JAMA Netw Open. 2023 Jan; 6(1): e2250941. Published online 2023 Jan 13.
doi: 10.1001/jamanetworkopen.2022.50941: 10.1001/jamanetworkopen.2022.50941

PMCID: PMC9857584 | PMID: 36637819

Emergency Department Pediatric Readiness and Short-term and Long-term Mortality Among Children Receiving Emergency Care

Craig D. Newgard, MD, MPH,[1] Amber Lin, MS,[1] Susan Malveau, MS,[1] Jennifer N. B. Cook, GCPH,[1] McKenna Smith, MPH,[2] Nathan Kuppermann, MD, MPH,[3,4] Katherine E. Remick, MD,[5,6] Marianne Gausche-Hill, MD,[7] Jeremy Goldhaber-Fiebert, PhD,[8] Randall S. Burd, MD, PhD,[9] Hilary A. Hewes, MD,[2] Apoorva Salvi, MS,[1] Haichang Xin, PhD,[1] Stefanie G. Ames, MD, MS,[2] Peter C. Jenkins, MD, MSc,[10] Jennifer Marin, MD, MS,[11,12,13] Matthew Hansen, MD, MCR,[1] Nina E. Glass, MD,[14] Avery B. Nathens, MD, PhD,[15] K. John McConnell, PhD,[1,16] Mengtao Dai, MS,[2] Brendan Carr, MD, MS,[17] Rachel Ford, MPH,[18] Davis Yanez, PhD,[19,20] Sean R. Babcock, MS,[1] Benjamin Lang, MD,[5,6] and N. Clay Mann, PhD, MS[2], for the Pediatric Readiness Study Group

[1]Department of Emergency Medicine, Center for Policy and Research in Emergency Medicine, Oregon Health & Science University, Portland

[2]Department of Pediatrics, University of Utah School of Medicine, Salt Lake City

[3]Department of Emergency Medicine, University of California, Davis School of Medicine, Sacramento

[4]Department of Pediatrics, University of California, Davis School of Medicine, Sacramento

[5]Department of Pediatric, Dell Medical School, University of Texas at Austin, Austin

[6]Department of Surgery, Dell Medical School, University of Texas at Austin, Austin

[7]Los Angeles County Emergency Medical Services, Harbor-UCLA Medical Center, Torrance, California

[8]Centers for Health Policy, Primary Care and Outcomes Research, Department of Medicine, Stanford University School of Medicine, Palo Alto, California

[9]Division of Trauma and Burn Surgery, Department of Surgery, Children's National Hospital, Washington, DC

[10]Department of Surgery, Indiana University School of Medicine, Indianapolis

[11]Department of Pediatrics, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania

[12]Department of Emergency Medicine, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania

[13]Department of Radiology, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania

[14]Department of Surgery, Rutgers New Jersey Medical School, Newark
[15]Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Ontario, Canada
[16]Center for Health Systems Effectiveness, Department of Emergency Medicine, Oregon Health & Science University, Portland
[17]Department of Emergency Medicine, Icahn School of Medicine at Mount Sinai, New York, New York
[18]Oregon Emergency Medical Services for Children Program, Oregon Health Authority, Portland
[19]Department of Anesthesia, Yale School of Medicine, New Haven, Connecticut
[20]Department of Biostatistics, Yale School of Public Health, New Haven, Connecticut
Corresponding author.

Article Information

Accepted for Publication: November 9, 2022.

Published: January 13, 2023. doi:10.1001/jamanetworkopen.2022.50941

Corresponding Author: Craig D. Newgard, MD, MPH, Department of Emergency Medicine, Center for Policy and Research in Emergency Medicine, Oregon Health & Science University, 3181 SW Sam Jackson Park Rd, Mail Code CR-114, Portland, OR 97239-3098 (newgardc@ohsu.edu).

Author Contributions: Dr Newgard had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Newgard, Cook, Kuppermann, Remick, Gausche-Hill, Jenkins, Carr, Ford, Lang.

Acquisition, analysis, or interpretation of data: Newgard, Lin, Malveau, Cook, Smith, Kuppermann, Goldhaber-Fiebert, Burd, Hewes, Salvi, Xin, Ames, Marin, Hansen, Glass, Nathens, McConnell, Dai, Yanez, Babcock, Mann.

Drafting of the manuscript: Newgard, Lin, Remick, Salvi, Marin, Ford, Yanez, Babcock.

Critical revision of the manuscript for important intellectual content: Newgard, Lin, Malveau, Cook, Smith, Kuppermann, Remick, Gausche-Hill, Goldhaber-Fiebert, Burd, Hewes, Xin, Ames, Jenkins, Hansen, Glass, Nathens, McConnell, Dai, Carr, Yanez, Lang, Mann.

Statistical analysis: Newgard, Lin, Smith, Salvi, Xin, Ames, McConnell, Dai, Yanez, Mann.

Obtained funding: Newgard, Remick.

Administrative, technical, or material support: Newgard, Malveau, Cook, Kuppermann, Hansen, Nathens, Ford, Mann.

Supervision: Newgard, Cook, Remick, Gausche-Hill.

Conflict of Interest Disclosures: Dr Newgard reported receiving a grant from the National Institutes of Health (NIH)/National Institute of Child Health and Human Development (NICHD) outside the submitted work. Ms Cook reported receiving grants from the NICHD and the National Heart, Lung, and Blood Institute outside the submitted work. Dr Kuppermann reported receiving grants from the NIH, Health Resources and Services Administration (HRSA), and Patient-Centered Outcomes Research Institute outside the submitted work. Dr Remick reported receiving a grant from HRSA outside the submitted work. Dr Hewes reported receiving a grant from HRSA outside the submitted work. Dr McConnell reported receiving grants from the NIH during the conduct of the study. No other disclosures were reported.

Funding/Support: This project was supported by the Eunice Kennedy Shriver NICHD (grant R24 HD085927) and the US Department of Health and Human Services HRSA (Emergency Medical Services for Children Targeted Issue Grant, grant H34MC33243-01-01).

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Group Information: A complete list of the member of the Pediatric Readiness Study Group appears in Supplement 2.

Disclaimer: The content is solely the responsibility of the authors. The views expressed in this manuscript are those of the authors and do not necessarily represent the views of these organizations.

Data Sharing Statement: See Supplement 3.

