Long-term outcomes of combat casualties sustaining penetrating traumatic brain injury

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BACKGROUND: Previous studies have documented short-term functional outcomes for patients sustaining penetrating brain injuries (PBIs). However, little is known regarding the long-term functional outcome in this patient population. Therefore, we sought to describe the long-term functional outcomes of combat casualties sustaining PBI.

METHODS: Prospective data were collected from 2,443 patients admitted to a single military institution during an 8-year period from 2003 to 2011. PBI was identified in 137 patients and constitute the study cohort. Patients were stratified by age, Injury Severity Score (ISS) and admission Glasgow Coma Scale (aGCS) score. Glasgow Outcome Scale (GOS) scores were calculated at discharge, 6 months, 1 year and 2 years. Patients with a GOS score of 4 or greater were considered to have attained functional independence (FI).

RESULTS: The mean (SD) age of the cohort was 25 (7) years, mean (SD) ISS was 28 (9), and mean (SD) aGCS score was 8.8 (4.0). PBI mechanisms included gunshot wounds (31%) and blast injuries (69%). Invasive intracranial monitoring was used in 80% of patients, and 86.9% of the study cohort underwent neurosurgical intervention. Complications included cerebrospinal fluid leak (8.3%), venous thromboembolic events (15.3%), meningitis (24.8%), systemic infection (27.0%), and mortality (5.8%). The cohort was stratified by aGCS score and showed significant improvement in functional status when mean discharge GOS score was compared with mean GOS score at 2 years. For those with aGCS score of 3 to 5 (2.3 [0.9] vs. 2.9 [1.4], $p < 0.01$), 32% progressed to FI. For those with aGCS score of 6 to 8 (3.1 [0.7] vs. 4.0 [1.2], $p < 0.0001$), 63% progressed to FI. For those with aGCS score of 9 to 11 (3.3 [0.5] vs. 4.3 [0.8], $p < 0.0001$), 74% progressed to FI. For those with aGCS score of 12 to 15 (3.9 [0.7] vs. 4.8 [0.4], $p < 0.00001$), 100% progressed to FI.

CONCLUSION: Combat casualties with PBI demonstrated significant improvement in functional status up to 2 years from discharge, and a large proportion of patients sustaining severe PBI attained FI. (*J Trauma Acute Care Surg*. 2012;73: 1525–1530. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Epidemiologic study, level III.

KEY WORDS: Trauma; head injury; traumatic brain injury; military; blast injury.

Penetrating brain injury (PBI) has historically been associated with a poor prognosis.[1] Although no longer uniformly fatal, PBI mortality rates remain high with military rates ranging from 6.8% to 61.1%[2–5] and civilian mortality ranging from 34% and 88.1%.[6–8] Prognostic studies offer assistance with triage and resource management, identifying the following factors with poor outcomes in the acute period after injury: initial low Glasgow Coma Scale (GCS) score, fixed or dilated pupils, hypoxia, hemodynamic instability, subarachnoid hemorrhage, bihemispheric trajectory, multilobar involvement, and posterior compartment injury.[9,10] However, this analysis is not complete without consideration of long-term patient outcomes.

Traumatic brain injury outcomes have traditionally been measured across multiple disciplines. Psychological, neurocognitive, behavioral, and functional outcomes are all impacted. The Functional Independence Measure (FIM), Rancho Los Amigos Scale (LCFS), Disability Rating Scale (DRS), Glasgow Outcome Scale (GOS) score and its extended version are all scales validated to test functional ability after head injury. Of these tests, the GOS is the most widely used, designed to track broad categories of functional outcome.[11] The LCFS, DRS, and FIM can be valuable supplements, each with a different focus—the LCFS assessing patient awareness and interaction with environment, while DRS and FIM are used by rehabilitation clinicians to assess and track level of disability over time (FIM).[12]

The National Naval Medical Center (NNMC) has provided definitive care for combat casualties injured in the recent conflicts including Operation Iraqi Freedom and Operation Enduring Freedom and has served as the Department of Defense referral center for severe PBI since 2003. After acute care has transitioned to a rehabilitative focus, NNMC has remained a strong base for follow-up medical care and patient advocacy, allowing the opportunity for long-term follow-up. Therefore, we sought to determine the long-term functional outcome of combat casualties who sustained PBI.

