

Evaluating the Joint Theater Trauma Registry as a Data Source to Benchmark Casualty Care

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ABSTRACT Just as data from civilian trauma registries have been used to benchmark and evaluate civilian trauma care, data contained within the Joint Theater Trauma Registry (JTTR) present a unique opportunity to benchmark combat care. Using the iterative steps of the benchmarking process, we evaluated data in the JTTR for suitability and established benchmarks for 24-hour mortality in casualties with polytrauma and a moderate or severe blunt traumatic brain injury (TBI). Mortality at 24 hours was greatest in those with polytrauma and a severe blunt TBI. No mortality was seen in casualties with polytrauma and a moderate blunt TBI. Secondary insults after TBI, especially hypothermia and hypoxemia, increased the odds of 24-hour mortality. Data contained in the JTTR were found to be suitable for establishing benchmarks. JTTR data may be useful in establishing benchmarks for other outcomes and types of combat injuries.

INTRODUCTION

Benchmarking has been used by the American College of Surgeons Committee on Trauma to evaluate civilian trauma care documented in the National Trauma Data Bank (NTDB). Benchmarking is a method for comparing an organization and processes against identified best practices in the field.¹ Businesses, including health care, use benchmarking to document effectiveness, improve performance, set goals, and determine best practices. Four iterative steps are generally described in the process: (1) determining specific goals, (2) selecting outcome measures for the goal, (3) gathering data, and (4) comparing data analysis results with existing benchmarks to identify gaps.² Just as data in the NTDB have been used to benchmark civilian trauma care, data in the Joint Theater Trauma Registry (JTTR) present a unique opportunity to benchmark combat casualty care.³ Benchmark analyses can be used to document the effectiveness of the combat care provided but may also reveal gaps in care needing improvement.

The Joint Theater Trauma System (JTTS), modeled on the civilian trauma systems, was created by the Department of Defense to improve battlefield care. The JTTR, a component of the JTTS, is based on the NTDB and contains medical information on all casualties treated in Iraq and Afghanistan. Data from the JTTR have been used to develop benchmark metrics assessing the quality of care related to mortality following blood transfusion in all casualties.³ However, there are currently no published benchmarks for 24-hour mortality in casualties with polytrauma and moder-

ate or severe blunt traumatic brain injury (TBI). Therefore, the purpose of this article is to report an evaluation of the suitability of the data in the JTTR and the development of benchmark metrics for 24-hour mortality in casualties with polytrauma and a blunt TBI.

BACKGROUND AND SIGNIFICANCE

Overall mortality following isolated TBI in combat casualties in the current conflicts was reported to be 8.4%.⁴ In the current theater of operations, most combat injuries result from blast trauma, which may cause substantial tissue destruction⁵ in the brain as well as other traumatic wounds. Hemorrhage was the main cause of death in 85% of combat casualties with potentially survivable injuries.⁶ In civilian patients with polytrauma, mortality increases when a TBI is present.^{7,8} However, mortality associated with polytrauma and a TBI has not been well documented in combat casualties. In addition, the care of combat casualties with polytrauma and blunt TBI has been understudied.

Benchmarks are essential to determine the quality of care delivered. The iterative steps of the benchmarking process and the existing JTTR data provide an opportunity to examine the care provided to casualties with polytrauma and TBI while establishing benchmarks for 24-hour mortality. We applied the four steps of the benchmarking process to evaluate the suitability of the JTTR data and developed benchmark metrics for 24-hour mortality in casualties with polytrauma and a blunt TBI. The next section presents literature specific to our application of the benchmarking process steps of determining the specific goal, selecting the outcome measures, and gathering data.

