Correspondence of the Boston Assessment of Traumatic Brain Injury-Lifetime and In-Theater Department of Defense Medical Records

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Abstract

Background: Since 2006, efforts have been made to increase the identification of traumatic brain injuries (TBIs) in post-9/11 military personnel. The BAT-L is the first validated instrument to diagnose TBIs throughout the lifespan in post-9/11 Veterans. The objective is to investigate the correspondence of the Boston Assessment of TBI-Lifetime (BAT-L) diagnostic prevalence and injury severity of traumatic brain injury with in-theater medical records from Department of Defense (DoD).

Methods: A convenience sample of 153 Veterans deployed in 2011 enrolled in the TRACTS longitudinal cohort study was examined. Retrospective review of DoD online medical records to determine diagnostic prevalence and injury severity for all head injury cases during deployment were compared with diagnostic prevalence and injury severity from the BAT-L clinical interview using Chi-square analyses.

Results: There was moderate correspondence for TBI diagnosis between the BAT-L and DoD records (κ = 0.42). Sensitivity was 72.7% and specificity was 82.8%. Comparison of injury severity also had moderate correspondence (κ = 0.41). Missing TBI diagnostic data from DoD records was frequent; 43% percent of TBIs reported on the BAT-L did not have any documentation of mTBI assessment or diagnosis in DoD records while 83% did not have in-theater documentation.

Conclusions: Diagnosis of TBI via the BAT-L retrospective interview was both sensitive and specific when compared to DoD medical records. However, diagnostic correspondence was only moderate. This lack of diagnostic agreement was related to multiple factors including lack of documentation of injury, differences in assessment tools and goals, and other combat-related motivational factors associated with failure to report injuries while deployed. Several policies were implemented to address underreporting and under-documentation of TBI, yet challenges remain. Findings suggest changes at both individual-level (e.g. service members) and system-level (e.g. DoD/military branches) are needed to adequately diagnose and document all TBI during deployment.

Background

Mild traumatic brain injury (mTBI) is prevalent among post-9/11 Veterans, comprising of an estimated 82% of total TBIs worldwide occurring from 2000 to 2018.[1] Approximately 20% of US troops experienced a probable TBI (mild, moderate, or severe). Of these, an estimated 57% were not clinically evaluated.[2] Underreporting and under-documentation of injury is likely driven by a variety of factors including unawareness of sustaining a mTBI, lack of knowledge regarding concussion evaluation, and/or military TBI screening policies that have evolved over the conflicts.[3] Further, some Veterans may have poor recollection of the head injury itself as a result of altered mental status (AMS) or posttraumatic amnesia (PTA) at the time of injury.[4] Mild TBIs are often not visible, not readily identified, and as a result often overlooked. Perceived stigma, a “tough it out” military mentality, confidentiality issues, commitment to duty/mission, and challenges with navigating the military healthcare system all contribute to underreporting.[5–7]

In 2006, the military services and Department of Defense (DoD) instituted a number of policies initiating screening measures to address underreporting and under-documentation of TBI among deployed service members.[8] In 2010, the DoD further mandated in-theater "event driven" TBI protocols for those who were within 50 meters of any blast explosion, were in a vehicle associated with a blast event, collision/rollover, or sustained a direct blow to the head,[9,10] In addition to screening measures and in-theater TBI protocols, the Post-Deployment Health Assessment (PDHA) was mandated to be administered to all being demobilized following deployment. The PDHA included a series of TBI screening questions, all of which must be endorsed to prompt a follow-up evaluation.[11]

Challenges in TBI screening and assessment

Retrospective TBI identification methods are prone to high false positive and false negative error rates. Many screening methods consist of closed-ended questions that overestimate prevalence rates, as they are designed to capture all potential head injuries that cause residual symptoms.[12] Most screening measures do not reliably assess severity of injury or duration of symptoms,[13] are not designed to disentangle acute TBI symptoms (AMS, PTA, LOC) from symptoms due to other etiologies (e.g., psychological sequelae associated with trauma, postconcussive symptoms), and fail to evaluate for multiple concussions.[13]

