Objective: To determine whether mortality and length of stay at a pediatric trauma center differ between patients admitted by interhospital transfer and those admitted directly from the injury scene.

Design: Analysis of prospectively collected data from a pediatric trauma center database.

Setting: A designated regional level I pediatric trauma center.


Main Exposure: Incident in-hospital mortality rates and length of stay at the trauma center were compared between patients admitted directly and those admitted by interhospital transfer, controlling for potential confounders.

Outcome Measures: In-hospital mortality and duration of hospitalization.

Results: Of 2192 patients admitted to the trauma center, 1175 (53.6%) were admitted directly from the injury scene. Patients admitted by interhospital transfer had higher injury severity and lower Glasgow Coma Scale scores at admission ($P < .01$). Of 31 deaths during the study period, 26 (83.9%) were among patients admitted by interhospital transfer. These patients had a 7-fold higher unadjusted incident rate of death (incidence rate ratio, 7.16; 95% confidence interval, 2.49-20.58) compared with those admitted directly. This finding remained (incidence rate ratio, 3.01; 95% confidence interval, 1.01-8.98) after adjustment for injury severity and Glasgow Coma Scale scores, elapsed time from injury until admission at the trauma center, and age. Among survivors, patients admitted by interhospital transfer stayed longer in the hospital than those admitted directly.

Conclusion: Pediatric trauma center mortality rates are lower among children admitted directly from the injury scene compared with those admitted by interhospital transfer.


TRAUMA IS A LEADING CAUSE of mortality and morbidity among children in the United States, with associated large societal burden. Prior studies show that where specialized pediatric emergency and critical care services are not available, the outcome of pediatric critical illness and injury is adversely affected. Availability of pediatric intensive care facilities has also been reported to favorably influence outcomes. Although pediatric intensive care facilities have increased in number and size over time, certain regions in the United States, particularly in rural areas, have limited access to such dedicated facilities. Such barriers to accessing specialized trauma care might delay receipt of definitive care with resultant adverse effects on patient outcomes. In many states, trauma care is regionalized, and studies of critically injured children show improved outcomes for children treated at designated pediatric trauma centers or centers with pediatric expertise. Early timing of definitive care at a trauma center is a basic tenet in the care of critically injured persons and might affect patient clinical outcomes and resource use at the trauma center.

It is, however, unknown whether patient outcomes and hospital resource use might vary according to the source of admission to pediatric trauma centers. It is hypothesized that among children admitted with traumatic injuries to a regional pediatric trauma center, patients admitted by interhospital transfer will have longer duration of hospitalization and higher in-hospital mortality rates compared with those who were hospitalized directly from the injury scene.
STUDY POPULATION AND STUDY SITE

All children from birth to 17 years of age admitted with traumatic injuries to the Intermountain Primary Children’s Medical Center (PCMC) between January 1, 2006, and September 30, 2007, were included in the study. There were no study exclusion criteria. The PCMC is designated a level I pediatric trauma center by the American College of Surgeons Committee on Trauma. It receives admissions from within and outside a vast network of 22 hospitals from the Intermountain Healthcare network and provides care to more than 1000 critically injured children annually, admitted from within the state of Utah and from surrounding states, including Arizona, Colorado, Idaho, Montana, New Mexico, and Wyoming. None of the referring hospitals was a pediatric trauma center.

DATA SOURCE

Data within the PCMC Trauma Registry database were analyzed for the study. The database contains patient information (eg, age and sex), physiologic data, and clinical outcomes at the trauma center, including survival status at hospital discharge and duration of hospital stay. Other data included the settings of care within the PCMC, including the operating room and the pediatric intensive care unit (PICU). For children who received treatment in the PICU, the use of medical devices or agents within the unit was documented, including arterial catheters, vasoactive medications, intracranial pressure monitors, central venous catheters, and mechanical ventilators. For these children, survival status at PICU discharge and duration of stay in the PICU were documented. The institutional review board at the University of Utah School of Medicine approved the study.