Additional Contributions: We would like to acknowledge and thank the departments of health, agencies, offices, and divisions of the following states for their help and collaboration with this project:

Arizona (Arizona Department of Health Services, Human Subjects Review Board and Bureau of Public Health Services); California (State of California Health and Human Services Agency, Committee for the Protection of Human Subjects and Office of Statewide Health Planning and Development, and California Department of Public Health, Health Information and Research Section); Florida (Agency for Health Care Administration, Florida Center for Health Information and Transparency, Bureau of Vital Statistics at the Florida Department of Health); Iowa (Iowa Hospital Association, Iowa Department of Public Health); Maryland (hMetrix, Maryland Department of Health, Vital Statistics Administration); Minnesota (Agency for Healthcare Research & Quality Healthcare Cost and Utilization Project); New Jersey (Rowan University Institutional Review Board, State of New Jersey Department of Health); New York (New York Department of Health Statewide Planning and Research Cooperative System, Bureau of Production Systems Management, and Institutional Review Board; New York City Department of Health and Mental Hygiene); North Carolina (Cecil G. Sheps Center for Health Services Research; North Carolina State Center for health Statistics); Rhode Island (Rhode Island Department of Health, Institutional Review Board, and Center for Health Data & Analysis); and Wisconsin (Agency for Healthcare Research & Quality Healthcare Cost and Utilization Project).

Received 2022 Jul 25; Accepted 2022 Nov 9.

Key Points

Question

Is high emergency department (ED) pediatric readiness (6 domains of preparedness) associated with lower short-term and long-term mortality among children?

Findings

In this cohort study of 796 937 children cared for in 983 EDs, there was 60% to 76% lower odds of in-hospital death associated with care in high-readiness EDs; among a subset of 545 921 children followed up beyond hospitalization, the benefit of high-readiness EDs persisted to 1 year. If all these EDs had high pediatric readiness, an estimated 1442 pediatric deaths may have been prevented.

Meaning

These findings suggest that care in EDs with high pediatric readiness is associated with lower short-term and long-term mortality among children.

This cohort study evaluates the association between emergency department (ED) pediatric readiness, in-hospital mortality, and 1-year mortality among injured and medically ill children receiving emergency care in 11 states.

Abstract

Importance

Emergency departments (EDs) with high pediatric readiness (coordination, personnel, quality improvement, safety, policies, and equipment) are associated with lower mortality among children with critical illness and those admitted to trauma centers, but the benefit among children with more diverse clinical conditions is unknown.

Objective

To evaluate the association between ED pediatric readiness, in-hospital mortality, and 1-year mortality among injured and medically ill children receiving emergency care in 11 states.

Design, Setting, and Participants

This is a retrospective cohort study of children receiving emergency care at 983 EDs in 11 states from January 1, 2012, through December 31, 2017, with follow-up for a subset of children through December 31, 2018. Participants included children younger than 18 years admitted, transferred to another hospital, or dying in the ED, stratified by injury vs medical conditions. Data analysis was performed from November 1, 2021, through June 30, 2022.

Exposure

ED pediatric readiness of the initial ED, measured through the weighted Pediatric Readiness Score (wPRS; range, 0-100) from the 2013 National Pediatric Readiness Project assessment.

Main Outcomes and Measures

The primary outcome was in-hospital mortality, with a secondary outcome of time to death to 1 year among children in 6 states.

Results

There were 796 937 children, including 90 963 (11.4%) in the injury cohort (mean [SD] age, 9.3 [5.8] years; median [IQR] age, 10 [4-15] years; 33 516 [36.8%] female; 1820 [2.0%] deaths) and 705 974 (88.6%) in the medical cohort (mean [SD] age, 5.8 [6.1] years; median [IQR] age, 3 [0-12] years; 329 829 [46.7%] female, 7688 [1.1%] deaths). Among the 983 EDs, the median (IQR) wPRS was 73 (59-87). Compared with EDs in the lowest quartile of ED readiness (quartile 1, wPRS of 0-58), initial care in a quartile 4 ED (wPRS of 88-100) was associated with 60% lower in-hospital mortality among injured children (adjusted odds ratio, 0.40; 95% CI, 0.26-0.60) and 76% lower mortality among medical children (adjusted odds ratio, 0.24; 95% CI, 0.17-0.34). Among 545 921 children followed to 1 year, the adjusted hazard ratio of death in quartile 4 EDs was 0.59 (95% CI, 0.42-0.84) for injured children and 0.34 (95% CI, 0.25-0.45) for medical children. If all EDs were in the highest quartile of pediatric readiness, an estimated 288 injury deaths (95% CI, 281-297 injury deaths) and 1154 medical deaths (95% CI, 1150-1159 medical deaths) may have been prevented.

Conclusions and Relevance

These findings suggest that children with injuries and medical conditions treated in EDs with high pediatric readiness had lower mortality during hospitalization and to 1 year.

Introduction

There are more than 30 million ED visits by children each year,[1] representing approximately 20% of children in the US.[2] More than 97% of EDs caring for children [3] are nonchildren's hospitals, accounting for 82.7% of pediatric ED visits. To address the highly variable emergency care of children,[4] the National Pediatric Readiness Project (NPRP) was created as a national quality improvement initiative to improve the quality and consistency of care for children in US EDs.[5] One aspect of the NPRP is increasing ED pediatric readiness, which includes care coordination, personnel and competencies, quality improvement, patient safety, policies and procedures, and availability of key equipment and supplies.[3,6] Previous studies[3,7,8] have shown that ED pediatric readiness varies widely among US hospitals and trauma centers, with children's hospitals having the highest overall scores.[7]

High levels of ED pediatric readiness are associated with lower mortality among children with critical illness[9] and those admitted to US trauma centers.[8,10] Whether the benefits of ED pediatric readiness extend beyond these groups is unknown. Other questions include the level of ED pediatric readiness required to improve survival, whether adequately prepared EDs can save children who would die in another ED, and the potential impact of ED readiness on long-term outcomes. One study[10] showed an association between high ED pediatric readiness and survival to 1 year among injured children admitted to trauma centers, but long-term outcomes have not been tested in other pediatric populations. Finally, the influence of hospital type and volume on the association between ED pediatric readiness and mortality remains incompletely characterized. Answers to these questions are important in determining the role of ED pediatric readiness in national health policy, hospital accreditation guidelines, and allocation of hospital resources. The objective of this study was to evaluate the association between ED pediatric readiness and in-hospital and 1-year mortality among injured and medically ill children receiving emergency care in 983 EDs in 11 states.

Methods

Study Design

We performed a retrospective cohort study that was reviewed and approved by institutional review boards at Oregon Health and Science University and the University of Utah School of Medicine, which waived the requirement for informed consent because the analysis was based on existing data and obtaining consent was not possible. We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines for cohort studies.[11]

Study Setting

We included 983 EDs with an NPRP assessment in 11 states over a 6-year period. To be included, each ED had to care for at least 10 children requiring hospitalization over the 6 years (including children admitted to the same hospital, transferred to another hospital, or dying in the ED). The 11 states were Arizona, California, Florida, Iowa, Maryland, Minnesota, New Jersey, New York, North Carolina, Rhode Island, and Wisconsin. We selected states on the basis of broad geographic representation and availability of the necessary hospital and patient identifiers.

