



Preventable pediatric intensive care unit admissions over a 13-year period at a level 1 pediatric trauma center[☆]



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ABSTRACT

Background: No formal criteria exist to determine the need for admission of injured children to the pediatric intensive care unit. Our objective was to analyze trauma patient admissions to the PICU at a level 1 pediatric trauma center.

Methods: The trauma registry was analyzed between 2002 and 2015. A preventable PICU admission was defined as a child discharged home or transferred out of the PICU within 30 h without surgical intervention, blood transfusion, or ventilator support.

Results: Of 16,209 children, 19% were admitted to the PICU: mean age 7.3 years, median ISS 17, and overall mortality 7%. Per our definition, 36% were preventable PICU admissions of which 83% suffered a head injury. The preventable admissions were younger (6.9 vs. 7.6 years, $p < 0.001$) with a lower median ISS (16 vs. 21, $p < 0.001$), shorter median PICU LOS (17 vs. 41 h, $p < 0.001$) and shorter median hospital LOS (51 vs. 121 h, $p < 0.001$). These admissions resulted in total facility charges of \$9,981,454.76 with 54% produced by children with an isolated head injury.

Conclusions: A significant number of children admitted to our PICU were classified as preventable. They carry a substantial economic burden to the health care system with an overutilization of resources. Methods to limit such admissions should be actively pursued.

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1. Background

Injury is the leading cause of childhood morbidity and mortality in the United States with treatment costs of these injuries exceeding \$20 billion annually [1,2]. Some of these injuries may require a high level of care with admission to a pediatric intensive care unit (PICU). Although care within a PICU has demonstrated improved outcomes [3], no real criteria exist to help direct the disposition of an injured child after initial evaluation within the trauma bay. The cost of the resources utilized in caring for some of those patients admitted to the PICU might not be justified, especially if they don't require ventilator management, aggressive resuscitation such as ongoing transfusion,

altered mentation with known intracranial hemorrhage, or surgical intervention. Although known to be expensive, literature examining the cost of PICU admissions is limited and not specific to trauma patients [4–6]. Management of injured children, especially those with a traumatic brain injury, can be anxiety provoking. The stress of their management might be alleviated through admission to a PICU, due to constant monitoring, a lower nurse to patient ratio, and in-house physician presence. The purpose of this study was to identify factors associated with trauma patient admissions to the PICU at a level 1 pediatric trauma center.

2. Methods

With Institutional Review Board (IRB) approval (#81,240), a retrospective analysis of the trauma registry was performed at Primary Children's Hospital (PCH), a freestanding, American College of Surgeons designated level 1 pediatric trauma center in Salt Lake City, UT. All children admitted to the PICU from January 2002 through February 2015 for traumatic injury were included. None of the children studied were directly admitted to the PICU. All were first evaluated by the trauma team in the emergency department (ED) then admitted to the

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PICU as directed by the trauma team following initial evaluation. The hospital trauma registry was reviewed to obtain: patient demographics (age, gender, zip code), trauma team activation status, ICD-9 code(s), injury severity score (ISS), non-pharmacological interventions including blood transfusion, mechanical ventilation, or surgical intervention, as well as admission and disposition information. Total facility charges were obtained by analysts within the systems improvement department of Primary Children's Hospital through a query of hospital billing records tied to each patient's encounter. The primary outcome of interest was a preventable PICU admission, which for the purpose of this study was defined as a child who was transferred out or discharged home from the PICU within 30 h of admission without mechanical ventilation, blood transfusion or surgical intervention.

Patient demographics, injury patterns, disposition, mortality rates, length of stay (both in ICU and hospital), injury severity score, and types of service received at PCH were summarized as mean, standard deviation (SD), median, and range for continuous variables or count (%) for categorical variables, and compared between preventable and necessary PICU admissions. For continuous variables with an approximately normal distribution, *t*-tests were used; otherwise Wilcoxon rank sum tests were used. For categorical variables, a chi-squared or Fisher's exact test (when any expected cell count was less than 5) was used. Significance was assessed at the 0.05 level and all tests were two-tailed.

Model averaging was used to construct a predictive model for preventable PICU admissions. Potential predictors include age, sex, mechanism of injury (circumstance that caused the injury), injury type (including chest, orthopedic, facial, non-accidental trauma, or other injuries), ICU length of stay (LOS), overall hospital LOS, highest abbreviated injury score (AIS) for head, abdominal and spinal injuries, trauma activation level (TR-1, TR-2, none), and injury severity score (ISS). All possible models were constructed from this set of potential predictors, and they were ranked using the posterior model probabilities constructed from the Bayesian information criteria (BIC). A posterior model probability ≥ 0.005 was used to select the top models, and the final model was constructed by averaging results from these top models. For each predictor in the final model we report the odds ratio, *p*-value, relative importance (sum of posterior model probabilities over the top models that included the variable, i.e. the probability that the variable is included in the most correct model), and the number of top models that included this variable. This model building procedure was done for the full data set and within two subgroups: head injury (highest head AIS > 0) and abdominal injury (highest abdominal AIS > 0). All statistical analyses were conducted in R 3.1.3. Model averaging was conducted using the MuMIn package [7]. Significance was assessed at the 0.05 level and all tests were two-tailed.

