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Trauma Bay Disposition of Infants and Young Children With Mild Traumatic Brain Injury and Positive Head Imaging

Corina Noje, MD^{#1}, Eric M. Jackson, MD^{#2}, Isam W. Nasr, MD³, Philomena M. Costabile, BSN, RN⁴, Marcelo Cerullo, MD, MPH⁵, Katherine Hoops, MD, MPH¹, Lindsey Rasmussen, MD⁶, Eric Henderson, NRP⁷, Susan Ziegfeld, MSN, PNP-BC³, Lisa Puett, RN^{3,4}, Courtney L. Robertson, MD¹

¹Department of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD.

²Department of Neurosurgery, Johns Hopkins University School of Medicine, Baltimore, MD.

³Division of Pediatric Surgery, Department of Surgery, Johns Hopkins University School of Medicine, Baltimore, MD.

⁴Division of Pediatric Surgery, Department of Nursing, The Johns Hopkins Hospital, Baltimore, MD.

⁵Department of Surgery, Duke University School of Medicine, Durham, NC.

⁶Department of Pediatrics, Stanford University School of Medicine, Palo Alto, CA.

⁷LifeStar Response of Maryland, Halethorpe, MD.

These authors contributed equally to this work.

Abstract

Objectives—To describe the disposition of infants and young children with isolated mild traumatic brain injury and neuroimaging findings evaluated at a level 1 pediatric trauma center, and identify factors associated with their need for ICU admission.

Design—Retrospective cohort.

Setting—Single center.

Patients—Children less than or equal to 4 years old with mild traumatic brain injury (Glasgow Coma Scale 13–15) and neuroimaging findings evaluated between January 1, 2013, and December 31, 2015. Polytrauma victims and patients requiring intubation or vasoactive infusions preadmission were excluded.

Interventions—None.

Measurements and Main Results—Two-hundred ten children (median age/weight/Glasgow Coma Scale: 6 mo/7.5 kg/15) met inclusion criteria. Most neuroimaging showed skull fractures

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with extra-axial hemorrhage/no midline shift (30%), nondisplaced skull fractures (28%), and intracranial hemorrhage without fractures/midline shift (19%). Trauma bay disposition included ICU (48%), ward (38%), intermediate care unit and home (7% each). Overall, 1% required intubation, 4.3% seizure management, and 4.3% neurosurgical procedures; 15% were diagnosed with nonaccidental trauma. None of the ward/intermediate care unit patients were transferred to ICU. Median ICU/hospital length of stay was 2 days. Most patients (99%) were discharged home without neurologic deficits. The ICU subgroup included all patients with midline shift, 62% patients with intracranial hemorrhage, and 20% patients with skull fractures. Across these imaging subtypes, the only clinical predictor of ICU admission was trauma bay Glasgow Coma Scale less than 15 ($p = 0.018$ for intracranial hemorrhage; $p < 0.001$ for skull fractures). A minority of ICU patients (18/100) required neurocritical care and/or neurosurgical interventions; risk factors included neurologic deficit, loss of consciousness/seizures, and extra-axial hemorrhage (especially epidural hematoma).

Conclusions—Nearly half of our cohort was briefly monitored in the ICU (with disposition mostly explained by trauma bay imaging, rather than clinical findings); however, less than 10% required ICU-specific interventions. Although ICU could be used for close neuromonitoring to prevent further neurologic injury, additional research should explore if less conservative approaches may preserve patient safety while optimizing healthcare resource utilization.

Keywords

optimal disposition; pediatric neurotrauma; traumatic brain injury

Pediatric traumatic brain injury (TBI) is a frequent emergency department (ED) diagnosis, encompassing many different mechanisms of injury. Pediatric trauma centers are facing increasing numbers of these injuries, with over 500,000 visits estimated each year (1). Although children with severe TBI are stabilized in the ED and subsequently transferred to the ICU for continued management, the optimal disposition of children with mild TBI, particularly those with positive head imaging, remains a dilemma (2–7). Given lack of specific guidelines, their disposition is often institution-dependent, or determined on a case-by-case basis by a multidisciplinary team including pediatric neurosurgeons, trauma surgeons, emergency medicine providers, and intensivists.

