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14. ABSTRACT
Combat-related moderate-to-severe traumatic brain injury (CRTBI) is a significant cause of wartime morbidity and mortality. As of August 2014, moderate-to-severe traumatic brain injuries sustained by members of the Department of Defense worldwide since 2000 totaled 32,996 cases. Previously published epidemiologic reviews describe CRTBI management at a "strategic" level, but they lack "tactical" patient-specific data required for performance improvement. In addition, scarce data exist regarding prehospital CRTBI care. This is a prospective observational study of consecutive CRTBI casualties presenting to US Role 3 medical facilities. Admission variables including demographics, initial clinical findings, and laboratory results were collected. Head computed tomographic scan findings were noted. Interventions in the first 72 postinjury hours were recorded. Early in-theater mortality was noted, but longer-term outcomes were not. Casualties were predominately injured by explosive blasts (78.6%). Penetrating injuries occurred in 42.9%. On arrival, Glasgow Coma Scale (GCS) score was less than 8 for 47.7%. Hypothermia (temperature < 95.0°F) was present in 4.5%, and hypotension (systolic blood pressure < 90 mm Hg) in 21.1%. Hypoxia (O2 saturation < 90%) was observed in 52.5%. Both hypercarbia ($PaCO_2$ > 45 mm Hg, 50%) and hypocarbia ($PaCO_2$ < 36 mm Hg, 20.3%) were common on presentation. Head computed tomographic scan most commonly found skull fracture (68.9%), subdural hematoma (54.1%), and cerebral contusion (51.4%). Hypertonic saline was administered to 69.7% and factor VIIa to 11.1%. Early in-theater mortality at Role 3 was 19.4%. Avoidance of secondary brain injury by optimizing oxygenation, ventilation, and cerebral perfusion is the primary goal in the contemporary care of moderate-to-severe CRTBI. Ideally, this crucial care must begin as early as possible after injury. Given the frequency of hypotension, hypoxia, and both hypercarbia and hypocarbia upon Role 3 arrival, increased emphasis on prehospital management is indicated.

15. SUBJECT TERMS
Traumatic brain injury; prehospital emergency care; secondary injury; ventilation; military medicine

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Early in-theater management of combat-related traumatic brain injury: A prospective, observational study to identify opportunities for performance improvement

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BACKGROUND: Combat-related moderate-to-severe traumatic brain injury (CRTBI) is a significant cause of wartime morbidity and mortality. As of August 2014, moderate-to-severe traumatic brain injuries sustained by members of the Department of Defense worldwide since 2000 totaled 32,996 cases. Previously published epidemiologic reviews describe CRTBI management at a "strategic" level, but they lack "tactical" patient-specific data required for performance improvement. In addition, scarce data exist regarding prehospital CRTBI care.

METHODS: This is a prospective observational study of consecutive CRTBI casualties presenting to US Role 3 medical facilities. Admission variables including demographics, initial clinical findings, and laboratory results were collected. Head computed tomographic scan findings were noted. Interventions in the first 72 postinjury hours were recorded. Early in-theater mortality was noted, but longer-term outcomes were not.

RESULTS: Casualties were predominately injured by explosive blasts (78.6%). Penetrating injuries occurred in 42.9%. On arrival, Glasgow Coma Scale (GCS) score was less than 8 for 47.7%. Hypothermia (temperature < 95.0°F) was present in 4.5%, and hypotension (systolic blood pressure < 90 mm Hg) in 21.1%. Hypoxia (O2 saturation < 90%) was observed in 52.5%. Both hypercarbia ($Paco_2$ > 45 mm Hg, 50%) and hypocarbia ($Paco_2$ < 36 mm Hg, 20.3%) were common on presentation. Head computed tomographic scan most commonly found skull fracture (68.9%), subdural hematoma (54.1%), and cerebral contusion (51.4%). Hypertonic saline was administered to 69.7% and factor VIIa to 11.1%. Early in-theater mortality at Role 3 was 19.4%.

