Evacuation Strategies for Patients with Traumatic Brain Injury (TBI)

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DECLARATION OF INTEREST

NOTICE AND SIGNATURE PAGE

EVACUATION STRATEGIES FOR PATIENTS WITH TRAUMATIC BRAIN INJURY (TBI)

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14. ABSTRACT-

Introduction: According to the Military Health System Traumatic Brain Injury (TBI) Center of Excellence, 51,261 service members suffered moderate to severe TBI in the last 21 years. Moderate to severe TBI in service members is usually related to blast injury in combat operations, which necessitates medical evacuation to higher levels of care. Prevention of secondary insult, and mitigation of the unique challenges associated with the transport of TBI patients in a combat setting are important in reducing the morbidity and mortality associated with this injury. The primary goal of this study was a secondary analysis comparing the impact of time to transport on clinical outcomes for TBI patients without polytrauma versus TBI patients with polytrauma transported out of the combat theater via Critical Care Air Transport Teams (CCATT). Our secondary objective was to describe the occurrence of in-flight events and interventions for TBI patients without polytrauma versus TBI with polytrauma to assist with mission planning for future transports.

Materials and Methods: We performed a secondary analysis of a retrospective cohort of 438 patients with TBI who were evacuated out of theater by CCATT from January 2007 to May 2014. Polytrauma was defined as abbreviated injury scale (AIS) of at least 3 to another region in addition to head/neck. Time to transport was defined as the time (in days) from injury to CCATT evacuation out of combat theater. We calculated descriptive statistics and examined the associations between time to transport and preflight characteristics, in-flight interventions and events, and clinical outcomes for TBI patients with and without polytrauma.

Results: We categorized patients into two groups, those that had a TBI without polytrauma (n=179) and those with polytrauma (n=259). Within each group, we further divided those that were transported on the same day of injury, within two days of injury, and three or more days of injury. Patients with TBI without polytrauma who were transported earlier were more likely to have a penetrating injury, an open head injury, a preflight GCS of 8 or lower, and were more likely to be mechanically ventilated. Patients with TBI without polytrauma who were evacuated early were more likely to have been mechanically ventilated and more likely to have received supplemental oxygen, blood products, paralytics and sedation compared to patients with TBI patients without polytrauma and later evacuations. Polytrauma patients who were evacuated later had higher hospital days (p=0.0008) compared to polytrauma with earlier evacuations. There was no significant difference in mortality between the groups.

Conclusions: In patients with moderate to severe TBI transported via CCATT, early evacuation was associated with a higher rate of in-flight hypotension in polytrauma patients. Furthermore, those who had TBI without polytrauma that were evacuated sooner received more in-flight supplemental oxygen, blood products, sedatives and paralytics. Penetrating injuries in TBI patients without polytrauma were associated with earlier transport out of theater.

15. SUBJECT TERMS- traumatic brain injury, evacuation, military, polytrauma

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TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

Gaps Addressed: 2017 ICL: AFMS (AMC) 28 - Patient Data Across Patient Movement/Care Spectrum; (AMC) 49 & (AFMC) 86 - Effects of Flight for Patients; (AMC) 137 - Research on Advanced Point of Injury through ERC; (AMC) 224 - Epidemiology and Clinical Evaluation Outcomes of Injured Patients during OIF/OEF

Modified Abstract

Background: According to the Military Health System Traumatic Brain Injury (TBI) Center of Excellence, 51,261 service members suffered moderate to severe TBI in the last 21 years. Moderate to severe TBI in service members is usually related to blast injury in combat operations, which necessitates medical evacuation to higher levels of care. Prevention of secondary insult, and mitigation of the unique challenges associated with the transport of patients with TBI in a combat setting are important in reducing the morbidity and mortality associated with this injury.

The primary goal of this study was to compare the impact of time to transport on clinical outcomes for TBI patients without polytrauma versus TBI patients with polytrauma transported out of the combat theater via Critical Care Air Transport Teams (CCATT).