Our adult colleagues are facing similar challenges. Ratcliff et al (8) showed no association between level of care provided for mild-moderate adult TBI and patient outcomes. Furthermore, evidence suggests that adult patients with mild TBI may not require repeat imaging or ICU admission (9). In pediatrics, there has been a paucity of data to guide providers in these decisions, and thus, many children are admitted to higher levels of care, such as the ICU. Pediatric admission to a higher level of care than necessary often entails longer hospital stay, decreased sleep and recovery for the patient, and overutilization of healthcare resources (10, 11).

More recently, several studies have evaluated various risk factors to determine the need for ICU admission for children with mild TBI, but all have focused on the pediatric population as a whole and have been inclusive of patients up to 16–18 years old (12–15). Nevertheless, the pediatric population with TBI is complex given its wide spectrum of brain maturity,

developmental levels, and mechanisms of injury, including nonaccidental trauma (NAT) (7, 11). Particularly for infants and young children, clinical neuromonitoring can be challenging, as Glasgow Coma Scale (GCS) scores are difficult to assess with accuracy for the younger ages, making this population even more likely to be hospitalized in the ICU.

We sought to better understand factors that dictate a provider's ultimate disposition decisions for infants and young children with isolated mild TBI and positive brain imaging and to evaluate whether ICU admission reflects a higher likelihood of disease progression or need for higher level of care. Our objectives were to 1) describe the disposition of infants and young children with mild TBI and neuroimaging findings evaluated at a level 1 pediatric trauma center and 2) identify factors more likely to be associated with their need for admission to an ICU setting.

MATERIALS AND METHODS

Study Design, Setting, and Patient Selection

After being acknowledged as a quality improvement initiative by the Johns Hopkins University Institutional Review Board, this project was conducted through a retrospective chart review of all children less than or equal to 4 years old with isolated mild TBI (GCS score 13–15) and positive neuroimaging by radiology report when evaluated at the Johns Hopkins Hospital between January 1, 2013, and December 31, 2015.

During the study period, our institution was Maryland's largest pediatric hospital with 205 beds, including 23 intermediate care unit (IMC) and 34 PICU beds. As the state-designated level 1 pediatric trauma center, the Johns Hopkins Hospital manages approximately 1,000 injured children yearly. Patients are evaluated in our institution's pediatric trauma bay by a multidisciplinary team; however, their disposition (home or admission to the general care ward, IMC, or PICU) is usually decided by a pediatric surgeon, with input from consulting services. The potential routes of inpatient disposition have variable clinical resources and levels of monitoring, including GCS scoring frequency (i.e., 4 hr on the ward; 2 hr in the IMC; 1 hr in the ICU).

Patients transferred from other hospitals (mostly via Johns Hopkins pediatric transport team), as well as trauma victims brought directly to our institution were included in the study. Patients were identified through the Pediatric Transport and Pediatric Trauma institutional databases. After inspection for accuracy, the two databases were merged and duplicates excluded. Subsequently, a chart review was performed by five investigators who used a standardized data collection form (see Supplemental Digital Content 1, <http://links.lww.com/PCC/B6>). To isolate TBI as the sole reason for admission, we excluded patients with polytrauma (injury severity score > 15) (16), cardiopulmonary arrest, hemorrhagic shock, need for intubation or vasoactive infusions preadmission, and non-TBI as a primary diagnosis.

Data Collection

Data were collected from several sources including transport charting, trauma bay evaluation documentation, and the hospital electronic medical record. We obtained basic demographics,

as well as data pertaining to the initial presentation and transport. Trauma bay data included trauma classification, GCS score, presence of neurologic deficit or distracting injuries, imaging results (including radiology interpretation of neuroimaging performed at referring institutions), interventions, medications, and disposition. Hospital data included length of stay (LOS), need for ICU interventions (nonelective intubation, seizure/status epilepticus management, neuromonitoring after neurosurgical procedures), repeat neuroimaging, NAT workup, serious reportable events (patient death, unplanned ICU transfer, emergent surgery or ICU admission post-home discharge), and outcomes (discharge disposition, presence of neurologic deficits at discharge, hospital readmission within 7 d of discharge).

