A National Simulation-Based Study of Pediatric Critical Care Transport Teams Performance

Erin E. Montgomery, RN[1], Ingrid A. Anderson, MD[2], Daniel J. Scherzer, MD[3], Grace M. Arteaga, MD[4], Ranna A. Rozenfeld, MD[5], Robyn Wing, MD, MPH[5], Rachel A. Umoren, MBBCh, MS[6], Jessica J. Wall, MD[6], Devin A. McKissic, MD[6], Gabriela I. Centers, MD, MSCR[7], Callie R. Searly, RN, BSN, C-NPT[8], Maria J. Mandt, MD[8], Brian M. Jackson, MD[8], Erin W. Hulfish, MD[9], Lauren M. Maloney, MD[10], Tina M. Duman-Bender, MSN, RN, CPN[11], Christopher Kennedy, MD[11,■], Mark Adler, MD[13], Jeffrey Naples, DO[11], Jeffrey Luk, MD[2], Stephen J. Gleich, MD[4], Riad Lutfi, MD[1], Kellie J. Pearson, RT[1], Sakina Erika Reames, MPH[13], Marc A. Auerbach, MD, MSc[14], and Kamal Abulebda, MD[1], Improving Pediatric Acute Care Through Simulation (ImPACTS)

Objectives To assess pediatric critical care transport (CCT) teams' performance in a simulated environment and to explore the impact of team and center characteristics on performance.

Study design This observational, multicenter, simulation-based study enlisted a national cohort of pediatric transport centers. Teams participated in 3 scenarios: nonaccidental abusive head injury, sepsis, and cardiac arrest. The primary outcome was teams' simulation performance score. Secondary outcomes were associations between performance, center and team characteristics.

Results We recruited 78 transport teams with 196 members from 12 CCT centers. Scores on performance measures that were developed were 89% (IQR 78-100) for nonaccidental abusive head injury, 63.3% (IQR 45.5-81.8) for sepsis, and 86.6% (IQR 66.6-93.3) for cardiac arrest. In multivariable analysis, overall performance was higher for teams including a respiratory therapist (0.5 points [95% CI: 0.13, 0.86]) or paramedic (0.49 points [95% CI: 0.1, 0.88]) and dedicated pediatric teams (0.37 points [95% 0.06, 0.68]). Each year increase in program age was associated with an increase of 0.04 points (95% CI: 0.02, 0.06).

Conclusions Dedicated pediatric teams, inclusion of respiratory therapists and paramedics, and center age were associated with higher simulation scores for pediatric CCT teams. These insights can guide efforts to enhance the quality of care for children during interfacility transports. *(J Pediatr 2025;276:114303)*.

Most acutely ill and injured children receive care at general emergency departments (EDs). These EDs are less prepared than pediatric academic medical centers (AMCs) to care for acutely ill children given their lower pediatric patient volume, the lack of pediatric resources and experts, and lower pediatric readiness compared with pediatric AMCs.[1,2] Consequently, health disparities have emerged, leading to lower survival rates among children seeking treatment at these nonspecialized EDs.[3,4] Pediatric critical care transport (CCT) has gained a prominent role in facilitating the safe transport of acutely ill and injured children to pediatric centers given their specialized training in pediatric acute care and better preparedness to care for this patient population compared with nonspecialized teams.[5] The pivotal role of pediatric CCT teams lies in being a critical link in the emergency continuum between general EDs and pediatric AMCs with higher pediatric emergency readiness and access to pediatric subspecialty care.

Although specialized pediatric transport teams have demonstrated improved outcomes compared with nonspecialized counterparts, variability persists

AMC	Academic medical center
CCT	Critical care transport
ED	Emergency department
ImPACTS	Improving Pediatric Acute Care Through Simulation
NAT	Nonaccidental abusive head injury
RN	Registered nurse
RT	Respiratory therapist

From the [1]Division of Pediatric Critical Care Medicine, Department of Pediatrics, Indiana University School of Medicine and Riley Hospital for Children at Indiana University Health, Indianapolis, IN; [2]Pediatric Emergency Medicine, Case Western Reserve University Hospitals Rainbow Babies & Children's Hospital, Cleveland, OH; [3]Nationwide Children's Hospital, Columbus, OH; [4]Mayo Clinic College of Medicine and Science; [5]Hasbro Children's Hospital; [6]University of Washington; [7]Medical City Children's Hospital, Dallas TX; [8]Children's Hospital Colorado, Aurora, CO; [9]Stony Brook Children's Hospital; [10]Brook University Hospital; [11]Akron Children's Hospital, Akron, OH; [12]Children's Mercy Hospital; [13]Ann and Robert H Lurie Children's Hospital of Chicago; and [14]Department of Emergency Medicine, Yale University School of Medicine, New Haven, CT

Collaborators: Improving Pediatric Acute Care Through simulation (ImPACTS) investigators: Patricia Carreiro (Hasbro Children's Hospital); and Paul DeCerbo (Hasbro Children's Hospital).

