# A National Analysis of Pediatric Trauma Care Utilization and Outcomes in the United States

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**Objectives:** More childhood deaths are attributed to trauma than all other causes combined. Our objectives were to provide the first national description of the proportion of injured children treated at pediatric trauma centers (TCs), and to provide clarity to the presumed benefit of pediatric TC verification by comparing injury mortality across hospital types.

**Methods:** We performed a population-based cohort study using the 2006 Healthcare Cost and Utilization Project Kids Inpatient Database combined with national TC inventories. We included pediatric discharges (≤16 y) with the *International Classification of Diseases, Ninth Revision* code (s) for injury. Descriptive analyses were performed evaluating proportions of injured children cared for by TC level. Multivariable logistic regression models were used to estimate differences in in-hospital mortality by TC type (among level-1 TCs only). Analyses were survey-weighted using Healthcare Cost and Utilization Project sampling weights.

**Results:** Of 153,380 injured children, 22.3% were admitted to pediatric TCs, 45.2% to general TCs, and 32.6% to non-TCs. Overall mortality was 0.9%. Among level-1 TCs, raw mortality was 1.0% pediatric TC, 1.4% dual TC, and 2.1% general TC. In adjusted analyses, treatment at level-1 pediatric TCs was associated with a significant mortality decrease compared to level-1 general TCs (adjusted odds ratio, 0.6; 95% confidence intervals, 0.4–0.9).

**Conclusions:** Our results provide the first national evidence that treatment at verified pediatric TCs may improve outcomes, supporting a survival benefit with pediatric trauma verification. Given lack of similar survival advantage found for level-1 dual TCs (both general/pediatric verified), we highlight the need for further investigation to understand factors responsible for the survival advantage at pediatric-only TCs, refine pediatric accreditation guidelines, and disseminate best practices.

**Key Words:** trauma center, injury, public health, outcomes

(*Pediatr Emer Care* 2016;00: 00–00)

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Disclosure: Dr Carr spends a portion of his time as the Director of the Emergency Care Coordination Center in the US Department of Health and Human Services. The views expressed here are not necessarily representative of the US Government. The other authors declare no conflict of interest.

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This project was funded by a grant from the National Institute of Child Health & Human Development (1R03HD061523-01), the Ruth L. Kirschstein National Research Service Award (F32HS018604-01) from the Agency for Healthcare Research and Quality, and the American Academy of Pediatrics' Ken Graff Young Investigators Grant. Dr Carr was funded by a career development award from the Agency for Healthcare Research & Quality (K08HS017960). Dr Myers was funded by a career development award from the National Cancer Institute (KM1CA156715). Dr Branas was funded by the Centers for Disease Control (R01CE001615).

This work was presented at the Pediatric Academic Societies' Annual Meeting 2011, Denver, CO.



ISSN: 0749-5161

## Background

Injury is the leading cause of death for children over a year of age. More than 8.7 million children are treated in emergency departments (EDs) for injury each year, including more than 7000 pediatric deaths.[1,2] Improving injury care has been recognized as a public policy priority by the US Department of Health and Human Services' Healthy People 2020 initiative.[3] The US trauma system plays a key role in maximizing injury survival by standardizing and improving prehospital, acute, and rehabilitation services. In all states with a formalized trauma system,[4,5] hospitals are verified by either a state accrediting body or the American College of Surgeons Committee on Trauma (ACS-COT).[6] Level-1 and 2 trauma centers (TCs) represent the highest level of trauma care, with rapid access to advanced resources (Table 1). Level-1 TCs have been demonstrated to provide a survival benefit to severely injured adults.[7]

