children 0–6 years old experienced longer hospitalizations compared with children 13–16 years old (5 vs 3 d;  $p = 0.04$ ) and greater frequency of PICU admission (83.3% vs 52.9%;  $p = 0.001$ ). Adjusting for severity of illness, children less than 7 years old were four-fold more likely to be admitted to the PICU than children 13–16 years old (aOR range, 3.9–4.6).

**CONCLUSIONS AND RELEVANCE:** Despite declines in pediatric firearm mortality across the United States, mortality did not decrease over time in our cohort and was higher than all-cause PICU mortality. Younger children with GSWs experience longer hospitalizations and require PICU care more often than older children. Our findings suggest that the youngest victims of firearm-related injury may be particularly at-risk of the long-term sequelae of critical illness and injury.

**KEY WORDS:** critical care; firearm, gun violence; gunshot wound; outcomes; pediatric gunshot wounds

Among high-income countries, the United States has the highest per capita death rate due to gun violence (1). Although the majority of gunshot wound (GSW) victims are adults, children also contribute to a significant share of the healthcare burden. Approximately 5,800 children are treated for GSW injury annually, with 20% mortality (2). Firearm-related injuries are the second leading cause of death for pediatric patients (3–5). Mortality rates per 100,000 individuals of 0.4 for 0–4 year olds, 0.7 for 5–14 year olds, and 14.1 for 15–24 year olds indicate that the likelihood of a child experiencing a fatal GSW increases with age (1). Nearly one-fourth of pediatric victims of gun violence die, and the vast majority of those who survive require significant hospital care. For those with the most severe injury, multidisciplinary critical care services provided in the PICU are often required. In 2019, The American

Maya A. Rhine, MD<sup>1</sup>

Emma M. Hegermiller, MS<sup>2</sup>

Jason M. Kane, MD, MS<sup>3</sup>

Mark B. Slidell, MD, MPH<sup>4</sup>

Anoop Mayampurath, PhD<sup>5</sup>

Alisa A. McQueen, MD, FAAP,  
FACEP<sup>6</sup>

Nina Mbadiwe, MD<sup>7</sup>

Neethi P. Pinto, MD, MS<sup>8</sup>

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Pediatric Surgical Association called attention to the urgent need for additional research regarding firearm injury, which is currently the least studied cause of death in proportion to its mortality rate (6, 7).

The city of Chicago has been in the national spotlight for gun violence with the highest absolute number of homicides of any U.S. city (8). Notably, Chicago has significant disparities in homicide rate by race, socioeconomic status, and neighborhood, with the highest concentration of violent crime affecting the South and West Side neighborhoods (8, 9). The University of Chicago Comer Children's Hospital is uniquely positioned to study the epidemic of gun violence and injury in children as the only quaternary-care, academic level I pediatric trauma center on the South Side of Chicago. Comer Children's Hospital treats a disproportionately higher number of pediatric trauma patients compared with other regional pediatric hospitals, including greater than 40% of all of Chicago's pediatric GSW patients (E-mail communication between M. Slidell and Illinois Department of Public Health, September 2021). Most pediatric trauma centers experience penetrating GSWs as 4.4% of their overall volume (4). Historically, GSWs constitute 10% (interquartile range [IQR], 8–16%) of pediatric trauma activations at our center annually, with an average of 13.8% over the past 5 years. Although a recently published study characterized PICU mortality among pediatric GSW patients, risk factors for admission remain unclear (10). The primary objective of this study was to characterize mortality, likelihood of PICU admission, and risk factors associated with PICU admission among children with GSWs in a single urban academic center with a disproportionately high volume of pediatric firearm injury.

## MATERIALS AND METHODS

### Design and Setting

We conducted a retrospective chart review of all pediatric patients ( $\leq 18$  yr old) evaluated in the Comer Children's Hospital Pediatric Trauma Center for penetrating trauma between 2010 and 2017, prior to the opening of the adult trauma center at The University of Chicago. We screened all patients who presented to the emergency department (ED) with a known outcome disposition (hospital admission, discharge from ED, or death). Patients were excluded if penetrating injury was not due to a GSW. The Institutional Review Board

(IRB) at The University of Chicago approved the study (IRB18-1786).