CONCLUSION: Avoidance of secondary brain injury by optimizing oxygenation, ventilation, and cerebral perfusion is the primary goal in the contemporary care of moderate-to-severe CRTBI. Ideally, this crucial care must begin as early as possible after injury. Given the frequency of hypotension, hypoxia, and both hypercarbia and hypocarbia upon Role 3 arrival, increased emphasis on prehospital management is indicated. (*J Trauma Acute Care Surg*. 2015;79: S181–S187.

LEVEL OF EVIDENCE: Therapeutic study, level IV; epidemiologic study, level III.

KEY WORDS: Traumatic brain injury; prehospital emergency care; secondary injury; ventilation; military medicine.

Combat-related moderate-to-severe traumatic brain injury (CRTBI) causes significant wartime morbidity and mortality. As of August 2014, moderate-to-severe traumatic brain injuries sustained by members of the Department of Defense (DoD) worldwide since 2000 totaled 32,996 cases.[1] Analysis of US military "died of wounds" combat deaths occurring after surgical facility arrival (Role 2) attributed 83% of nonsurvivable and 9% of potentially survivable deaths to CRTBI.[2] A published query of the DoD Joint Theater Trauma Registry identified 1,255 moderate-to-severe CRTBI casualties from 2003 to 2010 with 774 penetrating and 481 closed head injuries.[3] Compared with civilian trauma, penetrating TBI occurs much more frequently in the combat environment.

Contemporary TBI care focuses on prevention of secondary brain injury.[4,5] For optimal effect, this care must begin immediately after the primary injury has occurred. CRTBI outcomes reflect cumulative care delivered throughout the casualty care continuum including (1) battlefield first-responder care, (2) tactical field and tactical evacuation care, and (3) subsequent care across the global military care system (Fig. 1). Released in 2005, an evidence-based DoD Joint Trauma System Clinical Practice Guideline advises on the management of severe head trauma at Role 2 and higher.[6] Tactical Combat Casualty Care (TCCC) guidelines incorporated recommendations for prehospital CRTBI management in September 2012 (Fig. 2).[7]

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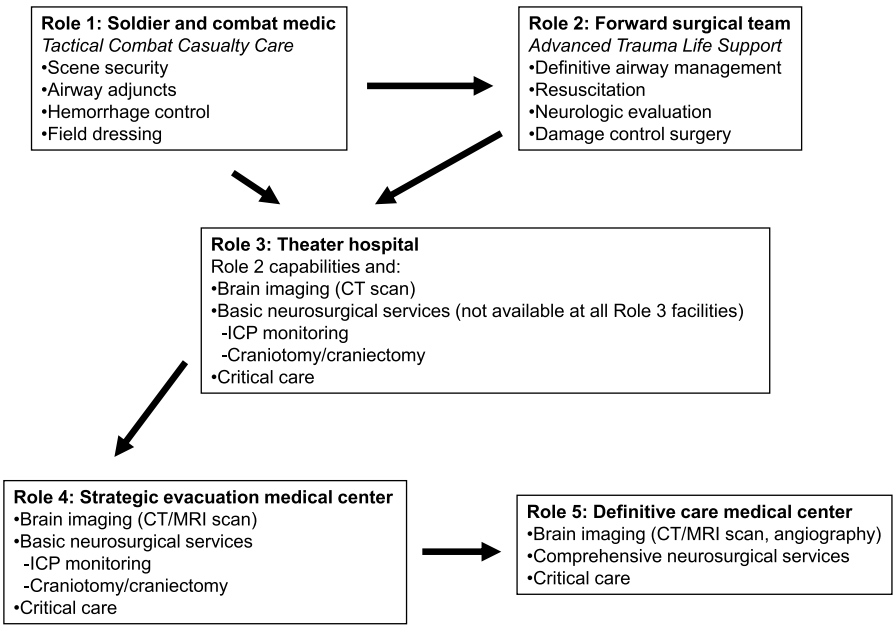

Figure 1. Military roles of care.