The Emergency Medical Services for Children program was created to ensure that injured children receive appropriate emergency care.[8] However, the integration of pediatric patients into the trauma system remains incomplete. In 2006, the Institute of Medicine, through a series of publications, made strong recommendations to improve triage, transport, and treatment of injured children by focusing on regionalization, accountability, and improving the pediatric skill of providers.[9] Although 84.1% of the US adult population have access to a TC within an hour, only 71.5% of the pediatric population have access to a pediatric TC since fewer exist, resulting in 17 million children without timely access to specialized trauma care.[10,11] Freestanding children's hospitals, which house many of the pediatric TCs, are growing in number, experiencing increases in patient volume,[12] and are federally funded to deliver pediatric training despite higher total costs per admission.[13,14]

## Importance

Although TC care has been shown to be lifesaving for adults,[7,15] no such data exist for children. In fact, despite multiple single-center and state-based studies, a recent review concluded that that there is currently insufficient evidence to determine the best location of care for injured children.[16] Empirically, one could question whether increased trauma volume at general TCs could outweigh any benefit of comfort with the care of pediatric patients at pediatric TCs. Missing from the literature is a large, nationally representative, inclusive study that discriminates outcome by center type. This type of analysis is needed for policy and systems planning. Previous studies have used Healthcare Cost and Utilization Project (HCUP) national databases to look at pediatric trauma, describing the demographics, cost of injury care and showing improved outcomes at self-reported children's hospitals.[17–19] However, these have been hampered by the inability to identify hospitals by their TC status, and therefore have been unable to evaluate the effect of TC verification on patient outcomes.

## Objectives

We sought to determine the impact of trauma care on injured children by performing the first nationwide study to (1) describe

**TABLE 1.** Trauma Center Definitions

| | |
|---|---|
| Verified TC | Verified as a TC by ACS-COT or a recognized state organization based on a published set of criteria with initial and ongoing verification of compliance with these criteria |
| Pediatric TC | Verified (as previously mentioned) as having the resources and personnel required to care for injured children |
| General TC* | Verified (as previously mentioned) as having resources and personnel required to care for injured patients |
| | Although some demonstration of an ability to stabilize children is included in general TC verification, these hospitals have no specific verification as a pediatric TC |
| Dual-certified TC | Separately verified as both a general TC and a pediatric TC |
| Level 1 | Highest level of trauma verification as a comprehensive TC with all personnel and resources readily available, a strong quality improvement program and ongoing trauma-specific research within the center |
| Level 2 | Second level of trauma verification as a TC which can provide definitive initial care, with nearly all personnel and resources readily available and a quality improvement program |
| Level 3 | Able to provide prompt assessment, resuscitation, surgical intervention, and stabilization of injured patients |
| Levels 4–5 | Able to provide stabilization and transfer to a higher level of trauma care |
| Non-TC | Has not sought, or been granted, TC verification of any kind |

Each hospital can seek verification as either a general TC, pediatric TC, or both. Each verification will carry a level (1–5) based on the extent of resources and personnel available for the care of trauma patients. In this table, we define each TC type and level.

*General TCs are also referred to as "Adult Trauma Centers" or just "Trauma Centers" by some verification bodies, including the ACS-COT.

where injured children receive care and (2) evaluate outcomes for injured children by TC level and type.

## METHODS

### Data Sources, Setting, and Study Design

We used the 2006 Kids Inpatient Database (KID), a nationally representative database created by the Agency for Healthcare Research and Quality as a part of HCUP,[20] to undertake a population-based cohort study. Although more recent KID versions exist, the proprietary list of pediatric TCs exists only for the year 2006. The KID provides incident-level data, representing an 80% sample of pediatric discharges from 3739 hospitals in 38 states, and is weighted to allow for the calculation of national estimates. General TC status was identified using data from the Trauma Information Exchange Program of the American Trauma Society,[21,22] and pediatric TCs were identified using a modified version of the Penn Pediatric Trauma Database (PPTD), which was used previously to describe pediatric TC distribution.[10] Trauma centers can be accredited by either the ACS-COT or state-based organizations. Hospitals can self-report as TCs, but would not be included in this analysis as TCs because they lack verification. The PPTD was modified using ACS-COT lists and Internet searches, phone, and email contact with each state department, to ensure complete inclusion of all hospitals with true TC verification. A similar proportion of level-1 and 2 general TCs and level-1 and 2 pediatric TCs are verified by the ACS-COT as opposed to state agencies. Of those hospitals categorized as level-1 pediatric TCs without general trauma accreditation in the PPTD, 86% are freestanding children's hospitals, defined as those hospitals receiving payments from the US Department of Health and Human Services under the Children's Hospitals Graduate Medical Education Payment Program.[13] Internally at HCUP, maintaining anonymity of hospitals, TC level was merged with the hospital ID number using AHA number and hospital name. This study was considered exempt by the Children's Hospital of Philadelphia Institutional Review Board.

