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Prognostic Factors to Reduce ICU Overtriage in Elderly Patients with Isolated Mild Traumatic Brain Injury

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Abstract

Introduction: Elderly patients with mild traumatic brain injury (mTBI) are frequently admitted to an intensive care unit (ICU), which is potentially both harmful and unnecessary. It is not known which patients may be safely observed in a non-ICU setting, potentially improving ICU utilization. The purpose of this study was to identify factors that predict which geriatric patients with traumatic brain injury may be admitted to a level of care other than the ICU. **Methods:** Adults ≥65+ years admitted with positive radiologic study demonstrating isolated mTBI (defined as Glasgow Coma Scale (GCS) 13 - 15) that was initially managed nonoperatively between January 2011-December 2016 were identified. Primary outcomes evaluated included over triage and Glasgow Outcome Scale (GOS). **Results:** 207 were identified. Most patients presented with GCS 15 (77.8%) and were admitted to ICU (85.5%). 27% (n = 55) met overtriage criteria. The most common TBI was subdural hemorrhage (SDH) (48.8%) followed by subarachnoid hemorrhage (SAH) (22.2%). Hemorrhage progression developed in 8.7% of subjects, but there was no difference across TBI type. 21.7% of patients developed a ≥2 point decrease in GCS during their hospital stay. Upon discharge, 89.9% had a GOS ≥ 4 - 5. Presence/type of a single intracranial hemorrhage (ICH) was not significantly associated with outcome, but presence of bilateral or multiple lesions was significantly associated with poor outcome (p = 0.04). **Conclusions:** Overtriage of patients to an ICU is costly, resource intensive, and avoidable. Here, we suggest a conservative framework to assist the determination of which patients can be safely observed in non-ICU setting. Future studies should determine if this framework is generalizable to the entire geriatric population who present with mTBI.

Keywords

Traumatic Brain Injury, Geriatric Trauma, Overtriage, Intensive Care Unit, Outcomes

1. Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability in the United States (US) with nearly 1.8 million people sustaining TBI each year [1]. An estimated 75% of those are classified as mild TBI, defined by a Glasgow Coma Scale (GCS) score of 13 - 15 [2] [3]. The highest rates of TBI have traditionally been observed in the very young (0 - 4 years), in adolescents and young adults (15 - 24 years), and in the elderly (65+ years) [4]. However, as a result of an aging trauma population, the epidemiology of TBI in several Western countries is changing, with an increasing proportion of TBI patients above the age of 65 [5] [6]. The most common mechanism of injury in this age group is falls, which are the leading cause of injury-related Emergency Department (ED) visits and of injury-related death in the United States (US) for this group [7] [8] [9].

In addition to adapting to an aging trauma population, providers are grappling with the crisis of rising costs in the US health care system [5] [10]. Falls represent a significant financial burden to taxpayers, with an estimated annual cost for medical treatment upwards of 50 billion dollars. Nearly 75% of that cost paid by Medicaid and Medicare [11]. This crisis has prompted the reevaluation of various diagnostic tests and their clinical application. In the area of traumatic brain injury, much of the literature has focused on repeat cranial computed tomography (CT), particularly in cases of mild TBI. Common practice at many institutions is to have the patient undergo a repeat head CT 12 - 24 hours after admission [12]. Results have been mixed, but numerous studies have demonstrated that routine re-scanning of asymptomatic patients with TBI who are managed non-operatively is unlikely to alter care unless a clinically important change in the patient occurs [12] [13] [14] [15] [16].

Compounding the cost of potentially unnecessary radiologic examinations is the common practice to admit elderly patients with mild TBI to intensive care units (ICU), the most expensive and resource intensive level of hospital care. The drawbacks to this are not only the financial considerations but also the well-known harm associated with a stay in the ICU, particularly for elderly patients [17]. Recent evidence has suggested that many patients with mild TBI do not require ICU admission and can be monitored safely in a lower acuity level ward. While this has been investigated in the pediatric setting, there is a paucity of literature regarding the safety of this practice in patients aged 65 and greater. The aim of this study is to identify a subset of elderly patients with mild TBI with low risk of clinical deterioration who could safely be monitored in a non-ICU setting.

