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The epidemiology, prognosis, and trends of severe traumatic brain injury with presenting Glasgow Coma Scale of 3

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ABSTRACT

Purpose: To characterize trends and prognosis of severe traumatic brain injury (TBI).
Methods: This 5-year multicenter retrospective study included patients with TBI and Glasgow Coma Scale of 3. We analyzed demographic and clinical characteristics and mortality using Pearson χ^2 tests, Cochran-Armitage trend tests, and stepwise logistic regression. Analyses were stratified by vehicular and fall etiologies; other etiologies were excluded (24%).
Results: Included were 481 patients. Fall-related injuries increased 58% ($P = .001$) but vehicular etiology did not change ($P = .63$). The characteristics of the populations changed over time; with falls, the population became older and increasingly presented with normal vital signs, whereas with vehicular etiology, the population became younger, with more alcohol-related injury ($P < .05$ for all). Mortality from falls increased substantially from 25% to 63% ($P < .001$), whereas death from vehicular injures remained statistically unchanged but with a downward trend (50%-38%, $P = .28$). Predictors of mortality included injury severity and age at least 65 years for both groups. Additional variables that were prognostic were abnormal vital signs and subdural hematoma for vehicular injuries, and sex for fall injuries.
Conclusions: The epidemiology of severe TBI is changing. These epidemiologic data may be used for management and resource decisions, monitoring, and directing injury prevention measures.

1. Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability in the United States [1]. The incidence of TBI is increasing in the United States and worldwide [2-4]. The epidemiology of TBI is also changing: falls have now surpassed vehicular accidents as the most common cause of injury in the United States [1]. According to the Centers for Disease Control and Prevention (CDC), fall-related TBI increased by 34% between 2002 and 2006 alone [4]. Understanding the evolving injury patterns seen in patients with TBI is essential for preclinical and translational research, acute care management, and preventative efforts.

Concisely stated, "TBI is defined as an alteration in brain function, or other evidence of brain pathology, caused by an external force" [5]. Severity classification is arguably the most important methodological consideration that influences epidemiologic studies of TBI. The Glasgow Coma Scale (GCS) score is the most widely used measure to define the extent and severity of TBI [6]. Glasgow Coma Scale scores range from 3, maximum neurologic deterioration, to 15, normal neurologic function; severe TBI is considered a GCS score of 3 to 8. When analyzed by severity, severe TBI incidence rates have risen, moderate TBI rates are level, and mild TBI hospitalizations have decreased [7]. Besides a GCS score of 15, a GCS score of 3 is the most frequent GCS score reported

Abbreviations: TBI, traumatic brain injury; GCS, Glasgow Coma Scale; *ICD9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification*; AIS, Abbreviated Injury Scale; ISS, injury severity score.

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at admission in patients with a head injury [8]. Although much of the literature has focused on severe TBI, there is little published in the GCS 3 population.

The study objectives are to describe the epidemiology and prognosis of patients with TBI presenting to the ED with a GCS 3, with special focus on changing trends over time. Because the presentation, pathophysiological mechanisms, biomechanics, and treatment of TBI are heterogeneous [2,9], we examined epidemiology and prognosis for patients with vehicular etiology (motor vehicle occupant, motorcycle, pedestrian) and fall etiology (ground level and from a height).

2. Materials and methods

2.1. Design, setting, and participants

We conducted a multicenter, retrospective cohort study of trauma patients treated at 3 adult trauma centers, including 1 level II (the Medical Center of Plano in Plano, Tex) and 2 level I trauma centers (St Anthony Hospital in Lakewood, Colo; Swedish Medical Center in Englewood, Colo). Institutional review boards approved this study at each facility; informed consent was waived.

Patients were selected from TraumaBase (CDM, Evergreen, Colo), a trauma database that contains a broad set of data prospectively collected by dedicated trauma registrars on patients with a traumatic injury. For this study, we included patients with a TBI, identified by the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD9-CM*) diagnosis codes 850-854, admitted between January 1, 2009 and December 31, 2013 with an emergency department (ED) GCS score of 3. The GCS was scored upon arrival to the ED. We included all patients with an ED GCS score of 3, although prehospital intubation and early respiratory and circulatory support were routinely used across these 3 trauma centers per TBI management guidelines. We excluded children (aged <18 years, n = 27) and patients who had concussion (*ICD9-CM*: 850) with no loss of consciousness (n = 29).

We focused this analysis on the most common etiologies of vehicular injuries (n = 285) and falls (n = 196); we excluded recreational injuries (n = 74), gunshot wounds (n = 35), assaults (n = 29), and other causes (n = 9).