### Population

We included all pediatric patients (≤16 y) in the KID with primary or secondary diagnoses of injury as defined by *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes 800–999 (excluding late effects).[23–26] The KID includes up to 15 *ICD-9* variables. Multiple injury codes could be present, and would affect injury severity calculations (see later). This age cutoff was used because, due to physiology and injury mechanisms similarities with adults, older patients are often primarily transported to general TCs. Patients in the 14- to 16-year age range may be discriminately transported to either pediatric or general TCs, and we did not wish to exclude these patients given theoretical benefits of experience and volume at general TCs for these patients. Patients who were seen and released from EDs are not included in the KID and were intentionally excluded given our focus on serious injury. Patients transferred in to the hospital (inpatient-to-inpatient) were excluded to avoid double-counting patients. ED-to-ED transfers are attributed to the hospital in which they are admitted, because the original ED encounter is not captured by the KID.

### Primary and Secondary Outcomes

We sought to describe the distribution of admitted injured pediatric patients across hospital types in the United States. Specifically, we sought to determine the proportion of injured children who were treated at pediatric TCs, general TCs, dual TCs, and non-TC hospitals (Table 1). We also sought to determine differences in adjusted survival by hospital type overall as well as for specific subgroups of patients including the most severely injured and the youngest.

### Covariates

In adjusted analyses, we included variables that would likely confound the relationship between hospital type and survival with both patient-level covariates (injury severity, age, gender, blunt vs penetrating trauma, APR-DRG mortality risk level) and hospital-level covariates (region, total hospital patient volume, total hospital pediatric volume, teaching status, rural–urban location). The All Patient Refined Diagnosis Related Groups (APR-DRG) classification scheme is assigned by HCUP to each admission as a DRG-based severity measurement adjustment for each admission.[27] Patients were categorized as having either blunt or penetrating injuries by *ICD-9* codes for injury mechanism. Categories were not mutually exclusive and patients with both blunt and penetrating injuries were classified as such. We also used *ICD-9* codes to injury-adjust by calculating an injury severity score (ISS) for each discharge using methods validated in the pediatric population.[28] Injury severity score is based on the level of injury severity by body region, and is scored on a 1 to 75 scale, with higher scores denoting less survivable injury patterns. Subjects for whom injury severity could not be calculated were excluded from the regression analysis (719/153,380 records; <0.5%). Children's hospital status was not included as a confounder because freestanding children's hospitals were highly collinear with pediatric-only TCs, and identification of children's hospitals beyond freestanding ones lacks rigor as it is primarily self-reported. Instead, number of pediatric discharges was used to denote experience with pediatric care.

## Data Analysis

Descriptive analyses were used to describe the characteristics of patients admitted to TC and non-TC, and to calculate the proportion of injured children hospitalized within each TC category overall and for key subgroups (ISS > 15; age < 5 y). Tests of proportion were used to determine differences by hospital type. Univariable logistic regression models were used to determine differences between groups. Healthcare Cost and Utilization Project sampling weights were used to create national estimates.