Determining the Specific Goal

Brain injury following a TBI results from a primary and secondary injury phase. An impact to the head damages the brain parenchyma, which initiates multiple biochemical

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cascades that alter the cerebral environment. Secondary insults, such as hypotension, hypoxemia, hypothermia, or hyperthermia, can expand the injury and worsen the outcome.^{9,10} Hypotension is considered the most critical secondary insult as its presence alone can increase mortality by as much as 150%.¹¹ Hemorrhage from polytraumatic injuries is often accompanied by hypotension, hypoxemia, and/or hypothermia. Each of these secondary insults can impact peripheral and cerebral tissue blood supply or demand and affect mortality. Combat medical providers rely on easily obtainable vital signs such as the systolic blood pressure (SBP), heart rate, oxygen saturation, and temperature to rapidly assess for the presence of these secondary insults. Therefore, the overall goal of the present study was to develop benchmark metrics in order to demonstrate the effectiveness of the implementation of the JTTS in caring for casualties with polytrauma and a moderate or severe blunt TBI. The aims of the study were to set clinical benchmarks for 24-hour mortality in this population, and to determine the association between admission vital signs and 24-hour mortality. Before benchmark metrics can be established, the JTTR must be evaluated as a secondary data source using established criteria.

Selecting Outcome Measures

Data from a large civilian trauma registry¹² indicates that the death rate associated with severe head trauma peaks between 6 and 24 hours postinjury. Based on this statistic derived from an initial benchmarking study for casualties with polytrauma and concomitant moderate or severe TBI, we selected mortality within 24 hours of injury as a primary outcome measure.

Gathering Data

A checklist, based on literature describing evaluation of secondary data sources,^{13,14} was developed to evaluate the appropriateness of the JTTR data in addressing the outcome measure. Published reports using information in the JTTR were used to examine the following components: general information, original sampling plan, original data collection procedures, variables included, and original instruments used (Table I).

General Information

The JTTR, a component of the JTTS, was chosen as the primary data source for this study. The JTTS was created to improve trauma care across the levels of combat care.¹⁵ In contrast to civilian trauma center levels, capabilities available at the combat facilities increase as the level designation numbers increase. Level III facilities provide the highest level of care available in the combat zone, Level IV facilities offer definitive care outside the combat theater, and Level V facilities are medical centers within the United States.¹⁶

Data input into the JTTR began in 2004 with the goal of capturing care and outcome data of all traumatically injured

TABLE I. Secondary Data Source Reliability Checklist

General Information
When was the primary data set created?
Who created the primary data set?
Why was the primary data set created?
Who owns the primary data set?
Who can access the primary data set?
How can the primary data set be accessed?
Sampling and Data Collection
What was the sampling plan for the primary data set?
What variables are included in the primary data set?
Who collected the data in the primary data set?
How were the data in the primary data set collected?
Advantages of the Primary Data Set
Limitations of the Primary Data Set

patients in southwest Asia from the point of injury to disposition from the U.S. military medical facility.^{17,18} The information in the JTTR is controlled by the U.S. Army Institute for Surgical Research (USAISR) and released after submission of an Institutional Review Board- and USAISR-approved protocol, and a signed data use agreement.¹⁹ A data dictionary is available from the USAISR upon request that contains operational definitions for each variable for which data are entered. Electronic or telephonic assistance is available from the USAISR to answer questions about various aspects of the data set.¹⁹

Sample and Data Collection

Modeled after the civilian trauma registries with added unique combat trauma data points, the intended uses of information in the JTTR are assessment of resource utilization, benchmarking, outcomes research, and quality improvement activities.^{20,21} Demographic, mechanistic, physiologic, diagnostic, therapeutic, and outcome data are extracted directly from the patient's medical records and entered into the JTTR¹⁷ by trained personnel within the combat zone at Level III facilities and in the Level IV and Level V facilities outside the combat zone.^{18,22}

The JTTR database entry fields consist of drop-down menus or free-text fields that are utilized to collect data for process improvement projects. There are no subjective clinical data such as provider's notes included in the JTTR. Original data collection is completed by multiple health care providers while treating the patients, sometimes in difficult circumstances, which can result in inconsistent documentation. Additionally, only predetermined variables, for which data are generated at specific time points in the care of the patient, are included. Documentation outside of the prescribed variables is not recorded.¹⁹ Data collection tools are not utilized as data are extracted directly from the patient's medical records.

