



Missed injuries and unplanned readmissions in pediatric trauma patients☆☆☆



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ABSTRACT

Background: We sought to determine the incidence and characteristics of missed injuries and unplanned readmissions at a Level-1 pediatric trauma center.

Methods: We conducted a retrospective review of all trauma patients who presented to our ACS-verified Level-1 pediatric trauma center from 2009 to 2014.

Results: Overall, there were 27 readmissions and 27 missed injuries (0.38%). Patients who were unplanned readmissions had a greater Injury Severity Score (ISS) (8.6 vs 5.2, $p = 0.03$), had longer hospitalizations (4.9 vs 2.5 days, $p = 0.02$), and were more likely to have required operative intervention (51.9% vs 32.3%, $p = 0.04$). Similarly, patients identified with missed injuries had a higher ISS (15.2 vs 5.2, $p < 0.0001$), greater length of stay (12.7 vs 2.5 days, $p < 0.0001$), and were also more likely to be intubated (25.9% vs 3.6%, $p < 0.0001$) or require critical care (48.1% vs 10.3%, $p < 0.0001$). Seven missed injuries were in patients who were deemed nonaccidental trauma (25.9%) and significantly altered their hospital course while 10 patients (37%) required operative intervention. On multivariate analysis, only ISS was found to be an independent risk factor for readmissions and missed injuries.

Conclusions: Missed injuries and unplanned readmissions were rare occurrences among our pediatric patient population. These events, however, did result in longer hospitalizations and additional procedures. Patients with multisystem injuries and compromised physical exam are at higher risk.

Level of Evidence: IV.

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Despite continued advances in trauma care, readmissions and missed injuries remain significant problems. Numerous studies have demonstrated the negative impact of readmissions and missed injuries in trauma patients on morbidity and hospital costs. These adverse events are considered quality measures that negatively reflect upon both the trauma team and hospital. In this present era with close attention to Patient Safety and Quality Improvement Measures, and hospital reimbursement affected by outcomes, efforts should be undertaken to minimize both events.

Missed injuries and readmission have been extensively studied in the adult trauma population. Reported readmissions rates for adult trauma patients have ranged from 4% to 8% in the literature [1–3]. Risk factors for adult trauma readmissions include medical comorbidities, higher Injury Severity Score (ISS), surgical site infection, length of stay (LOS), significant abdominal injury, and discharge to a skilled nursing facility [1,2,4]. Reported missed injury rates in adult trauma patients

have ranged from 8% to 15% [5–7]. Risk factors have included polytrauma, increased ISS, longer LOS, and significant traumatic brain injuries [5–7]. As a result of their impact on outcome, liberal use of cross-sectional imaging, in an effort to minimize the risk for missed injury, is supported in the adult literature.

In contrast to adult trauma patients, missed injury and readmission rates in injured children remain poorly defined. Developmental limitations may prevent a child's ability to communicate pain or elaborate on injury mechanism increasing the risk for these complications. The evolving restrictive use of cross-sectional imaging (computed tomography) to minimize radiation exposure on injured children, managed at pediatric trauma centers may impose an increased risk for missed injuries [8]. Given this, the purpose of our study is to identify contemporary risk factors for both missed injuries and readmissions within 30 days of discharge in our pediatric population.

1. Methods

St. Louis Children's Hospital is a state-designated and American College of Surgeons-verified Level-1 pediatric trauma center and serves a catchment area with an approximate 250-mile radius. After IRB approval (#201411124), we conducted a retrospective review of all pediatric trauma patients, age <18 years, managed for traumatic

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injuries at our institution. Only children meeting entry criteria trauma registry criteria were included. Trauma registry entry criteria included all patients admitted to hospital for at least 12 hours with an injury diagnosis, or received trauma service activation in the emergency unit (EU) (Trauma Stat, Trauma Minor, Trauma Consult). Children meeting entry criteria by trauma service activation, who were discharged home from the EU, were also included. Children managed by the EU and discharge home without trauma service evaluation were excluded.

The study period included all patients managed between November 1st, 2009 and October 31st, 2014. We excluded any patient who died. From this list of patients, we identified those who had either been readmitted to the hospital within 30 days of discharge or who had a missed injury, defined as injuries that were not identified at the time of initial evaluation in the EU [5]. Injuries that were not found on primary/secondary survey or were radiology overreads were considered missed injuries. This provided the broadest possible definition of missed injuries in order to capture the most patients. Data points extracted included patient demographics, mechanism, Injury Severity Score (ISS), date/time of admission, specific injuries, length of stay (LOS), length of intubation, pediatric intensive care unit (PICU) admission, operative intervention, and reason for readmission.

Statistical analysis was conducted using SAS v9.4 (SAS Institute Inc.; Cary, NC). Fisher's exact test was used for categorical variables, and Wilcoxon rank-sum test was used for continuous variables. Categorical variables are expressed as means $\pm$ SE. Statistical significance was determined to be $p < 0.05$. After univariate analysis, a multivariate analysis was conducted. Collinearity between independent variables was evaluated by assessing the variance inflation factor. Using multivariable logistic regression, a model was then developed to investigate variables found significant on univariate analysis. A p -value < 0.05 was used as the threshold for statistical significance.

