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Clinical Epidemiology of Adults with Moderate Traumatic Brain Injury

Arraya Watanitanon, MD^{1,2}, Vivian H. Lyons, MPH^{2,3}, Abhijit V. Lele, MBBS, MD, MS¹, Vijay Krishnamoorthy, MD^{2,4}, Nophanan Chaikittisilpa, MD^{1,2}, Theerada Chandee, MD^{1,2}, and Monica S. Vavilala, MD^{1,2}

¹Department of Anesthesiology and Pain Medicine, University of Washington, Seattle, WA

²Harborview Injury Prevention and Research Center, University of Washington, Seattle, WA

³Department of Epidemiology, University of Washington, Seattle, WA

⁴Department of Anesthesiology, Duke University

Abstract

Objective—To characterize admission patterns, treatments and outcomes among patients with moderate traumatic brain injury.

Design—Retrospective cohort study.

Setting—National Trauma Data Bank.

To whom correspondence should be addressed: Arraya Watanitanon, M.D. Visiting Scholar, Department of Anesthesiology & Pain Medicine, Harborview Injury Prevention and Research Center, University of Washington, 325, 9th Avenue, Box 359960, Seattle, WA, 98104, Tel: 1-206-744-9439, Fax: 1-206-744-9962, arrayawat@gmail.com.

Arraya Watanitanon, M.D. Visiting Scholar, Department of Anesthesiology & Pain Medicine, Harborview Injury Prevention and Research Center, University of Washington, 325, 9th Avenue, Box 359960, Seattle, WA, 98104, Tel: 1-206-744-9439, Fax: 1-206-744-9962, arrayawat@gmail.com

Vivian H. Lyons, MPH. Department of Epidemiology, School of Public Health, University of Washington, 1959 NE Pacific Street, Health Sciences Bldg, F-262, Box 357236, Seattle, WA 98195-7236. Tel: 1-206-412-5894. vlyons@uw.edu

Abhijit Vijay Lele, M.B.B.S., M.D., M.S. Associate Professor, Department of Anesthesiology & Pain Medicine Director, Neurocritical Care Service, Harborview Medical Center, University of Washington, 325, 9th Avenue, Box 356540, Seattle, WA, 98104, Tel: 1-206-744-7598, Fax: 1-206-744-8090, abhijit2@uw.edu

Vijay Krishnamoorthy, M.D., PhD. Assistant Professor, Department of Anesthesiology, Duke University, 2310 Erwin Road, Durham, NC, 27710, Tel: 1-919-684-8111, Fax: 1-919-684-0862, vijay.krishnamoorthy@duke.edu

Nophanan Chaikittisilpa, M.D. Visiting Scholar, Department of Anesthesiology & Pain Medicine, Harborview Injury Prevention and Research Center, University of Washington, 325, 9th Avenue, Box 359960, Seattle, WA, 98104, Tel: 1-206-744-9445, Fax: 1-206-744-9962, nopcha@uw.edu

Theerada Chandee, M.D. Visiting Scholar, Department of Anesthesiology & Pain Medicine, Harborview Injury Prevention and Research Center, University of Washington, 325, 9th Avenue, Box 359960, Seattle, WA, 98104, Tel: 1-206-744-9440, Fax: 1-206-744-9962, theerada@uw.edu

Monica Shanta Vavilala, M.D. Professor of Anesthesiology and Pediatrics Director, Harborview Injury Prevention and Research Center, University of Washington, Harborview Medical Center, 325, 9th Avenue. Box 359724, Seattle, WA 98104, Tel: 1-206-744-3210, Fax: 1-206-744-8090, Vavilala@uw.edu

This study was conducted at Harborview Injury Prevention and Research Center, University of Washington, Seattle, WA

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Patients—Adults (age > 18 years) with moderate traumatic brain injury (TBI ICD 9 codes and admission Glasgow Coma Scale score of 9-13) in the National Trauma Data Bank between 2007 and 2014.

Interventions—none.