The statistical analyses conducted in this study were performed by Gabriela Centers, who played a pivotal role in designing the study methodology, selecting appropriate statistical techniques, and interpreting the data.

This project was supported, in part, by Indiana University Health Values Grant: VFE-342 to K.A. and by a grant from the RBaby Foundation (Rbabyfoundation.org) to M.A.A.

https://doi.org/10.1016/j.jpeds.2024.114303

nationwide in terms of team composition, training prerequisites, and patient volume.[6] Recent survey studies have uncovered notable variability in training requirements, certifications, and team structures.[6] Despite this, no studies have yet been undertaken to quantitatively assess the performance of distinct pediatric CCTs, nor have the implications of these variables on their pediatric CCT quality of clinical care been thoroughly explored. Understanding the composition of centers and teams and its impact on performance outcomes is essential for addressing educational gaps and implementing well-designed curricula based on these findings.

The Improving Pediatric Acute Care Through Simulation (ImPACTS) is a national collaborative network of pediatric AMCs and community hospitals involving in situ simulation, education, and quality improvement to optimize pediatric emergency readiness and quality of care provided to acutely ill and injured children across the emergency continuum.[7-11] ImPACTS has successfully replicated its model, proving the feasibility of improving pediatric emergency readiness in diverse community EDs and pediatric primary care settings, all aimed at reducing disparities in the quality of care along the emergency care continuum.[12,13] However, no study to date has described and quantified the care provided by CCT teams that bridge these community EDs with dedicated pediatric EDs. We are now applying this model to describing and quantifying the care provided by CCT teams that bridge these community EDs with dedicated pediatric EDs.

There are limited published outcome metrics assessing the quality of pediatric resuscitative care within the pediatric CCT literature.[14] Although quality benchmarks have been established for select high-acuity pediatric conditions, investigation of quality outcomes during transport have been hindered by the infrequency, and unpredictable nature of pediatric resuscitations during interfacility transport. Challenges in data collection, compounded by logistical and ethical concerns, have further constrained investigations in this field. We conducted a descriptive study goal to investigate pediatric CCTs at multiple AMCs using simulation as a means of data collection, by characterizing team performance across 3 critical care scenarios.[15-17]

This descriptive study's objectives are to assess CCT team performance across 3 critical care scenarios within a simulated environment, and to explore the influence of specific team and center characteristics on overall performance.

Methods

Study Design

This observational, multicenter, in situ, and simulation-based cohort study aimed to describe the performance of pediatric CCT teams as they managed 3 simulated pediatric patients. The study was conducted between June 2021 and December 2022. Institutional review board approval was obtained from each collaborating AMC, following the specific requirements of each participating entity.

Study Setting and Sample

Twelve pediatric AMCs were involved in the study. Each transport center designated a champion, often the transport team educator or medical director, to lead participation in the ImPACTS collaborative. These champions coordinated study-related activities at their center. Each center was required to recruit at least 2 interprofessional teams. Recruitment was conducted through email invitations and sign-up documents distributed over a month, ensuring a minimum of 2 interprofessional teams from each center. Team comprised various roles, such as registered nurses (RNs), registered respiratory therapists (RTs), paramedics, and EMT-B's. Participants were excused from clinical duties during the simulations.

Recruitment and Training

Participating lead investigators and research coordinators from all collaborating AMCs underwent a standardized train-the-trainer session, conducted virtually by study principal investigators (K.A., I.A., E.M.). To ensure consistency among all raters (local site leads), all raters rated 3 exemplar videos created for this purpose by the study team. Scores were reviewed with the study team and all discrepancies were resolved. The training session also included completing the data collection instruments and data entry into a centralized online database.

The training session also included conducting the simulation sessions in the ED, completing the data collection instruments, and data entry into a centralized online database.

Simulation Sessions

Over a 14-month period, teams participated in a two-hour simulation session, encompassing 3 scenarios: (1) infant with nonaccidental abusive head injury (NAT) and increased intracranial pressure, (2) infant cardiac arrest, and (3) infant with septic shock. The simulations occurred in a transport vehicle for 2 scenarios and in the ED resuscitation room for the third, utilizing each center's actual equipment (eg, infusion pumps), supplies (eg, syringes), resources (eg, cognitive aids), and policies and/or guidelines (eg, sepsis/Pediatric Advanced Life Support. (**Supplementary Material 1**, online; available at www.jpeds.com).

Following the simulation sessions and completion of data entry by sites leads, the study team created site-specific snapshot performance reports for each site based on the simulated resuscitations, comparing each transport team to other pediatric CCT teams from all participating AMCs. These reports were distributed to each site PI at the end of the study to help guide their local efforts in improving their teams' performance. (**Supplementary Material 2**, online; available at www.jpeds.com).