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PATIENTS AND METHODS

Study Design

From April 2003 to January 2011, a total of 15,192 US military personnel were injured in the Operation Iraqi Freedom/Operation Enduring Freedom with 636 patients sustaining a PBI.[13] Prospective data were collected on all combat casualties admitted to NNMC during the study period (n = 2,443). PBI was identified in 137 of these patients and constituted the study cohort. Records were retrospectively reviewed and patients were stratified by age, Injury Severity Score (ISS) and admission GCS score. Additional demographic and clinical data were recorded including injury characteristics; trauma-related morbidity; hospital treatment course; GOS score at discharge, 6 months, 1 year, and 2 years; and patient mortality. A PBI was required for inclusion in this study. Exclusion criteria included all patients in whom primary demographic data could not be verified.

Definitions

Blast injury was defined as the direct or indirect effect of an explosive ordinance. Transit time considered all prehospital care before arrival at NNMC, including actual time spent traveling as well as care at lower level medical echelons. Patients were classified as having a cerebrospinal fluid (CSF) leak if this morbidity was documented in a note by the neurosurgery department. A venous thromboembolic event (VTE) included both pulmonary emboli and deep vein thromboses and was recorded based on either radiographic results or the documented decision to treat with anticoagulation owing to clinical symptoms. A patient was documented as having a seizure based on clinical documentation stating this diagnosis, owing to a witnessed epileptic event or capture of epileptiform activity on electroencephalography Diagnoses of infectious etiology were taken from documentation from an infectious disease specialist or the primary provider and were supported, when available, with culture data. Surgical procedures were defined by surgical documentation.

Interval GOS calculations were stratified according to NNMC arrival GCS score, except where otherwise specified, as adapted from Lu et al. (2010).[14] GOS scores were determined by a single neurosurgeon either through telephone contact or personal interview, when available, and supplemented by retrospective review of electronic medical records. To provide the best standardization of scoring, specific words/phrases were required for the assignment of each category:

1. Death;
2. Vegetative state—not conscious;
3. Severely disabled—conscious but not independent;
4. Moderately disabled—documentation stating "independent in activities of daily living" from a clinical provider, without note of the ability to drive a motor vehicle or participation in at least 50% of preinjury leisure activities;
5. Good recovery—documentation stating "independent in activities of daily living" from a clinical provider, with documentation of clearance to drive a motor vehicle and/or participation in at least 50% of preinjury leisure activities.

Statistical Analysis

Descriptive statistics were expressed as the mean (SD). Categorical variables were compared using a Fisher's exact test. Relationships between variables were tested using Pearson's correlation coefficients (Stata 6.0, StataCorp., College Station, TX). Differences were considered significant when $p < 0.05$.

RESULTS

Patient Demographics

The mean (SD) age of the cohort was 25.7 (6.6) years with the majority being male (98.5%). Mechanisms of injury included gunshot wounds (31.4%) and blast injuries (68.6%). Injury severity was high in the study cohort, with a mean (SD) ISS of 27.8 (8.8). The mean (SD) NNMC admission GCS score was 8.8 (4.0). ISS was found to be inversely related to NNMC admission GCS score. Resource use resulted in a mean (SD) hospital length of stay (LOS) of 26.0 (20.0) days, an intensive care unit (ICU) admission rate of 94.8% and a mean (SD) ICU LOS of 12.8 (12.1) days (Table 1).

Acute and Delayed Morbidity and Mortality

The morbidity associated with PBI during the acute hospitalization was high, but the associated mortality was low. The morbidities included CSF leaks (10.2%, n = 14), VTEs (15.3%, n = 21), meningitis/ventriculitis (24.8%, n = 34), and systemic infection (28.5%, n = 39). The mortality rate during initial admission was 5.8% (n = 8). Delayed morbidity reflects all complications that occurred within the period after discharge from NNMC until 2 years from date of injury. These morbidities included new onset seizures (39.1%, n = 25), meningitis/ventriculitis (13.2%, n = 9) and a delayed mortality rate of 1.5% (n = 1, Table 2).

Neurologic Intervention

Neurologic invasive monitoring was common in the study cohort at 79.6% (n = 109), with 35.8% (n = 49) of the patients requiring more than one type of monitor. An external ventricular drain was the most common type of monitor placed (60.6%), followed by an intracranial pressure monitor (37.2%), a Licox monitor (24.1%), and a lumbar drain (2.7%).