Methods: We performed a secondary analysis of a retrospective cohort of 438 patients with TBI who were evacuated out of theater by CCATT from January 2007 to May 2014. Polytrauma was defined as abbreviated injury scale (AIS) of at least 3 to another region in addition to head/neck. Time to transport was defined as the time (in days) from injury to CCATT evacuation out of combat theater.

Results:

- 3,867 patients with TBI were transported from an in-theater MTF to Landstuhl Regional Medical Center (LRMC) during the study time period.
- 438 who met inclusion criteria (≥ 18yrs, CCATT transport, head/neck AIS ≥ 3, ICD-9-CM code for TBI) were included in this analysis.
- 93% were US Active Duty service members and 97% were male with a median age 25 (IQR 21-30).
- Blast was the most common (70%) mechanism of injury. 65% of patients had penetrating injuries; 39% had severe TBI and 59% had polytrauma.
- Median time to transport (time from injury to departure from a Role III MTF) was 2 days (IQR 1–3) with a range of 0 to 18 days; all but two patients were transported within 7 days.
- Patients were categorized into two groups: 1) those that had a TBI without polytrauma (n=179) and 2) those with polytrauma (n=259).
- Within each group, we further divided those that were transported on the same day of injury, within two days of injury, and three or more days of injury.

- Patients with TBI without polytrauma who were transported earlier were more likely to have a penetrating injury, an open head injury, a preflight GCS of 8 or lower, and were more likely to be mechanically ventilated.
- Patients with TBI without polytrauma who were evacuated early were more likely to have received supplemental oxygen, blood products, paralytics and sedation compared to patients with TBI without polytrauma and later evacuations.
- Early evacuations with polytrauma were more likely to have had at least one episode of hypotension en route (p=0.0029) compared to polytrauma with later evacuations.
- Polytrauma patients who were evacuated later had higher hospital days (p=0.0008) compared to polytrauma with earlier evacuations.
- There was no significant difference in mortality between the groups.

Conclusions: In patients with moderate to severe TBI transported via CCATT, early evacuation was associated with a higher rate of in-flight hypotension in polytrauma patients. Furthermore, those who had TBI without polytrauma that were evacuated sooner received more in-flight supplementary oxygen, blood products, sedatives and paralytics. Penetrating injuries in TBI patients without polytrauma were associated with earlier transport out of theater.

Evidence Based Recommendations:

- Medical personnel should be aware of the potential implications of earlier transport in patients with TBI and other sources of trauma
- In this patient population, medical personnel should anticipate the potential medical events, such as hypotension, that certain subsets of the population may be more susceptible to and take necessary steps to try and mitigate any secondary insults
- Given the retrospective nature of this study and the potential for survival bias, a blanket policy mandating a delay in evacuation for TBI patients should not be instated.
- Future research should focus understanding why certain subsets of the study population have associated in flight events.
- In addition, future research should be designed to evaluate long-term outcomes in sub-groups of TBI casualties.

2.0 INTRODUCTION

Traumatic Brain Injury (TBI) is a leading cause of morbidity and mortality.[1] According to the Military Health System (MHS) Traumatic Brain Injury Center of Excellence, 51,261 service members suffered moderate to severe TBI in the last 21 years.[2] Moderate to severe TBI in service members is usually related to blast injury in combat operations, which necessitates medical evacuation to higher levels of care.[2,3] Prevention of secondary insult, and mitigation of the unique challenges associated with the transport of TBI patients in a combat setting are important in reducing the morbidity and mortality associated with this injury.[4,5] The combat injured are moved on various platforms across the continuum of military care, and the optimal timing of transport and its implications on secondary insult to patients with TBI is poorly understood.[6]

Exposure to altitude during aeromedical evacuation (AE) may impose additional physiologic risk to patients with TBI.[6,7] Some patients may benefit from delayed evacuation from theater to mitigate potential secondary insults. However, TBI is a heterogeneous injury and some injury patterns may benefit from expedited transport to a higher level of care. The survival of combat-related traumatically injured patients has improved in part due to the use of aeromedical evacuation (AE) platforms. However, the physiologic effects of AE are not well understood and have the potential to contribute to secondary injury for some patient populations, particularly patients with TBI.[4-6]