Another significant challenge in TBI identification methods is reliance on self-report of historical events. Experts have argued that TBI can only be accurately diagnosed at the time of injury or within the first 24 hours.[4] However, immediate TBI assessment, particularly in active combat settings is often not possible. Self-report using a validated TBI assessment instrument is currently considered the criterion standard for evaluating historical TBI.[13,15] Iverson and colleagues suggested that retrospective diagnostic challenges could be remediated with the development of validated, structured clinical interviews.[4,12] The Boston Assessment of Traumatic Brain Injury (BAT-L) addressed several of Iverson's suggestions.[14] The BAT-L is a well-validated, semi-structured, comprehensive clinical interview designed to assess TBI etiology specific to post-9/11 Veterans across the lifespan including exposure to blast munitions, TBIs sustained during military service (blast and blunt etiology), and civilian TBIs before and after military service.[13] The BAT-L uses an open-ended, forensic approach to establish a timeline for each TBI event and approximate duration of acute TBI symptoms (AMS, PTA, LOC). The BAT-L demonstrated strong correspondence with the Ohio State University TBI Identification Method (OSU-TBI-ID), a valid and reliable assessment tool used to determine lifetime history of TBI (Cohen $\kappa = 0.89$; Kendall τ -b = 0.95) and has strong inter-rater reliability (κ s > 0.80).[13,16]

The long-term consequences of mTBI remain unclear. [17–20] However, research suggests that mTBI may have a synergistic effect on functional[21,22] and mental health outcomes.[23] Identification of mTBI is essential to target treatment and understand long-term outcomes in military service members.[24] This study investigated the correspondance of retrospective TBI diagnosis on the BAT-L with in-theater (e.g., occurring during deployment) medical record documentation in close proximity date of injury. Specifically,

we compared incidence and severity of injury of each positive TBI diagnosis during military deployment from the BAT-L with DoD medical records. We further compared concordant (true positives; true negatives) with discordant (false positives; false negatives) groups to determine if there were any differences in demographics or clinical characteristics that may have contributed to discrepancy in TBI diagnosis. Lastly, using narrative injury accounts from the BAT-L, we explored reasons for diagnostic discrepancies.

Methods

Participants

Participants were Veterans (age 18-75) enrolled in the TRACTS longitudinal cohort study[25], which assesses the biological, neurobiological, psychological, and cognitive functioning of post-9/11 Veterans. Veterans were recruited by a recruitment specialist who attended military events involving US Air National Guard, Marine and Marine Reserves, and Army and Army Reserve Units. Exclusionary criteria were individuals with a history of neurological illnesses, seizure disorders, psychotic disorders, bipolar disorders, or active suicidal/homicidal ideations. This study has been approved by VA Boston by Institutional Review Boards for human participants' protection.

The Defense and Veteran Brain Injury Center, which is responsible for tracking military TBI data attained from Armed Forces Health Surveillance Branch and Theater Medical Data Store, reported the highest total worldwide TBI diagnoses occurred in 2011 with more than 30,000 diagnoses.[26] To target participants with greater likelihood of TBI assessment and documentation in-theater, we included participants from the larger TRACTS sample[25] who were positive for military TBI and deployed during the 2011 calendar year (n=163). We excluded study participants who deployed in other years, those who failed the Medical Symptom Validity Test (n=7), which could interfere with validity of self-report, and those who could not be identified in the Joint Legacy Viewer (JLV) clinical application that provided access to DoD online medical records (n=3). The final analytic sample included 153 individuals (149 men/4 women) with TBI occurring during military service as a result of blast (e.g., improvised explosive device) and/or blunt impact exposures (e.g., vehicular accident, combatives, fall). Three Veterans sustained two TBIs within their 2011 deployments, resulting in 156 injury events available for comparison (Figure 1).