2. Results

There were a total of 7143 trauma patients over the 5-year study period who met inclusion criteria. Of these, only 27 children missed injuries (0.38%) and 27 readmissions (0.38%) were identified. Seven (25.9%) of the 27 readmissions, were the result of missed injuries. Analysis of readmitted children demonstrated no differences in age, gender, secondary transfer, ICU care or intubation/mechanical ventilation (Table 1). Readmitted children did have higher ISS (8.6 vs 5.2, $p = 0.03$), increased length of stay (4.0 vs 2.5 days, $p = 0.02$), and requirement for operative interventions (51.9% vs 32.3%, $p = 0.04$) during their index admission. No collinearity, however, was detected between these variables, with variance inflation factors all < 10 . After multivariate analysis, only ISS remained statistically significant (OR 1.055 [95% CI 1.01–1.10]) as a factor associated with higher odds for readmission.

The average number of days between discharge and readmission was 4.4 ± 0.7 days. The average length of stay during readmission was 5.1 ± 1.2 days. Additionally, 10 patients (37.1%) required

operations during their readmission. Six out of the 10 patients underwent washout and debridement for infected wounds, 3 required reduction/fixations of missed extremity fractures, and 1 required a craniotomy for an epidural hematoma that was initially managed non-operatively but progressed after discharge. The most common reason for readmission was infection of abrasions or complex lacerations, which occurred in 12 out of 27 patients (44.4%; Table 2).

In the missed injury cohort, we similarly found no differences in age, gender, secondary transfer, or requirement for operative intervention (Table 3). However, 25.9% of patients with missed injuries were the result of non-accidental trauma (NAT), compared to only 3.6% of those without missed injuries ($p < 0.0001$). Patients with missed injuries also had a higher ISS (15.2 vs 5.2, $p < 0.0001$), lengths of stay (12.7 vs 2.5 days, $p < 0.0001$), requirement for ICU care (48.1% vs 10.3%, $p < 0.0001$), and intubation/mechanical ventilation (25.9% vs 3.6%, $p < 0.0001$). Again, no collinearity was detected between these variables, with variance inflation factors all < 10 . On multivariable analysis, only ISS remained statistically significant (OR 1.077 [95% CI 1.03–1.13]) as a factor associated with higher odds for missed injury.

Similar to other children's hospitals, our institution down sizes staffing during evenings and weekends. To determine if the frequency of missed injuries was impacted by our staffing model we analyzed patients for time and day of presentation (weekends or after-hours defined as 6 pm–6 am). There were 2486 patients (34.8%) who presented on a weekend and 4621 patients (64.7%) who presented after-hours. No differences in the frequency of missed injuries were identified (Table 4).

All missed injuries were in patients who were injured by blunt mechanism. The most common mechanisms were by falls or NAT, followed by motor vehicle related trauma (Table 5). The most common type of missed injury was an extremity fracture, which accounted for more than a third of missed injuries ($n = 10$, 37.0%). This was followed by facial ($n = 5$, 18.5%) and spine ($n = 4$, 14.8%) fractures (Table 6). Another 22% ($n = 6$) required operations secondary to their missed injury, most commonly for reduction and fixation of fractures.

The majority of missed injuries were not found within 24 hours of presentation. Diagnoses of missed injury occurred 7.1 ± 1.7 days after index admission. There were 9 patients with missed injuries that were found the following day, of which 7 were radiology overreads, and only 2 (7.4% of missed injury cohort) were additionally found via tertiary survey. In addition to these 7 radiology overreads, there were 2 additional radiology misses in which the original image had been finalized as normal but were then re-reviewed days after presentation because of persistent symptoms and were then found to have injuries, one of these was a rib fracture and the other a radius fracture.

3. Discussion

Readmissions and missed injuries in pediatric trauma patients are rare occurrences at our institution, comprising only 0.38% of our total patient cohort. While missed injury and readmissions rates specific for pediatric trauma have not been well studied, these results are well below rates reported in the adult literature and compare favorably to rates of 1%–16% described in limited pediatric trauma studies [9–12]. As in many of the adult studies, our readmitted patients had higher ISS, LOS, and also required operative intervention [1,2,4]. However, in

Table 1
Readmissions.

	Readmissions	Nonreadmissions	<i>p</i> -value
N	27	7116	–
Age	9.6 ± 1.1	8.3 ± 0.07	0.2
Gender (male)	18 (66.7%)	4611 (64.8%)	0.7
ISS	8.6 ± 1.7	5.2 ± 0.07	0.03*
LOS	4.9 ± 2.1	2.5 ± 0.09	0.02*
Transfer	18 (66.7%)	4417 (62.1%)	0.7
ICU	6 (22.2%)	740 (10.4)	0.06
Intubation	1 (3.7%)	259 (3.6%)	0.9
OR	14 (51.9%)	2300 (32.3%)	0.04*
NAT	1 (3.8%)	261 (3.7%)	0.9

ISS, Injury Severity Score; LOS, length of stay; ICU, intensive care unit; OR, operating room; NAT, nonaccidental trauma.

* p -values < 0.05 .

Table 2
Reason for readmission.

Reason for readmission	Frequency
Wound Infection	12 (44.4%)
Missed injury	7 (25.9%)
Pain	3 (11.1%)
Altered mental status	2 (7.4%)
Feeding issues	2 (7.4%)
Anemia	1 (3.7%)

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