TABLE 1. Patient Demographics

Patient Demographics		n
Sex (male)	98.50%	135
Age, mean (SD), y	25.7 (6.6)	137
Mechanism of Injury		
Blast	68.6 %	94
Gunshot wound	31.4 %	43
ISS, mean (SD)	27.8 (8.8)	137
GCS score 3–5	31.6 (13.6)	31
GCS score 6–8	27.3 (5.1)	38
GCS score 9–11	27.3 (7.0)	39
GCS score 12–15	25.0 (7.4)	29
Transit time to NNMC, mean (SD), d	5.8 (3.3)	137
Mean hospital LOS, mean (SD), d	26.0 (20.0)	137
Mean ICU LOS, mean (SD), d	12.8 (12.1)	137

TABLE 2. Morbidity

Morbidity	n (%)	Total
CSF leak	14 (10.2)	137
Overall VTE	21 (15.3)	137
DVT	11 (8.0)	137
PE	10 (7.3)	137
Overall seizure	37 (27.0)	137
Initial	12 (8.8)	137
Delayed	25 (39.1)	64
Overall meningitis/ventriculitis	41 (29.9)	137
Initial	34 (24.8)	137
Delayed	9 (13.2)	68
Overall mortality	9 (6.6)	137
Initial	8 (5.8)	137
Delayed	1 (1.5)	68

Initial morbidity accounts for all incidents occurring during the initial hospitalization.
Delayed morbidity reflects all complications that occurred within the period after discharge from NNMC until 2 years from date of injury.
DVT, deep vein thrombosis; PE, pulmonary embolism.

Similarly, most of the cohort required operative intervention (86.7%). The most common procedure performed was a craniectomy (78.8%) followed by a craniotomy (8.0%). Most of the craniectomies were performed in theater hospitals (n = 101), with four performed at the Landstuhl Regional Medical Center and four performed at the NNMC. Of those patients undergoing a craniectomy, 13.1% (n = 19) required bilateral craniectomies owing to injury location and severity (Table 3).

Neurologic Outcome

Patients were stratified by NNMC admission GCS score to trend GOS score measured at discharge, 6 months, 1 year, and 2 years. More than half of the study cohort regained independence in all activities of daily living, including 10 in the category of GCS scores 3 to 5, 34 in the category of GCS scores 6 to 8, 29 in the category of GCS scores 9 to 11, and the entire category of GCS scores 12 to 15. Seven patients returned to active duty status in the military; two from the category of GCS scores 6 to 8, one from the category of GCS scores 9 to 11 and four from the category of GCS scores 12 to 15. While significant improvement was seen overall throughout the entire 2-year period ($p < 0.0001$), the greatest range of improvement was seen in the groups with GCS score of 9 to 11 and 12 to 15, who improved from 3.3 (0.5) to 4.3 (0.8) and 3.9 (0.7) to 4.8 (0.4), respectively. The groups with GCS score 6 to 8 and GCS score 9 to 11 saw a significant improvement in neurologic function at 6 months, 1 year, and 2 years compared with discharge ($p < 0.05$). Similarly, the group with GCS score 12 to 15 demonstrated significant improvement in neurologic function at 1 year and 2 years compared with discharge ($p < 0.01$ and $p < 0.0001$), and the group with GCS score 3 to 5 demonstrated significant improvement at 2 years from discharge ($p < 0.01$,Table 4).

A similar analysis was completed stratifying initial field GCS score to trend GOS measurements at 6 months, 1 year, and 2 years. A field GCS score was documented in 114 patients. This cohort also demonstrated significant improvement during a 2-year follow-up period ($p < 0.0001$), with a mean (SD) improvement of GOS score from 3.1 (0.8) to 3.9 (1.2). Each of the four GCS categories (3–5, 6–8, 9–11, and 12–15) showed significant improvement during 2 years ($p < 0.01$). The group with field GCS score 9 to 11 showed the greatest range of improvement, starting at GOS score of 3.1 (0.4) and improving to 4.4 (0.7) (Table 5).

A subgroup analysis was completed for the 62 patients for whom all scores were available from initial field evaluation out to the 2-year follow-up end point. The entire cohort, as well as each subgroup, saw significant improvement within 2 years ($p < 0.01$, Table 6).