Despite inherent challenges to care in a wartime environment, a comparison of 604 casualties with severe isolated CRTBI between 2003 and 2007 abstracted from the Joint Theater Trauma Registry against similar propensity score–matched civilian TBI patients from the American College of Surgeons' National Trauma Data Bank demonstrated favorable outcomes in the CRTBI group.[8] Mortality was significantly better among military casualties overall (7.7% vs. 21.0%, $p < 0.001$) and particularly after penetrating injury (5.6% vs. 47.9%, $p < 0.001$). Previously published epidemiologic reviews describe CRTBI management at a "strategic," health care policy level but lack the "tactical" patient-specific data required to direct performance improvement efforts to achieve the overall goal of improved CRTBI care. Scarce data exist regarding prehospital CRTBI care. The purpose of this study was to prospectively capture CRTBI demographics and early management so that modifiable factors associated with in-theater mortality could be identified and targeted to further improve care.

PATIENTS AND METHODS

After institutional review board approval, a prospective cohort of 99 consecutive CRTBI patients (identified by admission Glasgow Coma Scale [GCS] score ≤ 13 and/or penetrating TBI) was collected from March 2009 to June 2010. The study group included coalition and host nation casualties presenting to US military Role 3 (comprehensive deployed hospitals) facilities in Iraq and Afghanistan. Admission variables including

Phase of Care	Care under fire	Tactical field care	Tactical evacuation care
Tactical Situation	Care at point of injury while medic and casualty are under effective hostile fire	Care rendered once no longer under effective hostile fire or injured without hostile contact	Care rendered once casualty picked up for transport
CRTBI Related Care Guidelines	• Return fire and take cover • Defer airway management • Stop life-threatening hemorrhage if tactically feasible	• Disarm casualty • Basic airway maneuvers • If available, pulse oximetry and supplemental oxygen for O_2 saturation > 90% • Hemorrhage control • Resuscitate to palpable radial pulse	•Monitor for: *-Level of consciousness* *-Pupillary dilation* *-SBP > 90 mm Hg* *-O_2 sat > 90%* *-Hypothermia* *-PCO_2 35-40 mm Hg if capnography available* *-Administer antibiotics for penetrating head trauma* *-Immobilize neck and assume spinal cord injury* •Temporizing measures for signs of cerebral herniation

Figure 2. TCCC guidelines.

casualty demographics, initial clinical examination findings, and laboratory results were collected. Head computed tomographic (CT) scan findings were noted. Therapeutic interventions within 72 hours after presentation to the first medical facility were recorded.

Univariate analysis was performed using Student's *t* test for analysis of variance for continuous variables and χ^2 tests for categorical variables to determine associations with mortality. Variables with a $p < 0.2$ on univariate analysis were subsequently entered into multivariate logistic regression analysis to identify independent predictors of mortality. Data were analyzed using the statistical package SPSS for Windows, version 12.0 (SPSS Inc., Chicago, IL).

RESULTS

Forty-three coalition and 56 host nation patients constituted the study cohort (Table 1). Patients were predominantly male (96.0%) and injured by explosive mechanisms (78.6%). Casualties most frequently presented to a Role 2 forward surgical unit (70.7%) capable of damage-control surgical interventions and critical care but without CT imaging or neurosurgical expertise. Associated spinal cord injuries occurred in 2.1% and penetrating brain injuries occurred in 42.9% of CRTBI patients. Early in-theater mortality was 19.4%.

At presentation, 47.7% of the patients had a GCS score of 8 or lower (Table 2). Hypothermia (temperature < 95.0°F) was present in 4.5%, and 21.1% were hypotensive (systolic blood pressure < 90 mm Hg). Hypoxia (oxygen saturation < 90%) was observed in 52.5%. The majority of patients had abnormal $Paco_2$ measurements; 50.0% presented with hypercarbia ($Paco_2$ > 45 mm Hg) and 20.3% with hypocarbia ($Paco_2$ < 36 mm Hg). A significant portion of patients were coagulopathic as defined by an international normalized ratio (INR) greater 1.2 at admission (41.7%), with more than 58% developing coagulopathy in the first 24 hours after admission. Most patients had normal serum sodium values and were not hypoglycemic.