### Patient and Hospitalization Characteristics

Patient demographics, hospitalization characteristics, and severity of injury were acquired from an institutional trauma database. Data collected included date of presentation to the ED, date of birth, Shock Index Pediatric Adjusted (SIPA), Injury Severity Score (ISS), Glasgow Coma Scale (GCS), mortality, patient disposition, hospital length of stay (LOS), and ventilator requirement (11–13). All data were cross-referenced with the electronic health record (EHR) to ensure accuracy. Additional patient-level and demographic data obtained from the EHR included race, ethnicity, insurance status, number of GSWs, location of GSWs, and requirement for operative intervention. Study data were collected and managed using Research Electronic Data Capture (REDCap) electronic data capture tools (REDCap Version 9.5.24, 2020 Vanderbilt University) (14).

### Outcome and Variables

The primary outcomes of interest were mortality and admission to the PICU. We examined the association of PICU admission and independent variables including severity of injury measures, calendar year, and patient demographics. We used three measures of injury severity: SIPA, ISS, and GCS to facilitate comparability with published studies. The SIPA is a shock index that denotes hemodynamic instability, and the ISS accounts for the three most severely injured body systems. Both scores are specific to trauma patients. SIPA scores were described according to whether scores were greater than published age-based thresholds ( $> 1.22$  for ages 0–6,  $> 1.0$  for ages 7–12, and  $> 0.9$  for ages 13–16) (13). Unlike SIPA and ISS, GCS can be calculated in real time, is used widely in all PICU patients, and was dichotomized into greater than or less than or equal to 8 (severe head injury) (15).

### Statistical Analysis

Patient demographics, indicators of severity of illness, and outcomes were summarized for the cohort. Means and standard deviations (or medians and IQRs) were reported for continuous variables, and counts and percentages were reported for categorical variables.

Associations were evaluated with chi-square tests for categorical variables and *t* tests for continuous variables. Logistic regression models were used to determine the association between PICU admission and potential predictor variables. Individual models were created for each measure of injury severity. All data analysis used R Version 3.6.3. (R Core Team [2013]. A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria) *p* values reported were based on two-sided alternatives with a *p* value less than 0.05 indicating statistical significance.