Measurement and Main Results—Demographics, mechanism of injury, hospital course, and facility characteristics were examined. Admission characteristics associated with discharge outcomes were analyzed using multivariable Poisson regression models. Of 114,066 patients, most were white (62%), male (69%), and had median admission GCS 12 (IQR 10-13). Seventy-seven percent had isolated TBI. Concussion, which accounted for 25% of moderate TBI, was the most frequent TBI diagnosis. Fourteen percent received mechanical ventilation and 66% were admitted to intensive care unit. Over 50% received care at a community hospital. Seven percent died and 32% had a poor outcome, including those with GCS 13. Compared to patients 18-44 years, patients 45-64 years were twice as likely (aRR 1.97; 95% CI 1.92-2.02), and patients over 80 years were five times as likely (aRR 4.66; 95% CI 4.55-4.76) to have a poor outcome. Patients with a poor discharge outcome were more likely to have had hypotension at admission (aRR 1.10; 95% CI: 1.06-1.14), lower admission GCS (aRR 1.37; 95% CI: 1.34-1.40), higher ISS (aRR 2.97; 95% CI: 2.86-3.09), and polytrauma (aRR 1.05; 95% CI: 1.02-1.07), compared to those without poor discharge outcomes.

Conclusions—Many patients with moderate TBI deteriorate, require neurocritical care, and experience poor outcomes. Optimization of care, and outcomes for this vulnerable group of patients are urgently needed.

Keywords

traumatic brain injury; adult; moderate; facility; trauma designation; age

Introduction

Traumatic brain injury (TBI) is a global public health concern, and the World Health Organization expects that TBI will become the third leading cause of death and disability worldwide by 2020 (1, 2). Traumatic brain injury also causes significant physical and cognitive disabilities among survivors, with 50% experiencing psychological and neurocognitive deficits that interfere with daily life (3, 4). The economic burden from TBI is also high (5).

Traumatic brain injury severity is traditionally categorized into three distinct clinical categories ranging from mild to moderate to severe. The medical literature has historically focused on severe TBI. Recently however, the diagnosis, treatment and long-term sequelae of mild TBI has become a serious public health concern (6, 7). It is estimated that 20% of hospital admissions for TBI are moderate, with an incidence ranging between 4 and 28% (4, 8, 9), but little attention has been paid to this middle TBI severity group. Consequently, little is known about the clinical epidemiology and short-term outcomes in this group. While there are evidence-based guidelines for the care of mild and severe TBI patients, similar guidelines in moderate TBI are lacking. Therefore, there is a need to better characterize the

needs of the large number of patients with moderate TBI. To bridge this important gap in knowledge, we describe the clinical epidemiology of patients with moderate TBI.

Methods

Data Source

The National Trauma Data Bank (NTDB) is the largest aggregation of the U.S. trauma registry data, is maintained by the American College of Surgeons and contains more than six million patient records from more than 700 trauma centers. Since submission to NTDB is voluntary, the proportion of hospital types may vary by year, and includes hospitals with no recorded trauma-level designation. Data acquisition since 2007 has been standardized since the implementation of the NTDB data standard; thus, we limited our analysis to NTDB data from 2007 to 2014. The study was reviewed and approved by the University of Washington institutional review board with a waiver of the requirement for informed consent because all data used in this study were deidentified in the NTDB dataset prior to this study being conducted.

Inclusion criteria

Patients 18 years or older, with an International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis code for TBI (ICD 800.1-800.4, 800.6-800.9, 850.0-854.9, 801.1-801.4, 801.6-801.9, 803.1-803.4, 803.6-803.9, 804.1-804.4, and 804.6-804.9) were included. The study population was further restricted to moderate TBI, defined as admission GCS of 9-13 (10). Patients with missing age data, age < 18 years and age > 100 years were excluded. Patients with head Abbreviated Injury Scale (AIS) 0 and 6 were also excluded due to potential miscoding (Figure 1).

Exposures

Potential predictors of adverse outcomes were specified *a priori* and included clinical characteristics, injury characteristics and facility level characteristics.

Clinical characteristics—We abstracted age, sex, and race. Admission systolic hypotension was defined as systolic blood pressure < 90mmHg (11). We also abstracted information on intracranial surgery, intracranial pressure (ICP) monitoring, mechanical ventilation, and intensive care unit (ICU) admission.