Multivariable logistic regression was used to compare in-hospital mortality by trauma level of hospital while adjusting for covariates. Our primary comparisons were made between level-1 pediatric-only TCs, level-1 dual-verified TCs, and level-1 general TCs. Given significant differences found in severity of illness (significantly lower) for those patients admitted to non-TCs, as compared to level-1 TCs (all types), our final analyses excluded patients admitted to non-TCs. Adjusted subgroup analyses were performed for severely injured patients, younger patients, and severely injured younger patients. All analyses were performed using Stata 11 SE (College Station, TX) using the survey functions to generate nationally representative estimates.

# RESULTS

## Characteristics of Study Subjects

After applying sampling weights, we identified 153,380 injured children admitted to US hospitals in 2006. Overall mortality was 0.9%. Our subgroups of interest included 44,597 young patients (<5 y), 13,423 severely injured patients (ISS > 15), and 3492 severely injured young patients.

The 42.5% of children injured severely enough to require hospitalization were admitted to level-1 TCs, 17.4% were admitted to level 2 TCs, 7.6% were admitted to level 3, 4, or 5 TCs and 32.6% were admitted to non-TCs. Of all children admitted for injury, 43.6% were admitted to a hospital with pediatric trauma credentials of any level.

Younger children, severely injured children, and young severely injured children were all more likely to be seen at level-1 or 2 pediatric TCs. Fifteen percent of severely injured children were treated in hospitals without any trauma certification. Table 2 describes admission patterns for the entire injured pediatric population.

## Main Results

Our planned primary analyses separately compared outcomes of injured patients treated in different types of level-1 TCs (pediatric TC, general TC, and dual-certified TC) and non-TCs, which encompassed 75.1% of the entire cohort. Overall unadjusted mortality rate was highest at general TCs (2.1%) and lowest at non-TCs (0.3%) (Table 3).

Demographic factors included in our model are described by hospital type for level-1 TCs in Table 4. Consistent with effective prehospital regionalization, APR-DRG mortality risk score were found to be lower at non-TCs, as compared to level-1 TCs (non-TC: low risk 95%/high risk 0.7%; $P < 0.01$ compared to pediatric TC). Although ISS were found to have the same median score of 4 across all hospital categories, there was a lower interquartile range at non-TCs (IQ range, 1–4 non-TC; 1–9 level-1) and a statistically significant difference between non-TCs and

**TABLE 2.** Proportion of Children Admitted to Each TC Category Across the Entire Population and Within Subgroups by Age and Injury Severity

| | Type of TC Verification | All Subjects n = 153,380 | Young (<5 y) n = 44,597 | Severely Injured (ISS > 15) n = 13,423 | Young and Severely Injured n = 3492 |
|---|---|---|---|---|---|
| **Level 1** | **General level 1** | **7.9** | **7.3*** | **12.5*** | **8.9†** |
| | **Pediatric level 1** | **13.3** | **16.2*** | **17.0*** | **26.0*†** |
| | **Dual-certified level 1** | **21.3** | **22.6*** | **30.5*** | **29.0*** |
| | General level 1/pediatric level 2 | 1.1 | 1.1 | 1.6* | 1.8* |
| | General level 2/pediatric level 1 | 0.2 | 0.1* | 0.2 | 0.1 |
| Level 2 | General level 2 | 8.4 | 6.0* | 8.9 | 4.3*† |
| | Pediatric level 2 | 4.0 | 5.0* | 4.8* | 7.1*† |
| | General level 2/pediatric levels 2 and 3 | 3.7 | 3.4* | 4.8* | 4.6* |
| Levels 3/4/5 | General level 3 | 5.9 | 4.8* | 3.9* | 2.4*† |
| | General level 4 or 5 | 1.7 | 1.8 | 0.5* | 0.4* |
| | Non-TC | 32.6 | 31.5* | 15.3* | 15.5* |

Hospitals can be verified as general TCs and/or pediatric TCs, with levels 1 to 5 based on resources and commitment to trauma care (see Table 1 for definitions).

Rows in bold type were selected for the further analysis of outcomes by TC verification.