Advantages and Limitations

Advantages of the JTTR are the large number of cases included—33,931 cases as of April 2009²³—and objective data recorded by trained personnel along the continuum of

care.¹⁸ By using the JTTR, investigators have access to thousands of cases representing the combat casualties who arrived at the Level III combat medical facilities alive. In addition, utilizing the existing data in the JTTR is a more time-efficient approach to analyzing combat casualty data, when compared to prospective primary data collection.

Limitations associated with the use of JTTR data are largely attributable to variations in individual provider's documentation habits and the conditions under which data are entered. For example, providers may delay documenting findings as a result of habit or the presence of continuing hostilities or do not document a normal finding. These variations can affect consistency, accuracy, and reliability of the data. The lack of strong data collection rigor usually applied by trained researchers not involved in the delivery of care and missing data are also issues encountered with the JTTR as other researchers have found that 12% of the cases in the JTTR had missing or incomplete data.¹⁷ The consistency of data input has increased over the life of the JTTR with the most complete data found since 2008. Data reflecting the initial care in the field or at a Level II facility are not consistently entered with at least 50% of vital signs data missing before arrival at the level III combat medical facility. Two potential threats to validity were recognized: any changes in patient treatment guidelines and the frequent turnover of health care personnel in the combat zone. Over the 7 years evaluated, practice guidelines were updated; however, no significant changes in practice related to the admission vital sign variables studied in this sample occurred. No obvious trends in missing data were discovered related to these practice or personnel changes. Data set consistency could be threatened by changes in the coding process for injuries. Although there were revisions to both the International Classification of Diagnosis—Ninth Revision and Abbreviated Injury Scale coding schemes over the study period, both values were included in the data set as separate variables.

Evaluation of the JTTR

Despite the limitations identified above, the JTTR was the most appropriate source of data for use in addressing the aims of this study. Access to the JTTR was straightforward once the appropriate approvals and agreements were in place. The primary purpose, original sample, and data collection plans for the JTTR were congruent with the goal, aims, and data analysis approach for this secondary data analysis study.

METHODS

This section describes the methodological approach for data analysis and the application of the benchmarking process step to analyze the data.

Created Sample

Following Institutional Review Board approval from the Uniformed Service University of the Health Sciences and

USAISR approval, cases of patients with polytrauma and a moderate or severe combat-related blunt TBI were requested from the JTTR. The inclusion criteria for data extraction were: American military casualties 18 years or older, entered into the JTTR between January 1, 2004 and December 31, 2010, with a recorded head Abbreviated Injury Scale score of 2 or more, indicating a moderate or severe head injury. After the extracted data were provided, the sample was created by sorting cases to include those who had a Glasgow Coma Scale (GCS) score of 12 or less upon admission to the Level III combat medical facility. We chose these GCS since scores of 8 or less indicate severe TBI and scores of 9 to 12 reflect moderate TBI. Penetrating head injuries were excluded because of the significantly different injury progression, treatment, and outcome compared to blunt TBI.¹²

Sample Size

Sample size was calculated based on the logistic regression equations proposed for the study. Using the approach described by Peduzzi and colleagues,²⁴ we used the 10 event per variable formula. An event is defined as the less observed outcome. For this study, the outcome was survival or death at 24 hours after injury and the event was defined as a death. A maximum of eight predictors were expected to be included in the equation. To ensure an adequate sample, 80 events were required.²⁴ Using the reported overall combat mortality rate for head injuries in Vietnam of 37%,²⁵ the required number of cases to ensure the necessary number of events was 216. Adding an additional 25% of cases to mitigate missing data brought the required number of cases to 270.

Data Analysis

Admission vital sign variables (SBP, oxygen saturation, and temperature) were chosen to represent the most frequently documented secondary insults following TBI.²⁶ Heart rate was included as an early indicator of shock.²⁷ Although SBP is accepted as a measure of cerebral perfusion, mean arterial pressure (MAP) is considered a more accurate indicator of cerebral pressure. Therefore, MAP was compared to SBP in data analysis. All selected secondary insults are associated with increased mortality and worse outcomes.^{7,10,11,26,28–30}

Statistical analysis was completed using the SPSS 18.0 Statistical Software Package (SPSS, Chicago, IL). Statistical significance was determined using an alpha less than 0.05 for all analyses. Univariate statistics were used to describe the sample characteristics and are reported as means with standard deviations for continuous variables, and as percentages for categorical variables. Relationships between the vital signs and 24-hour mortality were examined using both bivariate and sequential logistic regressions.