Outcome Measures

Teams and Centers Characteristics. A survey was used to collect characteristics of participating transport centers including annual pediatric patient volume, patient population (pediatric only vs mixed pediatric/adult patients), CCT team structure, previous use of simulation for training, and other center certification and training requirements. Similarly, team characteristics, including members' professional backgrounds, team structure, transport shifts per month, and individual provider's years of experience, were also recorded.

Simulated Performance. Performance measures were iteratively developed over 4 months. We used Messick's validity framework for this work. Content validity evidence was developed through the adaptation of existing guidelines and a modified Delphi review process involving 4 pediatric emergency medicine physicians, 4 pediatric intensive care physicians, and 4 CCT nurses via 3 conference calls. We used a piloting process at both the main study site (not included in the study data) and at each site as well as rater training and calibration to support our response process validity argument. The sepsis measures were derived from the international Surviving Sepsis Guidelines.[18] The cardiac arrest measures were derived from the American Heart Association 2020 updated guidelines.[19] The abusive head injury performance measures were developed based on established best practices related to the management of deteriorating pediatric patient with an abusive head injury, derived from the Guidelines for the Management of Pediatric Severe Traumatic Brain Injury.[20]

The primary outcome was teams' performance in each case calculated using equal weighting for all subcomponents and divided by the total number of possible elements to derive a score on a scale of 0%-100%.

Secondary outcomes included exploring associations between simulated performance and transport center and team characteristics.

Statistical Analysis

Descriptive data are presented as frequency (%) and median (IQR) for categorical and continuous variables, respectively. Correlations were assessed with Pearson correlation coefficient for continuous variables and Kendall's tau coefficient for categorical variables.

To account for clustering of teams within centers, we used a linear mixed effect model with random intercept for center. The dependent variable was the simulation performance score for each of the 3 simulation scenarios. We investigated the following independent variables at center level: age of the center in years, center size represented as the annual patient volume, number of hours of simulation per year required, whether or not the center requires simulation for credentialing, mixed or pediatric-only centers (whether or not the center contains both adult and pediatric transport teams), whether or not center's patient population is both adult and pediatric or just pediatric patients, and whether or not medical control is a pediatric intensive care unit. We investigated the following independent variables at team level: presence of a RN, presence of a RT and/or paramedic within the team, number of team members (2 vs 3 members), teams' years of experience, and average number of shifts worked per month by team members. To assess the factors associated with overall team performance across the main 3 scenarios, we standardized the score for each scenario and modeled the average z score for each team. As a sensitivity analysis, we analyzed performance indicators depicting similar tasks across the 3 scenarios per team.

Given the exploratory nature of our analyses we employed 2 model building strategies: hierarchical and best subsets, then chose the best model fulfilling both statistical and subject knowledge criteria.

The hierarchical strategy is a researcher-driven strategy, where the researcher chooses which variables to include or exclude from each step of the model. Progression from one step to the next is driven by improvement in model performance by newly added or removed variables. We first tested the team-level covariates, then center-level covariates. We eliminated or readded variables based on a combination of statistical significance and worsening of model fit. Nested models were assessed using likelihood ratio tests, with the final goal of achieving the most parsimonious model that explained most of the variance.

The best subset strategy is a data-driven strategy, where software iteratively tests all possible combinations of predictor variables and offers options for the best combinations. The researcher then selects the best model considering the bias – variance tradeoff: include as many predictors as necessary to keep the bias small (ie, the predicted value closest to the "truth" as possible), but also as few predictors as possible to keep the variance (error) of prediction small. When the estimated random effects for center were close to zero, we eliminated the random component. We present the final models in our results section and a comparison of model builds in our **Supplementary Tables I-V**, online; available at www.jpeds.com.

Analyses were performed using R version 4.2.2 (R Foundation for Statistical Computing) with statistical significance at a *P* value of less than .05.

Results

Centers and Teams Characteristics

A total of 78 transport teams comprising 196 members were recruited from 12 pediatric AMCs in North America. Among the centers, 66.6% served mixed pediatric and adult patient populations, while 75% of centers had dedicated pediatric teams. Only 33.3% of centers required simulation for initial provider credentialing. Center age and annual patient volume varied as presented in **Table I**.

The demographics of participants included 90 RNs, 57 RTs, 26 paramedics, and 23 EMT-Bs. All teams included nurses, with 65.3% having at least 1 RT. There was no physician (MD/DO) or advanced practice practitioners (APP) team members. The reminder of participants characteristics is summarized in **Table I**.