Procedures

BAT-L. Information collected from the BAT-L included diagnosis of TBI (positive or negative) and severity of TBI (mild, moderate, or severe) following ACRM and DoD criteria. For details regarding TBI diagnostic criteria and interview procedures see.[13]

DoD online medical records. Joint Legacy Viewer was used to access DoD records from deployment. Each Veteran's medical chart was filtered from 9/12/2001 to 3/24/2020 for review. All notes during this time period that clearly related to any head injury (blast or blunt etiology regardless of severity) and notes with no or ambiguous titles (e.g., consultation report, emergency visits) were thoroughly reviewed by a

clinical psychologist. Any documented head injury occurring within a deployment that overlapped any period within the 2011 calendar year was identified. In-theater notes closest in proximity to date of head injury were considered the primary data source. If they were not available, other notes (e.g., PDHA) were examined.[27] In order to examine the predictive validity of the BAT-L as compared to DoD records, each specific head injury case was matched based on the details of narratives available in both records. Specifically, narratives often provided information such as location, date, method of injury, and/or sequence of events that were used to match the head injury reported in the DoD records to the BAT-L.

Information from DoD was used to determine both TBI diagnosis and TBI severity. Diagnostic consensus for DoD documentation was held with at least two doctorate-level psychologists who were blinded to the BAT-L data and TBI was diagnosed if there was any information in the records that indicated AMS, PTA, or LOC had occurred. Severity was classified as mild, moderate, or severe based on clear documentation of the duration of LOC, AMS, and PTA.

Statistical Analyses

Chi-square analyses were used to compare diagnostic agreement (Yes/No TBI diagnosis; TBI severity) between the BAT-L and DoD records. Sensitivity, specificity, kappa, and Kendall's tau-b were calculated for TBI diagnosis and severity. Demographic information and other clinical characteristics were examined (Table 1). These characteristics were compared between concordant TBI cases ("true positives" = positive TBI diagnosis on BAT-L and DoD records; "true negatives" = negative TBI diagnosis on BAT-L and DoD records) and discordant TBI cases ("false positives" = negative TBI diagnosis on the BAT-L, but positive in DoD records; "false negatives" = positive TBI diagnosis on the BAT-L, but negative in DoD records) using chi square, Fisher exact test (expected cell counts < 5), and t-test analyses. All p-values reported were corrected for multiple comparisons using the false discovery rate method [28] and refer to two-tailed tests (Table 1). All analyses were conducted using SPSS 26.0.0.1 software (IBM Corporation, Armonk, NY).

Results

Mean participant age was 31.85 years old (range 20–64, SD = 9.06). Participants were predominantly white (78%) and male (97%; Table 1). Of the 156 injury events, 19% had in-theater DoD documentation, 43% had post-deployment notes only, and 38% did not have any notes in the DoD records.

Overall, individuals in concordant and discordant groups were similar in regard to clinical and demographic variables (Table 1). The discordant group reported greater occurrence of TBIs occurring during military service (M = 1.41, SD = 1.12; $p < 0.05$) compared to the concordant group (M = 0.63, SD = 1.10). Veterans in the concordant group had a greater number (M = 1.99, SD = 1.24; $p < 0.05$) and duration (M = 19.46, SD = 12.49; $p < 0.05$) of deployments. Veterans in the concordant and discordant groups did not differ on any clinical diagnostic categories other than anxiety disorder.

Table 1
Demographic and clinical characteristics

	n	Full sample	n	TBI concordant cases	n	TBI discordant cases	P-value*
Age, mean (SD)	153	31.85 (9.06)	127	32.54 (9.23)	29	29 (7.80)	0.1649
Males, n (%)	153	149 (97.39)	127	124 (97.64)	29	28 (96.55)	0.7286
Educ (years), mean (SD)	153	13.58 (1.95)	127	13.61 (2.01)	29	13.45 (1.66)	0.7935
Race, n (%)							
White	153	120 (78.43)	127	96 (75.59)	29	27 (93.10)	0.1443
Black	153	15 (9.80)	127	14 (11.02)	29	1 (3.45)	0.4722
Other	156	7 (4.49)	127	7 (5.51)	29	0 (0.00)	0.4830
Branch Service, n (%)							
Army	153	106 (69.28)	127	92 (72.44)	29	17 (58.62)	0.3184
Navy	153	2 (1.31)	127	2 (1.57)	29	0 (0.00)	0.9999
Marines	153	38 (24.84)	127	26 (20.47)	29	12 (41.38)	0.1029
Air Force	153	6 (3.92)	127	6 (4.72)	29	0 (0.00)	0.7426
Coast Guard	153	1 (0.65)	127	1 (0.79)	29	0 (0.00)	0.9999
Post 9/11 deployments, mean (SD)							
Number	153	1.92 (1.18)	127	1.99 (1.24)	29	1.52 (0.63)	0.0420
Duration (months)	153	18.40 (11.86)	127	19.46 (12.49)	29	13.45 (6.34)	0.0140
DRRI Combat exposure	145	18.48 (11.02)	121	17.92 (11.03)	27	22.04 (10.46)	0.2099
DRRI Other war-zone exposure	145	8.70 (4.44)	121	8.59 (4.45)	27	9.63 (4.30)	0.4315