2. Methods

2.1. Identification of Patients and Data Collection

Following approval by the institutional review board, consecutive patients over a six-year period (2011-2016) with an isolated mild traumatic brain injury were identified using the trauma registry (Trauma One version 4.21, Lancet Technology) at the Our Lady of the Lake Regional Medical Center Trauma Center in Baton Rouge, Louisiana. Mild traumatic brain injury was defined as those patients presenting with a GCS ≥ 13. Patients with an age of ≥65 years, a blunt mechanism of injury (MOI), and without additional injuries were included in the study. Those patients who underwent initial operative management by neurosurgery, who had a prior history of TBI, or who were intubated at the time of admission were excluded.

The charts of these patients were reviewed for patient characteristics (including age at admission, type of injury, gender, body mass index (BMI), mechanism of injury, and comorbid conditions), injury severity (including GCS, Injury Severity Score (ISS), admission systolic blood pressure and heart rate), and outcomes (including ICU length of stay (LOS), hospital LOS, in-hospital mortality, delayed neurosurgical intervention, cognitive decline, 30-day TBI-related readmission, and a poor outcome). Injury types included subdural hemorrhage (SDH), subarachnoid hemorrhage (SAH), intraparenchymal hemorrhage (IPH), other intracranial hemorrhage (ICH), and multiple types of hemorrhage. Discharge disposition (including home, inpatient rehabilitation, skilled nursing facility, hospice, and other) was identified and recorded. If a patient resided in a nursing home prior to admission and was discharged back to the nursing home after the hospital stay, the discharge disposition was categorized as home. Comorbid conditions evaluated included chronic obstructive pulmonary disorders, diabetes mellitus, history of stroke, renal failure/chronic kidney disease, atrial fibrillation, hypertension, coronary artery disease, and use of home antiplatelet/anticoagulant therapy.

2.2. Clinical Outcomes

Cognitive decline was defined as a decrease in GCS by ≥2, in-hospital loss of consciousness, seizure or increased/new hemorrhage on follow-up imaging. Increasing area of hemorrhage was defined as an increase in intracranial hemorrhage volume > 30% or new area of hemorrhage. Clinical outcome was determined using the Glasgow Outcome Scale, which assesses the functional ability of a patient and their extent of reliance on others to complete activities of daily living (ADL) [4]. The GOS has 5 categories: 1) death, 2) persistent vegetative state, 3) severe disability (interferes with ADL and requires dependence on others for care), 4) moderate disability (minor neurological deficits or short term physical disability but independent), and 5) good recovery (able to resume normal daily life and activities). Positive outcome was defined as a GOS 4 - 5 and poor outcome as GOS ≤ 3. Overtriage was defined as hospital stay ≤2 days, ICU

≤ 1 overnight stay, no surgery, no intubation, and discharged home.

2.3. Statistical Analysis

Descriptive statistics were used to describe the cohort. Normally distributed continuous variables were described as mean (standard deviation), while variables lacking normal distribution were described using median (interquartile range [IQR]). Patients with a positive outcome at discharge were compared to those with a poor outcome. Additionally, patients who met criteria for over triage were compared to those who did not. Chi Square analysis was used to examine categorical data between groups, while the Independent Samples t-test and Mann-Whitney U test were used where appropriate to examine continuous data between groups. Risk factors for overtriage and poor outcome were examined by univariate and multivariable logistic regression analysis. Receiver operating characteristic (ROC) curve analysis was used to assess the predictive probabilities of the regression models. Correlations were examined using Pearson's correlation. Statistical calculations were performed using Statistical Package for the Social Sciences (SPSS version 25, Armonk, NY) software. Significance was defined at a value of $P < 0.05$.

3. Results

A total of 234 patients were identified. Of those, 27 underwent emergent neurosurgical operative intervention and were excluded. The remaining 207 patients were included in the analysis. Figure 1 and Table 1 demonstrates a comparison of patient characteristics, injury severity, and outcomes between all patients and for those with a positive or poor outcome at discharge. Overall, these patients ranged in age from 65 - 98 years (mean = 79.6) and were largely female (60.4%). The most common mechanism of injury was falls (95.7%) and the median ISS was 16 (IQR = 9 - 16). The most common type of TBI was subdural hematoma (48.8%) followed by subarachnoid hemorrhage (22.2%). Only 5% of patients presented with no comorbidities, while nearly 30% of patients presented with 4 or more comorbidities. The most common comorbidity was hypertension (87.9%). This was followed by dementia (41.1%) and then by diabetes (32.9%). Only atrial