Simulation Performance Scores

The simulation performance scores, expressed as a percentage of the maximum potential score for the 3 scenarios, were as follows: NAT (median 89%, IQR 78-100), cardiac arrest (median 86.6%, IQR 66.6-93.3), and sepsis (median 63.3%, IQR

Table I. Critical care transport centers/teams characteristics

Center characteristics (n = 12)	Centers, n (%)
Center size (Annual number of patients transport)	
<500 (small)	2 (16.6%)
500-1000 (medium)	5 (41.6%)
1000-3000 (medium to large)	3 (25%)
3000-5000 (large)	0
>5000 (very large)	2 (16.6%)
Center age	
<10 years	1 (0.8%)
10-20 years	2 (16.6%)
20-30 years	4 (33.3%)
30-40 years	1 (0.8%)
>40 years	3 (25%)
Missing data	1 (0.8%)
Patient population	
Pediatric only	4 (33.3%)
Pediatric and adult	8 (66.6%)
Team types	
Pediatric only	9 (75%)
Pediatric and adult	3 (25%)
Requirement of simulation training for initial credentialing	
Yes	4 (33.3%)
No	8 (66.6%)
Requirement of simulation training to maintain competency	
Yes	11 (91.6%)
Missing data	1 (8.4%)
Number of sim hours of training required per year	
<10 hours/year	3 (25%)
11-20 hours/year	5 (41.6%)
>20 hours/year	3 (25%)
Missing data	1 (0.8%)
PICU medical control	
Yes	7 (58.3%)
No	5 (41.6%)
Team characteristics (n = 78)	**Teams, n (%)**
Clinical configuration	
Team includes RN	78 (100%)
Team includes ≥ respiratory therapy	51 (65.3%)
Team includes ≥1 paramedic	20 (25.6%)
Team includes neither paramedic nor respiratory therapy	10 (12.8)
Team includes both respiratory therapy and paramedic	3 (3.8%)
Team includes MD or APP	0
Number of monthly transport shifts per team member (n = 196)	Team members n (%)
≤6/month	7 (3.5%)
7-15/month	184 (93.8%)
≥16/month	5 (2.5%)
Years of experience per team member (n = 196)	
≤3	49 (25%)
3-11	98 (50%)
11-20	44 (22.5%)
>21	5 (2.5%)

PICU, pediatric intensive care unit.

45.5-81.8). For the 58 out of 78 teams that chose to intubate during the abusive head injury scenario, the airway management scores were 85.7 (IQR 71.4-100). Detailed performance data for each scenario are available in Table II.

Relationship between performance scores, teams, and centers characteristics

NAT Scores. In multivariable analysis, simulation performance was associated with the following covariates: presence of an RT or paramedic in the team, center age, center size, and teams belonging to centers containing both adult and pediatric teams (Table III). Specifically, the presence of an RT in the team was significantly associated with an average increase in score of 1.54 points (95% CI: 0.67, 2.41) and presence of a paramedic, with an average increase in score of 1.38 points (95% CI: 0.46, 2.31). Center age had a weak but significant positive effect on performance, for each year there was an increase in score of 0.04 points (95% CI: 0, 0.08). Teams belonging to larger sized centers tended to score lower than teams belonging to smaller centers. The only pairwise comparison that reached statistical significance was between large (1000 – 3000 transports/year) vs small centers (<500 transports/year): teams belonging to larger centers scored, on average, 1.29 points (95% CI: −2.51, −0.07) lower than teams belonging to smaller centers (Table III).

Airway Management Scores. We analyzed performance in airway management for the 58/78 teams who chose to intubate during the abusive head injury scenario. In multivariable analysis, simulation performance was associated with the following covariates: teams belonging to a center requiring simulation for credentialing and teams transporting both adults and children vs only children. Specifically, simulation requirement was associated with an increase of 0.88 points (95% CI: 0.35, 1.41). Teams transporting both pediatric and adult patients performed better on average by 0.68 points (95% CI: 0.25, 1.11).

Sepsis Scores. The only independent variable significantly associated with simulation performance was center age, which had a weak but significant positive association: for each year there was an increase in score of 0.1 points (95% CI: 0.07, 0.15).

Cardiac Arrest Scores. In multivariable analysis, simulation performance was associated with the following covariates: number of team members, center age, and presence of a paramedic in the team. Having 3 vs 2 team members was associated with an average higher score of 1.35 points (95% CI: 0.06, 2.64). Center age had a weak but significant positive effect on performance; for each year there was an increase of 0.07 points (95% CI: 0.02-0.12). Presence of a paramedic in the team was associated with 1.92 points increase in score (95% CI: 0.1, 3.75).

Correlations Across Performance Scores Within Teams. NAT score had a weak correlation with airway management score ($r = 0.31$, $P = .015$) and the cardiac arrest score ($r = 0.23$, $P = .045$) and no correlation with the sepsis score ($r = 0.05$, $P = .6$). Sepsis and airway scores were not correlated ($r = 0.2$, $P = .12$). Cardiac arrest and airway scores were not correlated ($r = 0.18$, $P = .16$).