Patient Population

We created a patient-level, chronological data set for consecutive children younger than 18 years receiving care in 983 EDs (records from 1 state allowed only event-level data). We identified the first ED visit for each child from January 1, 2012, through December 31, 2017, defined as the index ED visit (regardless of admission), marking time 0. The primary sample included children requiring hospitalization, transfer to another hospital, or dying in the ED during the index ED visit. For children residing in 6 states that granted approval to match state death records, we followed them for 1 year from the index ED visit (through December 31, 2018). For children transferred to another hospital, we matched available records from the second hospital to capture complete episodes of acute care. We excluded children who were treated in EDs without a matched NPRP assessment, missing hospital disposition, transferred out without a record from the second hospital, missing diagnosis codes or other key data, discharged alive from the ED, or treated in EDs that hospitalized fewer than 10 children during the 6-year study period (eFigure in Supplement 1). We divided the sample into children with injuries vs medical illnesses using hospital discharge *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* and *International Statistical Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM)* diagnosis codes to assess children with different clinical conditions and different systems of care (eg, regionalized trauma care for injured children).

ED Pediatric Readiness

The primary exposure variable was ED pediatric readiness for the initial ED, measured using the weighted Pediatric Readiness Score (wPRS) from the 2013 NPRP assessment.[3] We matched the NPRP assessment to the index ED record using hospital name, address, and zip code. The NPRP assessment was a national 55-question assessment based on national guidelines of US EDs providing emergency care 24 hours per day, 7 days per week, and completed by ED managers from January 1 through August 31, 2013.[3] The wPRS is a weighted score from 0 to 100, with higher scores denoting better readiness, developed by a national expert panel using a modified Delphi process and questions with moderate to high clinical relevance for children.[12] To create a consistent and generalizable definition for different levels of ED pediatric readiness, we calculated the quartiles of readiness (wPRS first quartile, 0-58; second quartile, 59-72; third quartile, 73-87; fourth quartile, 88-100) across all 983 EDs.

Variables

Patient-level variables included demographics (age, sex, race, and ethnicity), complex chronic conditions,[13] health insurance payer (a proxy of socioeconomic status), blood transfusion within 24 hours (a marker of acuity), Severity Classification System (1-5 scale, with higher numbers denoting higher clinical severity),[14] hospital procedures, injury severity and mechanism of injury (for injured children), and interhospital transfer. We used race and ethnicity, as collected in the hospital record, to account for potential inequities in care. For hospital procedures, we used the Agency for Healthcare Research and Quality Clinical Classification System[15] and mapped Clinical Classification System categories to standardized operative domains and blood transfusion. For injured children, we used the Abbreviated Injury Scale (AIS) score[16] and Injury Severity Score (ISS)[17] to measure injury severity. Because AIS and ISS are not included in administrative data, we used ICD ISS Map version 2.0 (Association for the Advancement of Automotive Medicine) to convert *ICD-9-CM* and *ICD-10-CM* diagnosis codes into standardized injury severity measures. We have previously validated ISS generated from *ICD-9-CM* diagnosis codes against hand-abstracted values.[18]

We characterized ED and hospital features using the NPRP assessment, American Hospital Association data,[19] and patient-level data. These variables included hospital type (based on children's hospital status, academic affiliation, trauma level, and specialty services), annual ED pediatric volume, annual pediatric ED admission volume, presence of a separate pediatric ED, and trauma center level (injured patients only).

Outcomes

The primary outcome was in-hospital mortality, including deaths in the ED. Among children residing in 6 states, we probabilistically linked[20] (LinkSolv version 9; Strategic Matching) state death records to generate time to death within 365 days from the index ED visit. We linked records for each state using validated linkage routines[21,22] and variables for date of birth, home zip code, date of service, sex, race, and ethnicity. We validated the linkage results for each state using in-hospital outcomes and estimated capture rates for deaths within 1 year (eTable 1 in Supplement 1).

Statistical Analysis

We used descriptive statistics to characterize children and hospitals by quartile of ED pediatric readiness. We performed all analyses separately for the injury and medical cohorts. Data analysis was performed from November 1, 2021, through June 30, 2022. To evaluate the association between ED pediatric readiness and in-hospital mortality, we used patient-level mixed effects logistic regression models with a random intercept to account for clustering by the initial ED,[5] stratified by children with injury vs medical conditions (SAS statistical software version 9.4; SAS Institute). The unit of analysis was the patient. The injury model was based on a standardized risk-adjustment model for trauma,[8,23] including age, sex, race, ethnicity, health insurance payer, comorbidities, clinical severity, blood transfusion, injury severity (ISS), mechanism of injury, transfer status, state, and year. The medical model included the same variables, except for mechanism of injury and ISS. We collapsed race to Black, White, and other (ie, American Indian, Alaska Native, Asian, Pacific Islander, or multiracial) to allow model convergence. We assessed model fit using the C statistic, influential values, and diagnostic plots. To estimate the number of additional lives that could be saved by increasing ED pediatric readiness, we used the marginal predicted probabilities of mortality by quartile of readiness to calculate the reduction in observed mortality for children cared for in lower pediatric readiness EDs (quartiles 1-3) compared with children cared for in quartile 4 EDs. We calculated 95% CIs using the bootstrap method.

We tested prespecified subgroups to assess whether children with different clinical conditions and severity of illness may be more or less sensitive to ED pediatric readiness. Among injured children, subgroups included ISS greater than or equal to 16,[17,24] head AIS greater than or equal to 3 (serious brain injury), and Severity Classification System score greater than or equal to 4.[14] Among children with medical conditions, subgroups included Severity Classification System score greater than or equal to 4 and different types of clinical illness (respiratory, cardiovascular, and neurologic) according to *ICD-9-CM* and *ICD-10-CM* diagnostic code groupings.[25] We conducted stratified analyses by age group and transfer status. We tested the robustness of the results by adding hospital-level variables to the model, including hospital type, ED volume, admission volume, pediatric ED structure, and trauma center designation level (injured children).

Among children with outcomes to 1 year, we examined time to death by quartile of ED pediatric readiness using a flexible parametric model with restricted cubic splines for censored survival data[26,27] and variance adjustment based on clustering by the initial ED[28] implemented by the stpm2 package in Stata statistical software version 16 (StataCorp). We assessed model fit using Akaike information criterion, deviance, and Martingale residuals. As a sensitivity analysis, we repeated the models after omitting children who died in the ED and (separately) those who died within 2 days of ED presentation.