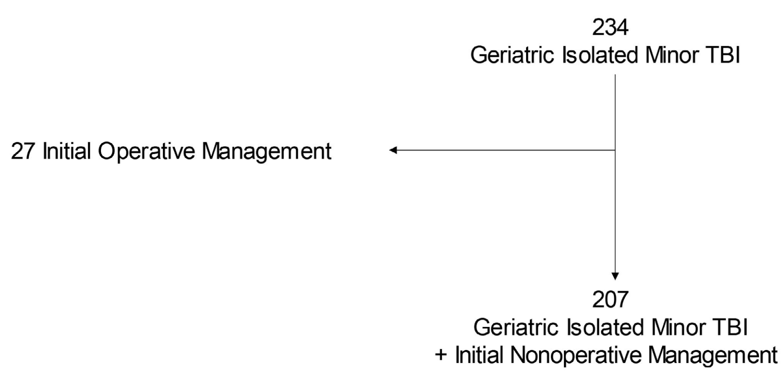

Figure 1. Geriatric TBI patients.

Table 1. Demographic and clinical characteristics of patient cohort at time of admission.

Descriptor	Total Cohort (n = 207)	Positive outcome (n = 186)	Poor outcome (n = 21)	P
Age groups in years				
65 - 74	57 (27.5)	54 (29)	3 (14.3)	0.152
75 - 84	86 (41.5)	78 (41.9)	8 (38.1)	0.735
≥85	64 (31)	54 (29)	10 (47.6)	0.081
Gender				
Male	82 (39.6)	72 (38.7)	10 (47.6)	0.429
Female	125 (60.4)	114 (61.3)	11 (52.4)	
Admitted from NH	32 (15.5)	31 (16.7)	1 (4.8)	0.153
# comorbidities/patient‡	3 (2 - 4)	3 (2 - 4)	4 (3 - 4)	**0.001**
Specific comorbidity				
Hypertension	182 (87.9)	164 (88.2)	18 (85.7)	0.743
Diabetes mellitus	68 (32.9)	58 (31.2)	10 (47.6)	0.128
Coronary artery disease	61 (29.5)	53 (28.5)	8 (38.1)	0.360
Atrial fibrillation	50 (24.2)	40 (21.5)	10 (47.6)	**0.008**
Congestive heart failure	38 (18.4)	31 (16.7)	7 (33.3)	0.061
Chronic obstructive pulmonary disorder	19 (9.2)	15 (8.1)	4 (19)	0.098
Renal failure/chronic kidney disease	18 (8.7)	12 (6.5)	6 (28.6)	**0.001**
History of stroke	29 (14.0)	21 (11.3)	8 (38.1)	**0.001**
Dementia	85 (41.1)	79 (42.5)	6 (28.6)	0.220
Injury Severity Score‡	16 (9 - 16)	16 (9 - 16)	16 (16 - 20)	**<0.001**
Mechanism of injury				
Fall	198 (95.7)	177 (95.2)	21 (100)	0.588
Motor vehicle crash	8 (3.9)	8 (4.3)	--	
Assault	1 (0.5)	1 (0.5)	--	
Admit vitals‡				
HR	80 (70 - 88)	80 (71 - 88)	84 (65 - 93)	0.822
BT (˚F)	98.1 (97.8 - 98.5)	98.2 (97.9 - 98.5)	97.9 (97.6 - 98.3)	0.125
SBP	143 (129 - 161)	143 (131 - 161)	139 (117 - 170)	0.280
RR	18 (16 - 20)	18 (16 - 19)	18 (15 - 19)	0.182
GCS	15 (15 - 15)	15 (15 - 15)	14 (14 - 15)	**<0.001**
Home antithrombotic				
None	87 (42.0)	84 (45.2)	3 (14.3)	**0.007**
Antiplatelet	81 (39.1)	70 (37.6)	11 (52.4)	0.189