Injury characteristics—The mechanism of injury that led to hospitalization was categorized using ICD-9 external cause of injury codes. Classification of injury mechanisms included falls, motor vehicle-related, struck by/against, other transport, firearm, and other. The following injury exposures were examined: severity of injury stratified by admission GCS, Injury Severity Score (ISS), isolated TBI (defined as all other body regions AIS < 2 except for AIS head), and TBI type (subarachnoid hemorrhage, intracerebral hemorrhage, subdural hemorrhage, epidural hemorrhage, contusion, and concussion) defined using ICD-9 codes. Patients who did not have a specific diagnosis detailed above were categorized as having an ‘other’ TBI type.

Facility characteristics—Facility-level exposures of interest were teaching status (teaching vs. non-teaching hospital), and American College of Surgeon trauma level designation.

Outcomes

The main composite outcome of interest was mortality or discharge from an acute hospital to hospice, skilled nursing facility or long-term care (12, 13).

Statistical analysis

Sociodemographic, injury and facility of care characteristics were assessed after stratifying by both admission GCS and age. We examined differences in the proportion of isolated and polytrauma patients who had intracranial surgery, ICP monitoring, mechanical ventilation and ICU admission by admission GCS using the Fisher's exact test with alpha equal to 0.05. For each potential predictor of adverse outcomes (clinical, injury, and facility characteristic defined above), we calculated the cumulative morbidity and mortality (including death, discharge to skilled nursing facility, long term care and hospice), specifying a Poisson distribution to allow calculation of 95% confidence intervals. To minimize potential bias due to missing data in our outcome variable, we conducted multiple imputation using chained equations to create ten imputed datasets. We assumed missing data at random, conditional on age, ISS, admission GCS, hospital bed size, trauma level and teaching status of the hospital. The association between *a priori* specified demographic, clinical, and injury characteristics with our primary outcome was assessed using a multivariate Poisson regression models with robust standard errors, using the imputed datasets. Each model was adjusted for its own minimally sufficient set of confounders that were identified using a directed acyclic graph approach to represent relationships between each predictor and the composite poor outcome variable. Relationships between variables in the acyclic graph were identified *a priori* and were based on subject matter knowledge and prior findings in the literature (14). See Table 1 for a complete list of confounders used in each model. We conducted a sensitivity analysis to examine the relative risk of poor outcomes using a data-driven selection of confounders (14) to confirm the robustness of our results.

All analyses were conducted in Stata13 (College Station, Texas).

Results

Over the eight year period, there were 1,946,212 patients admitted with a diagnosis of TBI. Moderate TBI accounted for 7.6% of all TBI admissions. After excluding 296 patients with head AIS score of 0 and 6, data from 114,066 patients with moderate TBI was examined (Figure 1).

Admission characteristics

Age, sex, and race—Baseline characteristics of patients are listed in Supplemental Table 1. Forty-one percent had admission GCS 13. Of all patients, most were male (69%) and white (62%). Median age was 48 (Interquartile range [IQR] 30-68) years and median

admission GCS was 12 (IQR 10-13). Age, sex, and race were similar in the admission GCS categories.

Injury characteristics—Falls (43%) and motor vehicle-related (34%) were most common mechanism of injury. Overall, median ISS and head AIS were 16 and 3, respectively. The majority of patients (77%) had isolated TBI. Polytrauma was associated with lower admission GCS compared to patients with isolated TBI (26.2% GCS 9 vs. 22.1% GCS 13, respectively), with Concussion, which accounted for 25% of moderate TBI, was the most frequently diagnosed TBI type (Supplemental Table 1). Female sex, falls, less polytrauma, multiple head CT lesions, subdural hemorrhage, and receipt of care at community hospitals were all associated with advancing age (Supplemental Table 2).

Management

Patterns of treatment—Of the entire moderate TBI cohort, 65.6% were admitted to the ICU, 14% received mechanical ventilation, 10% underwent intracranial surgery, and 4% received ICP monitoring. Compared to isolated TBI, more patients with polytrauma were admitted to the ICU (81% vs. 61%, $p < 0.05$), received mechanical ventilation (19% vs. 13%, $p < 0.05$), and received ICP monitoring (5% vs. 3%, $p < 0.05$) (Figure 2). Median length of stay (LOS) did not vary greatly by GCS score either among patients admitted to the ICU (LOS: 3 [IQR 2-6] days for GCS 13 vs. LOS: 4 [IQR 2-10 days] for GCS 9), or general hospital LOS (LOS: 4 [IQR 2-9] days for GCS 13 vs. LOS: 6 [IQR 2-15] days for GCS 9).

