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Estimates of Long-Term Disability Among US Service Members With Traumatic Brain Injuries

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Background: Traumatic brain injury (TBI) is a significant health issue in the US military. The purpose of this study was to estimate the probability of long-term disability among hospitalized service members (SMs) with TBIs, using the South Carolina Traumatic Brain Injury and Follow-up Registry (SCTBIFR) model developed on civilian hospitalized patients. **Methods:** We identified military patients in military or civilian hospitals or theater level 3 to 5 military treatment facilities (MTFs) whose first TBI occurred between October 1, 2013, and September 30, 2015. TBI-related disability at 1-year post–hospital discharge was estimated using regression coefficients from the SCTBIFR. **Results:** Among the identified 4877 SMs, an estimated 65.6% of SMs with severe TBI, 56.2% with penetrating TBI, 31.4% with moderate TBI, and 12.0% with mild TBI are predicted to develop long-term disability. TBI patients identified at theater level 4 and 5 MTFs had an average long-term disability rate of 56.9% and 61.1%, respectively. In total, we estimate that 25.2% of all SMs hospitalized with TBI will develop long-term disability. **Conclusion** Applying SCTBIFR long-term probability estimates to US SMs with TBIs provides useful disability estimates to inform providers and health systems on the likelihood that particular subgroups of TBI patients will require continued support and long-term care. **Key words:** *activities of daily living (ADL)*, *long-term disability*, *SCTBIFR*, *traumatic brain injury*, *US military*

IN THE UNITED STATES, traumatic brain injury (TBI) has long been considered a significant public health issue.[1] TBI, defined as "a bump, blow or jolt to the head or a penetrating head injury that disrupts the normal function of the brain," contributes to deaths and is a major cause of long-term disability.[2] In 2010, approximately 2.5 million TBIs occurred among civilians, leading to 280 000 hospitalizations and the death of more than 50 000 people.[1] Among civilian hospitalized TBI survivors, more than 40% developed long-term disabilities, including functional limitations, cognitive complaints, and decreased physical and psychosocial health.[3]

TBI is also a significant health issue among US military service members (SMs). Since 2000, an estimated 379 000 SMs have been diagnosed with at least 1 TBI. TBI is of special concern in the theater environment, where risk of sustaining a TBI is 91% higher than that in the nondeployed environment.[4] Some 2.5 million SMs have been deployed to Operation Enduring Freedom, Operation Iraqi Freedom, and Operation New Dawn,[5] with TBI identified as the single most frequent blast-related injury.[6] Although patients with mild TBIs (mTBIs) often recover fully from a concussion, several recent studies of military subjects with mild combat-related TBI have reported high levels of continued symptoms at 9 months or longer.[7,8] Those with disabilities due to combat-related TBI rated their health status as poor and were more likely to be medically retired than comparison groups.[5,9,10]

The purpose of this study was to identify top principal diagnoses among hospitalized SMs with TBIs and utilize publicly available models to estimate their

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long-term disability. Estimates of long-term disability for hospitalized TBI patients are important to inform providers and health systems on the long-term needs of patients with TBI, especially those likely to develop TBI-related disabilities.

DESIGN AND METHODS

This study is based on outcome data from the South Carolina Traumatic Brain Injury and Follow-up Registry (SCTBIFR), a broad TBI registry assessing TBI-related outcomes among persons with TBI, discharged alive from acute care facilities in South Carolina from 1999 to 2002.[11] As part of the SCTBIFR, disability-related outcome data on 2118 persons 15 years and older hospitalized with TBI were obtained 12 months postdischarge. On the basis of the outcome data from the SCTBIFR, Selassie et al[3] developed a calibrated and validated regression model with strong predictive power of a person's long-term disability based on his or her presentation at the initial hospitalization. Briefly, Selassie et al[3] validated the predictive powers of the model by taking 100 randomly split samples from the SCTBIFR where one-half of the each split sample was used to create the model and predict the disability of patients in the other half (validate). The final model reached a mean error in prediction of −0.0028, with an area under the receiver operating curve of 0.97, suggesting excellent predictive power. See Pickelsimer et al[12] and Selassie et al[3] for more details on the SCTBIFR and its data. In addition to being validated with strong predictive powers and publicly available models, regression coefficients from the SCTBIFR have been previously applied to the Healthcare Cost and Utilization Project–Nationwide Inpatient Sample data to estimate the national incidence of long-term disability following TBI hospitalization,[3] as well as the 2006 Kids' Inpatient Database, the largest publicly available all-payer pediatric inpatient care database in the United States.[13] Taking this idea further, in this study, we use the SCTBIFR regression coefficients to estimate the incidence of long-term disability following TBI hospitalization among US SMs.