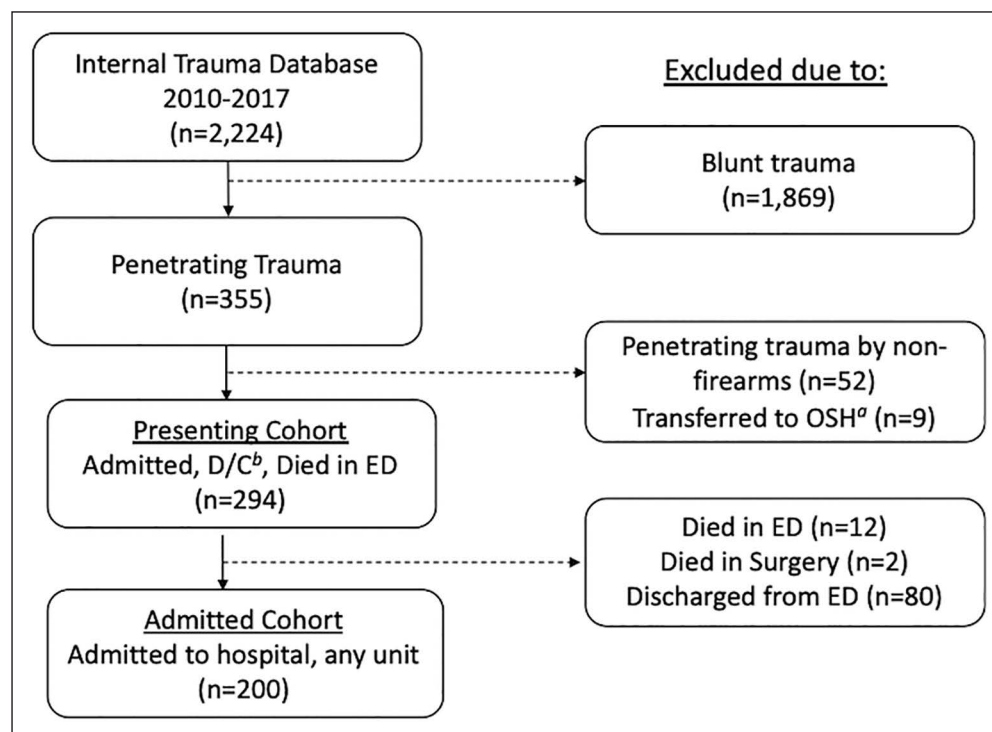
## RESULTS

Over the 8-year period, 2,224 children were evaluated for trauma. A total of 355 (16.0%) experienced penetrating trauma, including 294 (13.2% of trauma patients) with GSWs. Patient demographics and outcomes generally did not vary from year to year; overall mortality ranged from 2.6% to 18.5% over the study period without a consistent trend. (**Supplemental Table 1**, <http://links.lww.com/CCX/A906>) In any given year, the majority of children were between the 13–16 year old (> 58%), male (> 67%), African American (> 82%), non-Hispanic (> 79%), and publicly insured/uninsured (> 85%). The majority of children (68.0%)

required hospitalization (**Fig. 1**). Compared with children who were not admitted to the hospital, admitted children were younger (13.1 vs 14.1 yr; *p* = 0.03), required surgical procedures (57.0% vs 7.4%; *p* = 0.008), and experienced lower mortality (5% vs 14.9%; *p* < 0.001) (**Table 1**). Surgical procedures included operative intervention as well as bedside wound repair. Among nonadmitted patients who died, 12 died (86%) in the ED and two died (14%) in the odds range. The deaths occurred primarily among adolescents: nine patients (64%) 13–16 years old, four (29%) 7–12 years old, and one (7%) 0–6 years old. Children who died prior to admission had higher severity of illness scores compared with discharged and admitted children, using the ISS and GCS (**Supplemental Table 2**, <http://links.lww.com/CCX/A907>).

**Table 2** depicts differences in injury severity and outcomes by age among admitted children. The majority of children were 13–16 years old (76.5%). Mortality ranged from 2.5% to 3.9% and did not differ by age. Although injury severity was not different when using the SIPA or ISS, younger children had the highest proportion of severe injuries using GCS (0–6 yr: 29.2%, 7–12 yr: 21.7%, 13–16 yr: 7.2%; *p* = 0.002). They had a longer hospital LOS compared with older children (median LOS for 0–6 yr: 5 d, for

7–12 yr: 5 d, for 13–16 yr: 3 d; *p* = 0.041) and were more frequently admitted to the PICU (83.3% of 0–6 yr, 82.6% of 7–12 yr, and 52.9% of 13–16 yr; *p* = 0.001). Older children (13–16 yr) had a lower occurrence of head-penetrating GSWs (9.8% compared with 25.0% for 0–6 yr and 26.1% for 7–12 yr; *p* = 0.022). Children 7–12 years old had a greater occurrence of GSW to the buttocks (4.3%) compared with all other children (*p* = 0.021). There were no differences in occurrence of multiple GSWs or in other locations of GSW across age groups. Although there was



**Figure 1.** Study enrollment. <sup>a</sup>OSH = outside hospital. <sup>b</sup>D/C = discharged from ED. ED = emergency department.