CT scanning of the head identified a variety of traumatic pathologies. The most common finding reported was skull fracture, occurring in 68.9% of patients. The most common type of intracranial hemorrhage was subdural hematoma (54.1%).

Multiple therapeutic interventions occurred during prehospital and en route care as well as immediately after medical facility arrival (Table 3). Prehospital endotracheal intubation was accomplished in 21.3% of patients. Overall, 80.2% of casualties were intubated within 72 hours of admission. Seventy percent of casualties received hypertonic saline, and 11.1% received recombinant factor VIIa. Massive transfusion (≥10 U of packed red blood cells administered within 24 hours) was required in 7.1%. Neurosurgical procedures performed included intracranial pressure monitor placement (35.4%) and craniotomy/craniectomy (31.3%).

On univariate analysis, risk factors associated with in-theater mortality (Table 4) included admission hypotension, penetrating brain injury, GCS score of 8 or less on admission, any hypoxia within 72 hours of admission, evidence of cerebral herniation on head CT, massive transfusion, abnormal pupillary examination result on arrival, and abnormal motor examination on arrival. When the statistically significant predictors on univariate analysis were included in a logistic regression model, no independent predictors of mortality resulted.

DISCUSSION

This study sought to identify modifiable predictors of mortality using prospectively collected data to improve care. While we did not identify statistically independent predictors, we found that known contributors to secondary brain injury commonly existed during early care in the military setting. Hypoxia, both hypercarbia and hypocarbia, and hypotension were common upon casualty arrival to deployed medical facilities.

With short transport times to urban trauma centers, US civilian prehospital practice emphasizes rapid transfer to definitive care. Such rapid evacuation may not be feasible in the military setting for reasons to include long transport distances, ongoing combat actions, nonavailability of evacuation assets, or mission goals superseding casualty movement. In these situations, prolonged field care may be required. The combat medic attending to the battlefield injured may be isolated in an austere and dangerous environment with only his training, experience, and limited medical supplies to render care. The

TABLE 1. Patient Demographics

		Total (n = 99)	Coalition (n = 43)	Host National (n = 56)	*p*
Male, % (n)		96 (96/99)	97.6 (41/42)	98.2 (55/56)	*1.000*
Mechanism, % (n)	Explosive	78.6 (77/98)	76.2 (32/42)	80.4 (45/56)	*0.543*
	GSW	20.4 (20/98)	23.8 (10/42)	17.9 (10/56)	
	Blunt	1.0 (1/98)	0 (0/42)	1.8 (1/56)	
TBI type, % (n)	Penetrating	42.9 (42/98)	52.4 (22/42)	35.7 (20/56)	*0.099*
	Blunt	57.1 (56/98)	47.6 (20/42)	64.3 (36/56)	
Initial facility level treated, % (n)	Role II	70.7 (70/99)	67.4 (29/43)	73.2 (41/56)	*0.532*
	Role III	29.3 (29/99)	26.8 (15/56)	32.6 (14/43)	
Associated injuries, % (n)	Spinal cord injury	2.1 (2/97)	0 (0/42)	3.6 (2/55)	*0.504*
Mortality, % (n)		19.4 (19/98)	23.3 (10/43)	16.4 (9/55)	*0.392*

GSW, gunshot wound.