Cohort

Using the Department of Defense (DoD) TBI case definition,[14] we identified patients whose first military TBI occurred between October 1, 2013, and September 30, 2015. Cases were identified using the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) using data from the Standard Inpatient Data Record and TRICARE Inpatient Data for in-garrison admitted TBI patients. Theater TBI medical encounters were identified using the Theater Medical Data Store (TMDS). Data on the SM's occupation at time of injury and classification of deployment or non–deployment-related nature of TBI were obtained from the Armed Forces Health Surveillance Branch (AFHSB). TBIs identified while deployed or within 30 days upon SMs return were classified as deployment-related. Patients were included if TBI was diagnosed in a military or civilian hospital or theater level 3 to 5 military treatment facilities (MTFs) (see Supplement Digital Content Table 1, available at: http://links.lww.com/JHTR/A340). The official DoD TBI case definition includes an incidence rule stating that an individual is considered an incident case only once per lifetime. Later TBIs are not included.[14]

Predictor variables

We obtained hospitalization records for our cohort and extracted data on a number of variables considered by Selassie et al[3] to have strong predictive powers for long-term disability, based on the SCTBIFR population, in order to populate the regression model. Those variables include (1) severity of sustained TBI, grouped according to the Centers for Disease Control and Prevention TBI Barrel Matrix.[15] (2) Identification of up to 30 preexisting comorbid conditions using the Elixhauser Comorbidity index, which assigns variables that identify comorbidities in hospital discharge records using the diagnosis coding of *ICD-9-CM* when present in any of the first 10 diagnostic positions.[16] (3) The patient's discharge status following hospitalization where referral to post–acute care was defined as any SM discharged to one of the following: (*a*) a short-term hospital, (*b*) skilled nursing facility, (*c*) intermediate care facility, or (*d*) other facility. SMs who died in the hospital were removed from the cohort. Finally, (4) SM gender and (5) age were also used as important predictor variables. Unlike Selassie et al,[3] our age grouping had slightly larger groupings; however, since the age parameter was an indicator variable (over/under 65 years), this difference has no impact on estimates. All predictor variables used in our prediction models were replicated from the Selassie et al[3] study.

Other calculated variables

Injury severity was calculated by using the algorithms of the injury categorization program provided by the American College of Surgeons, which translates *ICD-9-CM* diagnosis codes into Abbreviated Injury Score (AIS) and New Injury Severity Score (NISS). In our study, NISS is only used to characterize injury at time of the SM's hospitalization, but it is not used in long-term disability calculations.

Predicted outcome variable–Disability

The probability of disability (P) provided in this study is a composite measure estimated for our SM cohort based on the values of predictor variables present at time of hospitalization:

$$P = \frac{\exp(a + B \times X)}{1 + \exp(a + B \times X)}$$

where a is the intercept, B, the set of β coefficients from the full set of SCTBIFR data as reported by Selassie et al,[3] and X, the set of predictor variables.

Based on the SCTBIFR, a person is deemed to be disabled if the person indicated any of the following at his or her 1-year follow-up interview: (*a*) functional limitations in performing at least 1 activity of daily living (ADL); (*b*) reported a significant postinjury symptom such as vision, paralysis, seizure, hearing or balance problems, irritability, and/or temper control; (*c*) reported cognitive complaints defined as 2 standard deviations (SDs) above the population norm ($\geq$2.22) on the Alertness and Behavioral scale of the Sickness Impact Profile measuring memory, attention, orientation, processing speed, clumsiness, and follow-through; or (*d*) was found to depart from the norm (at least 2 SD below norm) in the Mental Component Summary of the Medical Outcomes Study Short-Form Health Survey (SF-36).[3,12]