Abbreviations: CAPS = Clinician Administered PTSD Scale based on DSM-IV criteria; DRRI = Deployment Risk and Resiliency Inventory; NSI = Neurobehavioral Symptom Inventory; PCL = Post Traumatic Stress Disorder Checklist; SC = Service Connection

*Tests of significance between TBI concordant and discordant cases. P-values corrected using the false discovery rate method.

	n	Full sample	n	TBI concordant cases	n	TBI discordant cases	P-value*
Blast exposure (meters), mean (SD)							
< 10	153	3.57 (17.25)	127	3.93 (18.89)	29	1.86 (2.39)	0.4092
11–25	153	2.95 (9.52)	127	3.20 (10.39)	29	1.83 (2.17)	0.3466
26–100	153	29.44 (106.58)	127	33.90 (116.50)	29	7.724 (10.05)	0.0927
Military Blast exposures	153	35.96 (112.81)	127	41.03 (123.1)	29	11.41 (13.60)	0.0736
Close Blast < 10 meters, n (%)	153	70 (45.75)	127	54 (42.52)	29	19 (65.52)	0.1255
TBI aggregate time (min), mean (SD)							
LOC	153	11.68 (116.44)	127	13.81 (127.8)	29	1.167 (2.20)	0.4315
AMS	153	358.22 (2483.27)	127	417.5 (2723)	29	163.7 (545.6)	0.4830
PTA	153	115.73 (519.67)	127	136.0 (568.0)	29	116.3 (540.2)	0.9356
Military TBI, mean (SD)	153	0.74 (1.12)	127	0.63 (1.10)	29	1.413 (1.12)	0.0140
Psychiatric disorder (current), n (%)							
Mood disorders	153	37 (24.18)	127	30 (23.62)	29	9 (31.03)	0.5407
Anxiety disorders	153	24 (15.69)	127	15 (11.81)	29	10 (34.48)	0.0360
Other Substance use disorders	153	28 (18.30)	127	24 (18.90)	29	6 (20.69)	0.9168
Alcohol use disorders	153	24 (15.69)	127	21 (16.54)	29	5 (17.24)	0.9755
PTSD, n (%)	153	83 (54.25)	127	69 (54.33)	29	17 (58.62)	0.7935

Abbreviations: CAPS = Clinician Administered PTSD Scale based on DSM-IV criteria; DRRI = Deployment Risk and Resiliency Inventory; NSI = Neurobehavioral Symptom Inventory; PCL = Post Traumatic Stress Disorder Checklist; SC = Service Connection

*Tests of significance between TBI concordant and discordant cases. P-values corrected using the false discovery rate method.

	n	Full sample	n	TBI concordant cases	n	TBI discordant cases	P-value*
CAPS Total, mean (SD)	153	46.43 (28.03)	127	45.57 (26.48)	29	54.86 (35.55)	0.3686
PCL Total, mean (SD)	152	43.41 (16.76)	126	43.11 (16.21)	29	46.34 (19.01)	0.4830
Neurobehavioral symptoms, mean (SD)							
NSI vestibular	145	0.13 (0.18)	120	0.12 (0.17)	28	0.21 (0.22)	0.1600
NSI somatic	145	0.18 (0.17)	120	0.17 (0.16)	28	0.23 (0.21)	0.2252
NSI cognitive	144	0.31 (0.26)	119	0.29 (0.25)	28	0.41 (0.32)	0.1324
NSI affective	144	0.34 (0.26)	119	0.33 (0.25)	28	0.40 (0.29)	0.4089
NSI Total	145	21.55 (16.41)	120	20.54 (15.35)	28	27.61 (19.77)	0.1443
NSI Symptom validity score, mean (SD)	141	6.85 (6.53)	116	6.28 (5.93)	27	9.85 (8.28)	0.1443
Failed symptom validity, n (%)	141	4 (2.84)	116	2 (1.72)	27	2 (7.41)	0.3400
SC							
Applied for TBI SC, n (%)	45	13 (28.89)	40	10 (25)	6	4 (66.67)	0.2252
SC, mean (SD)	100	41.40 (36.54)	82	41.83 (36.86)	21	37.62 (36.59)	0.7770