3. Results

As demonstrated in Fig. 1, during this study period, 16,209 injured children were admitted to Primary Children's Hospital, of which 3042 were admitted to the PICU (see Fig. 1). The majority of children admitted to were male (64%) with a median age of 6.9 years (IQR 2, 12) and median injury severity score (ISS) of 17 (IQR 10, 25). Falls were the most common mechanism of injury (25%) followed by motor vehicle collisions (16%), bike injuries (9%), and child abuse (9%). A traumatic brain injury (TBI) was the most common injury (83%), followed by injury to the abdomen/pelvis (22%), and injury to the chest (20%). The median length of stay (LOS) in the PICU was 23 h (IQR 16, 54), with a median inpatient length of stay of 88 h (IQR 44, 183). Overall mortality was 7%.

Of the overall cohort of patients admitted to the PICU, 1092 (36%) were categorized as preventable admissions. As demonstrated in Table 1, when compared to necessary admissions, the preventable admissions had a lower mean age (6.9 vs. 7.6 years, $p < 0.001$). The median injury severity score (ISS) was lower for the preventable PICU

admissions group (16 vs. 21, $p < 0.001$). Motor vehicle collisions were the most common mechanism of injury for necessary PICU admissions (46%), whereas falls/sports were the most common mechanism for preventable PICU admissions (48%). Traumatic brain injury was most common in both groups (83% vs. 81%, $p = 0.37$). However, necessary PICU admissions were significantly more likely to have injuries of the chest, abdomen, face, spine, and extremities. Preventable admissions had a shorter median PICU length of stay (LOS) (17 vs. 41 h, $p < 0.001$) as well as a shorter median overall hospital length of stay (51 vs. 121 h, $p < 0.001$). Overall, 69% of the entire cohort was transferred after initial evaluation at another facility. The median time from injury to PICU admission was significantly longer in the transfer patients compared to those coming directly from the scene (5.4 h vs. 2.7 h, $p = 0$). Despite this length in time, a greater percentage of transfer patients were found to be preventable PICU admissions (25% vs. 11%).

When comparing PICU admissions to the days of the week, there were no significant differences in necessary or preventable admissions on any specific day of the week. Additionally, no significant differences were identified in admissions based on the time of day. In other words, more preventable admissions did not occur on weekends or during late night and early morning hours. The majority of children in both groups were eventually discharged home (91% for preventable vs. 71% for necessary admissions). One-hundred and two patients in the preventable admission subgroup (0.05%) were discharged directly from the PICU and 431 (40%) patients were discharged from the hospital within 48 h of admission.

The largest percentage (83%) of children admitted to the preventable PICU group were those with a suspected head injury with a median initial Glasgow coma score (GCS) of 15 (IQR 15, 15). The median ISS was 16, with a median ED arrival to PICU admission time of 1.6 h (IQR 1.1, 2.4), a median time in the PICU of 17 h (IQR 13, 20), and median overall hospital stay of 45 h (IQR 36, 73). Of these children, 96% underwent CT imaging with 67% demonstrating intracranial blood, but only 2% with findings of a subdural hematoma and another 2% with an epidural hematoma. Of the remaining, 12% had an isolated skull fracture, and 18% had no evidence of an intracranial injury. Regarding multiple injuries, 72% were admitted with a solitary head injury. Of the remaining, 7% had an associated abdominal injury and another 7% an associated thoracic injury.

Additionally, 19% of the preventable PICU admissions were children with an abdominal injury with a median ISS of 17 (IQR 14, 21), median ED arrival to PICU admission time of 2.6 h (IQR 1.7, 3.7), median PICU

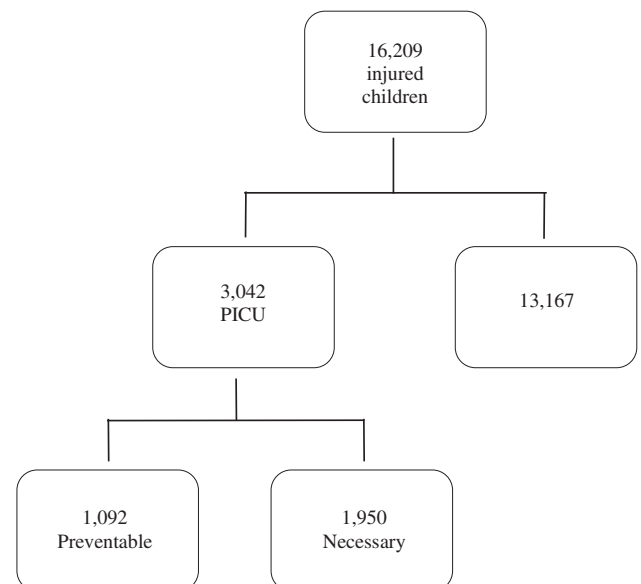


Fig. 1. Patient breakdown.

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