Both *t* test and analysis of variance (ANOVA) were used to test for differences among normally distributed groups or multiple-level groups; the Wilcoxon-Mann-Whitney test and nonparametric N-ANOVA (Kruskall-Wallis test) were used to test for differences among nonparametric distributed variables. Differences with a *P* value of less than .05 were considered statically significant. Analyses were done in SAS 9.4 (SAS Institute, Cary, North Carolina) and STATA 9 (StataCorp, College Station, Texas). These analyses are approved by the Human Research Protection Program Office (DV-15-02) and the US Army Medical Research and Materiel Command's Office of Research Protections, Institutional Review Board Office (ORP IRBO) (M-10436).

RESULTS

Between October 1, 2013, and September 30, 2015, we identified a total of 4877 SMs meeting our inclusion criteria. The population was 91.1% male, composed largely of white non-Hispanic SMs (64.3%), with 51.7% being aged 18 to 24 years, and Army soldiers being the largest service group (54.4%) (see Table 1).

Based on our prediction model, across the cohort, 32.8% of male SMs and 28.7% of female SMs are expected to be disabled at 1 year. Estimated disability rate was highest for those aged 45 to 64 years at 35.5%, with an average NISS of 11.6 at time of discharge. American Indian/Alaskan Native SMs had a significantly larger estimated disability rate (38.7%) than other groups. The estimated disability rate differed across services, with a low of 23.0% estimated among Air Force SMs to a high of 26.1% among Marine Corps SMs. The calculated average NISS according to SMs occupation at time of discharge was statistically significantly different ($P < .01$) and so was the estimated disability rate (see Table 1).

Table 2 shows cohort breakdown according to TBI and hospitalization characteristics. Based on the Barell Injury Classification Index, type 2 TBI was the largest TBI type (53.4%) with an average estimated disability of 13.6%.[15] Type 2 TBI Barell classification is characterized by concussions, closed head, closed skull of face, skull vault, or base fractures without mention of intracranial injury and with unspecified loss of consciousness (LOC) or LOC under 1 hour. Similarly, mTBIs, the largest severity group (52.0%) had an estimated disability rate of 12.0%. SMs with penetrating and severe TBI had a 56.2% and 65.6% estimated disability rate, respectively. This study includes SMs admitted to civilian hospitals. Predicted disability was higher among SMs in civilian hospitals (27.6%) than those in military or theater facilities included in study (24.6% and 18.1%, respectively). Civilian hospitals and theater facilities had a higher share of Reserve/Guard SMs than military hospitals (16.2% and 24.2% vs 9.2%, respectively). Of the 24.3% of SMs referred to continued care following admission, an estimated 71.1% were expected to be disabled at 12 months postinjury. Across the cohort, most SMs did not have a comorbidity at time of diagnosis (79.3%) and 14.9% had 1 comorbidity, 4.5% had 2 comorbidities, and 1.1% had 3 comorbidities (see Table 2). Those with 2 or more comorbidities, an estimated 70.1% were to be disabled within 12 months (data not shown). While the majority of cohort SMs had their TBI diagnosed in the nondeployment setting (77.6%), estimated disability was slightly higher among SMs diagnosed in the deployment setting (26.4%) than those in the nondeployed setting (24.8%) (see Table 2).

DISCUSSION

To assess long-term outcomes for those with TBI, researchers often conduct follow-up studies. Such studies are preferred yet are often cost-prohibitive, and if participating sites are not representative of the entire population, population inferences cannot be made. Use of registries in follow-up studies is encouraged as a way to deal with possible sample selection bias; however, currently no studies on US SMs utilize registries for long-term follow-up outcome assessment. In lieu of such efforts, this study estimated disability at 12 months after discharge for all SMs hospitalized for TBI at military and civilian hospitals, based on outcome data from the SCTBIFR cohort. This approach allowed application of SCTBIFR-derived regression parameters to the US SM cohort to estimate long-term disability. Across the study