TABLE 2. Admission and Subsequent 24-Hour (Exclusive of Admission) Clinical Findings and Laboratory Values

		Total	Coalition	Host National	*p*
GCS ≤ 8, % (n)		47.7 (42/88)	50.0 (18/36)	46.2 (24/52)	*0.722*
Pupillary examination, % (n)	Normal, symmetric reactivity	68.4 (54/79)	72.7 (24/33)	65.2 (30/46)	*0.688*
	Unilateral abnormal findings	12.7 (10/79)	9.1 (3/33)	1.2 (7/46)	
	Bilateral abnormal findings	19.0 (15/79)	18.2 (6/33)	19.6 (9/46)	
Motor GCS examination, % (n)	Normal, symmetric reactivity	57.7 (45/78)	59.4 (19/32)	56.5 (26/46)	*0.969*
	Unilateral abnormal findings	6.4 (5/78)	6.3 (2/32)	6.5 (3/46)	
	Bilateral abnormal findings	35.9 (28/78)	34.4 (11/32)	37.0 (17/46)	
Admission hypothermia (temperature < 95.0 F), % (n)		4.5 (3/66)	0 (0/23)	7.0 (3/43)	*0.546*
	Any hypothermia (temperature < 95.0 F), % (n)	6.2 (4/65)	0 (0/24)	9.8 (4/41)	*0.288*
Admission hyperthermia (temperature > 101.5 F), % (n)		4.5 (3/66)	0 (0/22)	6.8 (3/44)	*0.545*
	Any hyperthermia (temperature > 101.5 F), % (n)	10.8 (7/65)	16.7 (4/24)	7.3 (3/41)	*0.408*
Hypotension on arrival to hospital, % (n)		21.1 (4/19)	40.0 (2/5)	14.3 (2/14)	*0.272*
	Hypotension, first 24 h, % (n)	42.0 (21/50)	41.2 (7/17)	42.4 (14/33)	*0.933*
Hypoxia (O_2 saturation < 90%) on admission, % (n)		52.5 (42/80)	61.3 (19/31)	46.9 (23/49)	*0.210*
	Any hypoxia (O_2 saturation < 90%), first 24 h, % (n)	17.1 (13/76)	25.8 (8/31)	11.1 (5/45)	*0.095*
Hypercarbia ($Paco_2$ > 45) on admission, % (n)		50.0 (32/64)	36.0 (9/25)	59.0 (23/39)	*0.073*
	First 24 h, any hypercarbia ($Paco_2$ > 45), % (n)	55.7 (34/61)	40.0 (10/25)	66.7 (24/36)	*0.039*
Hypocarbia ($Paco_2$ < 36) on admission, % (n)		20.3 (13/64)	16.0 (4/25)	23.1 (9/39)	*0.492*
	First 24 h, any hypocarbia ($Paco_2$ < 36), % (n)	41.0 (25/61)	36.0 (9/25)	44.4 (16/36)	*0.510*
Anemia (Hgb < 10 mg/dL) admission, % (n)		9.6 (7/73)	9.7 (3/31)	9.5 (4/42)	*1.000*
	Anemia anytime first 24 h, % (n)	28.2 (20/71)	28.1 (9/32)	28.2 (11/39)	*0.994*
Admission sodium < 136		6.9 (5/72)	13.3 (4/30)	2.4 (1/42)	*0.153*
	Any sodium < 136, first 24 h, % (n)	11.8 (8/68)	20.0 (6/30)	5.3 (2/38)	*0.126*
Admission sodium > 160		1.4 (1/72)	0 (0/30)	2.4 (1/42)	*1.000*
	Any sodium < 160, first 24 h, % (n)	2.9 (2/68)	0 (0/30)	5.3 (2/38)	*0.500*
Admission INR > 1.2, % (n)		41.7 (5/12)	33.3 (1/3)	44.4 (4/9)	*1.000*
	Any INR > 1.2, first 24 h, % (n)	58.3 (7/12)	66.7 (2/3)	55.6 (5/9)	*1.000*
Admission base deficit < −5, % (n)		35.3 (6/17)	25.0 (1/4)	38.5 (5/13)	*1.000*
	Any base deficit < −5 first 24 h, % (n)	47.1 (8/17)	50.0 (2/4)	46.2 (6/13)	*1.000*
Admission pH < 7.36, % (n)		94.4 (17/18)	80.0 (4/5)	100 (13/13)	*0.278*
	Any pH < 7.36 first 24 h, % (n)	94.4 (17/18)	80.0 (4/5)	100 (13/13)	*0.278*
Admission hypoglycemia (BG < 60), % (n)		0 (0/64)	0 (0/26)	0 (0/38)	*N/A*
	Any hypoglycemia (BG < 60) first 24 h, % (n)	1.6 (1/64)	0 (0/26)	2.6 (1/38)	*1.000*