Missingness for individual variables is included in eTable 2 in Supplement 1. We used multiple imputation[29] to handle missing values and reduce bias in the analysis. The utility and validity of multiple imputation have been shown for emergency care cohorts built from similar data sources.[22,30] Because of differences between the injury and medical cohorts, we imputed missing data separately for the 2 cohorts using flexible chained equations, as implemented by Stata's mi impute chained command[31,32] and combined the results accounting for variance within and between data sets.[29,33]

Results

Among 22 033 662 children with an ED visit during the study period (eFigure in Supplement 1), 796 937 children were hospitalized and met the inclusion criteria (admission rate, 3.6%). Of the 796 937 children, 90 963 (11.4%) were in the injury cohort and 705 974 (88.6%) were in the medical cohort. Among the 90 963 injured children (mean [SD] age, 9.3 [5.8] years; median [IQR] age, 10 [4-15] years; 33 516

[36.8%] female), 1820 (2.0%) died during their hospital stay, including 1032 in the ED (57.0% of all injury deaths). Among 705 974 children in the medical cohort (mean [SD] age, 5.8 [6.1] years; median [IQR] age, 3 [0-12] years; 329 829 [46.7%] female), 7688 (1.1%) died during their hospital stay, including 6390 in the ED (83.1% of all medical deaths). Among the 983 EDs, 592 cared for injured children and 980 cared for children with medical illness. The median (IQR) wPRS across all 983 EDs was 73 (59-87). There were 539 714 (67.7%) children treated in quartile 4 EDs, 118 917 (14.9%) in quartile 3 EDs, 72 163 (9.1%) in quartile 2 EDs, and 66 143 (8.3%) in quartile 1 EDs. Patient characteristics for each cohort by quartile of ED pediatric readiness are included in Table 1 and hospital characteristics are shown in eTable 3 in Supplement 1.

The adjusted odds of dying in hospital were 60% lower among children cared for in high-readiness EDs in the injury cohort (wPRS quartile 4 vs 1, adjusted odds ratio [aOR], 0.40; 95% CI, 0.26-0.60) and 76% lower in the medical cohort (aOR, 0.24; 95% CI, 0.17-0.34) (Table 2). These results were consistent across all subgroups (Figure 1). Although there was a significant dose-response association between increased ED pediatric readiness and decreased mortality (linear trend for aORs across quartiles), the association with decreased mortality was most consistent for children treated in quartile 4 EDs. We estimate that increasing all lower readiness EDs (quartiles 1-3) to high readiness (quartile 4) could have resulted in an additional 288 lives (95% CI, 281-297 lives) saved in the injury cohort and 1154 lives (95% CI, 1150-1159 lives) saved in the medical cohort. The benefit of care in high pediatric readiness EDs was evident across all age groups (eTable 4 in Supplement 1), but varied for children requiring transfer to another hospital (eTable 5 in Supplement 1). The association between high pediatric readiness EDs (quartile 4) and lower mortality remained after accounting for ED structure, ED pediatric volume, ED admission volume, hospital type, and trauma level (eTable 6 in Supplement 1), when restricted to the 589 EDs that cared for children in both cohorts (eTable 7 in Supplement 1), and when removing the 1 state with event-level data (eTable 8 in Supplement 1). Model diagnostics indicated appropriate model fit, lack of multicollinearity, and a C statistic of 0.94 for the injury cohort and 0.92 for the medical cohort.

There were 545 921 children with outcomes to 1 year, including 62 588 (11.5%) injured children and 483 333 (88.5%) medical children. Among 1316 deaths in the injury cohort, 693 (52.7%) occurred in the ED, 477 (36.2%) as inpatients, and 146 (11.1%) following hospital discharge (2.1% cumulative 1-year mortality; median

[IQR] time to death, 0 [0-2] days). Among 6635 deaths in the medical cohort, 4150 (62.5%) occurred in the ED, 759 (11.4%) as inpatients, and 1726 (26.0%) following hospital discharge (1.4% cumulative 1-year mortality; median [IQR] time to death, 0 [0-7] days). Time to death was shorter among low-readiness EDs, with 90.6% of quartile 1 injury deaths (vs 72.5% of quartile 4 deaths) and 88.5% of quartile 1 medical deaths (vs 56.8% of quartile 4 deaths) occurring within 2 days (eTable 9 in Supplement 1). After accounting for ED case mix, the risk of death to 1 year was lowest among children treated in high-readiness EDs for the injury cohort (quartile 4 vs 1 adjusted hazard ratio, 0.59; 95% CI, 0.42-0.84) and the medical cohort (adjusted hazard ratio, 0.34; 95% CI, 0.25-0.45) (Figure 2 and eTable 10 in Supplement 1). Sensitivity analyses that excluded early deaths suggested that the association between high ED readiness and lower risk of death to 1 year was primarily secondary to the prevention of early deaths (eTable 11 in Supplement 1).

Discussion

In this cohort study, a high level of ED pediatric readiness was associated with lower short-term and long-term mortality among a heterogeneous group of hospitalized children receiving emergency care. The benefit was similar for children with different clinical conditions and severity of illness. These findings demonstrate the benefit of being adequately prepared to care for children with emergencies, regardless of hospital setting. To our knowledge, this study is the largest and most comprehensive evaluation of ED pediatric readiness to date, with major health policy implications.

Although the concept of acutely injured and ill children having lower mortality in EDs that are ready to care for them is intuitive, the evidence has been limited to children with critical illness[9] and those admitted to trauma centers.[8,10] The current study shows that the benefit extends to all hospitalized children cared for across a variety of settings. The mortality benefit persisted to 1 year, largely owing to the prevention of early deaths. Because the majority of children who die from acute injuries and illnesses do so early in their clinical course, EDs have the potential to change this trajectory. The mortality benefit was most consistent for EDs in the highest quartile of pediatric readiness (wPRS ≥88) and persisted after accounting for other hospital-level characteristics, suggesting a threshold effect. This finding is consistent with previous studies[8,9,10] and provides a target for EDs seeking to raise their level of pediatric readiness.

Our results have national policy implications. National hospital accreditation organizations could consider adopting high ED pediatric readiness standards for all hospitals caring for children, with similar state-level accreditation practices. The American College of Surgeons has already introduced a requirement to assess ED pediatric readiness as part of the 2022 trauma center verification guidelines.[34] ED pediatric readiness also could be tied to reimbursement for care. Such a value-based model would be consistent with other efforts by the Centers for Medicare & Medicaid Services and may incentivize hospitals to increase their level of ED pediatric readiness, as more than 60% of children seeking emergency care have public insurance.[1] In addition, the level of ED pediatric readiness could be made publicly available, allowing emergency medical services, physicians, and families to select high-readiness EDs. However, this option may have unintended consequences, such as worsened care in low-readiness EDs (based on further reductions in volume, clinician skill erosion, and greater quality divides), delays in care to avoid low-readiness EDs, and further competition among hospitals. Because 30% of children live more than 30 minutes from a high-readiness ED[35] and 27% of children transported by ambulance do not have a high-readiness ED available,[36] the optimal solution is to promote policies and incentives to increase ED pediatric readiness among all US hospitals, including rural and frontier regions.