Neuroimaging findings were abstracted from radiology reports (interpretations were provided by neuroradiologists), and subsequently divided into nine diagnostic groups for ease of data interpretation: nondisplaced/minimally displaced single skull fracture, displaced/comminuted skull fracture, multiple skull fractures, skull fracture(s) with subarachnoid hemorrhage, skull fracture(s) with extra-axial hemorrhage without midline shift, skull fracture(s) with intraparenchymal hemorrhage without midline shift, skull fracture(s) with intracranial hemorrhage (ICH) and midline shift, ICH without midline shift and no skull fracture(s), and ICH with midline shift and no skull fracture(s).

Statistical Analysis

Patients were stratified by trauma bay disposition (ICU vs non-ICU). Categorical variables were expressed as proportions and compared using the chi-square test or Fisher exact test, as appropriate. Continuous variables were summarized using median and interquartile range (IQR), and compared using the Student *t* test or Wilcoxon rank-sum test, as appropriate. A subgroup analysis examining patients admitted to the ICU from the trauma bay was then conducted, further stratifying patients by receipt of ICU interventions (critical care and/or neurosurgical procedures), to identify risk factors for requiring ICU interventions. We conducted univariable analyses of those clinical and demographic risk factors: age, trauma bay GCS, mechanism of injury, loss of consciousness (LOC), seizures, neurologic deficit, and imaging findings. Data were analyzed using Stata IC 14 (StataCorp, College Station, TX).

RESULTS

Two-hundred ten patients with mild TBI (median age 6 mo; 57% male) met inclusion criteria (median [IQR] cases/month: 6 [4–7]). Of those, 162 (77%) were transferred by our team from 30 hospitals and 63 (30%) were evaluated during weekends. Table 1 displays patients' characteristics.

Neuroimaging

Most neuroimaging showed skull fractures with extra-axial hemorrhage and no midline shift (30%), nondisplaced/minimally displaced skull fractures (28%), and ICH without fractures or midline shift (19%). Table 2 displays the patients' initial neuroimaging.

Trauma Bay Disposition

Trauma bay disposition varied: ICU (48%), ward (38%), IMC and home (7% each). All eight patients with midline shift, most patients with ICH with/without skull fractures (76/123, 62%), and a minority of patients with skull fractures only (16/79, 20%) went to the ICU. Figure 1 displays the trauma bay disposition versus neuroimaging.

No significant trauma bay clinical associations were predictive of ICU versus non-ICU disposition for the entire cohort; examined variables included: age less than 6 months, GCS less than 15, presence of neurologic deficit, history of LOC/seizures, and NAT listed as mechanism of injury. However, across imaging subtypes, trauma bay GCS less than 15 was associated with ICU disposition for patients with ICH with/without fractures ($n = 123$; $p = 0.018$) and skull fractures only ($n = 79$; $p < 0.001$).

Hospital Course

Details regarding the hospital course are found in Table 3. Overall, 1% of the cohort ($n = 2$) required intubation and 4.3% ($n = 9$) were treated for seizures/status epilepticus during their hospital stay. Nine patients (4.3%) required neurosurgical procedures: eight were admitted to the ICU and one to IMC. Upon evaluation by the hospital's child protective service team, 32 patients (15%) were diagnosed with NAT prior to discharge (close to 1-in-6 cases). Of the 210 patients, 81 (39%) had repeat head imaging while inpatients (between 1-in-2 and 1-in-3 cases). Changes in the follow-up neuroimaging were reported in 26 of 81 patients (32%). Of those, five had new or evolving clinically significant findings; their characteristics, including details of their neuroimaging findings, are included in Supplemental Table 1 (Supplemental Digital Content 2, <http://links.lww.com/PCC/B7>).