RESULTS

In the remaining sections of this article, we address the final step in the benchmarking process: comparing the data

analysis results to existing benchmarks and identifying gaps. The outcome measure selected as a benchmark metric was 24-hour mortality.

Demographic Summary

A total of 281 cases met the inclusion criteria. Characteristics of the sample are reported in Table II. The sample was predominantly male, U.S. Army personnel who were injured by explosive devices. Hyperthermia (temperature > 38°C) was present in 13.9% of the sample while hypothermia (temperature < 35°C) was seen only in 3.9% of the cases. Hypotension (SBP < 90 mm Hg) was recorded in 11% of casualties.

Level III combat medical facility admission vital sign data were well documented with rates of missing data ranging from 0.1% for heart rate to 17.4% for temperature and oxygen saturation. Missing data for individual vital signs before arrival at the Level III combat medical facility ranged from 63.5% to 98.9%.

Mortality within 24 hours of injury in the entire sample was 9.6%. This statistic does not include any casualties who expired before reaching the Level III combat medical facility. There were no deaths within 24 hours of injury in combat casualties with polytrauma combined with a moderate blunt TBI, while the mortality rate in those casualties who sustained a severe blunt TBI was 11.3%. Our original data analysis plan included analysis by severity of TBI; however, since no deaths occurred in the moderate TBI group, a more detailed analysis by severity of TBI was not performed.

Relationship between Secondary Injuries and Mortality

A Pearson's correlation was performed to investigate the relationship between all vital signs and 24-hour mortality (Table III). A significant negative correlation between 24-hour mortality and the oxygen saturation ($r = -0.335$), SBP ($r = -0.248$), and MAP ($r = -0.205$) was found. Bivariate logistic regression revealed only hypoxemia (oxygen saturation < 90%), hypothermia, SBP, and MAP were individual significant predictors of 24-hour mortality (Table IV).

TABLE II. Sample Characteristics

Male	97.9%
Mean Age	25.98 ± 6.33
Army	72.6%
OEF	51.6%
Mechanism of Injury—Explosive Device	87.2%
Mean ISS	40.85 ± 22.56
Mean GCS	4.42 ± 2.87
Hypothermia (Temperature < 35°C)	3.9%
Hyperthermia (Temperature > 38°C)	13.9%
Hypoxemia (Oxygen Saturation < 90%)	5%
Hypotension (SBP < 90 mm Hg)	11%
24-Hour Mortality	9.6%

Vital signs reflect admission to Level III facility; OEF, Operation Enduring Freedom.

TABLE III. Correlation Matrix

	SaO ₂	SBP	MAP	Heart Rate	Temperature
SaO ₂					
SBP	0.256*				
MAP	0.270*	0.886*			
Heart Rate	0.147*	0.028	0.008		
Temperature	0.090	0.097	0.140*	-0.051	
24-Hour Mortality	-0.335*	-0.248*	-0.205*	-0.085	-0.117

SaO₂, Oxygen saturation. *Significant at $p < 0.05$.

Hypoxemia increased the odds of 24-hour mortality by 6.87 and hypothermia by 7.32 when evaluated as single predictors.

Sequential logistic regression was performed to evaluate the independent effect of SBP or MAP on 24-hour mortality. Hypoxemia, hypothermia, hyperthermia, and heart rate were entered first into the equation to control their influence on mortality. Of the controlled variables, only hypothermia remained significant throughout the analysis ($p = 0.045$; OR 8.98; 95% CI 1.047 to 77.030). SBP was an independent predictor of 24-hour mortality ($p = 0.009$; OR = 1.03; 95% CI 0.949 to 0.993); however, MAP did not reach statistical significance ($p = 0.096$). A 1 mm Hg decrease in SBP increased the odds of 24-hour mortality by 3%.