STUDY VARIABLES

Source of Admission

Source of admission was the main exposure of interest. Two sources of admission to the trauma center were evaluated, namely, interhospital transfer admissions after initial stabilization at a referring hospital and direct admissions from the injury scene.

Mechanisms of Injury and Body Sites Injured

Mechanisms of injury included motor vehicle crashes, bicycle and motorcycle crashes, falls, sports injuries, intentional injuries, submersion injuries, and farming injuries. Isolated injuries to the head, neck, abdomen, extremities, chest, spine, or multiple body sites were evaluated.

Duration of Care Before Trauma Center Admission

Among patients admitted by interhospital transfer, the duration of care before admission encompassed the time from injury to hospitalization at the referring hospital, duration of care at the referring hospital, and the transport time between the referring hospital and the emergency department (ED) at the trauma center. For patients admitted directly, it was the time from injury until arrival at the PCMC ED.

Injury Severity Score

Injury severity scores (ISSs) were measured at discharge from the PCMC (or death). Values range from 1 to 75, with higher values signifying higher severity. The ISS also categorized to differentiate more severe (ISS ≥ 15) from less severe (ISS ≤ 15) injuries, as previously described.

The Glasgow Coma Scale (GCS) score17 was determined at admission to the ED at the PCMC. Coma was defined as a GCS score of 8 or less. The GCS was incorporated into the analysis as a key injury severity variable because head injury is the most common cause (20%-30% mortality) for trauma-related death in children, and neurologic injuries account for nearly one-fifth of all pediatric injuries.18

Vasoactive Medications and Outcome Measures

Dopamine hydrochloride, epinephrine, norepinephrine bitartrate, vasopressin, or dobutamine was administered for hemodynamic support while the patients were in the PICU. The main outcomes of interest in the study were survival status (dead or alive) at hospital discharge and length of hospital stay at the PCMC.

STATISTICAL ANALYSIS

Patient-level clinical and demographic characteristics were compared between patients admitted directly and by interhospital transfer using the χ2 test or Fisher exact test for categorical data and the t test or Mann-Whitney test for comparisons of continuous data. Among children who received treatment at a PICU, comparisons were made among the use of medical devices or agents, duration of PICU stay, and PICU mortality, according to the source of admission.

Negative binomial regression methods account for distributions with the mode at zero and probability masses that decrease as the count increases, as in phenomena with low expected rates, such as child mortality.17 The fit of the model was assessed with the likelihood ratio test, whereas pseudo-R2 assessed the variance in mortality explained by the variables in the model.

Multiple linear regression analysis estimated the incremental length of stay (and the accompanying 95% CIs) to compare mortality rates according to the source of admission to the PCMC, with multivariate adjustment for injury severity and other potentially confounding variables. Negative binomial regression models account for distributions with the mode at zero and probability masses that decrease as the count increases, as in phenomena with low expected rates, such as child mortality.17 The fit of the model was assessed with the likelihood ratio test, whereas pseudo-R2 assessed the variance in mortality explained by the variables in the model.

Multiple linear regression analysis estimated the incremental length of stay (and the accompanying 95% CIs) for patients admitted by interhospital transfer vs those admitted directly, after controlling for potentially confounding variables. All who did not survive were excluded from the analysis of length of hospital stay. Because of skewness in the distribution of data for hospital length of stay, models for hospital length of stay were fit after logarithmic transformation of the variable, and the incremental length of stay was determined after exponentiation of the estimate. The fit of the model was assessed with the coefficient of multiple determination (adjusted R2). A 2-sided α level of .05 was used as the threshold for statistical significance. Analyses were conducted using Stata statistical software, version 8, for Windows (StataCorp, College Station, Texas).
PATIENT INTERHOSPITAL TRANSFER PATTERNS AND CHARACTERISTICS

Of 2192 patients admitted to the trauma center during the 21-month study period, 1175 (53.6%) were admitted directly from the injury scene. Nineteen hundred thirty-eight patients (88.4%) were admitted from injury scenes within Utah, whereas the remainder were admitted from neighboring states, including Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, and Wyoming. There were 1017 patients admitted by interhospital transfer, 852 (83.8%) of whom were brought from hospitals within Utah. Four hundred sixty-three (54.3%) of all patients transferred from Utah hospitals were notably from hospitals outside the Intermountain Healthcare network to which PCMC belongs, reflecting the regional nature of the PCMC trauma center. As expected, patients admitted by interhospital transfer had a greater than 2 times longer median elapsed time from injury to arrival at the PCMC (Table 1). Only 356 (16.2%) of all trauma patients admitted to the PCMC were admitted within 60 minutes of injury (ie, the golden hour).