Abbreviations: CAPS = Clinician Administered PTSD Scale based on DSM-IV criteria; DRRI = Deployment Risk and Resiliency Inventory; NSI = Neurobehavioral Symptom Inventory; PCL = Post Traumatic Stress Disorder Checklist; SC = Service Connection

*Tests of significance between TBI concordant and discordant cases. P-values corrected using the false discovery rate method.

Correspondence between BATL and DoD

There was moderate correspondence for TBI diagnosis between the BAT-L and DoD records (κ = 0.42; Kendall τ-b = 0.45; Table 2). Sensitivity was 72.7% and specificity was 82.8%. Comparison of TBI severity between the BAT-L and DoD records was also moderate overall (κ = 0.41; Kendall τ-b = 0.46; Table 2). Sensitivity was 66.7% for mild TBI (n = 14) but 100% for moderate TBI (n = 1). There were no severe TBI cases; Specificity for TBI severity was 82.8%.

Table 2
Comparison of traumatic brain injury diagnoses and severity according to BAT-L with DoD records

DoD diagnosis of military TBI during 2011 deployment				
BAT-L diagnosis	**Negative (59 with no DoD notes)**		**Positive (0 with no DoD notes)**	**Total**
Negative	111		6	117
Positive	23		16	39
Total	134		22	156
DoD military TBI severity during 2011 deployment				
BAT-L severity	**None**	**Mild**	**Moderate**	**Total**
None	111	6	0	117
Mild	23	14	0	37
Moderate	0	1	1	2
Total	134	21	1	156

Description of diagnostic discrepancies

False Positives

Six Veterans were positive for TBI based on the DoD records, but were not diagnosed with TBI on the BAT-L (Table 3). Based on event narratives from BAT-L and DoD, almost all (five of six false positives cases) were confirmed to be the same head injury event on both the BAT-L and DoD records; one case was unable to be matched due to lack of information from DoD records. Diagnostic discrepancies were primarily due to difference in approach in TBI evaluation. The BAT-L used a forensically guided semi-structured interview focused on duration of acute TBI symtoms, while in-theater documentation consisted of brief screening.

Table 3
Description of Diagnosis Disagreement between BAT-L and DoD records (false positives)

Category	Number of Cases	Description (based on the BAT-L)	Example(s) (from the BAT-L)
Difference in approach of evaluations	3	Symptom checklist approach (DoD) vs. forensic approach (BAT-L)	Veteran reported vague symptoms (e.g., confusion) that lasted for a “few seconds” were not considered sufficient to warrant positive TBI diagnosis.
	1	Psychological vs. AMS symptomology	Veteran’s disrupted thinking after a blast explosion was determined to be more likely attributable to a psychological response rather than acute AMS from TBI.
	1	PCS vs. AMS symptomology	Veteran reported PCS symptoms only (e.g., headaches) that were misdiagnosed as AMS in DoD record.
Confounding factors	1	Unable to match head injury	One Veteran failed to report a TBI on the BAT-L that was documented in his DoD records.

False Negatives

Twenty-three Veterans were negative for TBI based on DoD records, but were diagnosed with TBI on the BAT-L. Only four of the false negative cases had in-theater documentation of injury, while 19 cases had either no DoD records (n = 10) or only post-deployment screening notes available (n = 9; Table 4).