Continued

Anticoagulation	32 (15.5)	27 (14.5)	5 (23.8)	0.264
Both	7 (3.4)	5 (2.7)	2 (9.5)	0.100
Admit lab values‡				
Platelets	210 (173 - 261)	209 (171 - 259)	221 (196 - 298)	0.227
PT	13.9 (12.3 - 15.1)	13.9 (13.2 - 15.1)	14.1 (13.3 - 25.3)	0.196
PTT	30 (27 - 34)	30 (27 - 34)	28 (25 - 35)	0.501
INR	1.1 (1.0 - 1.2)	1.1 (1.0 - 1.2)	1.1 (1.0 - 2.5)	0.153
TBI type				
SDH	101 (48.8)	91 (48.9)	10 (47.6)	0.910
SAH	46 (22.2)	44 (23.7)	2 (9.5)	0.140
IPH	6 (2.9)	6 (3.2)	--	0.404
Other ICH	25 (12.1)	23 (12.4)	2 (9.5)	0.705
Bilateral/multiple TBI	29 (14.0)	22 (11.8)	7 (33.3)	**0.007**
Hospital LOS‡	4 (2 - 7)	3 (2 - 6)	10 (6 - 17)	**<0.001**
ICU LOS‡	2 (1 - 3)	2 (1 - 3)	4 (1.5 - 9)	**0.003**
Discharge disposition				
Home/home health	140 (67.6)	139 (74.7)	1 (4.8)	**<0.001**
Rehabilitation	27 (13.0)	24 (12.9)	3 (14.3)	0.858
SNF	25 (12.1)	17 (9.1)	8 (38.1)	**<0.001**
Other/ICF	2 (1)	2 (1.1)	-	0.633
Hospice	10 (4.9)	4 (2.2)	6 (28.6)	**<0.001**
In-hospital mortality	3 (1.4)	--	3 (14.3)	definitional
30 day neuro-related readmission	31 (15)	28 (15.1)	3 (14.3)	0.918

All values are frequencies reported as n (%), unless marked by ‡, which denotes median (IQR). NH—nursing home; HR—heart rate; BT—body temperature; SBP—systolic blood pressure; RR—respiratory rate; GCS—Glasgow Coma Scale; PT—prothrombin time; PTT—partial thromboplastin time; INR—international normalized ratio; TBI—traumatic brain injury; SDH—subdural hematoma; SAH—subarachnoid hemorrhage; IPH—intra-parenchymal hemorrhage; ICH—intracranial hemorrhage.

fibrillation (P = 0.008), renal failure/chronic kidney disease (P = 0.001), and history of stroke (P = 0.001) were associated with a poor outcome. Home use of anticoagulant or antiplatelet medications was noted in 58% of the study population. Use of any of anticoagulation or antiplatelet therapy, alone or in combination, was not significantly associated with poor outcomes. However, the absence or non-use of these medications was found to be associated with positive outcome (P = 0.007). Median hospital length of stay was 7 days longer in subjects with poor outcome compared to those with a positive outcome (P < 0.001). The median number of ICU days was also significantly longer in the poor outcome cohort compared to the positive outcome group (4 vs 2 days, P = 0.003). All but one patient discharged to home had a positive outcome at discharge. The only patient discharged home with a poor outcome was sent there at the express wishes of their family. There was no difference between the two subgroups in frequency of discharge to rehabilitation, but discharge to skilled nursing facilities or hospice was significantly more likely to occur in those with a poor outcome (P < 0.001). The overall-day TBI-related readmission rates were 15% and did not differ between the two groups.

Utilization of imaging resources is examined in **Table 2**. Repeat imaging was pursued within the first 24 hours of presentation in nearly all patients (94.2%), and the most used imaging modality was CT alone or in combination with MRI (91.3%). Stated indications for repeat head CT were most commonly routine follow-up (85%) followed distantly by cognitive decline or altered mental status (2.9%). Patients with poor outcome had significantly more head CT scans compared to those with positive outcome (P < 0.001). There was no difference between prior to admission use of anticoagulant or antiplatelet therapy in time to repeat head CT in days (P = 0.713) (**Figure 1**). However, those who received combined antiplatelet and anticoagulation therapy received a significantly higher mean number of repeat head CT scans compared to those on monotherapy or

Table 2. Utilization of imaging resources.