Prevention of secondary injury and prehospital management of TBI have been studied.[7-11] The goals of treatment should be the prevention of hypoxia, hypocapnia, hypercapnia, and hypotension. Better outcomes are associated with PaO2 > 90%, systolic blood pressure > 90 mmHg, and an ETCO2 of 35-40 mmHg.[7-11] There is limited data on whether or not patients with TBI would benefit from delayed evacuation.[6,11] Additionally, the implications of concomitant injuries may necessitate expedited aeromedical evacuation to improve overall outcomes. Maddry et al. concluded in patients with moderate to severe TBI, delayed evacuation from the combat theater was associated with improved outcomes.[6] Our study builds on those findings with a secondary analysis of the same population to further inform evacuation strategies for different types of TBI and when there is associated polytrauma. Clinical interventions may need to vary depending on the etiology and type of brain injury (penetrating vs blunt), and the presence or absence of other concomitant injuries. Clinical care for brain injury in conjunction with other injury types may make decisions for interventions and timing of transport more challenging. Further understanding the implications of these other injuries can help mitigate some of those challenges. Characterizing traumatic brain injury types may further elucidate strategic recommendations for patient movement.

The primary goal of this study was a secondary analysis comparing the impact of time to transport on clinical outcomes for TBI patients without polytrauma versus TBI patients with polytrauma transported out of the combat theater via Critical Care Air Transport Teams (CCATT). Our secondary objective was to describe the occurrence of in-flight events and interventions for TBI patients without polytrauma versus TBI with polytrauma to assist with mission planning for future transports.

3.0 METHODS, ASSUMPTIONS AND PROCEDURES

We performed a secondary analysis of a retrospective cohort of patients with TBI who were evacuated out of theater by CCATT from January 2007 to May 2014. Data abstractors collected pre-flight and in-flight information including, laboratory values, vital signs, procedures, and clinical assessments. Outcomes were obtained from the Department of Defense Trauma Registry (DoDTR). Polytrauma was defined as abbreviated injury scale (AIS) of at least 3 to another region in addition to head/neck. Time to transport was defined as the time (in days) from injury to CCATT evacuation out of combat theater. We calculated descriptive statistics and examined the associations between time to transport and preflight characteristics, in-flight interventions and events, and clinical outcomes for TBI patients with and without polytrauma. Additional details of methodology have been previously published.[5] This study was approved by the U.S. Air Force 59th Medical Wing Institutional Review Board.

4.0 MAJOR EVENTS/MILESTONES/SUCCESS

In preparation for the execution of this project,

- Kick Off Meeting – June 2018
- IRB Approval – Sept 20, 2018
- Data abstraction complete Sept. 2019
- Data Analysis – December 2020
- Poster presentation – provide location and date: N/A
- Manuscript submitted to – Military Medicine – accepted pending minor edits
- Dissemination of Results – Evidence to Guide Practice Report to be disseminated to stakeholders

5.0 RISK ASSESSMENT

5.1 Risk Analysis:

This study presented no greater than minimal risks to the subjects. There were no interventions and no changes to the standards of care. The risk involved potential breaches of privacy and patient confidentiality should the data set be acquired by a person or agency outside of this research team. This risk is similar to basic patient care that would otherwise normally be carried out. The likelihood of this occurrence was mitigated by password protection of electronic files and removal of patient PHI.

5.2 Technical Challenges

Due to the retrospective nature of our study, we are able to identify associations but not causation. A prospective study may help compliment the data reported to help understand the implications of various injuries and transport times on patients with TBI with or without other injuries. Additionally, the data were extracted from medical records that may have had missing data secondary to incomplete documentation, difficulty accessing certain parts of the records and/or illegibility. Such missing data could have implications on the interpretation of the data in regards to Type I and Type II errors. Furthermore, the combat setting is complex and there are other factors that affect patient transport such as medical specialty availability, availability of transport platforms, availability of resources for medical intervention, and weather conditions. These variables were not described in this study.