DISCUSSION

PBI has historically been associated with poor outcome, leaving some to question the benefit of dedicating limited resources to this patient population.[15] However, long-term outcomes have been evaluated in closed head injuries, showing functional improvement throughout follow-up.[16] Even as late as 2 years to 5 years from injury, continuous significant functional improvement is observed in domestic and community activities.[17] Although there are a limited number of publications that address functional outcomes in PBI, these studies also document similar encouraging results. Two studies found similar short-term functional improvement for patients with PBI as compared with patients with closed head injuries.[18,19] A third study reported outcomes for patients sustaining PBI from a military conflict in Lebanon. These authors documented that 63% of patients were able to achieve a GOS score of 4 or greater within a 6-year follow-up time frame .[20] These results are similar to the current study, which found that 66% of the cohort improved to a GOS score of 4 or greater within 2 years. However, while additional studies suggest that patients, even those with low initial GCS score, improve significantly over time and can achieve reintegration with the community,[21–23] none compare with the improvement seen in the cohort with GCS score 3 to 5 of the current study, with 32% attaining a good functional outcome. Furthermore, 5.0% (n = 7) of the patients in the current study's cohort were able to meet the physical, mental, and psychological demands of returning to active duty military status.

TABLE 3. Neurosurgical Interventions

Intervention	n (%) (n = 137)
Monitor type	
None	28 (20.4)
ICP	51 (37.2)
EVD	83 (60.6)
Licox	33 (24.1)
Lumbar drain	4 (2.9)
Surgical intervention	
No intervention	18 (13.1)
Craniotomy	11 (8.0)
Craniectomy	108 (78.8)
Unilateral	89 (65.0)
Bilateral	19 (13.9)

EVD, extraventricular drain; ICP, intracranial pressure.

TABLE 4. NNMC Admission GCS and GOS Scores

	NNMC Admission GCS Score	Discharge GOS Score	6-mo GOS Score	1-y GOS Score	2-y GOS Score	*p* at Discharge to 2 y	Percentage of Those With GOS Score ≥4
Overall (n = 137)	8.8 (4.0) n = 137	3.1 (0.9) n = 133	3.5 (1.2)* n = 106	3.9 (1.3)* n = 92	4.0 (1.2)* n = 78	≤0.0001	68
GCS score 3–5 (n = 31)	3.7 (0.8) n = 31	2.3 (0.9) n = 31	2.4 (1.1) n = 26	2.4 (1.3) n = 20	2.9 (1.4)† n = 20	0.0033	32
GCS score 6–8 (n = 38)	6.8 (0.7) n = 38	3.1 (0.7) n = 36	3.5 (1.1)‡ n = 28	3.9 (1.6)* n = 25	4.0 (1.2)* n = 21	≤0.0001	63
GCS score 9–11 (n = 39)	10.3 (0.8) n = 39	3.3 (0.5) n = 38	4.0 (0.7)† n = 28	4.2 (0.8)* n = 26	4.3 (0.8)* n = 18	≤0.0001	74
GCS score 12–15 (n = 29)	14.6 (0.7) n = 29	3.9 (0.7) n = 28	4.3 (0.6) n = 24	4.7 (0.6)† n = 21	4.8 (0.4)* n = 19	≤0.0001	100

Fisher's exact test.
*$p < 0.0001$.
†$p < 0.01$.
‡$p < 0.05$.

Other studies have documented differences in outcome between military and civilian patients who sustain severe traumatic brain injuries. In a recent study, Dubose et al.[4] compared treatments and outcomes of military and civilian patients who sustained isolated severe traumatic brain injuries. The authors documented a threefold increase in neurosurgical operative intervention (21.5% vs. 7.2%, $p < 0.01$) and an eightfold increase in invasive intracranial monitoring (13.8% vs. 1.7%, $p < 0.01$) when comparing combat casualties with a matched civilian cohort. In addition, the military patients had a significantly lower mortality (7.7% vs. 21.0%, $p < 0.01$) compared with the matched civilian cohort. Although it cannot be stated that the mortality difference was directly related to a more aggressive approach to neurosurgical intervention, this was the greatest difference between the two cohorts.

Our group has previously described significant long-term functional improvement in a cohort of patients undergoing early decompressive craniectomy during the time frame of 2003 to 2008 and led to a recommendation for this procedure before medical evacuation from theater.[24] These and similarly reported results, such as those described by Dubose et al., reflect the aggressive approach currently outlined in the military's Joint Theater Trauma System clinical practice guidelines and are echoed with this current study. This points to why most of the study cohort underwent invasive intracranial monitoring (78.5%), with 86% of patients undergoing surgical intervention (i.e., craniotomy or craniectomy) and 19 patients undergoing bilateral hemicraniectomies.