Imaging utilization	Total cohort (n = 207)	Positive outcome (n = 186)	Poor outcome (n = 21)	P
Repeat imaging in 1st 24 hours	195 (94.2)	174 (93.5)	21 (100)	0.230
Repeat imaging type				
None	12 (5.8)	12 (6.5)	0	0.303
CT	174 (84.1)	156 (83.9)	18 (85.7)	
MRI	6 (2.9)	6 (3.2)	0	
Both	15 (7.2)	12 (6.5)	3 (14.3)	
Indication for repeat CT				
Routine repeat	176 (85.0)	159 (94.6)	17 (81)	**0.019**
Pre-op check	3 (1.4)	3 (1.8)	0	0.537
Post-op check	2 (1.0)	1 (0.6)	1 (4.8)	0.079
Cognitive decline/AMS	6 (2.9)	4 (2.4)	2 (9.5)	0.078
Post-seizure	2 (1.0)	1 (0.6)	1 (4.8)	0.079
Time to repeat head CT (days)‡	1.0 (1.0)	1.0 (1.0)	1.0 (1.0 - 2.0)	0.549
Range of days to follow up CT	0 - 13	0 - 5	0 - 3	
# of follow up CT head scans‡	1 (1 - 2)	1 (1 - 2)	2 (1 - 5)	**<0.001**

All values are frequencies presented as n (%) unless marked by ‡, which denotes median (IQR). CT—computed tomography; MRI—magnetic resonance imaging; AMS—altered mental status.

no therapy (P < 0.001). Number of repeat head CT scans was found to be significantly correlated with length of stay [r (206) = 0.793, P < 0.001]. Within the overtriaged subgroup, 8 of 55 (14.5%) received no follow up neuroimaging. Of the 47 that received repeat neuroimaging, all were noted as routine repeat scans with no incidence of cognitive decline, altered mental status, or seizure.

The association of patient factors with overtriage is detailed in **Table 3**. More than one-fourth (n = 55, 26.6%) of the study population met overtriage criteria. Age, injury severity, and admission GCS were not associated with increased odds of overtriage. Of the individual comorbidities examined, atrial fibrillation, congestive heart failure, and renal failure/chronic kidney disease were each significantly associated with decreased odds of overtriage. When the number of comorbidities was examined, presence of one comorbid condition was associated with significantly increased odds of overtriage (P = 0.030) but presence of 4 or more comorbidities was strongly associated with decreased odds of overtriage (P = 0.007). No difference was found for the presence of 2 or 3 comorbidities. Home pharmacotherapy of antiplatelet agents alone or in conjunction with an anticoagulant bore no effect on overtriage, but home use of an anticoagulant alone significantly decreased odds of overtriage (P = 0.017). The specific type of TBI incurred did not influence overtriage; however, a diagnosis of multiple traumatic brain injuries was significantly associated with decreased odds of overtriage.

The association of in-hospital factors complications and outcomes in appropriately placed vs overtriage cohorts are described in **Table 4**. No patient overtriaged to ICU experienced poor outcomes. Only 3 of 55 (5.5%) experienced a change in GCS of 2 or more points at least once during hospitalization, which was significantly lower than the 27.8% observed in the appropriately placed cohort (P = 0.001). Increased or new hemorrhage was identified in 12.1% of patients appropriately triaged compared to none in the overtriaged group (P = 0.012). No incidents of loss of consciousness or increased/new hemorrhage were observed in the overtriage group.

Type of TBI was not found to be associated with hemorrhage progression apart from multiple intracranial diagnoses, which increased odds of new or worsening hemorrhage four-fold [odds ratio (OR): 4.045, 95% confidence interval (CI): 1.190 - 13.758; P = 0.025]. No TBI type was found to be associated with increased odds of 2+ point decrease in GCS, but SAH was found to have significantly lower odds of decreased GCS (OR: 0.290, 95% CI: 0.094 - 0.888; P = 0.03). No association as observed between TBI type and in-hospital loss of consciousness (P = 0.703). Pre-injury use of home antithrombotic agents was not associated with delayed neurosurgical intervention (P = 0.151), increased or new hemorrhage (p = 0.898), or 30-day readmission (P = 0.409).

We then sought to determine which patient factors were predictors of a poor outcome (**Table 5**). In the model, increasing number of comorbidities present on admission was significantly associated with increased odds of poor outcome (P = 0.005). Neither home anticoagulant and/or antiplatelet medication use, nor

Table 3. Association of patient factors with overtriage.