Limitations

Our study has several limitations. Although the 11-state cohort included a variety of hospitals and ED practice settings, the inclusion of additional states could have changed our findings. We excluded very-low-volume EDs (ie, those admitting or transferring <10 children over 6 years), which also may have affected our findings. We used administrative state data, which can be subject to variations in coding and missing codes. However, we have validated the quality and accuracy of variables generated from similar data sources.[22,37] It is also possible that unmeasured confounding related to the selection of EDs and ED case mix could have influenced the results. We used multiple variables to assess known and potential confounders, and our results were consistent across multiple subgroups, strata, and sensitivity analyses.

Because we used the 2013 NPRP assessment of ED pediatric readiness, it is possible that the readiness of individual EDs has changed over time. The NPRP assessment was repeated in 2021, but these data and the accompanying patient-level ED and inpatient data are not yet available. An additional study is under way to evaluate changes in ED pediatric readiness from 2013 to 2021 and the impact on pediatric mortality. Because the pediatric readiness of EDs was not independently verified, inaccuracies could have been present.

Conclusions

In this cohort study, high ED pediatric readiness was associated with reduced in-hospital and 1-year mortality among injured and medically ill children receiving emergency care in 11 states, which appeared to be largely due to the prevention of early deaths. The findings of this study suggest that more than 1000 pediatric deaths may have been prevented in these states over 6 years by increasing the level of pediatric readiness among all EDs.

Notes

Supplement 1.

eFigure. Schematic of Cohort Creation

eTable 1. Linkage Validation

eTable 2. Missingness of Variables

eTable 3. Hospital Characteristics by Quartile of Emergency Department (ED) Pediatric Readiness

eTable 4. Stratified Analysis by Age Group for the Association Between ED Pediatric Readiness and In-Hospital Mortality

eTable 5. Stratified Analysis by Transfer Status for the Association Between ED Pediatric Readiness and In-Hospital Mortality

eTable 6. Sensitivity Analyses of Emergency Department Pediatric Readiness and In-Hospital Mortality, With the Sequential Addition of Hospital-Level Variables

eTable 7. Multivariable Models of Emergency Department (ED) Pediatric Readiness and In-Hospital Mortality When Restricted to EDs Serving Children in the Injury and Medical Cohorts (n = 589 EDs)

eTable 8. Multivariable Models of Emergency Department (ED) Pediatric Readiness and In-Hospital Mortality When Excluding the One State With Event-Level Data

eTable 9. Comparison of Days-to-Death Across Quartiles of Emergency Department Pediatric Readiness Among Children Who Died Within One Year in the Injury and Medical Cohorts (n = 7,951)

eTable 10. Time-to-Event Multivariable Spline Models

eTable 11. Sensitivity Analyses for Time-to-Event Multivariable Spline Models That Exclude Early Deaths

Supplement 2.

Pediatric Readiness Study Group

Supplement 3.

Data Sharing Statement

References

1. McDermott KW, Stocks C, Freeman WJ. Overview of pediatric emergency department visits, 2015. Healthcare Cost and Utilization Project Statistical Brief 242. August 7, 2018. Accessed December 7, 2022. https://www.ncbi.nlm.nih.gov/books/NBK526418/ [PubMed: 30277692]

2. National Center for Health Statistics . Emergency department visits within the pasts 12 months among children under age 18, by selected characteristics: United States, selected years 1997-208. 2019. Accessed December 7, 2022. https://www.cdc.gov/nchs/data/hus/2019/036-508.pdf

3. Gausche-Hill M, Ely M, Schmuhl P, et al.. A national assessment of pediatric readiness of emergency departments. *JAMA Pediatr*. 2015;169(6):527-534. doi: 10.1001/jamapediatrics.2015.138 [PubMed: 25867088] [CrossRef: 10.1001/jamapediatrics.2015.138]

4. Institute of Medicine, Committee on the Future of Emergency Care in the United States Health System . *Emergency Care for Children: Growing Pains*. National Academies Press; 2006.

5. Emergency Medical Services for Children (EMSC) National Resource Center . The National Pediatric Readiness Project. Accessed April 18, 2022. https://emscimprovement.center/domains/pediatric-readiness-project/

6. Remick K, Gausche-Hill M, Joseph MM, Brown K, Snow SK, Wright JL; American Academy of Pediatrics Committee on Pediatric Emergency Medicine and Section on Surgery; American College of Emergency Physicians Pediatric Emergency Medicine Committee; Emergency Nurses Association Pediatric Committee . Pediatric readiness in the emergency department. *Pediatrics*. 2018;142(5):e20182459. doi: 10.1542/peds.2018-2459 [PubMed: 30389843] [CrossRef: 10.1542/peds.2018-2459]

7. Remick K, Gaines B, Ely M, Richards R, Fendya D, Edgerton EA. Pediatric emergency department readiness among US trauma hospitals. *J Trauma Acute Care Surg*. 2019;86(5):803-809. doi: 10.1097/TA.0000000000002172 [PubMed: 30601455] [CrossRef: 10.1097/TA.0000000000002172]

8. Newgard CD, Lin A, Olson LM, et al.; Pediatric Readiness Study Group . Evaluation of emergency department pediatric readiness and outcomes among US trauma centers. *JAMA Pediatr*. 2021;175(9):947-956. doi: 10.1001/jamapediatrics.2021.1319 [PMCID: PMC8185631] [PubMed: 34096991] [CrossRef: 10.1001/jamapediatrics.2021.1319]

9. Ames SG, Davis BS, Marin JR, et al.. Emergency department pediatric readiness and mortality in critically ill children. *Pediatrics*. 2019;144(3):e20190568. doi: 10.1542/peds.2019-0568 [PMCID: PMC6856787] [PubMed: 31444254] [CrossRef: 10.1542/peds.2019-0568]

10. Newgard CD, Lin A, Goldhaber-Fiebert JD, et al.; Pediatric Readiness Study Group . Association of emergency department pediatric readiness with mortality to 1 year among injured children treated at trauma centers. *JAMA Surg*. 2022;157(4):e217419. doi: 10.1001/jamasurg.2021.7419 [PMCID: PMC8811708] [PubMed: 35107579] [CrossRef: 10.1001/jamasurg.2021.7419]

11. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative . The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008;61(4):344-349. doi: 10.1016/j.jclinepi.2007.11.008 [PubMed: 18313558] [CrossRef: 10.1016/j.jclinepi.2007.11.008]

12. Remick K, Kaji AH, Olson L, et al.. Pediatric readiness and facility verification. *Ann Emerg Med*. 2016;67(3):320-328.e1. doi: 10.1016/j.annemergmed.2015.07.500 [PubMed: 26320519] [CrossRef:

10.1016/j.annemergmed.2015.07.500]