Table 4
Description of Diagnosis Disagreement between BAT-L and DoD records (false negatives)

Category	Number of Cases	Description (based on BAT-L)	Example(s) (based on BAT-L)
No DoD records or only Post Deployments notes (screener) available	6	The Veteran reported he/she was not examined by a medic or physician following the head injury.	Veterans did not complete a TBI evaluation.
	9	Veteran reported he/she was examined by a medic, however there was no documentation in DoD records.	
	4	Veteran reported having other more serious injuries/conditions.	Veteran reported he sustained other injuries including a fractured shoulder that required more immediate attention.
In-theater notes available	4	Veteran was in the middle of a mission.	Veteran reported undergoing a concussion evaluation, but was subsequently sent back out to continue mission.

Discussion

In-theater documentation of head injury was unavailable in DoD records for the large majority of cases (81%). Among Veterans who reported injuries that met diagnostic criteria for TBI on the BAT-L but were negative for TBI on DoD records (false negatives), 43% of cases did not have any DoD documentation of injury (in-theater or post-deployment notes). Importantly, when DoD documentation was available, injury events could be confirmed in the large majority of cases based on corresponding narratives, supporting the predictive validity of the BAT-L retrospective TBI diagnosis. These findings indicate that although DoD and military services made substantial efforts to increase TBI screening, documentation of injury assessment was rare. We cannot determine if the lack of available records is due to lack of reporting, lack of documentation, or more likely, a combination of these factors.

The BAT-L yielded a diagnostic sensitivity of 73% and specificity of 83% for TBI with available DoD records. Further analyses of TBI severity ratings indicated that sensitivity was 67% for mild TBI and 100% for moderate TBI. Sensitivity and specificity are inversely related; an increase in sensitivity will result in a decrease in specificity and vice versa.[29] Due to this tradeoff, TBI assessment tools should be selected based on clinical utility. For example, initial screener tools, which have a primary goal of identifying all possible TBI, benefit from having higher sensitivity rates. After screening, individuals should receive a more comprehensive assessment to determine definitive diagnosis. Diagnostic agreement was lower for mTBIs, but was excellent for injuries of greater severity (moderate TBI).

The moderate correspondence observed for TBI diagnosis between the BAT-L clinical interview and DoD records was likely a result of multiple factors. Among the false negatives, six Veterans reported that they did not report injury or seek any care for their head injuries on the BAT-L. There are many potential reasons a Veteran may not report injury during deployment including lack of awareness they sustained a concussion, perceived stigma of TBI, a “battlemind” mindset related to military culture, confidentiality issues that may impact career advancement, and/or could delay returning home from deployment.[3,5,14]

Among those who were evaluated for TBI in-theater and had DoD documentation of the injury, there were four Veterans who reported (BAT-L) that they were mid-mission when their TBI event occurred and screened negative on in-theater TBI medic assessment. It is possible that these Veterans did not endorse symptoms because they did not want to disrupt their mission and/or wanted to return to the field.[4]

Another nine Veterans reported they were examined by a medic when queried specifically about in-theater medical attention during the BAT-L clinical interview. However, there was no documentation of any examination in DoD records. Although the reason(s) for lack of documentation is not clear, this issue is not unique. Terrio and colleagues used similar methods to compare the Warrior Administered Retrospective Casualty Assessment Tool with available DoD medical records among Veterans with a clinician confirmed TBI. Similarly, 73% of their sample had no corroborating documentation in their records.[30] One reason mTBIs are not documented may be the co-occurrence of other serious injuries that required immediate attention.[6] Four Veterans (of 23 false negative cases) were noted to have sustained other injuries (such as a fractured shoulder) that likely took precedence over mTBI assessment. Additionally, TBI assessments in battlefield conditions are understandably challenging. During combat/missions, the attending medic often provides triaged care, quickly evaluating a number of individuals, tending to critical needs first, or potentially participating in combat before he/she is able to attend to injuries. Documentation of mTBI under these circumstances may not always be feasible.