Average Comparative Scores. Independent variables significantly associated with average comparative performance were

Table II. Simulation performance score across the 3 scenarios and the optional airway management checklist

Simulation scenario	Percent correct
Nonaccidental abusive head injury	
Assess both airway and breathing. Verbalize in the first 3 minutes.	80%
Assess hemodynamics (BP, HR, pulses, cap refill) verbalize on clinical change	93%
Assess level of consciousness (reaction to tactile stimuli and pupil reactivity)	80%
Verbalize concern for increased ICP by stating HR, BP, and RR changes	85%
Apply neuroprotective measures (HOB elevated and keep head midline)	68%
Administer hyperosmolar solution (3% Hypertonic saline or mannitol)	95%
Perform BVM with correct hand position and verify good seal	95%
Verbalize need for definitive airway	97%
Medical control OR receiving facility contacted to update change in patient clinical status	92%
Performance score	89%
Airway management (if intubation performed, n = 60)	
Use induction agents for intubation	70%
Check the function of the blade	93%
Use appropriate size ETT (3,4)	96%
Use cuffed ETT	61%
Check suction catheter function	95%
Confirm ETT placement with ETCO2 monitoring	95%
Time to intubation in seconds, median (IQR)	30 (19, 45) seconds
Performance score	85.7%
Sepsis	
Verbalize suspected sepsis as potential differential	62%
Obtain a second access	56%
Administer 10-20 ml/kg crystalloid fluid bolus rapid infusion technique	78%
Reassess vital signs after fluid bolus (HR and BP)	83%
Reassess physical exam findings (at least 2 of the following: crackles/rales, hepatomegaly, or cap refill)	38%
Administer 10-20 ml/kg crystalloid fluid bolus rapid infusion technique	57%
Reassess vital signs after fluid bolus (HR and BP)	68%
Reassess physical exam findings (at least 2 of the following: crackles/rales, hepatomegaly, or cap refill)	23%
Administer inotropic agent.	83%
Verbalize need for second IV antibiotic	50%
Contact medical control of accepting hospital to notify of patient status change	97%
Performance score	63.3%
Cardiac arrest	
Check change in pulse/rhythm immediately	80%
Verbalize asystole and start CPR	75%
Start chest compressions (rate 100-120)	96%
Place appropriately sized pads correctly	90%
Verbalize use of waveform capnography to assess quality of chest compressions	37%
Administer epinephrine dose	96%
Perform pulse/rhythm check (central pulse) at 2 and 4 minutes	79%
Minimize CPR pause <10 seconds throughout case	82%
Verbalize ventricular fibrillation	78%
Verbalize "resume CPR" after V-Fib rhythm identified	80%
Defibrillate with 2-4 J/kg	88%
Minimize pause in chest compressions post shock delivery	85%
Verbalize ROSC at pulse check	85%
Use appropriate ventilation (1-2 breaths every 3 seconds) can be manual or mechanical	63%
Notify medical control or accepting hospital patient is in cardiac arrest	90%
Performance score	86.6%

BP, blood pressure; *CPR*, cardiopulmonary resuscitation; *HR*, heart rate; *IV*, intravenous.

center age, presence of an RT and paramedic within the team, and combined pediatric and adult teams. For each year increase in center there was an increase in z score of 0.04 points (95% CI: 0.02, 0.06). Presence of an RT was associated with an increase in score of 0.5 points (95% CI: 0.13, 0.86), whereas presence of a paramedic with increase of 0.49 points (95% CI: 0.1, 0.88). Combined pediatric and adult teams had on average lower scores compared with pediatric only teams by 0.37 points (95% CI: −0.68, −0.06) (III).

Sensitivity Analysis Results. Sensitivity results are presented in **Supplementary Table V**, online; available at www.jpeds.com.

Discussion

In this multicenter study, we used simulated in situ cases to assess the performance of pediatric CCT teams in a national cohort of transport centers. Our findings revealed variability in center characteristics among participants, with center age and presence of RTs and paramedics in the team being associated with higher simulation-based performance scores across all scenarios. Conversely, combined pediatric and adult teams had a lower score, on average, than pediatric teams across all scenarios. Other factors were scenario specific. This study represents the first effort to evaluate pediatric

Table III. Center and team variables associated with simulation performance for the 3 scenarios and the optional airway management checklist