	Appropriate (n = 152)	Overtriage (n = 55)	Odds Ratio	95% CI	P
Age‡	80 (73 - 85)	80 (75 - 87)	1.008	0.971 - 1.047	0.672
ISS‡	16 (9 - 16)	9 (9 - 16)	0.943	0.880 - 1.011	0.609
Admit GCS					
15	115 (75.7)	46 (83.6)	1.761	0.860 - 3.605	0.122
14	30 (19.7)	9 (16.4)	0.750	0.330 - 1.702	0.491
13	7 (100)	-			-
Comorbidities					
Hypertension	134 (88.2)	48 (87.3)	0.921	0.362 - 2.342	0.863
Dementia	61 (40.1)	24 (43.6)	1.155	0.619 - 2.155	0.651
Atrial fibrillation	45 (29.6)	5 (9.1)	0.238	0.089 - 0.635	**0.002**
CHF	34 (22.4)	4 (7.3)	0.272	0.092 - 0.807	**0.013**
RF/CKD	17 (11.2)	1 (1.8)	0.147	0.019 - 1.132	**0.035**
COPD	16 (10.5)	3 (5.5)	0.490	0.137 - 1.753	0.264
Hx CVA	25 (16.4)	4 (7.3)	0.398	0.132 - 1.202	0.093
CAD	46 (30.3)	15 (27.3)	0.864	0.435 - 1.718	0.677
Prior TBI	6 (3.9)	1 (1.9)	0.459	0.054 - 3.903	0.465
# of comorbidities					
0	6 (3.9)	5 (9.3)	2.483	0.726 - 8.496	0.136
1	20 (13.2)	14 (25.9)	2.310	1.070 - 4.985	**0.030**
2	33 (21.7)	16 (29.6)	1.518	0.754 - 3.057	0.240
3	41 (27.0)	11 (20.4)	0.693	0.326 - 1.470	0.337
≥4	52 (34.2)	8 (14.8)	0.334	0.147 - 0.761	**0.007**
Pre-injuryAT therapy					
None	58 (38.2)	29 (52.7)	1.808	0.970 - 3.368	0.061
Antiplatelet	59 (38.8)	22 (40)	1.051	0.559 - 1.974	0.877
Anticoagulant	29 (19.1)	3 (5.5)	0.245	0.071 - 0.839	**0.017**
Both	6 (3.9)	1 (1.8)	0.451	0.053 - 3.830	0.454
TBI type, n (%)					
SDH	73 (48.0)	28 (50.9)	1.122	0.606 - 2.080	0.714
SAH	29 (19.1)	17 (30.9)	1.897	0.942 - 1.536	0.071
IPH	4 (2.6)	2 (3.6)	1.396	0.248 - 7.845	0.703
Other ICH	20 (13.2)	5 (9.1)	0.660	0.235 - 1.854	0.428
Multiple TBI	26 (17.1)	3 (5.5)	0.280	0.081 - 0.964	**0.033**

All values are frequencies presented as n (%) unless marked by ‡, which denotes median (IQR). CI—confidence interval; ISS—Injury Severity Score; GCS—Glasgow Coma Scale; CHF—congestive heart failure; RF—renal failure; CKD—chronic kidney disease; COPD—chronic obstructive pulmonary disorder; Hx—history; CVA—cerebrovascular accident; CAD—coronary artery disease; TBI—traumatic brain injury; AT—antithrombotic; SDH—subdural hematoma; SAH—subarachnoid hemorrhage; IPH—intraparenchymal hemorrhage; ICH—intracranial hemorrhage.

Table 4. Examination of in-hospital complications/outcome in appropriately placed vs overtriage cohort.

Parameter	Total (n = 207)	Appropriate (n = 152)	Overtriage (n = 55)	P
Cognitive decline				
2 + point change in GCS	45 (21.8)	42 (27.8)	3 (5.5)	**0.001**
In-hospital loss of consciousness	7 (3.4)	7 (4.6)	0	0.104
Increased/new hemorrhage on follow up neuroimaging	18 (9.2)	18 (12.1)	0	**0.012**
Delayed neurosurgical intervention	16 (7.7)	16 (10.5)	0	**0.012**
Poor outcome	21 (10.1)	21 (13.8)	0	**0.004**

All values are frequencies reported as n (%). GCS—Glasgow Coma Scale.