Most children (61.5%) were male, with a mean age of 7 years. Severity of injury was greater among the patients admitted by interhospital transfer compared with those who had been admitted directly, as evidenced by the former patients having higher average ISSs and 2-fold higher frequency of more severe injury (ie, ISS >15) (Table 1). Furthermore, patients admitted by interhospital transfer were significantly more likely to be comatose when admitted to the trauma center compared with patients who had been admitted directly (P < .01). The predominant mechanisms of injury were falls, sports injuries, and motor vehicle crashes (Table 2). The head was the predominant site of injury to the children, whereas injuries to the extremities were a close second (Table 3).

HOSPITAL AND PICU RESOURCE USE

Treatment at a PICU was provided to 465 (21.2%) of the study sample, 300 (66.6%) of whom had been admitted by interhospital transfer. No difference was found in the use of medical devices or agents (Table 4) or length of PICU stay according to the source of admission (Table 5). Although the overall stay in the hospital was longer for patient admitted by interhospital transfer vs those admitted directly, no difference was found in overall hospital charges according to the source of admission (Table 5). In multivariate analysis, controlling for ISSs and GCS scores, elapsed time from injury until admission to the trauma center, and age, those patients who survived among those who had been admitted by interhospital transfer stayed 1.21 days (95%
than those who had been admitted directly (P<.01). Bivariate comparisons were performed with the χ² or Fisher exact tests. Percentages may not total 100% because only a fraction of the patients admitted to the pediatric intensive care unit received medical devices or agents.

Table 5. Mortality and Resource Use in a Regional Pediatric Trauma Center PICU and Hospital

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Direct Admission</th>
<th>Interhospital Transfer Admission</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PICU length of stay, median (IQR), h</td>
<td>23 (17-72) (n=165)</td>
<td>22 (15-48) (n=300)</td>
<td>.29</td>
</tr>
<tr>
<td>PICU mortality, %</td>
<td>3.0</td>
<td>7.7</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Hospital length of stay, mean (SD), d</td>
<td>6.6 (8.1) (n=1175)</td>
<td>9.3 (10.6) (n=1017)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Hospital mortality, %</td>
<td>0.4</td>
<td>3.6</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Hospital charges, median (IQR), $</td>
<td>7203 (3368-11 991)</td>
<td>7290 (3360-12 448)</td>
<td>.59</td>
</tr>
</tbody>
</table>

Abbreviations: IQR, interquartile range; PICU, pediatric intensive care unit. Bivariate comparisons were performed with the χ² and Fisher exact tests for categorical variables and the t test and Mann-Whitney test for continuous variables.

In this evaluation of a regionalized pediatric trauma care system, mortality rates were lower and hospital stay was shorter for children admitted directly from the scene of the injury vs those who underwent interhospital transfer to a regional pediatric trauma center. Contrary to the assumption that children who underwent stabilization at referring hospitals before interhospital transfer to a pediatric trauma center might have similar or better clinical status compared with those admitted directly on presentation to the pediatric trauma center, the patients admitted by interhospital transfer were sicker, as evidenced by higher ISSs and higher frequency of coma at the time of presentation to the study pediatric trauma center for definitive trauma care.

The study findings corroborate prior epidemiologic study of pediatric injuries, which suggests that most injuries occur in boys, with falls as the most frequent mechanism of injury, and injuries to the head and extremities are the most common.18 The study findings also provide insight into patterns of transfer to and outcomes for critically injured children at a level I pediatric trauma center that admits patients from multiple local and distant areas of injury, including interhospital referral from hospitals within and out of state. Few patients (16.2%) were transported to the trauma center within the critical golden hour, a factor that might be crucial to survival.19 This observation corroborates prior studies20,21 that reported longer transport times to trauma centers within rural regions, such as the study region, compared with urban settings. A notable finding regarding travel patterns among the study population and of the far-reaching effect of a regional pediatric trauma center was that more than half of all patients admitted by interhospital transfer were transported from outside the 22-hospital network to which PCMC belongs.