None of the ward/IMC patients required ICU transfer. However, one patient initially discharged home from the ED without neuroimaging returned the next day with emesis and lethargy. He had a head CT which showed a small parenchymal hemorrhage of the left basal ganglia and was admitted to the ICU. Median ICU and hospital LOS for the entire cohort was 2 days. Most patients (99%) were discharged home without neurologic deficits, with less than 4% readmitted within 7 days. Reasons for readmission (which generally occurred within 2 d from discharge) included nausea, emesis, and feeding intolerance ($n = 3$); altered mental status and lethargy ($n = 2$); need for further diagnostic testing ($n = 2$); and new injury related to NAT ($n = 1$). All patients readmitted for nausea, emesis, and feeding intolerance had stable follow-up neuroimaging (when performed) and were observed on the ward without need for interventions. Both patients readmitted for altered mental status and lethargy were monitored clinically without intervention. Patients readmitted for diagnostic testing (e.g., MRI) had stable neuroimaging without new neurologic findings. The patient readmitted with new injury related to NAT had new skull fractures and extension of his previously diagnosed subdural hemorrhage on follow-up imaging.

ICU Subgroup

Of the 210 patients, 100 (48%) went to the ICU (median [IQR] cases/month: 2 [1–4]), with 33 (33%) admitted during weekends. The ICU subgroup included all patients who ultimately required intubation, were treated for seizures/status epilepticus, had residual neurologic

deficits at discharge, and were discharged to inpatient rehabilitation centers. Median LOS for the ICU subgroup was 2 days in the ICU and 3 days in the hospital. Details are found in Table 3.

Eighteen ICU patients (18%) required interventions for their head injury. Eight of them (44%) were admitted during weekends. These 18 patients required 19 different interventions: nonelective intubation ($n = 2$), management of status epilepticus ($n = 9$), and neurosurgical intervention ($n = 8$). The patients had a median age of 4.5 months and median trauma bay GCS of 14. Their initial neuroimaging findings were: skull fracture(s) with extra-axial hemorrhage without midline shift (44%); ICH without midline shift and no skull fracture(s) (28%); displaced comminuted skull fracture(s) (11%); and skull fracture(s) with intraparenchymal hemorrhage without midline shift, skull fracture(s) with ICH and midline shift, as well as ICH with midline shift and no skull fracture(s) (5.6% each). Their median LOS was 4 days in the ICU (range, 1–12 d), and 6.5 days in the hospital (range, 2–16 d). Median ICU stay was longer for patients requiring intubation (8 d) and status epilepticus management (7 d) compared with patients requiring neurosurgical interventions (2.5 d). Among the patients who received ICU interventions were also seven of 32 patients (21.9%) ultimately diagnosed with NAT: four required management of status epilepticus, two had neurosurgical interventions, and one was nonelectively intubated. As detailed in Table 4, several risk factors for receiving ICU interventions were identified on univariate analysis: presence of neurologic deficit (relative risk [RR] = 4.04; $p = 0.003$), LOC/seizures post-trauma (RR = 2.57; $p = 0.04$), and initial neuroimaging with evidence of extra-axial hemorrhage (RR = 3.53; $p = 0.013$) particularly epidural hematoma (RR = 3.04; $p = 0.029$).

Within the ICU subgroup, 28 patients (28%) had ICU LOS greater than 2 days (range, 3–12 d). Thirteen patients received ICU interventions. Fourteen patients stayed in the ICU for monitoring or due to lack of inpatient bed availability (NAT workup; anticoagulation for cerebral venous sinus thrombosis; new/evolving findings on repeat imaging). One patient had ICU needs unrelated to his TBI (noninvasive positive pressure titration for preexistent obstructive sleep apnea).

ICU Bed Utilization

During the study period, there were 5,313 PICU admissions (median [IQR] cases/month: 159 [139–169]) with a mean LOS of 5.46 days (i.e., 29,009 ICU bed-days). As such, the average ICU occupancy rate was close to 80% (not accounting for transient lower capacity due to inadequate staffing). There were 143 incoming transfer denials (median [IQR] denials/month: 3 [1–6]) for lack of ICU capacity. Patients less than or equal to 4 years old with mild TBI represented 1.5%, 1.9%, and 2.2% of all PICU admissions in 2013, 2014, and 2015, respectively (i.e., median of 2 cases/month out of 159 monthly ICU admissions). The monthly variation in both total and mild TBI ICU admissions followed a similar pattern with bi-annual peaks (late winter-early spring and late fall-early winter). The 82 children in our cohort who did not receive neurocritical care/neurosurgical interventions (median ICU LOS 2 d) occupied the ICU for 164 bed-days, which represented less than 1% ICU-days/3-yr period. However, having triaged them to a non-ICU bed could have potentially avoided some of the same-day denials.