TABLE 1 *Predicted disability and injury severity according to demographics of the cohort*

	n **(%)**	**Estimated disability rate, %, Avg (95% CI)**	**NISS, mean (SD)**
Gender			
Male	4441 (91.1)	25.9 (24.4-27.4)[a]	11.9 (9.6)[a]
Female	436 (8.9)	18.4 (14.5-22.8)	9.6 (8.5)
Age, y			
15-17	<5 (<1)	4.4 (NA)[b]	5.7 (2.9)[b]
18-24	2532 (51.9)	22.6 (20.8-24.6)	11.1 (9.2)
25-34	1684 (34.5)	27.5 (25.1-30.2)	12.1 (9.6)
35-44	476 (9.8)	28.6 (24.0-33.8)	12.8 (10.3)
45-64	181 (3.7)	31.3 (23.8-40.8)	12.8 (10.2)
Other	<5 (<1)	11.4 (NA)	9.0 (NA)
Race			
American Indian/Alaskan Native	57 (1.2)	34.3 (21.4-54.2)[b]	13.4 (7.9)[b]
Asian/Pacific Islander	178 (3.6)	28.6 (21.3-37.7)	11.2 (8.9)
Black non-Hispanic	632 (13.0)	22.0 (18.5-26.0)	10.5 (8.9)
Hispanic	638 (1.1)	21.1 (17.8-25.0)	10.9 (9.3)
Other	237 (4.7)	24.4 (18.6-31.6)	11.7 (10.6)
White non-Hispanic	3135 (64.3)	26.4 (24.6-28.3)	12.1 (9.6)
Service			
Army (all)	2633 (54.0)	25.6 (23.7-27.6)[b]	10.9 (9.4)[b]
Active duty	2061 (78.3)	24.4 (22.3-26.7)	10.6 (9.3)
National Guard	393 (14.9)	31.6 (26.2-37.6)	12.3 (9.9)
Reserves	179 (6.8)	26.8 (19.8-33.6)	11.5 (9.7)
Navy (all)	715 (14.7)	25.0 (21.5-28.9)	12.5 (9.9)
Active duty	671 (93.8)	24.9 (21.3-28.9)	12.4 (8.2)
Reserve	44 (6.2)	25.6 (12.5-44.7)	14.5 (14.9)
Air Force (all)	716 (14.7)	23.0 (19.5-26.7)	11.9 (9.4)
Active duty	599 (83.7)	21.7 (18.1-25.7)	11.5 (9.0)
National Guard	84 (11.7)	33.1 (22.2-48.2)	13.6 (11.0)
Reserves	33 (44.6)	19.6 (7.0-39.6)	14.0 (10.5)
Marine Corps (all)	813 (16.7)	26.1 (22.7-29.8)	13.0 (9.4)
Active duty	774 (95.2)	26.1 (22.6-29.9)	13.0 (9.3)
Reserve	39 (4.8)	26.2 (12.3-47.1)	13.8 (10.5)
Top occupations			
Infantry/artillery/combat engineering	1349 (27.7)	26.1 (23.4-28.9)[b]	11.3 (9.3)[b]
Repair/engineering	1280 (26.2)	25.0 (22.3-27.9)	12.7 (10.2)
Other	894 (18.3)	26.0 (22.8-29.6)	11.4 (9.2)
Communications/intel	850 (17.4)	24.3 (21.0-27.8)	11.3 (9.2)
Healthcare	312 (6.4)	22.8 (17.7-28.7)	11.3 (9.3)
Armor/motor transport	192 (3.9)	25.1 (18.4-33.1)	10.6 (8.4)

Abbreviations: CI, confidence interval; NA, not available; NISS, New Injury Severity Score.
[a]Wilcoxon: $P < .05$.
[b]N-ANOVA/Kruskal-Wallis test: $P < .05$.

cohort, in the deployed and nondeployed settings, age was associated with a higher disability. This suggests that older SMs are more vulnerable to long-term consequences after TBI than younger SMs. In our cohort, while the calculated NISS at time of discharge was significantly different between top occupations, estimated disability at 1 year was not. While NISS is not a model predictor of disability, it was expected that a higher NISS at time of discharge would translate into a higher disability rate. This was surprising as younger SMs are more likely to be enlisted and assigned to occupations, such as infantry, artillery, and engineering, and more likely to be exposed to potentially concussive events.[17] While comparisons between services showed nonsignificantly different disability rate estimates, within-service comparisons showed that Army and Air Force National Guard SMs had higher NISS and significantly higher estimated disability rates than other SMs. These elevated disability estimates were a somewhat surprising finding that deserves further attention. National Guard and Reserve units tend to be deployed in roles similar to active component SMs but may have extended exposures to