2.2. Data collection and analysis

Demographics and clinical characteristics, as well as trends, were examined as follows: specific TBI injuries identified by *ICD9-CM* code, demographics (age, sex, comorbid condition, alcohol-related injury [intoxication at presentation or history of alcoholism]), general injury characteristics (abnormal ED vital signs [including systolic blood pressure <90 mm Hg, respiratory rate <12 or >20 breaths/min, or heart rate <60 or >120 beats/min], injury severity score [ISS], the presence of a severe concomitant extracranial injury [a non–head injury with Abbreviated Injury Scale {AIS} score ≥3 to the chest, extremity, neck/spine, abdomen/pelvic, facial, and external injuries], the severity of the TBI [head AIS score <4 vs ≥4], mechanism), and treatment information (transfer status, intubation and paralytics at the time of the ED GCS assessment, neurosurgical intervention with craniotomy or craniectomy, and neurosurgical monitoring). In-hospital mortality was also reported.

Statistical analysis was performed using commercially available software (SAS version 9.3; SAS Institute, Cary, NC). We used Pearson χ^2 tests and Cochran-Armitage trend tests to analyze trends by year across demographic and injury characteristics and mortality by etiology. A multivariate stepwise logistic regression model with entry criteria of $P < .15$ and exit criteria of $P < .05$ was used to identify predictors of mortality by etiology; covariates included demographics, general and TBI-specific injury characteristics, and TBI diagnoses, defined above. Statistical significance was P value < .05.

3. Results

3.1. Causes of injury and trends over time

There were 481 patients with TBI and a GCS 3 meeting our inclusion criteria: 59% were vehicular injuries and 41% were falls. Within vehicular injuries, 56% were occupants, 29% were motorcycle accidents, and 15% were pedestrians. Within falls, 61% were ground level falls.

Using all TBI with GCS3 as the denominator (n = 628), the proportion of patients with a vehicular injury did not change over time (48.7%-43.6%, $P = .63$). On the contrary, there was a significant 59% increase in falls over time (25.6%-40.6%, $P = .007$).

There were significant changes in the make-up of both the vehicular and fall population over time. With vehicular injuries, the population became increasingly younger, more likely to have an alcohol-related injury, more likely to present with normal vital signs and paralytics, and less likely to have skull fractures and cerebral contusions (Fig. 1, $P < .05$ for all). The fall population became increasingly older, more often female, and less likely to present with abnormal vital signs, with less neurosurgical monitoring (Fig. 2, $P < .05$ for all).

3.2. Patient demographics and presenting characteristics

There were significant differences in the demographics and clinical characteristics depending on etiology (Table 1). Patients with a vehicular injury were predominantly younger men with significant additional extracranial injuries, whereas patients suffering from falls were more likely to be older patients with comorbid conditions, have no extracranial injury, and have an alcohol-related injury (29%). Diagnoses of TBI differed by etiology: patients suffering from falls experienced a high rate of subdural hematomas (SDHs; 71%); vehicular injuries had a high proportion of "other" intracranial injuries including diffuse axonal injury and more patients with isolated concussions.

Not surprisingly, the GCS 3 population was found to have anatomically severe TBI, with 71% having a head AIS score of at least 4; fall etiology had more severe TBI (Table 1). The rate of anatomically severe TBI (head AIS score ≥4) did no differ when GCS scores were potentially complicated by intubation and/or paralytics (71%) compared with "uncomplicated" GCS scores (76%). Still, a significant proportion of our patients had potentially complicated GCS scores. This can be evidenced in a high 11% rate of patients presenting with GCS 3 and minor head injuries with AIS score of 2, mostly with TBI diagnoses of concussion with brief loss of consciousness and isolated subarachnoid hemorrhage.

Fall etiology had greater utilization of neurosurgical management with craniotomy and less neurosurgical monitoring, compared with vehicular etiology (Table 1); this latter comparison was largely driven by significantly less monitoring with falls over time (Fig. 2).

3.3. Mortality

Overall mortality was 43% and was not significantly different based on etiology: 40% vehicular vs 48% falls ($P = .08$). However, mortality from falls increased by 25% to 63% ($P = .001$), particularly in those 65 years or older (25%-92%, $P = .002$). Death from vehicular injures remained statistically unchanged but with a downward trend (50%-38%, $P = .28$).

Variables that were univariately associated with mortality in the fall population were as follows: age ≥ 65 years, female sex, non–alcohol-related injury, severe head injury, contusion/laceration, and absence of epidural hematoma ($P < .05$ for all). Variables that were univariately associated with mortality in the vehicular injury population were as follows: age ≥ 65 years, abnormal vital sign, presence of comorbidity, non–alcohol-related injury, severe extracranial injury, severe head injury, and presence of SDH or subarachnoid hemorrhage ($P < .05$ for all).

Independent predictors of in-hospital mortality are shown in Table 2. Not unexpectedly, the presence of a very severe injury defined