6.0 TRANSITION PLAN

6.1 Military Relevance

TBI comprises a significant proportion of the injuries sustained by the combat casualty population, and associated mortality has been reported as high as 30%. The long-term effects of TBI can significantly impact the injured warfighter's quality of life and costs associated with this injury have been reported to be 60 billion dollars. The main priority of TBI care is to prevent secondary insults. The combat injured are moved within the continuum of military care on various platforms and the threat this poses for secondary insult to patients with TBI is poorly understood.

6.2 Transition Strategy

The results of this study provided new knowledge about the influence of transport time on combat casualty care and ensures that providers are equipped and prepared for the challenges faced in the delivery of care during evacuation. Data collected was filtered into the database for Project Mercury, can be queried to conduct retrospective analysis to support and provide research to investigators, and allows for performance improvement initiatives. Lessons learned establish the ground work for CPG development and standardization of care. The results were also disseminated to the following:

1. The research community through national civilian and military academic conferences and meetings to include the Military Health Science Research Symposium (MHSRS).
2. Completed manuscripts submitted to peer-reviewed journals for publication.
3. The Defense Technical Information Center (DTIC) for publishing on their website.
4. Appropriate military leadership and training agencies.

7.0 RESULTS

We reviewed the records of 438 patients transported via CCATT from a Role III facility to Landstuhl Regional Medical Center (LRMC). We categorized patients into two groups, those that had a TBI without polytrauma (n=179) and those with polytrauma (n=259). Within each group, we further divided those that were transported on the same day of injury, within two days of injury, and three or more days of injury.

Most patients were male with a median age of 25 years [IQR 21-30] (Table 1). Patients with TBI without polytrauma who were transported earlier were more likely to have a penetrating injury, an open head injury, a preflight GCS of 8 or lower, and were more likely to be mechanically ventilated. Those who had polytrauma and were transported earlier, were less likely to have received blood products prior to flight.

Patients with TBI without polytrauma who were evacuated early were more likely to have been mechanically ventilated and more likely to have received supplemental oxygen, blood products, paralytics and sedation compared to patients with TBI without polytrauma and later evacuations (Table 2). Early evacuations with polytrauma were more likely to have had at least one episode of hypotension en route (p=0.0029) compared to polytrauma with later evacuations (Table 3). Polytrauma patients who were evacuated later had higher hospital days (p=0.0008) compared to polytrauma with earlier evacuations (Table 4). There was no significant difference in mortality between the groups.

8.0 CONCLUSION/DISCUSSION

Discussion: In patients with moderate to severe TBI transported via CCATT, early evacuation was associated with a higher rate of in-flight hypotension in polytrauma patients. Preventing secondary injury, such as hypotension, is important in TBI management and treatment. Transport decisions that may mitigate the risk of secondary insults can have a positive impact on outcomes. Previously, Maddry et al reported a study targeted to characterize the effects of aeromedical evacuation on mortality and secondary injury.[5] They found that in patients with moderate to severe TBI, delayed aeromedical evacuation was associated with lower odds of mortality, ventilation at transfer or discharge, and a higher likelihood of discharge to home and return to duty dispositions. In this study, we further characterize this population to understand the implications of having sustained other injuries in addition to TBI on transport time and need for interventions during en route care.

We found that those with polytrauma were evacuated later and had longer hospital stays than patients with TBI and no polytrauma. Those with polytrauma evacuated earlier may be subject to secondary insult as those patients with early evacuation and polytrauma were more likely to become hypotensive during the en route care continuum. Our study is not able to determine whether this is an increase in secondary insults due to early transport or whether these insults would have occurred at the ground ICU regardless of transport time. However, TBI patients with polytrauma may benefit from further treatment and stabilization in theater prior to CCATT evacuation.

In 2019, Patel et al reported on a retrospective case series characterizing TBI in patients from Operation Enduring Freedom. 18.5% of their study population sustained penetrating brain injuries and 41% of their study population sustained comorbid injuries.[12] In 2011, DuBose et al compared patients sustaining severe TBI on the battlefield to the civilian population using the National Trauma Data Bank.[13] They found that the patients who sustained a penetrating injury on the battlefield had a higher rate of neurosurgical intervention compared to civilian counterparts. They highlighted the need for further research to understand the optimal treatment of penetrating brain injuries on the battle field. In our study, 59% of the patients had polytrauma. There were 285 penetrating injuries in our study population. We found that those that had a brain injury with a penetrating injury were more likely to have been evacuated from theater early. Furthermore, we found that those patients with polytrauma that were evacuated earlier were more likely to become hypotensive in flight.