*$P < 0.01$ in 2-group analyses with "all subjects" group as reference.

†$P < 0.01$ between severely injured and young and severely injured groups.

**TABLE 3.** Number of Injured Patients Discharged From Non-TCs and Level-1 TCs Along With Breakdown of That Total Injury Admission Number by Age and Severity of Illness

| | Level-1 Pediatric TC | Level-1 Dual-certified TC | Level-1 General TC | Non-TC |
|---|---|---|---|---|
| Injury discharges, n | 20,415 | 32,624 | 12,040 | 50,048 |
| Severely injured (ISS > 15), n (%) | 2282 (11.2) | 4091 (12.5) | 1683 (14.0) | 2059 (4.1) |
| Young (<5 y), n (%) | 7229 (35.4) | 10,075 (30.9) | 3273 (27.2) | 14,048 (28.1) |
| Young and severely injured, n (%) | 907 (4.4) | 1011 (3.1) | 311 (2.6) | c541 (1.1) |
| Died, n | 204 | 462 | 251 | 165 |
| % of total | 1.0 | 1.4 | 2.1* | 0.3* |
| % among severely injured (ISS > 15) | 7.1 | 9.2 | 12 | 6.2 |
| % among young (<5 y) | 1.6 | 1.7 | 2.1 | 0.4 |
| % among young and severely injured | 11 | 13 | 13 | 5.7 |

Mortality for each hospital type also presented overall and by subgroup. See Table 1 for TC and level definitions.

*$P < 0.01$ with pediatric TCs as reference.

level-1 TCs, with lower ISS at the non-TCs. No significant difference was found between level-1 TCs (pediatric TC, dual TC, general TC) for either ISS or APR-DRG mortality risk score. Given the significant difference in risk of mortality and injury severity between level-1 TCs and non-TCs, we were concerned that our model could not fully severity-adjust differences between TCs and non-TCs.

We thus performed unadjusted and adjusted weighted logistic regression analyses to evaluate differences in mortality between the 3 types of level-1 TCs only (Table 5). In a fully adjusted analysis among level-1 TCs, we found that injured children treated at level-1 pediatric-only TCs were less likely to die than children treated at general TCs (odds ratio, 0.6; 95% confidence intervals, 0.4–0.9). There was no significant difference in

**TABLE 4.** Hospital and Demographic Factors by Trauma level

| | Level-1 Pediatric TC | Level-1 Dual-certified TC | Level-1 General TC |
|---|---|---|---|
| Age median (25–75 percentile) | 7 (2–12) | 9 (3–14)* | 11 (4–15)* |
| Male, % | 64.5 | 65.2 | 66.0 |
| ISS median (25–75 percentile) | 4 (1–9) | 4 (1–9) | 4 (1–9) |
| Penetrating, % | 3.8 | 4.3 | 7.7 |
| Zip income quartile, % | | | |
| Low (0–37,999) | 32.1 | 29.0 | 34.7 |
| Low-medium (38,000–46,999) | 21.2 | 24.7 | 25.2 |
| High-medium (47,000–61,999) | 24.6 | 23.4 | 23.1 |
| High (62,000+) | 22.1 | 22.9 | 17.0 |
| APR-DRG mortality risk, % | | | |
| Low | 88 | 87 | 85 |
| Low-medium | 6.2 | 6.4 | 7.5 |
| High-medium | 3.1 | 4.1 | 4.4 |
| High | 2.3 | 2.5 | 3.4 |
| Urbanicity, % | | | |
| Central metro (≥1 million) | 51.7 | 39.6 | 43.3 |
| Fringe metro (≥1 million) | 25.6 | 27.1 | 13.4 |
| Metro (250,000–999,999) | 6.5 | 15.9 | 18.9 |
| Metro (50,000–249,999) | 4.1 | 5.4 | 8.7 |
| Micro (20,000–50,000) | 6.8 | 7.2 | 9.9 |
| Non-micro (<50,000) | 5.3 | 4.8 | 5.8 |
| Pediatric discharges median (25–75 percentile) | 12,494 (11,225–14,478) | 7835* (5611–12,443) | 6742* (5150–9867) |
| Regions, % | | | |
| Northeast | 12.3 | 29.7 | 16.5 |
| Midwest | 41.6 | 21.2 | 17.6 |
| South | 20.4 | 33.3 | 44.9 |
| West | 25.7 | 15.8 | 21.1 |

See Table 1 for TC definitions.