For Veterans who were evaluated and in-theater DoD documentation was available, there were a number of disagreements between the BAT-L and DoD records. The primary cause of the discrepancies was the differing nature of the TBI assessment tools. In-theater assessments necessarily involve briefer screening, usually limited to a symptom checklist format, designed to be more sensitive than specific, and prone to false positives errors to catch all potential injuries. Furthermore, the PDHA, which was admistered post-deployment, contained a single yes/no question to assess AMS. Service members were asked only if they were “dazed and confused or seeing stars.” Without additional information, endorsement of this single item may have also contributed to a high false positive rate, especially in the context of a combat situation (e.g., chaos of battle, stress, acute traumatic reaction).[14]

Comparatively, the BAT-L clinical interview adopts a more conservative, forensic approach including a detailed narrative and timeline for each injury event. Semi-structured diagnostic interviews administered by a qualified clinician are considered the criterion standard for diagnosing lifetime history of TBI.[4,15] Combat settings pose unique diagnostic challenges given common co-occurring physical and psychological sequelae. Therefore, the BAT-L probes for eyewitness accounts, severity of other injuries,

and other factors that may be misinterpreted as an acute symptoms of TBI. Examiners query the Veteran's psychological state at the time of the head injury to provide context to assess whether confusion may be better explained by shock/acute trauma reaction. Lastly, the BAT-L guides the examiner to disentangle acute AMS symptoms from lingering PCS (e.g., generally slowed thinking versus acute disruption of thinking at the time of injury), which are often inappropriately lumped together in briefer screening assessments as demonstrated in at least one diagnostic discrepancy in this study. Thus, the BAT-L, by design, was more conservative in rendering a positive TBI diagnosis.

Study Limitations

Although TRACTS Veteran self-selected for research participation, they are representative of US Veterans in terms of demographics, and other factors.[25] Additionally, DoD documentation was limited to records available in the JLV system, which included both computer records and scanned, handwritten field notes. Paper records within DoD that have not been scanned to the JLV system may possibly provide additional information.

Conclusions

Mild TBI is a common injury among deployed post-9/11 Veterans and is critical to clinical conceptualization and treatment. Particularly when mTBI occurs in combination with other psychiatric factors (e.g., PTSD, depression), it has been shown to worsen outcomes and complicate treatement as soliders reintegrate back into the civilian life. [21,22] Thus, it is crucial to accurately diagnose mTBI in order to aid clinical decision making and treatment. These findings suggest that TBI, and mTBI in particular, are vastly under-documented in military DoD records. This finding is very relevant to Veteran health as well as to their potential compensation for injury. Both system-level and individual-level solutions are needed to address injury reporting among military personnel. Before deploying to a military zone, service members should be provided with education regarding TBI risk, acute symptom identification, and protocols to support evaluation and documentation, as this may increase the likelihood they will report a head injury when it occurs. Along with the implementation of DoD policies, qualified clinicians should be thoroughly trained in TBI protocols and understand the selected assessment tool's strengths and limitations. In-theater assessment should include mandatory post-mission assessment using an open-ended format with queries for actue TBI symtoms and queries to rule out confounding etiologic factors that may impact symptom presentation as close to date of injury as possible. Finally, a combination of both retrospective self-report and review of in-theater medical records should be used to determine diagnoses in future conflicts.

Abbreviations

Altered mental status (AMS)

Boston Assessment of Traumatic Brain Injury-Lifetime (BAT-L)

Department of Defense (DoD)

Joint Legacy Viewer (JLV)

Loss of Consciousness (LOC)

Mild Traumatic Brain Injury (mTBI)

Post-Deployment Health Assessment (PDHA)

Posttraumatic Amnesia (PTA)

Posttraumatic Stress Disorder (PTSD)

Traumatic Brain Injury (TBI)

Translational Research Center for TBI and Stress Disorders (TRACTS) National TBI Network Center

Declarations

Ethics approval and consent to participate: This study has been approved by VA Boston by Institutional Review Boards for human participants' protection.

Consent for publication: Not applicable.