HOSPITAL SURVIVAL

Overall, 31 deaths occurred during the study period, 26 (83.9%) of which were among the patients admitted by interhospital transfer. Those patients had a 7-fold higher unadjusted incident rate of death (incidence rate ratio, 7.16; 95% CI, 2.49-20.58) compared with patients who had been admitted directly. After adjustment for ISSs and GCS scores, elapsed time from injury until admission to the trauma center, and age, patients admitted by interhospital transfer still had higher in-hospital mortality rates (incidence rate ratio, 3.01; 95% CI, 1.01-8.98; model pseudo-R²=0.49; likelihood ratio χ²=150.12; P<.001) than those who had been admitted directly (Table 6).

POST HOC ANALYSIS

In an effort to evaluate mortality associated with lack of appropriate transfer, we queried the Utah trauma database and screened for patients younger than 17 years treated at hospitals other than the level I pediatric trauma center. Although an exact analytic comparison with the current study cohort was not possible because of missing GCS scores in 425 of 1884 patients (22.6%), non–trauma center admission was associated with a trend toward an increased mortality rate (odds ratio, 2.7; 95% CI, 1.0-7.3) compared with direct trauma center admission, adjusted for patient age, sex, and ISS.
Trauma systems are organized on the premise that timely receipt of definitive trauma care within specialized trauma centers, where multidisciplinary expertise and coordination of care occur, might improve outcomes. Because of the paucity of such specialized pediatric-specific trauma centers nationally, prehospital triage is critical to ensuring that the most severely injured children are transferred to level I pediatric trauma centers, while avoiding inappropriate triage of mildly injured children to such centers. It is important that hospitals not designated as level I pediatric trauma centers receive injured children be able to provide necessary and appropriate resuscitative care and rapid transfer to level I pediatric trauma centers, if necessary. A 2-fold higher frequency (31% vs 14%) of major injury severity was observed among patients admitted by interhospital transfer compared with those who had been admitted directly. Similar to the results of a prior study, such observation connotes some discrepancy between actual clinical practice and guidelines that recommend that the most severely injured receive care at a specialized trauma center. The finding highlights the need for further study of triage for critically injured children with emphasis on improved understanding of the processes involved and the barriers to direct triage of children with major injury severity to level I trauma centers. Such barriers might include, among other factors, geographic distance, local resource limitations, and a perceived need to transport to the nearest ED regardless of institutional capacity to provide appropriate trauma care. It is critically important to identify barriers to appropriate patient triage that might be amenable to mitigation.

Similar to prior studies among injured adults, the present study suggests that outcomes for critically injured children might be worse if receipt of definitive care is delayed by initial stabilization at referring hospitals before interhospital transfer to a pediatric trauma center. To limit such delay, most trauma systems are believed to err on the side of minimizing undertriage of pediatric trauma cases rather than minimizing overtriage to level I trauma centers. In the present study, it was not possible to ascertain what clinical or nonclinical factors might have influenced prehospital triage. Clinical triage factors might include clinical decision making by the emergency medical personnel and severity of patient injury, whereas nonclinical factors might include parental or other caregiver preferences; state, regional, or local regulations that affect the choice of destination hospital; and hospital and emergency medical system capability and capacity. Concerns regarding lower levels of familiarity of prehospital emergency care professionals with pediatric vs adult emergency care management issues have led to calls for the presence of pediatric-specific experts within emergency medical systems. The involvement of such individuals in prehospital triage might improve efficiencies of care with minimization of undertriage and overtriage to level I trauma centers.