Facility type—Overall, over 50% were admitted to community/non-teaching hospital and approximately 32% were admitted to medium or small hospitals (26.4% medium and 5.3% small hospitals). Thirty-seven percent were admitted to non-trauma (Supplemental Table 1).

Discharge outcomes

Overall, 31.8% patients experienced poor outcomes. Poor outcomes ($N=36,247$ for all GCS) occurred at a higher proportion in patients with lower admission GCS (38% GCS 9 vs. 27% GCS 13). Overall, seven percent ($N=8,203$) died, 49% were discharged home, and the remainder were either transferred to other hospitals or received rehabilitation. Compared to admission GCS 13, a higher proportion of patients with admission GCS 9 were discharged to hospice (2% vs. 1%, respectively), long-term care (17% vs. 11%, respectively), or died (11% vs. 5%) (Figure 3; Supplemental Table 3). Across the range of admission GCS scores, a comparable proportion (11%) was discharged to SNF.

Association between clinical characteristics and poor outcomes

The association between demographic and clinical characteristics and poor outcomes is shown in Table 1; all examined demographic and clinical characteristics were associated with a statistically significant higher risk of poor outcomes with an alpha of 0.05. Older age was associated with an increased risk of poor outcomes. Specifically, compared to patients 18-44 year, the 45-64 year age group had an almost two fold increased risk (aRR 1.97; 95% CI: 1.92-2.02), and the over 80 year age group had an almost five fold increased risk of (aRR 4.66, 95% CI 4.55-4.76) of a poor outcome. Other risk factors for poor outcomes included

admission hypotension (aRR 1.10; 95% CI: 1.06-1.14), GCS 9 (aRR 1.37; 95% CI: 1.34-1.40 vs. GCS 13), ISS 16 (aRR 2.97; 95% CI: 2.86-3.09 vs. ISS < 9), and polytrauma (aRR 1.05; 95% CI: 1.02-1.07) (Table 1).

Discussion

In this study, we aimed to elucidate and provide new information on the clinical epidemiology of moderate TBI. The main findings in this cohort of predominantly isolated TBI are: 1) Approximately, one-third have poor discharge outcomes, 2) Risk factors for poor outcomes are advancing age, admission hypotension, lower GCS, and polytrauma, 3) Many require neurocritical care including mechanical ventilation and ICP monitoring, and 4) Over one-third received TBI care at non-trauma hospitals or community hospitals, particularly the elderly. This is the largest formal examination of admission characteristics, hospital course, treatment, and outcomes of patients with moderate TBI. Together, these findings show that patients with moderate TBI are at significant risk for neurological deterioration, worsening of TBI, and poor clinical outcomes. However, clinical trials have primarily been performed in patients with severe TBI, and yet, patients with less severe injury might be better candidates for treatment than those with more severe injury. This study in patients with moderate TBI allows for deeper understanding and may spawn future research and development of treatment guidelines of in this “middle” TBI severity group.

We report a 7.2% mortality rate, which is lower than the 15-20% previously reported for patients with moderate TBI treated at high-level U.S. trauma centers (3, 9, 15). One explanation may be that we included patients with GCS 13 who are expected to have a better outcome than those with GCS 9-12. However, almost one-third of moderate TBI patients had a poor discharge outcomes and 5-6% of patients with higher GCS and isolated TBI died. These findings suggest that even in predominantly moderate isolated TBI patients, TBI and downstream effects are likely large contributing factors to death and disability of these patients.