BG, blood glucose; Hgb, hemoglobin; $Paco_2$, partial pressure of carbon dioxide in arterial blood.

combat medic must recognize potential CRTBI in a casualty with multiple injuries and then resuscitate and support the patient to minimize secondary brain injury.

Airway and breathing management are critical to mitigate secondary brain injury. Both hypoxia and abnormalities in carbon dioxide levels are detrimental, yet all commonly occurred. TCCC guidelines do not recommend performing airway management during "care under fire" as efforts to manage an impaired airway or provide respiratory support during this phase of care expose both the casualty and rescuer to unacceptable risk. After scene risk is reduced, TCCC guidelines for airway management remain limited to chin-lift/jaw-thrust maneuvers, placement of a nasopharyngeal airway, and surgical cricothyroidotomy. If available, TCCC recommends

TABLE 3. Early Therapeutic Interventions (First 72 Hours)

		Total	Coalition	Host National	*p*
Prehospital endotracheal intubation, % (n)		21.3 (17/80)	22.2 (8/36)	20.5 (9/44)	*0.848*
Prehospital + early hospital endotracheal intubation, % (n)		80.2 (77/96)	70.7 (29/41)	87.3 (48/55)	*0.044*
Hyperventilation, % (n)		14.1 (14/99)	7.0 (3/43)	19.6 (11/56)	*0.073*
Therapeutic hypothermia, % (n)		4.0 (4/99)	4.7 (2/43)	3.6 (2/56)	*1.000*
Hypertonic saline, % (n)		69.7 (69/99)	58.1 (25/43)	78.6 (44/56)	*0.028*
Factor VII, % (n)		11.1 (11/99)	16.3 (7/43)	7.1 (4/56)	*0.201*
Mannitol, % (n)		22.2 (22/99)	27.9 (12/43)	17.9 (10/56)	*0.233*
Blood product administration, % (n)		58.6 (58/99)	46.5 (20/43)	67.9 (38/56)	*0.033*
Massive transfusion, % (n)		7.1 (7/99)	11.6 (5/43)	3.6 (2/56)	*0.234*
ICP monitoring, % (n)		35.4 (34/96)	30.0 (12/40)	39.3 (22/56)	*0.348*
	Ventriculostomy, % (n)	26.0 (25/96)	17.5 (7/40)	32.1 (18/56)	*0.107*
	Subdural bolt, % (n)	9.4 (9/96)	12.5 (5/40)	7.1 (4/56)	*0.483*
Craniotomy/craniectomy, % (n)		31.3 (30/96)	27.5 (11/40)	33.9 (19/56)	*0.503*

ICP, intracranial pressure.

supplemental oxygen and pulse oximetry to maintain an oxygen saturation of greater than 90% but provides no guidance for ventilation during tactical field care.