**TABLE 1.**  
**Baseline and Hospitalization Characteristics of Children With Gunshot Wound by Admission Status**

Characteristic	Admitted (n = 200)	Not Admitted (n = 94)	p
Age <sub>continuous</sub> , mean (SD)	13.10 (3.9)	14.06 (2.5)	0.03
Age <sub>cat-SIPA</sub> , n (%)			
0–6	24 (12.0)	3 (3.2)	0.044
7–12	23 (11.5)	14 (14.9)	
13–18 <sup>a</sup>	153 (76.5)	77 (81.9)	
Female, n (%)	38 (19.0)	20 (21.3)	0.764
Race, n (%)			
White	3 (1.5)	1 (1.1)	0.861
Black or African American	185 (92.5)	85 (90.4)	
More than one race	5 (2.5)	3 (3.2)	
Unknown/not reported	7 (3.5)	5 (5.3)	
Ethnicity, n (%)			
Hispanic or Latino	12 (6.0)	5 (5.3)	0.932
Not Hispanic or Latino	178 (89.0)	85 (90.4)	
Unknown/not reported	10 (5.0)	4 (4.3)	
Insurance status, n (%)			
Public	126 (63.0)	49 (52.1)	0.067
Private	18 (9.0)	6 (6.4)	
Uninsured	56 (28.0)	39 (41.5)	
SIPA, <sup>b</sup> n (%)	50 (25.0)	17 (18.1)	0.242
Injury Severity Score, mean (SD)	11.90 (13.8)	8.16 (19.7)	0.061
Glasgow Coma Scale <sub>cat</sub> : ≤8, n (%)	23 (11.5)	10 (10.6)	0.984
Surgery, n (%)	114 (57.0)	7 (7.4)	< 0.001
Ventilation, n (%)	50 (25.0)	-	-
Mortality, n (%)	10 (5.0)	14 (14.9)	0.008
PICU admission, n (%)	120 (60.0)	-	-
Hospital length of stay in days, median (interquartile range)	3.00 (2.0–8.0)	-	-

SIPA = Shock Index Pediatric Adjusted.

<sup>a</sup>One patient in the nonadmitted group was 18 years old. All other patients were < 17 yr old.

<sup>b</sup>Cut-off Shock Index Values for significant injury by age: > 1.22 (age 0–6), > 1.0 (7–12), > 0.9 (13–16).

no difference in mortality across age groups, children who were admitted to the PICU due to firearm injury demonstrated an increased mortality rate of 5% overall compared with both institutional and national all-cause PICU mortality rates of approximately 2.4% (16, 17).

We examined the association between age and PICU admission after adjusting for patient characteristics (sex, race, ethnicity, and insurance status), year of admission, and individual measures of injury severity

for the 200 admitted patients (**Supplemental Fig. 1**, <http://links.lww.com/CCX/A908>). In the adjusted analyses, younger children (0–6 yr) were four times more likely to be admitted to the PICU than older children (13–16 yr) (adjusted odds ratio [aOR] [95% CI], 4.1 [1.3–15.3];  $p = 0.021$ ) when using SIPA, (4.6 [1.4–17.9];  $p = 0.017$ ) when using ISS, and (3.9 [1.2–15.2];  $p = 0.028$ ) when using GCS. Children between 7 and 12 years old were also four times more likely to be admitted to



**TABLE 2.****Injury Severity and Outcomes Among Children With Gunshot Wound Admitted to the Hospital**

Characteristic	Age Category			p
	0–6 yr (n = 24)	7–12 yr (n = 23)	13–16 yr (n = 153)	
Shock Index Pediatric Adjusted, <sup>a</sup> n (%)	10 (41.7)	5 (21.7)	35 (22.9)	0.132
Injury Severity Score, mean (sd)	12.46 (9.97)	12.83 (7.39)	11.67 (15.03)	0.913
Glasgow Coma Scale <sub>cat</sub> : ≤8, n (%)	7 (29.2)	5 (21.7)	11 (7.2)	0.002
Multiple GSW, n (%)	2 (8.3)	6 (26.1)	39 (25.5)	0.174
Location of GSW, n (%)				
Head	6 (25.0)	6 (26.1)	15 (9.8)	0.022
Chest	2 (8.3)	2 (8.7)	29 (19.0)	0.241
Abdomen	5 (20.8)	2 (8.7)	18 (11.8)	0.386
Back	1 (4.2)	5 (21.7)	37 (24.2)	0.085
Buttocks	0 (0)	1 (4.3)	0 (0)	0.021
Pelvis	1 (4.2)	2 (8.7)	6 (3.9)	0.586
Extremities	11 (45.8)	12 (52.2)	97 (63.4)	0.189
Mortality n (%)	3 (2.5)	1 (4.3)	6 (3.9)	0.198
PICU admission, n (%)	20 (83.3)	19 (82.6)	81 (52.9)	0.001
Hospital length of stay in days, median (interquartile range)	5.00 (2.00–8.00)	5.00 (3.00–12.50)	3.00 (1.00–7.00)	0.041

GSW = gunshot wound.