Although initial studies used GCS 9-12 (16), we defined moderate TBI as GCS 9-13 consistent with more recent work (3, 10, 11, 14), which report high rates of intracranial lesions (33.8%) and surgical requirements (10.8%) (17). The wide range of GCS scores of 9-13 used to define moderate TBI suggests that the pathophysiology, trajectory, and outcomes are heterogeneous. Some patients with moderate TBI talk and then die (18, 19), suggesting that while patients with moderate TBI initially may have less serious TBI than patients admitted with a formal diagnosis of severe TBI, there are many patients with moderate TBI who may also benefit from severe TBI treatments if they deteriorate. Although the exact cut point for defining moderate TBI can be debated, and while lower admission GCS is associated with worse outcomes, almost 30% of patients admitted with GCS 13 had poor discharge outcomes, which is greater than what is expected for patients with “mild” TBI. While polytrauma emerged as a risk factor for poor outcomes, a large number of patients with isolated TBI and admission GCS 13 also had poor outcomes. Similarly, some patients with admission GCS 13 deteriorated and received escalation of care while in hospital. Collectively, these findings support previous arguments (9, 17, 20) that patients who are typically considered to have lower risk TBI based on GCS, in-fact, are still

at risk for serious adverse outcomes, thus, admission GCS 13 should not be considered a mild TBI. In light of present findings, TBI severity likely represents a spectrum where outcomes may not be deterministically related to GCS within and between GCS categories.

Results of this study show that older patients with moderate TBI have worse outcomes. Traumatic brain injury specific reasons for worse outcomes with advancing age may include altered physiological status, such as cerebral dysautoregulation which may affect TBI outcomes, even in moderate TBI (21). Given the aging population in some parts of the world, these findings are particularly pertinent. Although secondary insults are studied in severe TBI (22) but not in moderate TBI, these insults may be responsible for deterioration. This would be problematic because present findings show that 2-3% had admission hypotension. Finally, while the NTDB does not contain measures of frailty, older patients are often more frail which may portend worse outcomes (23). Patients with polytrauma had worse outcomes than those with isolated TBI (24) and advancing age was associated with less polytrauma. While this relationship may initially seem reassuring, our data suggest that the poor outcomes in older adults are largely driven by TBI factors despite equivalent head AIS scores, or comorbidities. In either case, older adults are particularly vulnerable to the consequences of moderate TBI. An additional criteria for American College of Surgeons trauma center verification is the mandate for specialized geriatric services for elderly trauma patients as this may be helpful in mitigating poor outcome attributable to additional comorbid diseases present in this patient population. These results provide new information on the relationship between advancing age and outcomes in adults with moderate TBI.

The large number of patients with isolated moderate TBI who required critical care services and experienced poor outcomes is important, especially in light of the observation that over one-third received care at community centers, which may not be resourced to care. These patients who deteriorate after admission might require care similar to patients with severe TBI (25). Our consideration on the triage and care of TBI patients may be incomplete for two main reasons. First, unlike the Brain Trauma Foundation guidelines which specifically address triage and transfer to a level one trauma center and make recommendations for the acute care of patients with severe TBI, there are no such guidelines for patients with moderate TBI. Second, the TBI guidelines do not address in-hospital adoption of the TBI guidelines when patients deteriorate to the severe TBI category. These omissions represent a significant gap in TBI practice. However, the 2011 Centers for Disease Control and Prevention (CDC) guidelines (26) did recommend transport of patients with GCS 13 to trauma centers. They also highlight that the risk of injury/death increases after 55 years of age. We did not examine whether patients with isolated moderate TBI who receive care in a community setting fare worse than those in a level 1 trauma center. However, a retrospective study by DuBose et.al. in 2008 shows that patients with isolated severe TBI have better survival rates and outcomes if they are treated in a level 1 trauma centers compared with those treated in ACS-designated level 2 centers (27). Since many patients with isolated moderate TBI require comparable neurocritical care to patients with severe TBI, we think that some patients with isolated moderate TBI, especially those with lower GCS in the moderate TBI GCS range, would fare better having received care at a higher level trauma center.