Training advanced medics to perform rapid sequence intubation and emphasizing to all combat medics the importance of effective bag-valve-mask support might improve management during tactical field care. In this study, 21.3% of patients underwent prehospital intubation, and 80.2% eventually were intubated within 72 hours of admission. A review of 1,003 combat casualties in Afghanistan between 2009 and 2011 identified 60 patients who would have likely benefited from prehospital intubation, but only 28 arrived successfully intubated.[9] Prehospital rapid sequence intubation has shown improved 6-month neurologic outcomes for a civilian severe TBI population.[10] However, other studies associated paramedic intubation of TBI patients with increased mortality and morbidity.[11–14] These worsened outcomes were attributed to hypocarbia from hyperventilation following intubation as well as hypoxia during intubation. During tactical evacuation care, TCCC recommends eucapnia reflected by end-tidal CO_2 levels of 35 mm Hg to 40 mm Hg unless the patient shows evidence of cerebral herniation when hyperventilation to end-tidal CO_2 levels less than 35 mm Hg may be a temporizing measure. For CRTBI casualties with extended prehospital times, improved awareness of secondary brain injury, specific bag-valve-mask ventilation training, and end-tidal CO_2 monitoring may decrease the incidence of hyperventilation and hypoventilation.[15]

Maintaining cerebral perfusion after brain injury is paramount to successful CRTBI management. "Hypotensive resuscitation" is advocated for potentially bleeding patients until definitive hemorrhage control is achieved, but hypotension after TBI worsens outcomes. TCCC recommends maintaining systolic blood pressure of greater than 90 mm Hg during tactical evacuation care. Regular blood pressure measurements may not be feasible during tactical field care, or the resources may not be available to sustain a target blood pressure. Eastridge et al.[16] suggested that battlefield "permissive hypotension" should target 100 mm Hg as a more clinically relevant threshold for tissue hypoperfusion as opposed to the traditional threshold of 90 mm Hg. In the nonbleeding CRTBI casualty, systolic blood pressure targets closer to 120 mm Hg may be more effective in minimizing secondary injury particularly in settings without intracranial pressure monitoring capabilities.[17]

This study has limitations. The cohort size of 99 patients may be too small to determine true mortality associations, and deaths in the cohort following departure from Role 3 were not captured. The cohort was a heterogeneous mix of coalition and host nation patients with differences in baseline characteristics such as underlying physiologic condition, individual body armor protection, and immediate battlefield care, which may confound the mortality results. However, these limitations are irrelevant to the observations of abnormal $Paco_2$ levels, hypoxia, and hypotension on casualty presentation.

The DoD Joint Trauma System's mission is to optimize care of the combat-injured casualty from the point of wounding and across the subsequent global continuum of care. A seminal analysis of US military combat deaths reported that 25% of deaths were "potentially survivable" under idealized conditions and that 90% of these deaths occurred in the prehospital setting leading to an increased focus on improving Role 1 care.[18] US Army Combat Flight Medics are currently elevating their occupational standards to require civilian flight paramedic certification servicewide. This increase in skill level will enhance their capabilities to perform airway assessments, airway adjuncts, and assisted respirations and, from retrospective experience, is anticipated to improve casualty care outcomes.[19]

Avoidance of secondary brain injury by optimizing oxygenation, ventilation, and cerebral perfusion is the primary goal in the care of moderate-to-severe CRTBI. Ideally, this care must begin as early as possible after injury. Given the frequency of hypotension, hypoxia, and both hypercarbia and hypocarbia upon Role II/III arrival, increased emphasis on prehospital management is indicated. Observational studies such as this one can identify areas for additional improvements in manpower, training, equipment, and clinical practice guideline development.

TABLE 4. Univariate Predictors of Early Mortality in Combat-Related Traumatic Brain Injury