DISCUSSION

This cohort represents our 3-year experience with isolated mild TBI and positive neuroimaging in infants and young children evaluated at a level 1 pediatric trauma center. Our current practice was found to be safe yet nonsystematic and revealed a high utilization of ICU services. The optimal disposition of children with mild TBI is unknown due to paucity of data and lack of expert consensus. Recent studies suggest that children with mild TBI have a higher-than-needed ICU admission rate across all age groups, hence the interest in developing predictive models to determine their ICU need (12, 13, 15). For instance, admission to ICU was reported to occur in 36.8–94.6% of children evaluated for mild TBI and found to have abnormal neuroimaging (12–15). However, critical care interventions rates were reported to be much lower (9.7–14.1%) (12–14). Not accounting for differences in design, all studies report a similar trend, with need to optimize inpatient disposition of children with mild TBI and neuroimaging findings. Risk factors for intensive care admission vary due to the heterogeneity in defining critical care interventions and ICU need. The only risk factor identified by all these studies is midline shift. In our cohort, all eight patients with midline shift were admitted to the ICU; however, only two (25%) ultimately required ICU interventions. Since we wanted to determine ICU need based solely on patients' brain injury, we excluded patients with significant other injuries; therefore, applying these scores to our population may fail to identify all those who received ICU interventions. For instance, the Children's Intracranial Injury Decision Aid risk scores (15) of the 18 patients with ICU interventions in our cohort ranged from 0 to 14 (median 7). Using a cutoff for ICU admission at greater than 0 points, three of 18 patients (median ICU LOS 4 d; range, 1–5 d) who required ICU interventions would be triaged out of the ICU. Within our cohort, trauma bay risk factors predictive of ICU interventions were presence of neurologic deficit, LOC/seizures, and extra-axial hemorrhage (particularly epidural hematoma). However, none of these factors in isolation would have significant diagnostic impact to identify a patient in need and ICU interventions may not be entirely synonymous to ICU need.

We chose to focus on infants and young children because their developmental level poses challenges when assessing their GCS and neurologic examination for subtle changes. This population is also more likely to have higher rates of NAT and thus increased risk of needing ICU care (13). Therefore, this age limitation leads to a higher likelihood of ICU hospitalization for close neuromonitoring. We excluded children with obvious ICU needs, as well as victims of polytrauma due to the multitude of non-TBI related factors that may contribute to the decision to admit to ICU.

We found that nearly half of the children less than or equal to 4 years old with isolated mild TBI and positive neuroimaging were briefly monitored in the ICU. We can conclude that patient disposition in this cohort was safe, as all patients who needed interventions and all those who retrospectively required a higher level of care were triaged to the ICU. Furthermore, we did not identify serious reportable events in our population of interest (the child who needed ICU admission after being discharged home was not known to have abnormal neuroimaging during the initial ED visit—he was imaged, found to have ICH, and admitted to ICU during a subsequent ED visit). However, disposition did not appear to be systematic, and may not have been resource-efficient. For instance, patients with ICH with/

without skull fractures had a split ICU/non-ICU disposition (60/40), yet outcomes were not different and non-ICU patients did not require higher level of care. Also, median LOS was 2 days for both ICU and hospitalization, and 22% of ICU patients were discharged home directly from the ICU. Of the 100 ICU patients, only 18 required interventions and 14 had LOS greater than 2 days due to neuromonitoring (most on them in the context of NAT), suggesting that ICU admission was probably not necessary for many patients with this disposition.