<sup>a</sup>Cutoff Shock Index values for significant injury by age: > 1.22 (age 0–6), > 1.0 (7–12), > 0.9 (13–16).

the PICU than children 13–16 years when using SIPA (aOR [95% CI], 4.0 [1.3–4.9];  $p = 0.0230$ ). A similar trend was observed for these children when using the ISS and GCS (aOR [95% CI], 3.3 [1.0–13.1];  $p = 0.066$  and 2.9 [0.9–11.4];  $p = 0.087$ , respectively).

## DISCUSSION

Chicago is highlighted as an epicenter of firearm violence with annual GSW incidence surpassing New York and Los Angeles combined (18, 19). There were no demographic nor mortality trends over the 8-year study period, likely due to limitations in the number of GSW deaths. However, GSW victims had differential hospitalization outcomes. Children with GSWs admitted to our PICU demonstrated a two-fold increase in mortality compared with all-cause PICU mortality rates of ~2% nationally (16). Younger patients experienced longer hospital stays and were four times more likely to require PICU admission. Our findings improve our understanding of pediatric firearm injury, reflecting experience in a city with a significant burden of gun violence.

Despite an increase in overall firearm violence in Chicago, there have been no significant changes in pediatric GSW incidence (20–22). This finding is sobering compared with national trends. Across the United States, child firearm homicide rates exhibited a 36% significant decline between 2007 and 2014 (2). Unfortunately, we did not observe a similar decrease in GSW mortality and found that these children were more likely to die than other children in the PICU. The majority of our patients were male, African American, non-Hispanic, and publicly insured/uninsured, reflecting institutional demographics and national trends (23) and highlighting the disproportionate impact of this public health problem on minority and poor communities. Notably, pediatric firearm-related mortality rates in the United States are unparalleled globally, and one in three U.S. homes with children less than 18 years old reports the presence of firearms (5). Similarly, the magnitude of firearm injury in Chicago occurs in the context of more guns per capita being recovered in Chicago than in New York and Los Angeles combined (24).

Although older children comprised the vast majority of our population, similar to national trends, we found unique local patterns of injury severity and healthcare utilization. For example, in Los Angeles, patients with intentional GSW injury (predominantly older children) exhibited increased number of injuries, mortality, and healthcare utilization (25). In contrast, we found younger children were more likely to require longer hospitalizations and PICU services. Our data are similar to data for children with accidental GSWs (a younger cohort) in the aforementioned study (25) and other multicenter data (22). Sixty percent of children in our study were admitted to the PICU, exceeding a national average of 29% among 28 children's hospitals in the Pediatric Health Information System database (22).

Younger children with GSW injuries were more likely to require the PICU independent of initial severity of illness. Our findings may reflect institutional practice of preemptively admitting a young child to the PICU due to a high risk of subtle deterioration. Similarly, the increased LOS among these children may reflect important social factors (e.g., adequacy of home safety, supervision, and custody) rather than an ongoing physiologic indication. However, whether admission to the PICU and continued hospitalization is driven by institutional practice, psychosocial factors, or pathophysiology, our findings may have important sequelae. Use of intensive monitoring, invasive PICU therapies (e.g., mechanical ventilation, vasoactive medications, etc.), and imaging may result in additional costs, resource utilization, and secondary medical problems (22). Nonetheless, triaging GSW patients to the PICU is a reasonable conservative management strategy, given high mortality in this population overall and the low physiologic reserve among young patients. Furthermore, although the development of validated scoring systems has allowed for judicious initial management of solid organ injury and traumatic brain injury outside of the PICU (26), similar risk stratification systems have yet to be validated for GSW injuries.

