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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 2009–2014.

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 non-accidental 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.

Keywords

Pediatric trauma; missed injuries; readmission

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1. Introduction

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 4–8% in the literature.[1–3] Risk factors for adult trauma readmissions include medical co-morbidities, 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 8–15%.[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.

2. 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 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.

3. 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 nonoperatively 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 6pm-6am). 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 due to persistent symptoms and were then found to have injuries, one of these was a rib fracture and the other a radius fracture.

4. 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 contrast to adult series, only ISS was associated with increased risk of readmission after multivariate analysis in our patient population.

Consistent with the adult literature, the most common reason for readmission at our institution was infection.[2] There were 12 patients who were readmitted for infection of abrasions/complex laceration, but 7 (58.3%) had already undergone debridement during their index hospitalization. Among all readmitted patients with a wound or burn, 31.8% underwent a debridement during their index hospitalization. Similarly, 33.5% of patients with a wound/burn who were not readmitted also underwent a wound debridement. Thus,

there were no statistically significant differences in the frequency of debridement in either groups ($p = 0.87$).

Missed injury was the second most common reason for readmission in our cohort. Although our overall rate of missed injuries was low, the impact was significant as it resulted in additional interventions and LOS. Patients at risk were those with increased ISS, LOS, requirement for ICU care, and intubation, which is similar to other pediatric trauma studies. [9–11] However, similar to our readmissions, only ISS was associated with increased risk of missed injury on multivariate analysis in our series.

Although we had hypothesized that age may contribute to missed injury due to inability to verbalize pain, no impact was identified. It is likely we were unable to see a difference in age due to the overall very low number of patients with missed injury. While we did find a larger percentage of NAT patients in the missed injury group (all of whom were less than a year old), however, this was balanced by the number of teenagers with missed injuries (5 patients between the age of 15–17 years old, 18.5% of the missed injury population). Other reports have demonstrated that NAT patients are typically younger and have higher risk for missed injuries. In the cohort of NAT patients in Magoteaux et al., the median age was 8 months.[13] Additionally, Estroff et al. also found that patients with NAT were younger than patients with accidental trauma (1.8 ± 3.3 vs 6.8 ± 4.2 $p < 0.01$).[14]

Missed injuries were also only found in patients who suffered from blunt mechanism. Physicians may have had a lower threshold to CT scan or operatively explore patients with penetrating mechanism, which may decrease the risk of missed injuries. Most of our missed injuries were extremity fractures, again commonly seen in pediatric[15] and adult trauma patients.[5]

Although there was no difference in the number of patients with NAT and readmissions, our data demonstrated a 25.9% missed injury rate in victims of NAT. This is approximately 7 times higher than the rate observed in children without missed injuries (3.7%). The overall missed injury rate in our NAT population was only 2.7%. Magoteaux et al. found that in their cohort of patients with NAT, 12.8% had missed injuries and 12.8% had readmissions. [13] While our missed injury rate in the NAT population is low, it is still nearly 10x higher for our NAT population when compared to our non-NAT population (0.29%).

Our data demonstrated no association between missed injuries/readmissions and discharge (disposition home) from the EU. Of those with missed injuries, 22.2% ($n = 6$) were discharged home from the EU compared to 27.4% of patients without missed injuries ($p = 0.55$). In patients who were readmitted, only 14.8% of readmitted patients were initially discharged home from the EU. In contrast, 27.4% of patients who were not a readmitted were discharged home. This difference was not found to be statistically significant ($p = 0.14$), likely due to the overall small sample size of the readmitted population. Regardless, our data suggests that discharge home from the EU does not increase risk for readmission or missed injuries.

Nine missed injuries (33.3%) were secondary to initial radiology miss and identified on later review. For the entire population radiology miss with resulting overread occurred in only

0.13%. At our institution, all trauma radiographs are reviewed by an attending radiologist during the day. Overnight, a radiology resident gives the preliminary report of the imaging, and these reports are finalized by an attending radiologist the following morning. Attending board certified pediatric radiologists are available 24 hours per day for consultation. If there is an overread, the attending radiologist directly contacts the trauma service if the patient is admitted or the EU attending if the patient was discharged. A mandatory radiology consult is obtained on all imaging obtained prior to patient transfer to our institution.

Consistent with staffing models at other pediatric trauma centers, our institution functions with an “on-call” staff in house for evenings, holidays and weekends. Despite this, no differences in the number of missed injuries were identified based on time or day of patient presentation. In contrast, a 10-year review of 54,030 adult trauma patients found that the odds of a missed injury were 1.2 times higher if the patient presented after-hours or on a weekend.[16] The presence of a dedicated trauma nurse practitioners, who are typically only present during weekdays, has also improved patient outcomes. Resler et al. discovered that missed injuries decreased 3.0% to 0.4% after the staffing addition of pediatric trauma nurse practitioners.[17] Fanta et al. also found that pediatric trauma patients admitted to a trauma nurse practitioner service had decreased LOS compared to patients admitted to a resident service.[18] This effect may be secondary to improved charting and consistent staff performing tertiary surveys,[17] as well as better familiarity with protocols as nurse practitioners are a constant presence on trauma teams.