Simulation scenario	Variable	Effect estimate* (95% CI)	*P* value
Nonaccidental abusive head injury	RT (yes vs no)	1.54 (0.61, 2.48)	.002
	Paramedic (yes vs no)	1.38 (0.39, 2.38)	.008
	Program age (years)	0.04 (0.00, 0.08)	.05
	Program size		
	Medium vs small	−0.77 (−1.64, 0.09)	.25
	Medium to large vs small	−1.2 (−2, −0.36)	.04
	Very large vs small	−1.3 (−2.5, −0.09)	.17
	Combined pediatric/adult teams vs pediatric teams	−0.76 (−1.56, −0.04)	.07
Sepsis	Program age (years)	0.11 (0.07, 0.15)	<.001
	Transporting adult and pediatric patients (vs pediatric only)	0.7 (−0.24, 1.63)	.15
Cardiac arrest	Number of team members (3 vs 2)	1.35 (0.06, 2.64)	.042
	Program age (years)	0.07 (0.02, 0.12)	.005
	Paramedic (yes vs no)	1.92 (0.1, 3.75)	.04
	RT (yes vs no)	1.27 (−0.32, 2.85)	.12
Airway management (Optional, n = 58)	Simulation test required for credentialing	0.88 (0.35, 1.41)	.002
	Paramedic (yes vs no)	0.47 (−0.12, 1.05)	.12
	PICU medical control (yes vs no)	0.46 (−0.03, 0.96)	.07
	Transporting adult and pediatric patients (vs pediatric only)	0.68 (0.25, 1.11)	.004
Comparative performance (z score), averaged over non-accidental head injury, sepsis and cardiac arrest	RT (yes vs no)	0.5 (0.13, 0.86)	.009
	Paramedic (yes vs no)	0.49 (0.1, 0.88)	.015
	Program age (years)	0.04 (0.02, 0.06)	<.001
	Combined pediatric/adult teams vs pediatric teams	−0.37 (−0.68, −0.06)	.022
	Program size		
	Medium vs small	−0.12 (−0.62, 0.38)	.63
	Medium to large vs small	−0.72 (−1.2, −0.24)	.004
	Large vs small	−0.4 (−1.12, 0.32)	.28

95% CI, 95% confidence intervals; *PICU*, pediatric intensive care unit.
*Coefficients are estimated from mixed effects multivariate linear regression, the dependent variable is each scenario's score (or intubation checklist). Clustering at center level is included in the model only if random effects are significant (intraclass correlation coefficient of at least 0.1).

CCT performance in a simulated setting and to explore the impact of center and team characteristics.

In the NAT scenario, the overall median score was 89, indicating strong performance by the participating teams. The item with the lowest performance was the application of neuroprotective measures, with only 68% of teams demonstrating familiarity with target therapy for increased intracranial pressure following pediatric head injury. This finding highlights the potential need for more focused education or implementation of guidelines to improve adherence to best practices in high-acuity conditions.

The median score for the cardiac arrest scenario was 86.6. The lowest performing items were the use of waveform capnography to guide chest compression quality (37% of teams) and the appropriate ventilation rate (63% of teams). These findings underscore the need for better adherence to up-to-date guidelines, as suboptimal compliance with ventilation rates during cardiac arrest resuscitation has been reported even in tertiary children's hospitals.[21-24]

Teams in the sepsis scenario showed a median performance score of 63.3%, lower than the performance in the other scenarios. Despite extensive research and international initiatives to improve the quality of pediatric sepsis care through implementing guidelines and policies, the actual implementation of these guidelines in pediatric CCT settings remains uncertain.[18] It is also important to consider that the scoring rubric used in this study may not have encompassed all necessary elements for effective sepsis evaluation and treatment. The performance in reassessing patients following fluid boluses and the relatively low verbalization of sepsis as a potential diagnosis suggest that transport centers may benefit from more robust quality initiatives and guidelines for pediatric sepsis care. In addition, the sepsis case was conducted in a simulated ED room instead of a simulated transport vehicle, which represents another common practice environment for CCT teams when receiving patients from referral EDs. Consequently, the transition of care from the ED team to the CCT team may have influenced team performance.

Notably, the common independent variables associated with better performance scores across all 3 scenarios was center age in years and presence of RTs and paramedics in the team. Although it is difficult to make definitive conclusions about contribution of center's age, it may suggest that longer-established centers develop more robust protocols and gain more experience over time, which results in greater provider knowledge and familiarity with clinical pathways and guidelines. This may lead to improved decision-making and more effective interventions when managing complex cases, such as critically ill patients. In addition, older centers may have better-established systems for communication and collaboration among health care team members, further enhancing the quality of care. RTs expertise plays a vital role in the assessment, diagnosis, and management of respiratory issues during transport. This specialized skill set likely aids in timely and effective interventions, which can lead to higher performance scores during simulations. Similarly, paramedics are trained to handle emergencies, assess patients quickly, and provide critical care during transport, which enhance the team's ability to manage acute situations effectively, ensuring that critically ill children receive appropriate care throughout their transport.

On the other hand, combined pediatric and adult teams had a lower score, on average, than pediatric teams across all scenarios. One possible explanation for this lower performance could be the inherent differences in the management of critically ill pediatric vs adult patients, during transport. Pediatric care often requires specialized knowledge and skills that differ from adult care, including developmental considerations and child-specific treatment protocols. As such, the presence of adult providers might inadvertently shift focus away from these critical aspects of pediatric care, potentially causing misalignment of clinical strategies among team members.