Table 5. Multivariable logistic regression examining patient and injury characteristics as prognostic of poor outcome.

Parameter	Odds ratio	95% CI	P
# of comorbidities	1.690	1.172 - 2.438	**0.005**
Pre-injury AT therapy	2.810	0.753 - 10.483	0.124
Admit GCS	0.457	0.214 - 0.975	**0.043**
ICU admission	1.126	0.233 - 5.684	0.886
Multiple TBI	3.540	1.080 - 11.607	**0.037**

AT—antithrombotic; GCS—Glasgow Coma Scale; ICU—intensive care unit; TBI—traumatic brain injury.

ICU admission were associated with poor outcomes (P = 0.124 and 0.886, respectively). Higher admission GCS decreased odds of poor outcome significantly (P = 0.043), while presence of multiple intracranial hemorrhages on admission imaging was the strongest predictor of poor outcome [odds ratio 3.540, 95% confidence interval (1.080 - 11.607); P = 0.037]. A ROC curve of the predictive probabilities of the model revealed an area under the curve (AUC) and 95% CI of 0.810 (0.727 - 0.892) which was statistically significant at P < 0.001.

An examination of patient factors available at time of admission to identify which contributed to increased odds of overtriage is detailed in Table 6. Increasing number of comorbidities and the presence of multiple TBI diagnoses were each significantly associated with reduced risk of overtriage (P = 0.031 and P = 0.006, respectively). A ROC curve of the predictive probabilities of the model revealed an area under the curve (AUC) and 95% CI of 0.723 (0.649 - 0.797), respectively, which was statistically significant at P < 0.001.

4. Discussion

An increasing proportion of traumatic brain injury patients are geriatric and represent a population shift that is changing the epidemiology of TBI. Elderly

Table 6. Multivariable logistic regression of patient factors at admission and risk of over-triage.

Parameter	Odds ratio	95% CI	P
Admit GCS	1.463	0.682 - 3.137	0.328
SDH	Ref.		
SAH	1.009	0.457 - 2.226	0.982
IPH	1.269	0.196 - 8.221	0.803
Other ICH	0.800	0.253 - 2.532	0.705
Multiple TBI	0.234	0.063 - 0.877	**0.031**
Antithrombotic-None	Ref.		
Home antiplatelet	1.194	0.563 - 2.535	0.644
Home anticoagulant	0.317	0.083 - 1.204	0.091
Both	0.795	0.081 - 7.758	0.843
# of comorbidities	0.658	0.488 - 0.877	**0.006**

GCS—Glasgow Coma Scale; SDH—subdural hematoma; SAH—subarachnoid hemorrhage; IPH—intraparenchymal hemorrhage; ICH—intracranial hemorrhage; TBI—traumatic brain injury.

patients with mild traumatic brain injury are frequently admitted to an ICU, which is potentially both harmful and unnecessary. Treatment protocols and admission practices for mild TBI differ widely and remain a topic of controversy. Here, we focus exclusively on the growing geriatric patient population and demonstrate a significant and unnecessary use of ICU resources for low risk mTBI as well as provide a conservative outline to guide admission decisions.

Previous studies of protocol-driven efforts to safely evaluate mTBI in an observation unit to standardize admitting practices and better inform resource allocation have demonstrated lower inpatient admission rates from the ED, reduced costs, and decrease lengths of hospital stay [19] [20] [21] [22]. However, many have included all age groups and did not focus on geriatric patients. This includes the well-known Brain Injury Guidelines (BIG), which defined management guidelines based on individual patient features and clinical findings [23]. The BIG guidelines include 3 categories and a definitive therapeutic plan for each of the three. The BIG 3 category recommends hospitalization, repeat head CT, and neurosurgical consultation if a patient presents on antithrombotic agents such as coumadin, aspirin, or clopidogrel. Our findings suggest that this may not be necessary, even in an older patient population. More than half of the present patient population presented on antithrombotic therapy, yet both univariate analysis and multivariate logistic regression revealed that there was no significant increase in frequency or odds of poor outcome for patients on antiplatelets, anticoagulants, or both. These findings are supported by a recent multicenter study which examined records of more than 33,000 patients aged 65 years and higher, approximately half of whom were on single or combination antithrombotic therapy [7]. The authors demonstrated that pre-injury antithrombotic use had minimal impact on TBI incidence, surgery rates, or mortality and concluded that antithrombotic use may have a negligible impact on clinical management. This is an important consideration given that anticoagulant use is increasing, in concert with longer life expectancy and the comorbidities that often accompany advanced age [24]. Physicians should take care to consider a patient's existing comorbidities and overall frailty as more impactful than antithrombotic status when making triage decisions in cases of mTBI.