13. Feudtner C, Feinstein JA, Zhong W, Hall M, Dai D. Pediatric complex chronic conditions classification system version 2: updated for *ICD-10* and complex medical technology dependence and transplantation. *BMC Pediatr*. 2014;14:199. doi: 10.1186/1471-2431-14-199 [PMCID: PMC4134331] [PubMed: 25102958] [CrossRef: 10.1186/1471-2431-14-199]

14. Alessandrini EA, Alpern ER, Chamberlain JM, Shea JA, Holubkov R, Gorelick MH; Pediatric Emergency Care Applied Research Network . Developing a diagnosis-based severity classification system for use in emergency medical services for children. *Acad Emerg Med*. 2012;19(1):70-78. doi: 10.1111/j.1553-2712.2011.01250.x [PubMed: 22251193] [CrossRef: 10.1111/j.1553-2712.2011.01250.x]

15. Agency for Healthcare Research and Quality . HCUP Clinical Classifications Software (CCS) for ICD-9-CM. March 6, 2017. Accessed January 8, 2018. https://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp

16. Association for the Advancement of Automotive Medicine . *Abbreviated Injury Scale (AIS) 2005 Manual*. Association for the Advancement of Automotive Medicine; 2005.

17. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14(3):187-196. doi: 10.1097/00005373-197403000-00001 [PubMed: 4814394] [CrossRef: 10.1097/00005373-197403000-00001]

18. Fleischman RJ, Mann NC, Dai M, et al.. Validating the use of ICD-9 code mapping to generate injury severity scores. *J Trauma Nurs*. 2017;24(1):4-14. doi: 10.1097/JTN.0000000000000255 [PMCID: PMC5323458] [PubMed: 28033134] [CrossRef: 10.1097/JTN.0000000000000255]

19. American Hospital Association . Annual survey data collection methods. Accessed December 11, 2022. https://www.ahadata.com/academics-researchers

20. Jaro MA. Probabilistic linkage of large public health data files. *Stat Med*. 1995;14(5-7):491-498. doi: 10.1002/sim.4780140510 [PubMed: 7792443] [CrossRef: 10.1002/sim.4780140510]

21. Newgard CD. Validation of probabilistic linkage to match de-identified ambulance records to a state trauma registry. *Acad Emerg Med*. 2006;13(1):69-75. doi: 10.1197/j.aem.2005.07.029 [PubMed: 16365326] [CrossRef: 10.1197/j.aem.2005.07.029]

22. Newgard CD, Malveau S, Zive D, Lupton J, Lin A. Building a longitudinal cohort from 9-1-1 to 1-year using existing data sources, probabilistic linkage, and multiple imputation: a validation study. *Acad Emerg Med*. 2018;25(11):1268-1283. doi: 10.1111/acem.13512 [PubMed: 29969840]

[CrossRef: 10.1111/acem.13512]

23. Newgard CD, Fildes JJ, Wu L, et al.. Methodology and analytic rationale for the American College of Surgeons Trauma Quality Improvement Program. *J Am Coll Surg*. 2013;216(1):147-157. doi: 10.1016/j.jamcollsurg.2012.08.017 [PubMed: 23062519] [CrossRef: 10.1016/j.jamcollsurg.2012.08.017]

24. Champion HR, Sacco WJ, Lepper RL, Atzinger EM, Copes WS, Prall RH. An anatomic index of injury severity. *J Trauma*. 1980;20(3):197-202. doi: 10.1097/00005373-198003000-00001 [PubMed: 7359593] [CrossRef: 10.1097/00005373-198003000-00001]

25. Centers for Medicare & Medicaid Services . ICD-10: official CMS industry resources for the ICD-10 transition. 2022. Accessed October 27, 2022. https://www.cms.gov/Medicare/Coding/ICD10

26. Royston P, Parmar MK. Flexible parametric proportional-hazards and proportional-odds models for censored survival data, with application to prognostic modelling and estimation of treatment effects. *Stat Med*. 2002;21(15):2175-2197. doi: 10.1002/sim.1203 [PubMed: 12210632] [CrossRef: 10.1002/sim.1203]

27. Lambert PC, Royston P. Further development of flexible parametric models for survival analysis. *Stata J*. 2009;9(2):265-290. doi: 10.1177/1536867X0900900206 [CrossRef: 10.1177/1536867X0900900206]

28. Williams RL. A note on robust variance estimation for cluster-correlated data. *Biometrics*. 2000;56(2):645-646. doi: 10.1111/j.0006-341X.2000.00645.x [PubMed: 10877330] [CrossRef: 10.1111/j.0006-341X.2000.00645.x]

29. Rubin D. *Multiple Imputation for Nonresponse in Surveys*. John Wiley & Sons, Inc; 1987. doi: 10.1002/9780470316696 [CrossRef: 10.1002/9780470316696]

30. Newgard C, Malveau S, Staudenmayer K, et al.; WESTRN investigators . Evaluating the use of existing data sources, probabilistic linkage, and multiple imputation to build population-based injury databases across phases of trauma care. *Acad Emerg Med*. 2012;19(4):469-480. doi: 10.1111/j.1553-2712.2012.01324.x [PMCID: PMC3334286] [PubMed: 22506952] [CrossRef: 10.1111/j.1553-2712.2012.01324.x]

31. Raghunathan TE, Lepkowski JM, Van Hoewyk J, Solenberger P. A multivariate technique for multiply imputing missing values using a sequence of regression models. *Surv Methodol*. 2001;27:85-95. Accessed December 7, 2022. https://www150.statcan.gc.ca/n1/en/pub/12-001-x/2001001/article/5857-eng.pdf?st=F20lS1Kw

32. van Buuren S. Multiple imputation of discrete and continuous data by fully conditional

specification. *Stat Methods Med Res*. 2007;16(3):219-242. doi: 10.1177/0962280206074463 [PubMed: 17621469] [CrossRef: 10.1177/0962280206074463]

33. Little R, Rubin D. *Statistical Analysis With Missing Data*. 2nd Edition. John Wiley & Sons; 2002.

34. American College of Surgeons . Resources for optimal care of the injured patient: 2022 standards. 2022. Accessed December 7, 2022. https://www.facs.org/quality-programs/trauma/quality/verification-review-and-consultation-program/standards/

35. Ray KN, Olson LM, Edgerton EA, et al.. Access to high pediatric-readiness emergency care in the United States. *J Pediatr*. 2018;194:225-232.e1. doi: 10.1016/j.jpeds.2017.10.074 [PMCID: PMC5826844] [PubMed: 29336799] [CrossRef: 10.1016/j.jpeds.2017.10.074]

36. Newgard CD, Malveau S, Mann NC, et al.; Pediatric Readiness Study Group . A geospatial evaluation of 9-1-1 ambulance transports for children and emergency department pediatric readiness. *Prehosp Emerg Care*. Published online May 13, 2022. doi: 10.1080/10903127.2022.2064020 [PMCID: PMC9681031] [PubMed: 35394855] [CrossRef: 10.1080/10903127.2022.2064020]

37. Newgard CD, Zive D, Jui J, Weathers C, Daya M. Electronic versus manual data processing: evaluating the use of electronic health records in out-of-hospital clinical research. *Acad Emerg Med*. 2012;19(2):217-227. doi: 10.1111/j.1553-2712.2011.01275.x [PMCID: PMC3278860] [PubMed: 22320373] [CrossRef: 10.1111/j.1553-2712.2011.01275.x]

Figures and Tables

Table 1.