TABLE 2 *Predicted disability and injury severity according to hospitalization characteristics*

	n (%)	Estimated disability rate, %, Avg (95% CI)	NISS, mean (SD)
TBI classification (Barell)			
Type 1	1798 (37.0)	46.4 (43.3-49.6)[a]	16.6 (10.7)[a]
Type 2	2604 (53.4)	13.6 (12.2-15.1)	8.8 (7.5)
Type 3	105 (2.2)	17.2 (10.2-27.1)	15.1 (6.5)
Type 4	370 (7.6)	6.2 (3.9-9.3)	6.8 (5.3)
TBI classification (DoD)			
Mild	2520 (52.0)	12.0 (10.7-13.5)[a]	8.3 (6.8)[a]
Moderate	1676 (34.4)	31.4 (28.7-34.2)	14.1 (9.5)
Penetrating	276 (5.7)	56.2 (47.7-65.7)	17.8 (10.3)
Severe	346 (7.1)	65.6 (57.4-74.7)	22.2 (11.8)
Not classifiable	59 (1.2)	32.4 (19.3-50.3)	5.4 (7.2)
Top principal diagnoses[b]			
Concussion with no LOC (850.0)	423 (8.7)	4.8 (2.9-7.3)	5.2 (2.8)
Concussion, unspecified (850.9)	281 (5.8)	6.8 (4.1-10.1)	5.5 (4.3)
Concussion with LOC of unspecified duration (850.5)	272 (5.6)	8.6 (5.6-12.1)	7.6 (4.9)
Concussion, with LOC of ≤30 (850.11)	245 (5.0)	7.4 (4.3-11.6)	3.6 (5.4)
Top 10 injury groups			
Internal organ	2238 (51.22)	20.8 (19.5-22.0)[a]	10.1 (9.3)[a]
Fractures	1553 (35.55)	36.4 (34.5-38.2)	16.7 (9.0)
Unspecified	203 (4.65)	5.8 (4.4-7.3)	5.0 (2.8)
Open wounds	159 (3.64)	18.2 (14.4-22.0)	8.6 (5.6)
Amputations	63 (1.44)	45.0 (37.3-52.7)	22.0 (7.6)
Sprains and strains	53 (1.21)	11.8 (6.7-17.0)	7.7 (5.5)
Superficial/contusion	32 (0.73)	10.7 (4.0-17.3)	6.4 (2.9)
System-wide and late effects	15 (0.34)	31.1 (10.4-51.9)	8.6 (8.9)
Dislocation	14 (0.32)	25.9 (8.0-43.8)	12.3 (5.4)
Blood vessels	13 (0.3)	61.0 (38.4-83.7)	31.7 (13.7)
Top comorbidities[b]			
Fluid and electrolyte disorders	401 (8.2)	65.2 (61.9-68.5)	17.8 (11.1)
Hypertension	127 (2.6)	58.3 (52.7-63.8)	14.5 (8.8)
Weight loss	99 (2.1)	85.5 (80.3-90.6)	24.5 (11.3)
Coagulopathy	96 (1.97)	77.7 (72.4-83.1)	22.6 (13.3)
Psychoses	60 (1.23)	58.6 (49.8-67.4)	13.4 (12.1)
Depression	94 (1.93)	51.9 (45.6-58.2)	11.3 (7.8)
No. of comorbidities[c]			
0	3869 (79.3)	15.5 (14.8-16.3)[a]	10.4 (8.5)[a]
1	729 (14.9)	59.2 (56.8-61.5)	16.4 (10.8)
2	219 (4.5)	68.4 (64.1-72.9)	17.9 (13.1)
3	52 (1.1)	76.3 (67.9-84.6)	17.8 (10.5)
4	6 (0.1)	86.6 (69.7-1.00)	21.0 (7.9)
Hospital or treatment facility			
Military hospital	1213 (25.0)	24.6 (21.8-27.5)[a]	11.5 (9.1)[a]
Civilian hospital	2864 (58.7)	27.6 (25.6-29.5)	13.7 (9.9)
Theater facility (role 3-5)	800 (16.4)	18.1 (15.3-21.3)	4.3 (2.7)
Post–acute referral			
Referred	1184 (24.3)	71.1 (66.4-76.1)[d]	17.8 (12.0)[d]
Not referred	3693 (75.7)	10.5 (9.4-11.6)	9.7 (7.6)
Length of stay, mean (SD), d	5.0 (9.5)	38.1 (29.7-48.4)	17.3 (9.6)
Injury location			
Deployment-related	1091 (22.4)	26.2 (23.4-29.6)[d]	8.7 (8.7)[d]
Non–deployment-related	3785 (77.6)	24.8 (23.3-26.5)	12.5 (9.6)