DISCUSSION

Because published benchmarks for casualties with polytrauma and blunt TBI are lacking, we compared our data to benchmarks that have been reported for all combat casualties or those with isolated TBI. There were three major findings from our study. First, data contained in the JTTR are consistent beginning at the point of admission to the Level III facility. Second, in our sample, none of the combat casualties with polytrauma and a moderate blunt TBI died within 24 hours of injury. Third, hypothermia, although seen rarely in our sample, was a significant predictor of 24-hour mortality.

Overall, the most consistent data included in the JTTR begins at admission to the Level III facility. Before this point in the continuum of care, data are missing in over half of the entered cases. Additionally, only predetermined data points are recorded, and therefore data in the JTTR can only be utilized to benchmark combat casualty care using these specific data. Future research involving the JTTR should concentrate on data from admission to the Level III facility through discharge from the military medical facility.

Mortality at 24 hours after injury was 9.6% in our sample. DuBose and colleagues⁴ reported an 8.4% overall mortality rate in combat casualties with isolated TBI. Polytraumatic injuries sustained by our casualties may account for this difference. Conversely, we found mortality at 24 hours to be considerably less than the overall mortality (17%) in civilian isolated TBI reported by Zafar and colleagues.³¹ Injury severity was found to predict mortality in Zafar's sample, which was not supported by our findings. Over 70% of our

TABLE IV. Individual Bivariate Logistic Regression

	B	SE	Wald	df	Sig	Exp(B)	95% CI
Hypoxemia	1.927	0.662	8.471	1	0.004*	6.867	1.876–25.131
Hypothermia	1.991	0.678	8.611	1	0.004*	7.321	1.937–27.673
Hyperthermia	-0.148	0.652	0.051	1	0.821	0.863	0.240–3.099
SBP	-0.027	0.007	14.237	1	<0.001*	0.974	0.960–0.987
MAP	-0.031	0.010	10.005	1	0.002*	0.969	0.951–0.988
Heart Rate	-0.010	0.007	2.028	1	0.154	0.990	0.976–1.004
ISS > 25	1.210	0.628	3.714	1	0.054	3.352	0.980–11.469

Results of logistic regression performed using each variable as a single predictor; CI, Confidence Intervals. *Significant at $p < 0.05$.

sample had an Injury Severity Score (ISS) > 25, an indication of severe injury, which could explain why ISS did not reach statistical significance as a predictor of mortality. Furthermore, Zafar's study³¹ examined death at hospital discharge instead of mortality within 24 hours after injury used in our study, which may help to explain the dramatic difference.

As expected, those with a severe blunt TBI had a higher 24-hour mortality rate than the overall group; however, there were no deaths in any of the casualties with polytrauma and concomitant moderate blunt TBI who received care at a Level III facility. Although providers strive to prevent death, TBI survivors can be left with cognitive and/or functional deficits that alter the ability to return to duty or to care for himself or herself placing financial, emotional, and social strains on the injured person, their family, and their community.³² Implications of 100% survival in casualties with a moderate blunt TBI suggest a focus on interventions to prevent or mitigate the damage from secondary insults following a moderate blunt TBI to improve functional outcome.

Secondary insults following TBI can increase mortality and worsen outcome. Other studies have reported an increase in overall mortality in civilian patients with hypotension and TBI^{10,11,26,33,34} although at least one study did not report an increase in mortality.³⁵ To our knowledge, this is the first study to demonstrate that hypotension in combat casualties suffering from both polytrauma (usually blast-induced) and blunt TBI increases the odds of death at 24 hours postinjury 10-fold for each 10-point decrease in blood pressure. Furthermore, we found that hypoxemia was a significant predictor associated with 24-hour mortality, with the odds of death 6.9 times more likely when hypoxemia was present. Although not all researchers agree,¹⁰ our data not only support previous reports demonstrating the effects of hypoxemia on mortality in samples of civilian trauma patients,^{11,36} but also extend these findings to individuals who have both blunt TBI and polytrauma resulting from combat.