*$P < 0.01$ as compared to level-1 pediatric TC.

 

**TABLE 5.** Odds Ratio of Death From Injury in Level-1 TCs by Verification Type of Admitting Hospital, Derived From Fully Adjusted Multivariable Regression Models Taking Into Account Survey Weighting

| | Level-1 General TC | Level-1 Dual-certified TC | Level-1 Pediatric TC |
|---|---|---|---|
| All patients | | | |
| Unadjusted (n = 65,087) | 1.0 | 0.7 (0.5–0.9)* | 0.5 (0.3–0.7)* |
| Adjusted (n = 61,278) | 1.0 | 0.9 (0.6–1.1) | 0.6 (0.4–0.9)* |
| Severely injured (ISS > 15) | | | |
| Unadjusted (n = 8056) | 1.0 | 0.7 (0.6–0.9)* | 0.5 (0.4–0.7)* |
| Adjusted (n = 7676) | 1.0 | 0.8 (0.6–1.2) | 0.6 (0.4–1.0) |
| Young (<5 y) | | | |
| Unadjusted (n = 20,579) | 1.0 | 0.8 (0.5–1.3) | 0.8 (0.4–1.3) |
| Adjusted (n = 19,440) | 1.0 | 1.0 (0.6–1.5) | 0.6 (0.4–1.0) |
| Young and severely injured | | | |
| Unadjusted (n = 2229) | 1.0 | 0.9 (0.6–1.3) | 0.8 (0.5–1.1) |
| Adjusted (n = 2132) | 1.0 | 1.3 (0.7–2.2) | 0.9 (0.5–1.6) |

See Table 1 for definitions of TCs.

*$P < 0.05$, all odds ratio point estimates are followed with 95% confidence intervals.

mortality between dual-certified TCs and general TCs. There was a higher risk of mortality at dual-certified TCs as compared to pediatric-only TCs, but this did not reach significance (odds ratio, 1.4; 95% confidence intervals, 1.0–1.9). Our subgroup analyses demonstrated similar trends to the overall outcomes analysis, with improved survival among younger and severely injured children at pediatric TCs, but these did not achieve statistical significance.