Availablity of data and materials: The data that support the findings of this study are available upon reasonable request from the corresponding author, CBF. The data are not publicly available due to restrictions: 1) a subset of participants did not consent to share their data in a data repository and 2) the dataset contains information that could compromise the privacy of research participants.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: SK and BB reviewed participant charts and were responsible coding information. SK, AC, and JRF analyzed and interpreted the patient data. SK, CF, and AK were involved in consensus of diagnoses, and major contributors in writing the manuscript. All authors read and approved the final manuscript

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Figures

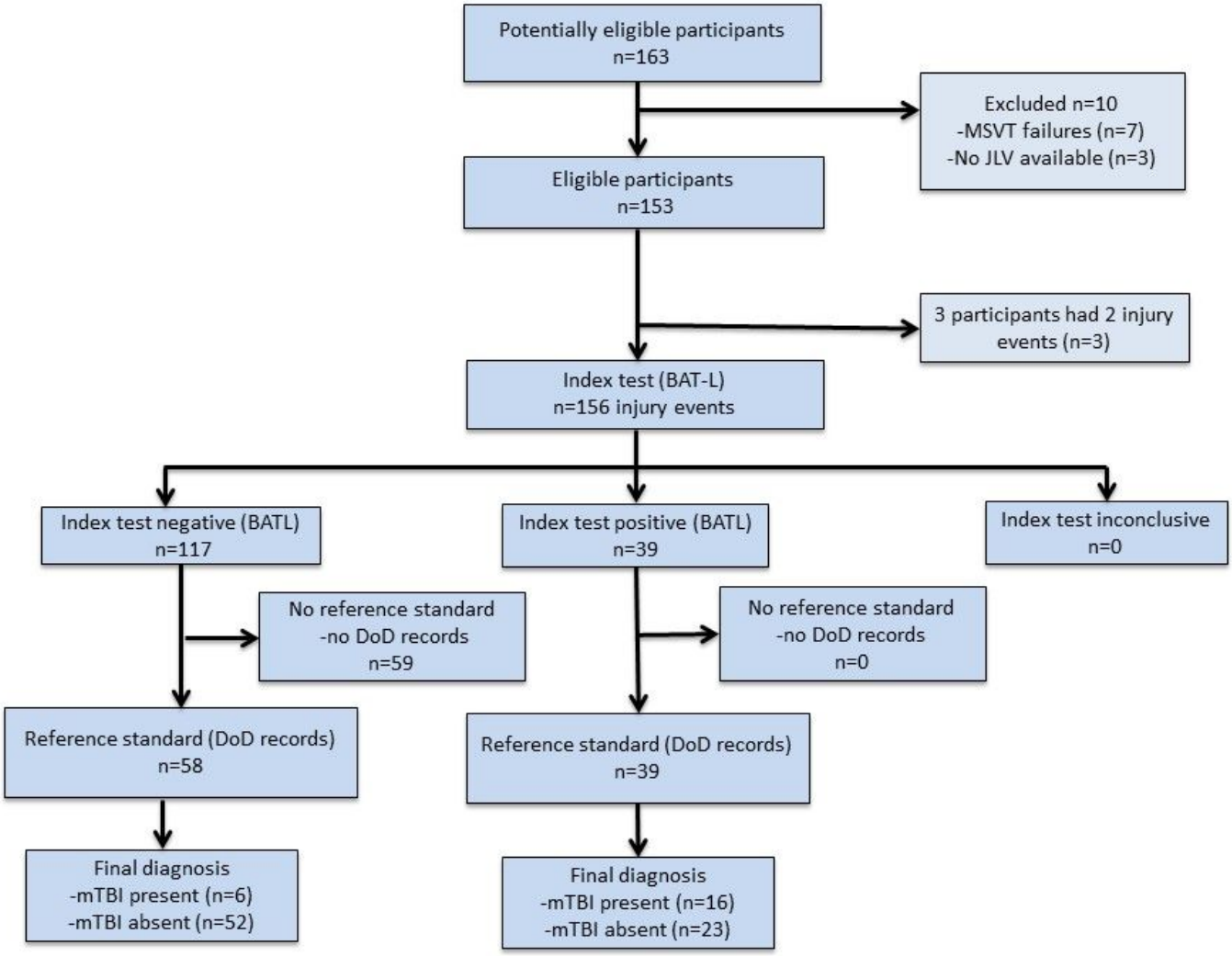

Figure 1

Standards for Reporting of Diagnostic Accuracy (STARD) flowchart