Current understanding of the effects of secondary insults on the brain following a TBI is not complete. Reports from rodent research indicate that the brain is particularly susceptible to secondary insults during first 24 hours after injury.⁹ Potential mechanisms that enhance this susceptibility to hypotension include reduced cerebral blood flow, impaired vasodilatory response to the microenvironment, impaired

pressure autoregulation, and impaired metabolism-flow coupling.⁹ A larger and more prolonged disruption of the blood-brain barrier was reported in hypoxic rats following a TBI.⁹ Hypoxemia and hypotension frequently occur together, and effects of the combination have been reported to be either additive¹¹ or not associated.^{10,36} Oxygen delivery and blood flow are so interconnected that the determination of effect of either individual insult is difficult. Decreased oxygen in the blood or decreased blood flow to the tissues may explain the damage incurred by secondary insults.

Similar to reports of increased mortality when hypothermia accompanies polytrauma in the civilian sector,^{36–38} our data indicate that combat injured individuals with hypothermia on admission to a Level III facility are 7.3 times more likely to die within 24 hours.³⁹ Interestingly, Jeremitsky and colleagues²⁶ found that hypothermia increased overall mortality in civilian patients with blunt trauma and an apparent severe TBI. Poorer outcomes and increased mortality have been noted in civilian patients with hyperthermia following a TBI.^{29,40,41} Hyperthermia did not reach statistical significance as a predictor of 24-hour mortality in our sample. One explanation for this difference in results may be the time frame used in the studies. Outcome was assessed at 6 to 12 months following injury in the civilian studies and temperature data were collected for 5 to 10 days after hospital admission.^{29,40,41} Our data were confined to the first 24 hours following injury. It is possible that an extended period of hyperthermia must be present for any detrimental effects to occur or the effects of hyperthermia are not evident within the first 24 hours postinjury. Additionally, 13.9% of our sample had hyperthermia, but temperature documentation was missing in 17.4% of our sample. As discussed earlier, missing data was a limitation of our study making it impossible to unequivocally state that hyperthermia had no effect on 24-hour mortality. These results indicate a need for further study evaluating the effects of hyperthermia following a combat-related blunt TBI. Given that 13.9% of these casualties were hyperthermic, closer attention to temperature maintenance in combat casualties should be encouraged.

Our findings add to the current body of trauma care knowledge. Combat injuries are typically more complex and result from a higher energy source than civilian traumatic injuries.⁶ Yet, combat care guidelines⁴² are based in part on

civilian trauma research. The findings of this study support previous civilian results that secondary insults increase mortality following a TBI and expand the finding to casualties with blunt TBI and polytrauma. We also have identified the significant contribution of hypothermia to mortality in these casualties reinforcing the importance of temperature maintenance following injury.

There are four limitations of this study. First, the study is retrospective in nature; thus, analysis was limited based on the data set available. Second, original data collection was completed during patient care in extreme conditions and without the scientific rigor usually applied to primary data collection for research. Third, only single point in time data analysis can be completed with the JTTR. The amount of missing data before Level III facility admission prevented any analysis of trends or the description of any secondary insults that may have occurred earlier in care. Fourth, an inherent survival bias is present in the JTTR. Only those casualties who arrived alive at the Level III facility were entered into the JTTR. Even with these limitations, the results of this study support the importance of monitoring and interventions to prevent secondary insults, especially hypotension, hypoxemia, and hypothermia, in casualties with polytrauma and a moderate or severe blunt TBI.

CONCLUSION

Benchmarks are used to evaluate a facility's care against best practices and identify any gaps. The JTTR has been used to benchmark some aspects of casualty care; however, before this article, evaluation of the JTTR as a data source has not been published. Our results indicate that the JTTR is a suitable source and provides a unique opportunity to benchmark casualty care beginning at the Level III medical facilities. We have developed benchmark metrics for 24-hour mortality in casualties with polytrauma and a moderate or severe blunt TBI. Future research should be directed towards the development of benchmarks for morbidity in this population and also to further identify the factors associated with mortality. Deployed military members place themselves in harm's way every day to protect the freedoms of all Americans. Benchmarks using the data contained in the JTTR will ensure that we provide the most effective care to heal their wounds.

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