Abbreviations: Barell, Barell Injury Classification Index; CI, confidence interval; DoD, Department of Defense; LOC, loss of consciousness; NISS, New Injury Severity Score; TBI, traumatic brain injury.
[a]N-ANOVA/Kruskal-Wallis: $P < .05$.
[b]Condition not mutually exclusive.
[c]Two cases omitted.
[d]Wilcoxon-Mann-Whitney test: $P < .05$.

high-intensity combat during their compressed deployment cycles,[18] possibly influencing their exposures.

In the TRACK-TBI study, using a Glasgow Outcome Scale-Extended (GOS-E) score less than of 8, Nelson et al[19] reported that at 12 months, 53% (95% CI, 49-56) of mTBI patients presenting to US level I trauma centers reported functional limitations, dropping to 49% for those with a negative computed tomographic (CT) scan.[20] These outcomes are still higher than our finding for those presenting at civilian hospitals of 27.6%. The SCTBIFR disability definition is somewhat more restrictive than a GOS-E score of less than 8 used by Nelson et al or a GOS-E score of less than 7 used by MacDonald et al.[21] Furthermore, according to the DoD TBI classification system, if a patient's CT scan is positive, as used in the Nelson et al[19] study, the patient's TBI severity is classified as moderate. While still lower than reported by Nelson et al,[19] among moderate TBI patients in our study, estimated disability rate was 31.4%.

The concept of disability itself is one that is not standardized and varies considerably between studies. It is often measured as the extent individuals have limitations in performing ADL, such as bathing or performing activities needed for independent living, such as managing money. We used the SCTBIFR operationalization of disability assessed at 12 months postdischarge, which among other criteria, also includes a functional limitation in performing at least 1 ADL as part of the disability definition. Based on SMs' injury at time of admission, we estimate that 25.2% of SMs will meet the SCTBIFR definition of being disabled 1 year postinjury.

In a cohort study of nonhospitalized soldiers, Schwab et al[7] showed that close to half of those sustaining an mTBI while deployed reported severe neurobehavioral symptoms within 3 months postinjury. At 6 months, Van der Naalt et al[22] found that 44% of mTBI patients at emergency departments had functional limitations using a GOS-E score of less than 8. Measuring outcomes at 3, 6, and 12 months postinjury as part of the TRACK-TBI cohort study, McMahon et al[23] reported that more than 75% of patients reported at least 1 postconcussive symptom, with 22.0% of patients classified as functionally impaired at the 1-year mark, using the GOS-E score of less than 7 and a failure to return to full functional status at work and in daily activities.[23] While our estimate of disability at the 1-year mark is similar to that reported by McMahon et al,[23] the 2 studies differ on the definition of impairment/disability at 1 year. McMahon et al[23] measured global functional outcome using the GOS-E, whereas we relied on the SCTBIFR operationalization. In a separate study measuring outcomes at 6 to 12 months following injury, using the GOS-E score of less than 7, MacDonald et al[21] reported that between 62% and 96% of mTBI study SMs experienced poor outcomes.[23] These estimates are significantly higher than our 25.2% disability rate studywide and 12.0% for mTBI patients alone. This could be due to a number of reasons. In contrast to our study of 4877 SMs hospitalized in civilian or military hospitals, the MacDonald et al[21] study followed 194 SMs originating in theater, of which 154 (79%) were theater medically evacuated casualties to the Landstuhl Regional Medical Center (LRMC). While the evacuated SMs met the criteria for mTBI, mTBI is rarely a sufficient cause for a medical evacuation, suggesting evacuated SMs included in the study were more severely injured and likely impacting GOS-E scores at 1-year follow-up. This likely created a more severely injured patient sample, not indicative of mTBI disability outcomes population-wide. McDonald et al[21] reported that those evacuated had a significantly higher likelihood of disability than those not medically evacuated from theater, further supporting the argument that the 194 SMs likely form a more severely injured group.[21] In our data, TBI patients identified at theater level 4 and 5 MFTs, including LRMC, had an average long-term estimated disability rate of 56.9% and 61.1%, respectively, near the lower end of the MacDonald et al[21] study disability estimates (data not shown).