Given that hourly neurochecks can only occur in the ICU, it is important to examine these data closely to determine how we can improve ICU triage. If we consider neurocritical care and neurosurgical interventions as surrogate for ICU need, then less than 10% of the cohort benefited from being admitted to the ICU. It can be argued that not all patients who underwent neurosurgical intervention required ICU-level neuromonitoring (e.g., certain skull fracture elevations). However, it is difficult to measure the added benefit of close neuromonitoring, particularly given the challenges in predicting which patients are more likely to develop new or worsening brain injury. For instance, Hollingworth et al (17) reported that 20% patients with mild TBI had new or worsening brain injuries on second CT scan, yet only 1% were treated surgically after that scan. Within their population, patients with intraparenchymal injury on the initial head CT were more likely to show worsening brain injury and undergo neurosurgical intervention. In our cohort, 81 patients had repeat neuroimaging, yet only five (6%) had new/evolving clinically significant findings and all were admitted to the ICU at the time of their repeat scan. Two of them were among the subgroup of 18 patients who required ICU interventions (treatment of seizures/status epilepticus); the other three were among the 14 with LOS greater than 2 days who remained in the ICU for neuromonitoring, but did not require interventions.

We found no significant clinical predictors of provider triage to ICU for the entire cohort. Neuroimaging was the most important factor for triage, with initial GCS likely playing a role for certain imaging subgroups. Trauma patients with a report of hemorrhage on CT tend to get admitted to the ICU; however, it is important to distinguish a report of hemorrhage or “cannot exclude” hemorrhage from a clinically significant hemorrhage. For instance, during the time of our study, our institution initiated a quality improvement project to reduce CT imaging in pediatric patients by developing MRI protocols for children with hydrocephalus (18) and head trauma. As such, many patients had brain MRI as part of their trauma evaluations (most common as follow-up studies). Given MRI’s increased sensitivity, this has led to additional findings on imaging; however, the mere presence of these findings should not necessarily indicate a need for a higher level of care, as they often did not represent an actual change in the patient’s condition.

In our cohort, children admitted to higher-than-needed level of care did not represent a significant proportion of the total ICU admissions, nor did they occupy the ICU for a significant number of bed-days. However, having triaged those who did not require ICU interventions to a non-ICU bed might have prevented some of the denials for lack of PICU beds in our institution over the 3-year period. Although risk-stratifying children less than or equal to 4 years old with isolated mild TBI may not significantly impact resource utilization, it is important to identify subgroups of patients that can be safely cared for on the wards,

particularly considering the multitude of competing priorities in the modern-day ICU and the effects of the nationwide nursing shortage (anticipated to worsen through 2030) on ICU bed availability (19, 20). Future directions include development of predictive models for ICU requirement, followed by their implementation utilizing telehealth and smart-phone technology. Approaching the triage process systematically may contribute to improvements in healthcare resource utilization while avoiding preventable adverse outcomes.

Notable limitations to this study include the retrospective nature of the data collection, as well as the use of institutional databases for patient selection. As a result, important information could not be accurately retrieved (e.g., time of admission, frequency of GCS scoring actually received, ICU admits due to lack of IMC beds). Also, while our exclusion criteria targeted patients that would have been more likely to be hospitalized in the ICU, the lack of a universally agreed-upon definition for pediatric polytrauma, for instance, could have added an element of bias to the data collection process. Additionally, reporting head CT findings was challenging given the lack of validated pediatric scoring systems (e.g., adult-validated Rotterdam score), particularly for children with mild TBI (21–23). Despite performing a thorough chart review, it was also difficult to tell exactly how the decision to admit was made. The heterogeneity in provider background, level of training, degree of experience, and nonetheless personal clinical preference may have played a role in the decision to admit to ICU versus non-ICU setting for some children. Also, institutional idiosyncrasies (e.g., propensity to admit infants to ICU) as well as the significant hour-to-hour variability in inpatient bed availability likely added to the inconsistency in decision-making patterns for some patients. Given that hourly neurochecks are done only in the ICU, one of the challenges of such a project is retrospectively deciding who benefited the most from the ICU-level neuromonitoring. Here, we have used intervention (unplanned intubation, seizure/status epilepticus management, neurosurgical procedures) as a surrogate for ICU need. However, certain institutions may also consider neonatal NAT or need for follow-up neuroimaging as justifiable reasons for ICU admission.