Another potential explanation for differential mortality according to admission source might be the provision of poor-quality care to critically injured children at any level in the continuum of care between the injury scene through hospitalization at the level I trauma center. Although it is unlikely that poor care will be differentially provided to the patients admitted by interhospital transfer, a limitation of the present study is the inability to assess quality of care at the injury scene, the pediatric trauma center, and, for patients admitted by interhospital transfer, the referring hospitals. Further study of the quality of prehospital and in-hospital care might provide opportunities to improve processes of care and clinical outcomes for the critically injured.

Our study findings are contrary to prior findings by Larson et al., who reported that direct transfer of critically injured children was not associated with better outcomes in comparison with admission by interhospital transfer. Unlike in the study by Larson et al., we found differences in injury severity according to the source of admission, and mortality rates remained higher among the patients admitted by interhospital transfer after adjusting for injury severity and other potential confounders. Such multivariate analysis was not performed in the aforementioned study, thereby making it difficult to directly compare the findings from both studies. Other differences between the 2 studies are, however, worthy of note. The present study demonstrated a larger sample size with admissions from multiple hospitals in several states vs a single-state study. Also, unlike the study by Larson et al. in which interhospital transfer admissions were restricted only to those admitted to their trauma center via air ambulance, our study analyzed data with regard to children who arrived via all forms of transport, likely reflecting a different and more varied case mix. Larson et al. acknowledged their inability to include GCS score and transport time to the trauma center in their analysis, whereas in the current study, we included the time elapsed since injury, thereby obviating the need to use methods to estimate travel time or travel distances that incorporate several assumptions regarding topography, travel speed, transport time, and the actual locations of hospitals and patient retrieval services. We were also able to incorporate the GCS score as a measure of injury severity, permitting a more robust analysis.

The study findings should be interpreted in light of certain limitations. We were not able to ascertain the quality of field triage or the quality of care provided at the various care points, including the injury scene, referring hospitals, and the pediatric trauma center. This limited the ability to investigate any delay in resuscitative care, which might affect clinical outcomes and resource use at the trauma center. Further in-depth study of triage and care provided at the injury scene and at referring hospitals is warranted to identify opportunities to optimize outcomes. Such study will need to characterize the types of hospitals that provide care to critically injured children and ascertain their resource capability and pediatric trauma care expertise. An evaluation of barriers to appropriate referral to level I trauma centers is also warranted.

The study findings might have limited application to all regions in the United States. However, because the PCMC is the only level I pediatric trauma center within a 6-state corridor in the West Mountain region, the findings are tangible, and although they might not generalize to urban regions with a denser population of trauma
centers, they convey the features of a busy trauma care system with a wide catchment area, varying patient case mix, and disparate access to definitive trauma care. The cross-sectional nature of the study precluded the ability to determine long-term patient morbidity and functional status even after hospital discharge. An expanded view of mortality and morbidity after trauma is likely to be a more sensitive measure of outcome because in-hospital mortality from pediatric trauma is relatively infrequent. Finally, there is likely to be an underestimation of mortality because trauma patients who died at the injury scene or at referring hospitals were not included in this analysis. Most trauma deaths occur at the injury scene, followed by deaths that occur within the first few hours of injury, which are highly sensitive to the timing of appropriate definitive trauma care. The latter patients are most likely to benefit from optimal definitive care for the most severely injured children at a pediatric trauma center. Further research is warranted with regard to preventable deaths among critically injured children admitted to nontrauma centers. An understanding of the severity of their injuries and the care provided might be critical to improving outcomes for critically injured children.

The provision of timely and optimal care to critically injured children might improve outcomes. Study of triage and care provided at the injury scene and at referring hospitals is warranted to optimize outcomes for critically injured children.

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Author Contributions: Dr Odetola had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Odetola, Mann, and Bratton. Acquisition of data: Mann, Hansen, and Bratton. Analysis and interpretation of data: Odetola and Patrick. Drafting of the manuscript: Odetola, Patrick, and Bratton. Critical revision of the manuscript for important intellectual content: Odetola, Mann, Hansen, Patrick, and Bratton. Statistical analysis: Odetola and Mann. Administrative, technical, and material support: Hansen and Bratton.

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REFERENCES