## Limitations

We present the first nationally representative evidence of the survival benefit associated with treatment at pediatric TCs. We acknowledge, however, our study limitations. First, the KID is a weighted sample and although the weighting factors include hospital size, teaching status, and urban/rural location, TC status is not one of the sampling strata. Thus, caution must be used in applying the sampling weights to our study. We chose to use the weighted sample because the proportions of TCs in the sample matches the proportion of TCs among hospitals across the country and the hospital characteristics used in the weighting vary with TC level and are likely to result in a representative sample. Indeed, 4.7% of US hospitals were level-I general TCs and 5.2% of hospitals within the KID sample were level-I general TCs, and 3.7% of hospitals in the United States were level-1 pediatric TCs and 3.2% of hospitals within the KID were level-1 pediatric TCs. A second important limitation is that the KID contains incident-level data and we, therefore, cannot track patients who are transferred from one facility to another. Also, since the KID samples admitted patients, patients may have been transferred from one ED to another before admission. If patients are treated initially in the ED of non-TCs and then transferred to higher levels of care for admission, we would expect this to bias our results toward the null. Estimates of effect size would underestimate the true effect given that the sickest patients are likely transferred out of non-TCs and TCs without pediatric credentialing, therefore being counted in the mortality estimates of tertiary pediatric referral centers only. Additionally, although we have adjusted for both injury severity and mortality risk, there is still a possibility that unmeasured confounding of severity of illness biases our results. It is for these reasons that we limited our analysis to level-1 TCs, among which we could find no significant differences in severity of illness and where transfer out is less likely. Although coding practices at the hospital level could vary, with either over-reporting or under-reporting injuries, the reliance of billing on complete coding increases the likelihood that clinically important injuries would be reported. The likelihood that a child with a primary injury mechanism would not have a single injury *ICD-9* code is low; therefore, this is unlikely to bias study inclusion, but difference in the number of *ICD-9* codes reports could affect the injury severity calculations. We know of no reason that this coding practice would vary by TC type, and this practice of ISS calculation based on *ICD-9* coding has been previously verified in pediatric trauma. Identification of TCs was purposefully done by verification status only, as we are interested in the effect of the verification process. Hospitals may act as TCs in the eyes of EMS and the hospital but be unwilling to go through the verification process for a variety of reasons. In our analysis, these hospitals would be classified as non-TCs and, if they perform at a higher level than “true” non-TCs, they would be expected to bias our analysis toward the null. Finally, although HCUP databases exist for years more recent than 2006, these could not be used because there is no reliable, updated inventory which allows for the identification of verified pediatric TCs across the United States. Investment in such an inventory would be vital to continue to rigorously study national variability in trauma care and outcomes.

## DISCUSSION

Previous studies have found that access to pediatric trauma care is limited compared to adult trauma care in the United States.[10] We found that less than half of all children injured severely enough to require hospital admission are admitted to pediatric TCs of any level (44.1%), and more than 1 in 7 seriously injured children are admitted to non-TCs. Even among the most vulnerable, this relationship persisted; more than 30% of the youngest (<5 y) and most seriously injured patients (ISS > 15) were admitted to hospitals with no pediatric trauma verification; 15% were admitted to hospitals with no trauma verification at all; and just under half (45%) were treated outside of level-1 pediatric TCs. Among severely injured patients, younger age is associated with an increased likelihood of admission to a pediatric level-1 TC and a lower likelihood of admission to a dual-verified level-1 TC, without change in the likelihood of admission to general or non-TCs. Despite recent efforts and progress, the trauma system's funneling of pediatric patients to the optimal location for admission has yet to achieve its ideal. Given limited bed space, not all injured children could be cared for at level-1 pediatric TCs, nor should they be. Increasing the use of lower level pediatric TC verification could function to ensure availability of age-appropriate resources at a larger number of hospitals, and may allow for local definitive care, especially for older and less severely injured children. Improving triage and transport, as well as increasing the number of verified level-1 TCs could ensure level-1 pediatric TC beds are available for the younger and more severely injured patients.

Improving access to pediatric TCs is relevant only if TC care is associated with improved outcomes. We demonstrate for the first time, in a nationally representative data set, that care at verified pediatric TCs may improve survival for injured children. We demonstrate a 40% lower odds of death among injured children treated at level-1 pediatric TCs compared to those treated at level-1 general TCs. Although our data cannot directly address the mechanisms underlying this survival difference, a number of factors about trauma system design are notable. Level-1 pediatric trauma verification requires validation of personnel and equipment specifically designed for the care of children beyond that required for level-1 general TC verification. It also creates a specific focus on pediatric trauma within the hospital as a result of compliance with the verification process and external audits. In addition, it is possible that verification as a pediatric TC may subsequently increase pediatric trauma volume at that center, thereby increasing experience. Regardless of the etiology, these data support the fact that pediatric trauma verification may improve outcomes for injured children. Although the overall mortality for injured children is low at 0.9% and we recognize that 0% mortality is an infeasible goal, we should still strive to create a system where a child's likelihood of death is the same regardless of where they are treated.