In the sensitivity subtasks analysis, older programs demonstrate better performance across all areas (assessment, diagnosis, and intervention), outlining the role of transport center's age in improved providers performance during transport. The presence of RTs in the team was associated with better performance in both assessment and diagnosis categories.

The requirement for simulation for initial credentialing was associated with lower scores in the assessment subtask. This association may have been spurious, as centers using simulation for initial credentialing were also less likely to have a paramedic in their teams. The number of simulation hours per year had a positive association with performance in the diagnostic subtask, showing the potentially important contribution of simulation training for enhancing the diagnostic skillsets of health care providers.

In this study, the majority of transport centers utilized simulation for continuing medical education; however, only a third of centers used it for initial credentialing, yet over 90% used it for maintenance of certification, similar to a recent national survey-based report.[6]

There are several limitations to consider. This study was conducted on a convenience sample of pediatric CCT centers at AMCs, which may not fully represent the broader landscape of CCT teams nationwide. A larger, more comprehensive and randomly selected sample could offer better representation of the factors influencing team performance nationwide. Although simulation-based scenarios offer a controlled and standardized environment, they may not fully capture the complexities and challenges encountered during actual interfacility transports. Furthermore, despite using modified Delphi approach in obtaining content validity of scenarios and checklists, the checklists used have limited validity evidence in the domains of internal structure, relationship to other variables and consequences. Finally, crucial aspects of pediatric transport care, such as communication, coordination, and team dynamics, were not comprehensively assessed. Future studies should consider incorporating a broader range of performance measures to achieve a more thorough evaluation of pediatric CCT teams.

In conclusion, this study provides valuable insights into understanding the performance of pediatric CCT teams using simulated in situ scenarios. We found an association between center age, presence of RTs and paramedics, and dedicated pediatric teams with higher CCT performance across various high acuity scenarios. Future research should aim to enhance the performance of pediatric CCT teams by integrating some of the findings from this study. ■

CRediT authorship contribution statement

Erin E. Montgomery: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ingrid A. Anderson:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Daniel J. Scherzer:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Grace M. Arteaga:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Ranna A. Rozenfeld:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Robyn Wing:** Writing – review & editing. **Rachel A. Umoren:** Writing – review & editing, Conceptualization. **Jessica J. Wall:** Writing – review & editing. **Devin A. McKissic:** Writing – review & editing. **Gabriela I. Centers:** Writing – review & editing, Formal analysis, Data curation. **Callie R. Searly:** Writing – review & editing. **Maria J. Mandt:** Writing – review & editing. **Brian M. Jackson:** Writing – review & editing. **Erin W. Hulfish:** Writing – review & editing. **Lauren M. Maloney:** Writing – review & editing. **Tina M. Duman-Bender:** Writing – review & editing. **Christopher Kennedy:** Conceptualization. **Mark Adler:** Writing – review & editing, Methodology, Conceptualization. **Jeffrey Naples:** Writing – review & editing. **Jeffrey Luk:** Writing – review & editing. **Stephen J. Gleich:** Writing – review & editing. **Riad Lutfi:** Conceptualization. **Kellie J. Pearson:** Writing – review & editing, Conceptualization. **Sakina Erika Reames:** Writing – review & editing, Project administration, Data curation. **Marc A. Auerbach:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Kamal Abulebda:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare no conflicts of interest.

The ImPACTS collaborative acknowledges the contributions of members of the International Network for Simulation-based Pediatric Innovation, Research and Education (INSPIRE) who have helped to shape this project and the International Pediatric Simulation Society (IPSS) for providing INSPIRE with space at their annual meetings for our research group.

Submitted for publication Dec 20, 2023; last revision received Aug 29, 2024; accepted Sep 9, 2024.

Reprint requests: Kamal Abulebda, MD, Associate Professor of Clinical Pediatrics, Division of Pediatric Critical Care, Department of Pediatrics, Riley Hospital for Children at IU Health, 705 Riley Hospital Dr, Phase 2, Room 4900, Indianapolis, IN 46202-5225. E-mail: kabulebd@iu.edu