CONCLUSIONS

Nearly half of the children in our cohort were briefly monitored in the ICU, with trauma bay imaging reports rather than clinical findings likely explaining the disposition. Notwithstanding potential benefits arising from ICU-level neuromonitoring, less than 10% required actual ICU interventions (many of them in the context of NAT); at risk were patients with extra-axial hemorrhage (especially epidural hematoma), neurologic deficits, and LOC/seizures post-trauma. In our study, ICU burden from infants and young children with mild TBI admitted to higher-than-needed level of care did not appear to be statistically significant. Nevertheless, it is important to explore opportunities for development and implementation of predictive models to determine optimal disposition that preserves safety while balancing healthcare resource utilization.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Graph displaying trauma bay disposition versus patient neuroimaging. ICH = intracranial hemorrhage, IMC = intermediate care unit, MLS = midline shift, SAH = subarachnoid hemorrhage.

TABLE 1.Characteristics of Patients With Mild Traumatic Brain Injury and Neuroimaging Findings ($n = 210$)

Patient Characteristics	<i>n</i>
Demographics	
Age, mo, median (IQR)	6 (2–20)
Male, <i>n</i> (%)	119 (56.7)
Weight, kg, median (IQR)	7.5 (5–11)
Transport data	
Trauma transfers, <i>n</i> (%)	162 (77.1)
Transport mode, <i>n</i> (%)	
Ground	139 (85.8)
Air	23 (14.2)
Interhospital distance in miles, median (IQR)	17 (7–31)
Physician in transport, <i>n</i> (%)	16 (9.9)
Trauma bay data	
Glasgow Come Scale score, median (IQR)	15 (14–15)
Mechanism of injury, <i>n</i> (%)	
Fall	159 (75.7)
Motor vehicle accident	14 (6.7)
Initial diagnosis of nonaccidental trauma	13 (6.2)
Blunt trauma	4 (1.9)
Sports related	2 (1)
Animal related	2 (1)
Other	2 (1)
Unknown	14 (6.7)
History of loss of consciousness/seizures post-trauma, <i>n</i> (%)	20 (9.5)
Neurologic deficit, <i>n</i> (%)	4 (1.9)
Distracting injuries ^a , <i>n</i> (%)	10 (4.8)
Disposition, <i>n</i> (%)	
PICU	100 (47.6)
Intermediate care unit	15 (7.1)
Ward	80 (38.1)
Home	15 (7.1)

IQR = interquartile range.

^aPatients with injury severity score ≥ 15 .

TABLE 2.Neuroimaging Characteristics of Patients With Mild Traumatic Brain Injury ($n = 210$)

Neuroimaging Characteristics ^a , n (%)	n
Nondisplaced/minimally displaced single skull fracture	58 (27.6)
Displaced/comminuted skull fracture	11 (5.2)
Multiple skull fractures	10 (4.8)
Skull fracture with subarachnoid hemorrhage.	11 (5.2)
Skull fracture with extra-axial hemorrhage without MLS	62 (29.5)
Skull fracture with intraparenchymal hemorrhage without MLS	10 (4.8)
Skull fracture with ICH and MLS	3 (1.4)
ICH without MLS and no skull fracture	40 (19.1)
ICH with MLS and no skull fracture	5 (2.4)

ICH = intracranial hemorrhage, MLS = midline shift.

^aData abstracted from radiology reports of initial neuroimaging evaluated at the Johns Hopkins Hospital.

TABLE 3.