Children With Injuries and Medical Conditions Presenting to EDs, by Quartile of ED Pediatric Readiness

Cohort	Children, No. (%)			
	First quartile (wPRS 0-58)	Second quartile (wPRS 59-72)	Third quartile (wPRS 73-87)	Fourth quartile (wPRS 88-100)
Injury cohort (n = 90 963 children; n = 592 EDs)				
Children, No.	6409	8458	10 950	65 146
Age group, y				
<1	418 (6.5)	461 (5.5)	831 (7.6)	6179 (9.5)

1-4	882 (13.8)	1185 (14.0)	1630 (14.9)	13 383 (20.5)
5-9	1087 (17.0)	1556 (18.4)	2089 (19.1)	14 374 (22.1)
10-12	679 (10.6)	914 (10.8)	1207 (11.0)	8415 (12.9)
13-15	1560 (24.3)	1946 (23.0)	2408 (22.0)	12 373 (19.0)
16-17	1783 (27.8)	2396 (28.3)	2785 (25.4)	10 422 (16.0)
Sex				
Female	2373 (37.0)	3012 (35.6)	3997 (36.5)	24 134 (37.1)
Male	4036 (63.0)	5446 (64.4)	6953 (63.5)	41 012 (62.9)
Race and ethnicity				
Black	694 (10.8)	1377 (16.3)	1366 (12.5)	11 212 (17.2)
Other or multiple[a]	1366 (21.3)	1954 (23.1)	2544 (23.2)	15 869 (24.4)
White	4349 (63.0)	5127 (60.6)	7040 (64.3)	38 065 (58.4)
Hispanic	1736 (27.1)	2080 (24.6)	2996 (27.4)	19 670 (30.2)
Comorbidities				
None	5922 (92.4)	8003 (94.6)	10 252 (93.6)	59 922 (92.0)
1	385 (6.0)	362 (4.3)	539 (4.9)	3873 (6.0)
≥2	102 (1.6)	93 (1.1)	159 (1.5)	1351 (2.1)

Abbreviations: ED, emergency department; wPRS, weighted Pediatric Readiness Score.

[a] Other includes American Indian, Alaska Native, Asian, and Pacific Islander.

[b] Major surgery included brain, spine, thoracic, abdominal, pelvic, and neck procedures.

Table 2.

Multivariable Models of ED Pediatric Readiness and In-Hospital Mortality for Children With Injuries and Medical Conditions Presenting to EDs[a]

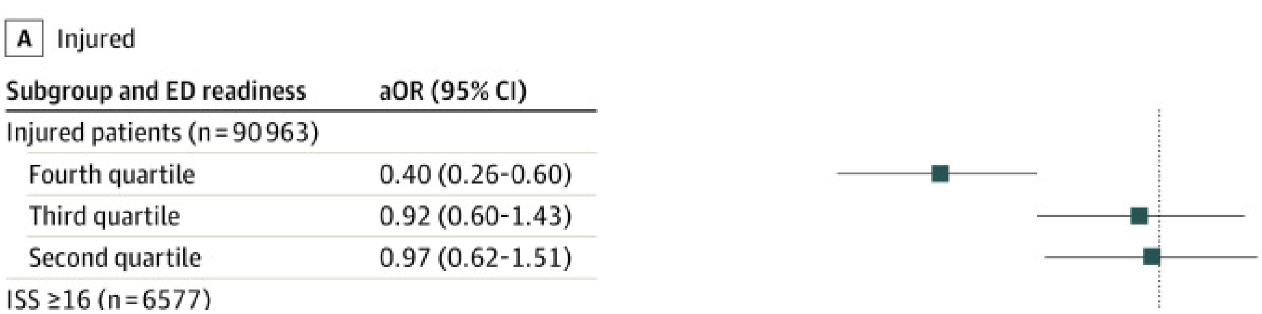
Variable	OR (95% CI)	
	Injured children (n = 90 963; 592 hospitals)	Medical children (n = 705 974; 980 hospitals)
ED wPRS		
First quartile (wPRS 0-58)	1 [Reference]	1 [Reference]