There are some limitations to this study. The NTDB data are administrative, and not collected primarily for research; therefore, granularity on the details of hospitalization, such as co-morbidities, and detailed CT findings were not available (28). Our analysis may be prone to residual confounding, although this was mitigated by our large sample size and the robustness of our findings in multiple sensitivity analyses. Some variables had missing data; however, none of these variables were primary exposures or outcomes, and we used multiple imputation to help increase the precision of our risk estimates. The dataset was limited to discharge disposition; thus, we are unable to comment on long-term neurological or quality of life outcomes. Finally, although the NTDB contains a large sample size, participation is voluntary and varies year to year, which precludes a formal analysis of yearly trends. The NTDB data are not nationally representative, and this may limit the generalizability of our findings. However, these data are important given the large worldwide moderate TBI burden.

Conclusion

Patients with moderate TBI are at significant risk for neurological deterioration, worsening of their TBI, and poor clinical outcomes where older age, admission hypotension, and polytrauma are risk factors. Despite the potential to deteriorate and require critical care services, a significant proportion of moderate TBI patients are treated at non-trauma centers, particularly those who are elderly who have the highest likelihood of a poor outcome. This study provides new insights into the clinical epidemiology and needs of patients with moderate TBI, and suggests that prospective, rigorous studies are needed in patients with moderate TBI to serve as the basis for formal guideline development.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure. 1.

Flow chart of the adult traumatic brain injury patients in National Trauma Data Bank from 2007-2014 included in the study by emergency department Glasgow Coma Scale.

Figure. 2.

Management of moderate traumatic brain injury stratified by polytrauma and admission Glasgow Coma Scale score.

Percentage shown is of each variable within the isolated traumatic brain injury or polytrauma group.

Figure. 3.

Discharge disposition after moderate traumatic brain injury by admission Glasgow coma scale score (GCS) and polytrauma.

Disposition data to the left of midline represents good outcome (home, transfer to other hospital, rehabilitation or other) and data to the right of midline represents poor outcome (Long term facility [LTC], skilled nursing facility [SNF], death or hospice).

Table 1

Association between admission characteristics and poor outcomes (in-hospital mortality, skilled nursing facility, hospice and long term care) in patients with moderate traumatic brain injury.

Exposure Characteristics	Total (n)	Poor Outcome (n)	Cumulative morbidity and mortality ^a N%	95% Confidence Interval	Adjusted Relative Risk (aRR) ^b (95% Confidence Interval)
Demographics					
Age (years)					
- 18-44	51,012	7,670	15.0	14.7-15.4	1.0 (ref)
- 45-64	32,995	9,647	29.2	28.7-29.8	1.97 (1.92-2.02)
- 65-79	15,803	8,952	56.7	55.5-57.8	3.78 (3.69-3.86)
- 80	14,256	9,978	70.0	68.6-71.4	4.66 (4.55-4.76)
Male	78,723	22,508	28.6	28.2-29.0	1.37 (1.35-1.39)
Clinical					
Admission SBP < 90 mmHg	3,980	1,703	42.8	40.8-44.9	1.10 (1.06-1.14)
Admission GCS					
- GCS 13	46,774	12,823	27.4	26.9-27.9	1.0 (ref)
- GCS 12	21,856	6,744	30.9	30.1-31.6	1.11 (1.08-1.13)
- GCS 11	17,892	6,307	35.3	34.4-36.1	1.21 (1.19-1.24)
- GCS 10	15,375	5,714	37.2	36.2-38.1	1.24 (1.21-1.27)
- GCS 9	12,169	4,659	38.3	37.2-39.4	1.37 (1.34-1.40)
Injury severity					
- ISS <9	23,291	2,034	8.7	8.4-9.1	1.0 (ref)
- ISS 9-15	25,779	6,460	25.1	24.4-25.7	2.07 (1.99-2.16)
- ISS 16	61,898	27,532	44.5	44.0-45.0	2.97 (2.86-3.09)
- Polytrauma ^c	26,524	10,521	39.7	38.9-40.4	1.05 (1.02-1.07)

^a Includes death and discharge to hospice, skilled nursing or long term care facility.

^b Adjusted using the following minimum sets identified using a DAG for each variable with imputation:

Age: none

Hypotension: age, ISS, isolated, mechanism

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admission GCS: ISS, age, mechanism, isolated, systemic hypotension
Systemic hypotension: ISS, age, mechanism, isolated
ISS: age, male, mechanism, isolated
Polytrauma: age, male mechanism
Other body region AIS 3