In 2008, Selassie el al[3] applied the SCTBIFR outcome model to the 2003 National Inpatient Survey (NIS) hospital discharge data, a representative sample of US hospital discharge data for that year. Selassie et al[3] found that 43.3% (42.9%-43.6%) of civilian TBI admissions in 2003 were deemed as being disabled, higher than the 25.2% population-wide estimate for our study. However, the NIS is representative of the US population, significantly older than those in our study; thus, disability rates are expected to be higher. Specifically, among the younger civilian patients, their estimated disability rate ranged from 24.0% for those aged 20 to 24 years to 26.7% for those aged 30 to 34 years, similar to the 22.6% disability rate among those aged 18 to 24 years and 27.5% among the 25- to 34-year-olds in our cohort. Separately, in a 1-year postinjury study of 1591 hospitalized Coloradoans with TBI, using ADL, Whiteneck et al[24] reported that more than one-third of all hospitalized TBI patients reported a disability requiring the assistance of another person in performing physical and/or cognitive ADL, similar to our estimated disability rate range of 21.7% for mild, 31.4% for moderate, and 65.6% among severe patients. In addition, Whiteneck et al[24] reported that 26% of mild, 37% of moderate, and 42% of severe TBI patients responded that their quality of life was fair or poor.

LIMITATIONS

To establish representative disability estimates for hospitalized SMs, cohort selection must be representative.

We used the AFHSB list of SMs with their first military TBI as our population frame to identify hospitalized SMs with TBI. This ensured that our population resembles as closely as possible to the population of all hospitalized SMs with TBI. However, limitations exist. Some SMs with sustained TBIs may not have been identified in hospital discharge data and thus not included in this study. This may have occurred because of delayed diagnosing of sustained TBI. In some cases, especially multiple trauma cases, it is possible that the TBI diagnosis may be assigned in an outpatient setting, after an SM was discharged.[25] This misclassification, whereby we exclude hospitalized TBI patients who were inadvertently not coded as such, may lead to an overestimation of estimated disabilities, especially if those not included sustained less severe injuries. This study only includes SMs with a recorded code denoting TBI in any diagnostic position at the time of hospitalization. In our study, such cases would have been excluded if, during the inpatient stay, the patient was not assigned a TBI diagnostic code.

The SCTBIFR selected civilian hospitalized patients for follow-up based on the AIS head region injury score (AIS/head = 2-5), rather than on the patient's overall injuries, better characterized by the injury severity score (ISS). If our military cohort, especially the 22% with deployment-related injuries, indeed differ significantly in their nonhead region injuries from a civilian cohort, even if head injuries are comparable, the estimated disability may underestimate the true burden of their injuries. Using data from the Joint Theater Trauma Registry (JTTR), Orman et al[26] showed that theater sustained TBIs are often associated with multiple trauma and have a relatively high injury severity (50% > ISS 26); thus, civilian derived estimates may underestimate disability among a military population since SCTBIFR measured outcomes, such as functional limitations, may be influenced by the presence of nonhead region injuries.[26] However, the JTTR cohort represents a uniquely injured military population, with an AIS/head region score of 3 to 6 among its population, having stricter inclusion criteria than the SCTBIFR, and not representing the average hospitalized TBI SMs. Across our cohort of incident hospitalized SMs with TBI, only 6% of the cohort have an ISS over 26. Nonetheless, given the lack of a representative military cohort with long-term assessed outcomes, estimates in this study may serve as a floor estimate of disability among hospitalized SMs with TBI.