Repeat head CT in mild traumatic brain injury has been well documented as having little to no effect on management, outcomes, or in identification of patients who require surgical intervention [15] [25] [26] [27] [28]. Despite the ample literature supporting this position, utilization of repeat head CT scans, even in the absence of abnormal or worsening neurologic condition, remain standard practice at most US trauma centers, particularly in patients who present on antithrombotic therapy. This may be, at least in part, due to the wildly conflicting results of previous studies of mild TBI that range from recommending that imaging may not always be indicated to recommendations of serial imaging in patients even after an initial negative head CT to identify delayed hemorrhage, including in elderly patients who have no history of antithrombotic therapy [29] [30] [31] [32]. Of the 189 repeat head CTs observed in the present study, only 8 (4.2%) were due to neurological worsening. Within the overtriaged cohort, all follow up cranial scans were ordered as routine repeats and had no evidence of neurological decline. A lack of evidence-based guidelines to provide a structured management protocol combined with a heightened degree of clinical suspicion regarding mTBI patients who are on antithrombotic therapy results in many physicians resorting to reflexively obtaining repeat cranial imaging in effort to avoid a missed injury and potential subsequent litigation. This practice can result in clinically significant consequences such as increased length of hospital stay in addition to being financially burdensome.

ICU resource utilization/availability has long been discussed in hospitals across the US, but the COVID-19 pandemic has brought this issue to the forefront of national attention and conversations regarding health care delivery. Availability dwindled to zero or near zero in many places during the peak of the pandemic, and allocation policies were widely adopted to help determine who received ICU care under these conditions of scarcity. This entailed providers attempting to determine who was most likely to benefit from the resources of an ICU and from whom these resources should be withheld or withdrawn. This crisis-fueled approach proved problematic because, in addition to the newness of the disease with its many unknowns, prognostic accuracy of providers in predicting outcomes has been to shown to be only slightly better than chance [18]. This prognostic uncertainty is also a significant driver of the wide variability in admitting practices for patients with mTBI.

It is imperative that the safety needs of patients are matched with the appropriate level of care to reduce waste as well as to avoid unnecessarily subjecting patients to the downsides of ICU exposure, namely cost and increased risk of post-intensive care syndrome (PICS). We propose a conservative framework to guide decision making regarding which patients can be safely observed in a non-ICU setting without an increase in adverse outcomes. Specifically, we propose that elderly patients with 2 or fewer comorbidities, admission GCS 14 - 15, a single ICH lesion (excluding EDH), and no other moderate to severe associated injuries can be safely monitored in a non-ICU setting. Application of this criteria to the present population would have resulted in 34 avoided ICU admissions, a 62.8% reduction in overtriage. This reduction would have resulted in a net savings of 66 ICU days.

5. Limitations

This study has several inherent limitations. The primary limitation of this study is that it is retrospective. This precludes exclusion of selection bias and unevaluated differences as potential confounding variables. In addition, this allows only for associations to be made, and cannot account for potential confounding differences. Finally, since this study examined trauma patients exclusively from a single trauma center (Our Lady of the Lake Regional Medical Center, the ACS Level 1 trauma center in Baton Rouge, Louisiana), application of the results to other populations should be done cautiously, especially when treatment modalities other than those described above are applied.

6. Conclusion

Overtriage of patients to an ICU is costly, resource intensive, and avoidable. We propose a conservative framework to guide decision making regarding which patients can be safely observed in a non-ICU setting without an increase in adverse outcomes. Future studies should determine if this framework is generalizable to the entire geriatric population who present with mTBI.

Author Contribution

Study conception and design: Jacome and Tatum. Acquisition of data: Cage, Laborde, Nguyen, Tatum. Analysis and interpretation of data: Tatum, Jacome, Cage, Laborde, Nguyen. Drafting of manuscript: Tatum and Jacome. Critical revision: Jacome, Lewis and Tatum.

Conflicts of Interest

All authors have no conflict of interest.

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