While there has been a movement to restrict cross sectional imaging in pediatric trauma patients, there have also been concerns that this may increase the frequency of missed injuries. Liberal use of CT scanning has been supported in the adult population. Tillou et al. found that limiting CT scans in blunt trauma patients would have resulted in missing injuries in 17% of adult trauma patients.[19] Our data, however, suggests that restricting CT scan imaging does not negatively impact patients as there was an overall very low missed injury rate. Similarly, Willner et al. discovered that pediatric patients with a delay in diagnosis of injury had a similar number of plain radiographs but actually had more CT scans compared with patients without any delay in diagnosis of injury.[15] Most of these injuries (75%) were orthopedic in nature, and it was concluded that any delayed diagnosis was not attributable to the lack of CT scan use.[15] The success of having restrictive CT scan use and a low missed injury rate may be due to selective imaging practices based on PECARN algorithms in which pediatric trauma patients undergo Head or Abdominal CT scans based on presenting symptoms, physical exam findings, and mechanism.[20, 21]

The greatest limitations to this study are that it is retrospective and from a single institution. Readmissions/missed injuries are rare occurrences, and so there is limited power in our data. While most pediatric patients are healthy at baseline, patients were also not risk stratified by existing medical co-morbidities. We did not specifically compare the number of CT scans to outcomes. We also did not analyze the true clinical or financial cost of missed injuries, as some did not impact hospital course while others prolonged admissions and required additional interventions. We did not include patients who died for several reasons: 1) pediatric trauma deaths are rare and 2) the majority of pediatric patients who die have non-survival injuries. Additionally, all trauma patients who died are reviewed by a

multidisciplinary conference at our institution, and there were no deaths attributable to a missed injury during this time period. Another limitation is that despite serving a considerable catchment area, only trauma patients who returned to our hospital were captured for study. It is possible that patients may have gone to other hospitals after discharged, which would make our readmission (and also potentially missed injuries) numbers lower.

In conclusion, missed injuries and unplanned readmissions were extremely rare occurrences in our pediatric population. When these events did occur, they resulted in longer hospitalizations and additional procedures. Patients with significant injuries and compromised physical exams were at higher risk. A multicenter study to develop contemporary benchmarks for pediatric trauma is warranted.

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Table 1

Readmissions

	Readmissions	Nonreadmissions	p-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

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%)

Table 3

Missed Injuries

	Patients with missed injuries	Patients without missed injuries	p-value
N	27	7116	–
Age	7.2±1.1	8.3±0.07	0.2
Gender (Male)	19 (70.4%)	4613 (64.8%)	0.7
ISS	15.2±2.4	5.2±0.06	< 0.0001
LOS	12.7±0.8	2.5±0.02	< 0.0001
Transfer	14 (51.2%)	4420 (62.1%)	0.3
ICU	13 (48.1%)	733 (10.3%)	< 0.0001
Intubation	7 (25.9%)	253 (3.6%)	< 0.0001
OR	9 (33.3%)	23054 (32.4%)	0.9
NAT	7 (25.9%)	255 (3.6%)	< 0.0001

ISS, Injury Severity Score; LOS, Length of Stay; ICU, Intensive Care Unit; OR, Operating Room; NAT, Nonaccidental Trauma

Table 4

Missed Injuries based on timing of presentation

	Patients with missed injuries	Patients without missed injuries	p-value
Presented on a Weekend	8 (29.6%)	2478 (34.8%)	0.7
Presented during night (6pm-6am)	13 (48.1%)	4608 (64.8%)	0.7

Table 5

Mechanism in patients with Missed Injuries

Mechanism	Frequency
Fall	8 (29.6%)
NAT	7 (25.9%)
MVC	5 (18.5%)
Pedestrian struck by Motor Vehicle	4 (14.8%)

NAT, Nonaccidental Trauma; MVC, Motor Vehicle Collision

Table 6

Missed Injuries

Injury	Frequency
Extremity fracture	10 (37.0%) – tibia ×2, clavicle, femur ×3, radius/ulna ×2, humerus ×2
Face fracture	5 (18.5%)
Spine fracture	4 (14.8%)
Skull fracture	3 (11.1%)
Intracranial Hemorrhage	2 (7.4%)
Intra-abdominal	1 (3.7%) – liver laceration
Vascular	1 (3.7%)
Rib fracture	1 (3.7%)