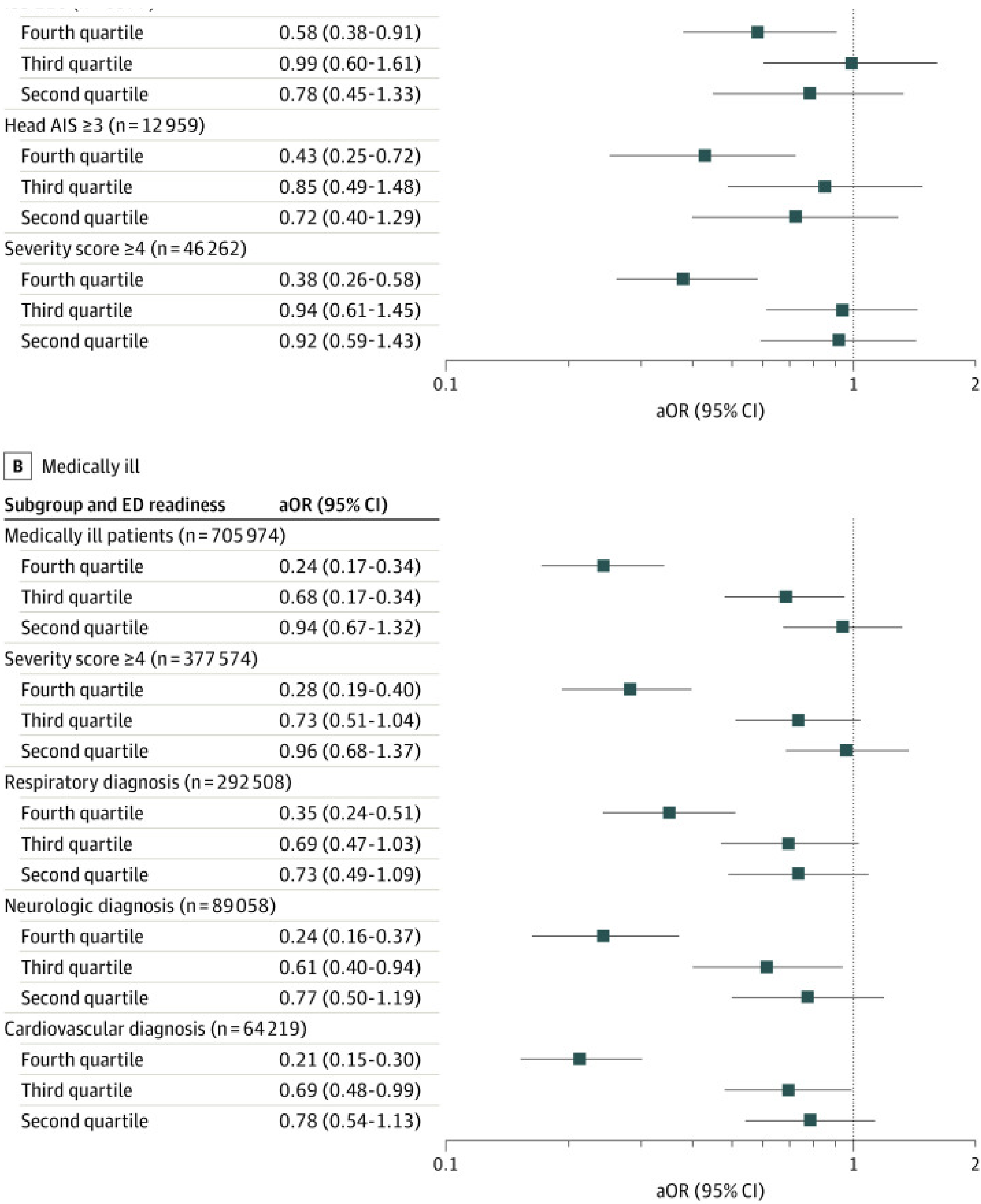
Second quartile (wPRS 59-72)	0.97 (0.62-1.51)	0.94 (0.67-1.32)
Third quartile (wPRS 73-87)	0.92 (0.60-1.43)	0.68 (0.48-0.95)
Fourth quartile (wPRS 88-100)	0.40 (0.26-0.60)	0.24 (0.17-0.34)
Female sex	1.03 (0.91-1.15)	0.89 (0.85-0.94)
Age group, y		
0	1 [Reference]	1 [Reference]
1-4	0.98 (0.79-1.21)	0.47 (0.44-0.51)
5-9	0.52 (0.41-0.65)	0.23 (0.21-0.25)
10-12	0.39 (0.30-0.50)	0.21 (0.19-0.23)
13-15	0.28 (0.22-0.35)	0.14 (0.13-0.16)
16-17	0.24 (0.19-0.30)	0.08 (0.07-0.09)
Race		
Black	0.98 (0.83-1.16)	1.68 (1.55-1.81)
Other	1.02 (0.88-1.19)	0.99 (0.92-1.07)
White	1 [Reference]	1 [Reference]
Hispanic ethnicity	0.88 (0.76-1.02)	0.56 (0.51-0.60)

Abbreviations: ED, emergency department; OR, odds ratio; NA, not applicable; wPRS, weighted Pediatric Readiness Score.

[a] The models also included fixed effects for state and year. Race was collapsed to Black, other (American Indian, Alaska Native, Asian, Pacific Islander, and multiracial), and White to allow model convergence.

Figure 1.

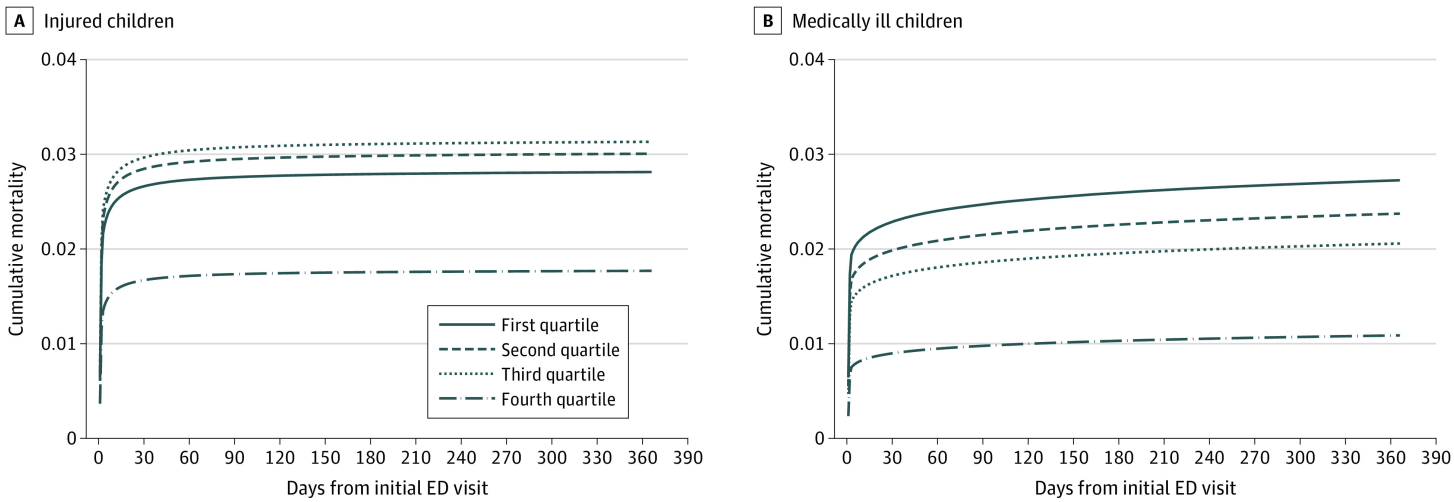




Adjusted Odds Ratios (aORs) for In-Hospital Mortality Among Children With Injuries and Medical Conditions Across Quartiles of Emergency Department (ED) Pediatric Readiness, Including Subgroups

We measured ED pediatric readiness using the weighted Pediatric Readiness Score (wPRS). The reference group for all analyses was the first quartile of ED pediatric readiness (wPRS score of 0-58). The x-axis is in the natural logarithm (ln) scale. Results are shown for the injury cohort (A) and medical cohort (B). The Severity Classification System score ranges from 1 to 5, with scores of 4 or higher representing high clinical severity. AIS indicates Abbreviated Injury Scale; ISS, Injury Severity Score.

Figure 2.



Adjusted Time to Death for Injured and Medical Children, by Emergency Department (ED) Pediatric Readiness

Graphs show data for the injured cohort (A; 62 588 children) and the medical cohort (483 333 children). The adjusted hazard ratio (aHR) for death to 1 year for quartile 4 (weighted Pediatric Readiness Score [wPRS] 88-100) vs quartile 1 (wPRS 0-58) of ED pediatric readiness was 0.59 (95% CI, 0.42-0.84) for the injury cohort and was 0.34 (95% CI, 0.25-0.45) for the medical cohort. In the medical cohort, comparison of quartile 3 (wPRS 73-87) vs quartile 1 of ED pediatric readiness showed an aHR of 0.68 (95% CI, 0.51-0.92).