Despite the frequent use of decompressive craniectomy in the military, the role and timing of this procedure in the civilian community has remained controversial. A recently published multicenter randomized controlled study, the Decompressive Craniectomy in Diffuse Traumatic Brain Injury (DECRA) trial, sought to define the role of decompressive craniectomy for patients sustaining closed head injury. Patients with refractory intracranial hypertension who sustained closed head trauma were randomized to receive either bifrontal craniectomy or continued medical management. Analysis of results showed no difference in mortality between the groups. Furthermore, a significant difference in functional outcome was reported, with surgical patients faring worse than the standard-care group at 6 months of follow-up.[25]

However, the DECRA trial has also undergone significant criticism. Results are not widely applicable, with only 155 of 3,500 potentially eligible patients enrolled.[26,27] Among those excluded are patients with mass lesions and patients with PBI, thus limiting the trial's scope and providing results that are not applicable to our cohort. Further criticisms include the validity of the trial's definition of refractory intracranial hypertension because many do not consider intracranial pressure greater than 20 mm Hg for 15 minutes as refractory.[27] Similarly, the study's procedural choice has been questioned because unilateral craniectomy is more common than bifrontal intervention,[26] although patients undergoing a bilateral procedure have been described to achieve good long-term functional outcomes.[28,29] Similarly, many wonder if a 6-month follow-up

TABLE 5. Field GCS and GOS Scores

Field GCS	NNMC Admission GCS Score	Discharge GOS Score	6-mo GOS Score	1-y GOS Score	2-y GOS Score
Overall (n = 114)	8.6 (3.8) n = 114	3.1 (0.8) n = 112	3.6 (1.1)* n = 89	3.9 (1.2)* n = 76	4.0 (1.2)* n = 62
GCS score 3–5 (n = 36)	6.1 (2.9) n = 36	2.4 (0.8) n = 34	2.8 (1.1) n = 29	2.9 (1.3)* n = 23	3.0 (1.5)* n = 20
GCS score 6–8 (n = 25)	7.8 (3.0) n = 25	3.0 (0.5) n = 25	3.6 (0.8)† n = 16	4.1 (0.9)† n = 14	4.2 (0.9)† n = 10
GCS score 9–11 (n = 14)	8.9 (3.3) n = 14	3.1 (0.4) n = 14	4.2 (0.9)† n = 11	4.4 (0.7)† n = 10	4.4 (0.8)† n = 10
GCS score 12–15 (n = 39)	11.2 (3.7) n = 39	3.7 (0.6) n = 39	4.2 (0.7)‡ n = 33	4.5 (0.6)* n = 29	4.6 (0.6)* n = 22

Fisher's exact test.
*$p < 0.0001$.
†$p < 0.01$.
‡$p < 0.05$.

TABLE 6. Field GCS and GOS Scores, Subset Analysis

Field GCS Score	NNMC Admission GCS Score	Discharge GOS Score	6-mo GOS Score	1-y GOS Score	2-y GOS Score
Overall (n = 62)	8.5 (4.0) n = 62	3.1 (0.9) n = 61	3.6 (1.2)* n = 57	3.9 (1.2)† n = 58	4.0 (1.2)† n = 62
GCS score 3–5 (n = 20)	5.9 (2.7) n = 20	2.3 (0.9) n = 19	2.6 (1.2) n = 19	2.8 (1.4)‡ n = 18	3.0 (1.5)* n = 20
GCS score 6–8 (n = 10)	8.9 (3.7) n = 10	3.1 (0.3) n = 10	3.9 (0.6)‡ n = 8	4.1 (0.9)‡ n = 9	4.2 (0.9)* n = 10
GCS score 9–11 (n = 10)	8.1 (3.6) n = 10	3.1 (0.3) n = 10	4.2 (0.9)‡ n = 9	4.4 (0.7)* n = 19	4.4 (0.8)* n = 10
GCS score 12–15 (n = 22)	10.8 (4.1) n = 22	3.9 (0.7) n = 22	4.1 (0.9) n = 21	4.3 (0.7)‡ n = 22	4.4 (0.8)* n = 22

Fisher's exact test.
*$p < 0.01$.
†$p < 0.0001$.
‡$p < 0.05$.

period is long enough, as continuous significant long-term functional improvements are reported after decompressive craniectomy.[30,31] Finally, 18% of the standard-care group underwent compassionate craniectomy for a lifesaving intervention, yet outcomes for these patients are included with the nonsurgical group owing to the intention-to-treat design. Therefore, while the DECRA trial evaluates an important controversial topic in neurotrauma, its limited applicability and significant crossover may not provide a fair comparison to serve as a basis for treatment recommendations.