		Mortality	*p*	Odds Ratio (95% CI)
Admission hypotension (SBP <90 mm Hg)	Yes	50% (2/4)	*0.035*	2.00 (0.751–5.33)
	No	0% (0/15)		
Any hypotension (SBP < 90 mmHg) first 24 h	Yes	23.8% (5/21)	*0.726*	1.44 (0.36–5.80)
	No	17.9% (5/28)		
Type of brain injury	Penetrating	33.3% (14/42)	*0.003*	0.20 (0.07–0.61)
	Blunt	9.1% (5/55)		
Required prehospital intubation	Yes	35.3% (6/17)	*0.066*	*3.68 (1.06 – 12.74)*
	No	12.9% (8/62)		
GCS score ≤ 8 on admission	Yes	38.1% (16/42)	*<0.001*	27.08 (3.39–216.23)
	No	2.2% (1/45)		
Hypoxia (O_2 saturation < 90%) on admission	Yes	22.0% (9/41)	*0.082*	3.28 (0.82–13.20)
	No	7.9% (3/38)		
Any hypoxia (O_2 Saturation < 90%) first 24 h	Yes	46.2% (6/13)	*0.002*	9.77 (2.36–40.54)
	No	8.1% (5/62)		
Hypothermia (temperature < 95.0 F) on admission	Yes	33.3% (1/3)	*0.399*	2.94 (0.24–35.95)
	No	14.5% (9/62		
Hyperthermia (temperature > 101.5%) on admission	Yes	33.3% (1/3)	*0.399*	2.94 (0.24–25.95)
	No	14.5% (9/62)		
Admission hypercarbia ($Paco_2$ > 45)	Yes	21.9% (7.32)	*0.805*	1.17 (0.34–3.97)
	No	19.4% (6/31)		
Admission hypocarbia ($Paco_2$ < 36)	Yes	16.7% (2/12)	*1.000*	0.73 (0.14–3.82)
	No	21.6% (11/51)		
Anemia (Hgb <10 mg/dL) on admission	Yes	42.9% (3/7)	*0.106*	4.13 (0.80–21.30)
	No	15.4% (10/65)		
Hyponatremia (Na < 136) on admission	Yes	40.0% (2/5)	*0.224*	3.33 (0.50–22.35)
	No	16.7% (11/66)		
INR (>1.2) on admission	Yes	20.0% (1/5)	*0.417*	1.25 (0.81–1.94)
	No	0% (0/7)		
Elevated INR (>1.2) anytime first 24 h	Yes	14.3% (1/7)	*1.000*	1.17 (0.86–1.58)
	No	0% (0/5)		
Base deficit < 5 admission	Yes	33.3% (2/6)	*0.110*	1.50 (0.85–2.64)
	No	0% (0/11)		
Base deficit < 5 anytime first 24 h	Yes	25.0% (2/8)	*0.206*	1.33 (0.89–1.99)
	No	0% (0/9)		
pH < 7.36 on admission	Yes	11.8% (2/17)	*1.000*	1.13 (0.95–1.35)
	No	0% (0/1)		
Herniation on initial CT	Yes	37.5% (6/16)	*0.011*	6.24 (1.59–24.46)
	No	8.8% (5/57)		
Required massive transfusion	Yes	57.1% (4/7)	*0.025*	6.76 (1.37–33.33)
	No	16.5% (15/91)		
GCS score ≤ 8 and abnormal head CT finding	Yes	27.5% (11/40	*0.018*	3.79 (1.20–12.00)
	No	9.1% (5/55)		
GCS score ≤ 8 and any hypotension within first 72 h	Yes	38.1% (8/21)	*0.007*	5.08 (1.61–15.98)
	No	10.8% (8/74)		
Abnormal pupillary examination finding on arrival	Yes	48.0% (12/25)	*<0.001*	0.42 (0.01–0.21)
	No	3.8% (2/53)		
Abnormal motor examination finding on arrival	Yes	33.3% (11/33)	*0.001*	0.10 (0.02–0.47)
	No	4.5% (2/44)		

Hgb, hemoglobin; $Paco_2$, partial pressure of carbon dioxide in arterial blood; SBP, systolic blood pressure.
Boldface indicates clinically significant predictors on univariate analysis.

AUTHORSHIP

R.F. contributed to the literature search, data interpretation, writing, and critical revision. M.M. contributed to the literature search, data analysis, data interpretation, and writing. J.J.D. contributed to the literature search, data analysis, data interpretation, writing, and critical revision. L.C.C. contributed to the data collection, data interpretation, and critical revision. S.S. contributed to the data interpretation and critical revision. L.H.B. contributed to the study design, data collection, and critical revision.

DISCLOSURE

The authors declare no conflicts of interest.

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