Experience across U.S. PICUs is similar. Children with GSWs have longer PICU and hospital LOSs than other penetrating injuries (3). A recent study from 135 PICUs in the Virtual Pediatric Systems database provides further evidence of the burden associated with PICU admission secondary to firearm injury; these children demonstrate a five-fold increase in mortality

compared with all-cause mortality and survivors exhibit increased disability at discharge (10). To mitigate this risk of postintensive care syndrome-pediatrics, the constellation of long-term physical, cognitive, emotional, and social problems experienced by PICU survivors, pediatric GSW patients may benefit from long-term follow-up (27).

There were limitations to this study. Our database was retrospective, limiting our ability to understand historical context, changes in institutional practice, and factors such as severity of injury or age that may have contributed to the observed variability in GSW admissions and mortality. Although our data do not reflect experience after 2017, the lack of mortality decline we observed over the 8-year study period is concerning and highlights the crisis in Chicago, especially in the context of a declining national GSW mortality rate at this time. Understanding the magnitude of the firearms problem in cities with high prevalence within the United States is important to understanding why the United States outranks all other countries with regard to firearm mortality rates among children and adolescents (36.5 times as high as rates in 12 high-income countries and five times as high as mortality rates in seven low-to-middle-income countries per 2016 data from the World Health Organization) (5). The ability to discern risk factors for intentional versus unintentional injury may further inform prevention strategies; unfortunately, our data did not elucidate this because decisions regarding intent were often determined by local authorities after discharge and were not linked to the medical record. Our data reflect a single-center experience, potentially limiting generalizability. However, given the high rate of local gun violence and trauma referral patterns, our capture rate for pediatric GSW is likely very high. Data from 2012 to 2015 from the Illinois Department of Public Health support the scope of our experience. Our pediatric trauma center receives greater than 40% of all pediatric GSWs, two adult centers cared for 14% and 18% of Chicago's pediatric GSW patients, and the remaining pediatric and adult hospitals in Chicago cared for less than five pediatric patients/yr (E-mail communication between M. Slidell and Illinois Department of Public Health, September 2021). Thus, our findings represent a majority of Chicago's pediatric GSW population, contributing novel information to what is known about pediatric firearm-related injury.

## CONCLUSIONS

In sum, our findings importantly focus our attention on the most vulnerable children who experience pediatric gun violence—children 6 years old or younger. Children who experience injury due to firearms have higher rates of PICU mortality than other critically ill or injured children. Younger children experience longer hospitalizations and require PICU care more often than older children, independent of injury severity. Our findings suggest that young victims of firearm-related injury who require PICU admission, in particular, may benefit from longitudinal follow-up to minimize the long-term sequelae of critical illness. Establishment of long-term follow-up programs with an interprofessional team (e.g., intensivists, physiatrists, psychiatrists, neuropsychologists, physical and occupational therapists, etc.) equipped to screen, treat, and provide resources is imperative to optimizing the health and well-being of children who survive firearm-related injury.

- 1 Pritzker School of Medicine, The University of Chicago, Chicago, IL.
- 2 Department of Pathology, The University of Chicago, Chicago, IL.
- 3 Section of Critical Care, Department of Pediatrics, The University of Chicago, Comer Children's Hospital, Chicago IL.
- 4 Section of Pediatric Surgery, Department of Surgery, The University of Chicago, Chicago, IL.
- 5 Department of Pediatrics and Center for Research Informatics, Biological Sciences Division, The University of Chicago, Chicago, IL.
- 6 Section of Emergency Medicine, Department of Pediatrics, The University of Chicago, Comer Children's Hospital, Chicago, IL.
- 7 Department of Pediatric Emergency Medicine, Advocate Christ Medical Center, Oak Lawn, IL.
- 8 Division of Critical Care Medicine, Department of Anesthesiology and Critical Care Medicine, University of Pennsylvania, Children's Hospital of Philadelphia, Philadelphia, PA.

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Dr. Rhine and Ms. Hegermiller contributed equally as cofirst authors.

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Address requests for reprints to: Neethi P. Pinto, MD, MS, Division of Critical Care Medicine, Department of Anesthesiology and Critical Care Medicine, University of Pennsylvania, Children's Hospital of Philadelphia, Philadelphia, PA. E-mail: [pintonp@chop.edu](mailto:pintonp@chop.edu).

Study was performed at the University of Chicago.

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