Hospital Course for Included Patients

Measure	All Patients (<i>n</i> = 210)	ICU Patients (<i>n</i> = 100)	Non-ICU Patients ^a (<i>n</i> = 110)
Diagnosed with nonaccidental trauma, <i>n</i> (%)	32 (15.2)	24 (24)	8 (7.2)
Required nonelective intubation, <i>n</i> (%)	2 (1)	2 (2)	0
Seizure/status epilepticus management, <i>n</i> (%)	9 (4.3)	9 (9)	0
Required neurosurgical intervention, <i>n</i> (%)	9 (4.3)	8 (8)	1 (0.9)
Skull fracture elevation	6 (2.9)	5 (5)	1 (0.9)
Epidural hematoma evacuation	2 (1)	2 (2)	0
Subdural peritoneal shunt placement	1 (0.5)	1 (1)	0
Required surgical intervention, <i>n</i> (%)	1 (0.5)	0	1 (0.9)
Repeat neuroimaging performed, <i>n</i> (%)	81 (38.6)	60 (60)	21 (19.1)
First repeat imaging was MRI	58 (27.6)	41 (41)	17 (15.5)
First repeat imaging was CT	21 (10)	17 (17)	4 (3.6)
First repeat imaging was head ultrasound	2 (1)	2 (2)	0
Indication for repeat neuroimaging, <i>n</i> (%)			
Monitor progression	73 (34.8)	56 (56)	17 (15.5)
Clinical changes	6 (2.9)	3 (3)	3 (2.7)
Concern for vascular injury	2 (1)	1 (1)	1 (0.9)
Changes in repeat neuroimaging, <i>n</i> (%)	26 (12.4)	19 (19)	7 (6.3)
Due to difference in imaging modality	14 (6.7)	9 (9)	5 (4.5)
New/evolving findings	5 (2.4)	4 (4)	1 (0.9) ^b
Postoperative changes	4 (1.9)	3 (3)	1 (0.9)
Improved findings	3 (1.4)	3 (3)	0
ICU length of stay, d, median (IQR)	2 (1–3)	2 (1–3)	Not applicable
Hospital length of stay, d, median (IQR)	2 (2, 3)	3 (2–4.5)	2 (1, 2)
Neurologic deficit at discharge, <i>n</i> (%)	6 (2.9)	6 (6)	0
Home discharge, <i>n</i> (%)	208 (99)	98 (98)	110 (100)
Inpatient rehabilitation center discharge, <i>n</i> (%)	2 (1)	2 (2)	0
Hospital readmission within 7 d, <i>n</i> (%)	8 (3.8)	4 (4)	4 (3.6)

IQR = interquartile range.

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Patients evaluated in the trauma bay and triaged to non-ICU settings: intermediate care unit ($n = 15$), ward ($n = 80$), home ($n = 15$).
Patient was initially discharged home from the emergency department without imaging, however returned, was found to have small basal ganglia hemorrhage on head CT, and was then admitted to the ICU where he had his repeat scan.

TABLE 4.

Trauma Bay Risk Factors for Receiving ICU Interventions

Risk Factors	Patients With ICU Interventions ^a , n = 18, n (%)	Patients Without ICU Interventions, n = 192, n (%)	Relative Risk (95% CI)	p
Glasgow Coma Scale < 15	12 (66.7)	63 (32.8)	2.00 (0.81–4.93)	0.13
Presence of neurologic deficit	2 (11.1)	2 (1)	4.04 (1.61–10.16)	0.003
Loss of consciousness and/or seizures post-trauma	4 (22.2)	16 (8.3)	2.57 (1.04–6.35)	0.04
Age < 6 mo	9 (50)	98 (51)	0.69 (0.30–1.61)	0.39
Unknown mechanism of injury	3 (16.7)	11 (5.7)	1.61 (0.55–4.74)	0.38
Epidural hematoma	4 (22.2)	14 (7.3)	3.04 (1.12–8.31)	0.029
Extra-axial hemorrhage	13 (72.2)	76 (39.6)	3.53 (1.30–9.58)	0.013
Intraparenchymal hemorrhage/subarachnoid hemorrhage	3 (16.7)	37 (19.3)	0.85 (0.26–2.80)	0.79
Displaced/comminuted fractures	2 (11.1)	9 (4.7)	2.38 (0.74–7.64)	0.15
Midline shift	2 (11.1)	6 (3.1)	1.44 (0.40–5.20)	0.58

^aNonelective intubation, seizure/status epilepticus management, neuromonitoring post surgical/neurosurgical procedures.Boldface values indicate statistical significance ($p < 0.05$).