Interestingly, we found no significant survival difference between level-1 general TCs and level-1 dual-verified TCs. It is possible that even with a nationally representative data set, we lack sufficient power to find a small difference between these centers given the relative rarity of pediatric trauma death. However, this finding raises the possibility that structures and processes beyond those required by pediatric trauma verification, but which tend to exist at pediatric-only TCs, impart this survival benefit. For example, initial resuscitative leadership may be different between these 2 TC types. In a pediatric-only level 1 TC, the leadership of the resuscitation will typically include a pediatric trauma surgeon, whereas in dual-verified level 1 TCs, the initial responding physician leader responsible for resuscitative care may be an adult trauma surgeon. In addition, most level-1 pediatric-only TCs are freestanding children's hospitals (86%). Therefore, it may be the breadth of pediatric patients seen that imparts this advantage. Although similar research and quality improvement efforts must be demonstrated for all level-1 TCs, in a freestanding children's hospital, these efforts have a pediatric-specific focus. The ACS is advancing efforts to improve trauma care across the United States through initiatives such as the Trauma Quality Improvement Program. This program allows participating TCs to benchmark risk-stratified outcomes to other TCs. This program was recently made available for pediatric TCs as well, allowing comparison of outcomes by centers, which may identify translatable practices that improve outcomes.[29]

Although it was not the original purpose of this work, given the striking overlap between level-1 pediatric-only TCs and freestanding children's hospitals, these results provide some important evidence for the benefit of freestanding children's hospitals. The United States has invested in freestanding children's hospitals as a way to provide high-level clinical care to sick children and training to pediatric subspecialists.[13] Although there is evidence that the cost of care delivered at freestanding children's hospitals is higher than that for general hospitals,[14] to date there has been little evidence that this higher cost leads to improved outcomes. Given that 86% of the level-1 pediatric-only TCs studied here were also freestanding children's hospitals, we provide some of the first evidence that care at freestanding children's hospitals leads to improved survival. This evidence can, and should, be used to strengthen the support of freestanding children's hospitals as a public health benefit, especially in the wake of recent threats to Children's Hospital Graduate Medical Education Payment Plan funding and changes in Medicaid policies.[14,30,31]

We recognize that it is practically and financially unrealistic to create a network of freestanding pediatric level-1 TCs across the country. It is thus important to develop strategies that will allow for best practices to be disseminated. To do this, we must first determine the structures and processes of care which impart the observed survival benefit. We must then develop and trial implementation initiatives that allow for these best practices to be exported. This may mean broadening or adapting the current verification requirements for pediatric TCs within general hospitals. Or, it may mean using technology, such as telemedicine, to deliver knowledge and support from providers in high-volume centers to areas without access. Population-based strategies in which all hospitals in a region share responsibility (and financial risk) for the health outcomes of injured children could incentivize innovation and cooperation.

In summary, we have found that most pediatric trauma patients with injuries severe enough to require hospital admission are treated outside of pediatric TCs. In addition, we describe the first national evidence of improved survival at level-1 pediatric TCs, as compared to level-1 general TCs. We show a 40% lower odds of mortality at these verified pediatric-only TCs, which are comprised primarily of freestanding children's hospitals. This is the first national evidence of such a survival advantage and supports the continued movement toward improving pediatric access to specialized pediatric trauma care. Given the fact that level-1 dual TCs do not show this survival benefit, the findings raise the possibility that there are elements outside of those currently required for pediatric trauma credentialing that convey clinical benefit. Identifying these elements and then finding creative solutions to implement them within the framework of the current trauma system is the next step to improving the public health of children.

## ACKNOWLEDGMENTS

*The authors thank Drs Ryan Mutter and Claudia Steiner from the Agency for Healthcare Research & Quality for the assistance with the special data request; Ms Rama Salhi and Mr Michael Kallan for the data management assistance; Ms Catherine Wolff for the help with project management; and Dr Patrick Reilly, Chief of the Division of Traumatology, Surgical Critical Care and Emergency Surgery at the University of Pennsylvania School of Medicine, for the critical review of this article.*

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