References

1. Whitfill T, Auerbach M, Scherzer DJ, Shi J, Xiang H, Stanley RM. Emergency care for children in the United States: epidemiology and trends over time. J Emerg Med 2018;55:423-34.
2. Remick K, Gausche-Hill M, Joseph MM, Brown K, Snow SK, Wright JL, et al. Pediatric readiness in the emergency department. J Emerg Nurs 2019;45:e3-18.
3. Newgard CD, Lin A, Olson LM, Cook JNB, Gausche-Hill M, Kuppermann N, et al. Evaluation of emergency department pediatric readiness and outcomes among US trauma centers. JAMA Pediatr 2021;175:947-56.
4. Newgard CD, Lin A, Malveau S, Cook JNB, Smith M, Kuppermann N, et al. Emergency department pediatric readiness and short-term and long-term mortality among children receiving emergency care. JAMA Netw Open 2023;6:e2250941.
5. Orr RA, Felmet KA, Han Y, McCloskey KA, Dragotta MA, Bills DM, et al. Pediatric specialized transport teams are associated with improved outcomes. Pediatrics 2009;124:40-8.
6. Patel MM, Hebbar KB, Dugan MC, Petrillo T. A survey assessing pediatric transport team composition and training. Pediatr Emerg Care 2020;36:e263-7.
7. ImPACTS. Accessed September 30. 2024. https://www.impactscollaborative.com/
8. Auerbach M, Whitfill T, Gawel M, Kessler D, Walsh B, Gangadharan S, et al. Differences in the quality of pediatric resuscitative care across a spectrum of emergency departments. JAMA Pediatr 2016;170:987-94.
9. Abulebda K, Lutfi R, Whitfill T, Abu-Sultaneh S, Leeper KJ, Weinstein E, et al. A collaborative in situ simulation-based pediatric readiness improvement program for community emergency departments. Acad Emerg Med 2018;25:177-85.
10. Abulebda K, Whitfill T, Mustafa M, Montgomery EE, Lutfi R, Abu-Sultaneh S, et al. Improving pediatric readiness and clinical care in general emergency departments: a multicenter retrospective cohort study. J Pediatr 2022;240:241-8.e1.
11. Alsaedi H, Lutfi R, Abu-Sultaneh S, Montgomery EE, Pearson KJ, Weinstein E, et al. Improving the quality of clinical care of children with diabetic ketoacidosis in general emergency departments following a collaborative improvement program with an academic medical center. J Pediatr 2022;240:235-40.e1.
12. Abulebda K, Yuknis ML, Whitfill T, Montgomery EE, Pearson KJ, Rousseau R, et al. Preparedness for pediatric office emergencies: a multicenter, simulation-based study. Pediatrics 2021;148:e2020038463.
13. Yuknis ML, Abulebda K, Whitfill T, Pearson KJ, Montgomery EE, Auerbach MA, et al. Improving emergency preparedness in pediatric primary care offices: a simulation-based interventional study. Acad Pediatr 2022;22:1167-74.
14. Bigham MT, Schwartz HP, Collaborative ONPTQ. Quality metrics in neonatal and pediatric critical care transport: a consensus statement. Pediatr Crit Care Med 2013;14:518-24.
15. Bond WF, Lammers RL, Spillane LL, Smith-Coggins R, Fernandez R, Reznek MA, et al. The use of simulation in emergency medicine: a research agenda. Acad Emerg Med 2007;14:353-63.
16. Cheng A, Auerbach M, Hunt EA, Chang TP, Pusic M, Nadkarni V, et al. Designing and conducting simulation-based research. Pediatrics 2014;133:1091-101.
17. Eppich WJ, Adler MD, McGaghie WC. Emergency and critical care pediatrics: use of medical simulation for training in acute pediatric emergencies. Curr Opin Pediatr 2006;18:266-71.
18. Weiss SL, Peters MJ, Alhazzani W, Agus MSD, Flori HR, Inwald DP, et al. Surviving sepsis campaign international guidelines for the management of septic shock and sepsis-associated organ dysfunction in children. Pediatr Crit Care Med 2020;21:e52-106.
19. Duff JP, Topjian AA, Berg MD, Chan M, Haskell SE, Joyner BL, et al. 2019 American Heart Association focused update on pediatric advanced life support: an update to the American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Pediatrics 2020;145:e20191361.
20. Kochanek PM, Carney N, Adelson PD, Ashwal S, Bell MJ, Bratton S, et al. Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents–second edition. Pediatr Crit Care Med 2012;13:S1-82.
21. Topjian AA, Raymond TT, Atkins D, Chan M, Duff JP, Joyner BL, et al. Part 4: pediatric basic and advanced Life support: 2020 American Heart Association guidelines for cardiopulmonary resuscitation and emergency Cardiovascular care. Circulation 2020;142:S469-523.
22. Cheng A, Duff JP, Kessler D, Tofil NM, Davidson J, Lin Y, et al. Optimizing CPR performance with CPR coaching for pediatric cardiac arrest: a randomized simulation-based clinical trial. Resuscitation 2018;132:33-40.
23. Andreatta P, Saxton E, Thompson M, Annich G. Simulation-based mock codes significantly correlate with improved pediatric patient cardiopulmonary arrest survival rates. Pediatr Crit Care Med 2011;12:33-8.
24. Hunt EA, Walker AR, Shaffner DH, Miller MR, Pronovost PJ. Simulation of in-hospital pediatric medical emergencies and cardiopulmonary arrests: highlighting the importance of the first 5 minutes. Pediatrics 2008;121:e34-43.