Presence of comorbidities at time of admission was a significant predictor of long-term disability in the SCTBIFR outcome model. We rely on coded comorbidities to correctly apply the SCTBIFR mode, and any records with missing comorbidity codes in medical record may lead to underestimated disability probability rates. In addition, comorbidities specific to the military environment, such as posttraumatic stress disorder (PTSD), repeat combat exposure that may be related to long-term disability cannot be accounted for, since they are not included in the SCTBIFR data. We attempted to attenuate this by only selecting cases whose first lifetime TBI occurred during our study period, thus estimating disability on their first TBI, not cumulative combat exposures and/or TBIs, so it more closely resembles a likely civilian case. A few comorbidities, especially PTSD, are not accounted since they are not explicitly used in the model by Selassie et al; hence, it may underestimate long-term disability of those with PTSD at time of TBI diagnosis. Unfortunately, there is little that can be done to adjust for this since there are no data on SCTBIFR on outcome for those with PTSD; thus, no coefficient estimates are available.

SMs identified with TBIs sustained in theater and reported in the TMDS may represent SMs treated in theater who were not medically evacuated and thus were less severely injured. SMs medically evacuated to LRMC or Continental United States (CONUS) for treatment likely sustained severe injuries, in addition to TBI. In our study, the estimated disability rate for those receiving care in roles 4 and 5 was as high as 61.1%; however, it is likely that other SMs medically evacuated never received their TBI diagnosis code applied to their medical record at time of admission, hence may have been excluded from this study, lowering disability rate estimates. Differences between estimated disability rates between theater and nontheater identified SMs may also be due to the misclassification of sustained TBI. SMs admitted for inpatient treatment outside of theater would be classified to have non–deployment-related TBIs, although injury may have been sustained while deployed but diagnosed at an inpatient facility in CONUS. This may underestimate disability due to deployment-sustained TBI.

To apply SCTBIFR model specifications to our data, we had to ensure our data matched the variable definitions of the SCTBIFR model. This was especially difficult for theater-sustained injuries, as both ambulatory and hospitalized patients are recorded in the same database, with discharge and referral documentation not clearly delineated. The SCTBIFR model assigns a specific β to referred cases; thus, any misclassification, or alternate definition of "referred," would impact disability rate estimates.

CONCLUSION

Health outcomes from sustained TBI are important to the identification of long-term care needs for those injured and, in turn, for planning and offering needed services. This and other studies show the high prevalence of disability following TBI. Schwab et al[7] showed that close to half of those sustaining an mTBI while deployed reported severe neurobehavioral symptoms within 3 months postinjury.[7] MacDonald et al[21] reported that between 62% and 96% of mTBI study SMs experienced poor outcomes.[22] In longer follow-up studies of moderate and severe TBI patients, Andelic et al[27] showed that 44% of patients at the 10-year mark and 43% at 20-year mark were deemed to be functionally disabled, defined as GOS-E score of 6 or less. When taken together, these studies indicate that disability often accompanies injured TBI patients long after discharge, especially those with moderate and severe TBIs. These findings carry significant implications for the Military Health System (MHS) as it plans for the continued care needs of injured SMs. However, the link that is missing between clinical diagnosis and disability studies is the clinical care. The models for TBI care continue to evolve on the basis of injury diagnosis and clinical presentation; however, there are unclear demarcations of when to start and stop treatment including rehabilitation services to maximize recovery and transition to long-term planning as required. These results should help the MHS appreciate the burden of TBI long after injury is sustained in order to estimate resource needs and attribute cost to TBI. Furthermore, the study results suggest a need to track SMs after discharge, especially those with moderate and severe TBIs, given their especially high estimated disability rate at 1 year postdischarge. Some form of systematic follow-up should be in place for all those who sustain TBI in order to reduce chronic problems after TBI. This study also points to the need for collaborative and joint care between the MHS and the Veterans Affair (VA) system, given the high likelihood that SMs will continue to receive VA care upon being medically discharged from the military. Studies have shown that one major barrier to receiving care is knowing where to get help, even long after sustaining injury.[28] This further implies that wide availability of services is needed and access to care is critical for effective long-term care efforts.

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