Other prospective randomized controlled trials have evaluated the impact of decompressive craniectomy with results that contradict those seen by DECRA. Three European trials addressed outcomes after cerebral infarction, each finding benefit in the surgical arm of the study. Results of these trials were pooled to find an absolute risk reduction in mortality of 50% with similar rates of severe disability between the two groups.[32] We continue to await the results of the RescueICP trial, still in accrual phase, which seeks to compare the outcome in trauma patients who have undergone decompressive craniectomy with those treated with continued medical management. In contrast to the DECRA trial, the RescueICP study has broader inclusion criteria, sets a higher intracranial pressure threshold before intervention, evaluates surgical intervention performed at a broader time range after injury, and follows long-term outcomes for 2 years.[33]

A common theme seen in the previously mentioned trials evaluating outcomes after decompressive craniectomy is that none include patients with PBI. Levi et al. (1990)[20] described functional outcomes in their cohort of military patients with PBI that are similar to the results observed in the current study, with two thirds of the population achieving good outcomes (GOS score ≥ 4). This may suggest that patients with PBI represent a unique subpopulation of neurotrauma with a need for separate treatment recommendations. Alternatively, this may suggest that the applicability of current prospective studies are too limited and do not provide optimal generalized treatment recommendations.

In addition to long-term functional outcomes, this current study also evaluated the acute and delayed morbidity in this patient population. Overall, the morbidity rates were similar, but the mortality rate was lower (6.6% vs. 10–15%) compared with other studies after arrival to a military treatment facility.[34,35] Acute morbidities included thromboembolic events (15.3%), which were also similar to previously described ranges (5–63%) within a trauma population, with the previously identified independent risk factors as follows: history of blood transfusion, history of surgery, lower-extremity orthopedic injury, and head/spinal cord injury, often present in our cohort.[36] Rates of systemic infection (28.5%) were within range of those reported for severe head injury, although rates for meningitis (24.8%) were elevated compared with other studies.[37] Elevated rates of meningitis in this current study may be attributed to the high rate of neurosurgical instrumentation in this cohort combined with the high rate of exposure to multiple contaminated extremity wounds. A notable finding in our follow-up interval was the incidence of delayed-onset seizures, occurring in 39.0% of patients who were followed up for 2 years who did not have a seizure during their initial hospital course. The rate of delayed-onset seizures is comparable, however, with the incidence reported in the ongoing follow-up of Vietnam veterans who sustained a traumatic brain injury.[38]

The current study has several limitations. First, it is a retrospective study and therefore does not provide a complete data set for all patients and does not account for follow-up at precise intervals. Furthermore, to reduce interpretation error, the study relied on the availability of documentation of specific descriptor words such as *conscious*, *awake*, *independent in all activities of daily living* as well as the mention of *driving/leisure activity status* for those patients not available for direct interview or examination. If omitted from documentation, the assigned GOS may be underrepresented. Second, while several studies have found no difference in outcomes of PBI according to number of penetrating wounds, caliber or weapon, distance from the weapon, intent of injury, or interval to evaluation, we cannot make a statement concerning these or other population differences between our patients and injured civilians.[39,40] Third, 43% of our cohort had been lost to follow-up since initial assessment. These patients may not have followed the same improvement trajectory as the patients that were included in the study, thereby potentially skewing the results. Finally, our results likely represent some degree of selection bias. The Defense and Veterans Brain Injury Center reports 636 patients sustained penetrating brain injuries during the time frame of our study, whereas only 137 (22%) were treated at our institution.[13]

In conclusion, combat casualties with PBI continued to show significant improvement in functional status up to 2 years from discharge. A large proportion of this group attained functional independence (GOS score ≥ 4) despite initial GCS classification. Therefore, long-term outcomes should be considered when creating triage protocols for severely brain injured patients. In addition, further studies are warranted to determine the etiology of improvement in functional status/independence in these patients and the effects that aggressive neurosurgical monitoring and operative intervention have on outcomes.

AUTHORSHIP

C.R., W.D., M.S., and J.R.D. designed the study. A.B.W., R.B., C.N., and R.A. collected the data. A.B.W., C.R., and J.R.D. analyzed the data and created tables. A.B.W. and J.R.D. prepared the manuscript, which all authors reviewed and critically revised.

DISCLOSURE

The authors declare no conflicts of interest.

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