In 2020, Maddry et al reported on the effects of cabin altitude restriction (CAR) on outcomes in patients with moderate or severe TBI.[9] They found that the groups flown with CAR and those without CAR did not have a significant difference in mortality rates, hospital days, ICU days or ventilator days. In our study, we found patients with a TBI without polytrauma who were evacuated early were more likely to have been on a ventilator and less likely to receive supplemental oxygen and early evacuations with polytrauma were more likely to have had at least one episode of hypotension en route (p=0.0029) compared to polytrauma with later evacuation. Anticipating hypotension in this patient population can help develop preventative measures to prevent potential secondary injury in this patient population.

Conclusion: In patients with moderate to severe TBI transported via CCATT, early evacuation was associated with a higher rate of in-flight hypotension in polytrauma patients. Furthermore, those who had TBI without polytrauma that were evacuated sooner received more in-flight supplementary oxygen, blood products, sedatives and paralytics. Penetrating injuries in TBI patients without polytrauma were associated with earlier transport out of theater.

9.0 DELIVERABLES

9.1 Publications:

Ng PC, Arana AA, Savell SC, Davis WT, Cutright J, Perez CA, Bebarta VS, Maddry JK. Evacuation Strategies for U.S. Casualties with Traumatic Brain Injury.

Mil Med. 2022 Jan 5;usab543. doi: 10.1093/milmed/usab543. Online ahead of print.

9.2 Presentations:

10.0 COST

This work was funded by a DHA J-9 award. Total funding awarded for this Project Code Number J917EC05 in the amount of $388,000 were expended by September 30, 2020.

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FIGURES AND TABLES:

Table 1. Baseline and preflight characteristics for TBI without polytrauma and polytrauma patients, grouped by time to transport

	TBI without polytrauma (n=179)				Polytrauma (n=259)			
Variable	**≤1 day (n=84)**	**2 days (n=61)**	**≥3 days (n=34)**	**p**	**≤1 day (n=81)**	**2 days (n=102)**	**≥3 days (n=76)**	**p**
Age	24.0 [21.0-29.8]	25.0 [22.0-29.0]	25.5 [21.0-29.0]	0.4468	25.0 [22.0-30.0]	25.0 [22.0-30.0]	23.0 [21.0-29.0]	0.1837
Male gender	96.4	100	97.1	0.4040	97.5	96.1	98.7	0.6415
Injury severity score	21.0 [16.0-27.0]	21.0 [16.5-26.0]	19.5 [16.8-26.0]	0.8879	33.0 [26.0-41.0]	34.0 [27.0-42.3]	34.0 [29.0-41.0]	0.3128
Gunshot wound	29.8	23	17.6	0.3459	9.9	2	7.9	0.0663
Blast injury	53.6	62.3	44.1	0.2231	76.5	87.3	76.3	0.0978
Penetrating injury	63.1	70.5	44.1	0.0383*	63	69.6	68.4	0.6129
Open head injury	39.3	34.4	11.8	0.0137*	11.1	11.8	9.2	0.8498
Head AIS >3	66.7	72.1	67.6	0.7737	54.3	51	57.9	0.6565
Intracranial hemorrhage	66.7	49.2	58.8	0.1066	42	37.3	36.8	0.7534
Preflight GCS ≤8	45.2	41	14.7	0.0070*	56.8	61.8	59.2	0.7921
Preflight interventions								
Supplementary O2	11.9	16.4	32.4	0.0284*	12.3	13.7	13.2	0.9630
Mechanical ventilation	70.2	59	35.3	0.0021*	79	80.4	81.6	0.9212
Surgery: abdomen	1.2	8.2	2.9	0.0834	30.9	37.3	38.2	0.5679
Surgery: extremities	17.9	24.6	20.6	0.6135	60.5	73.5	73.7	0.1050
Surgery: head	73.8	65.6	61.8	0.3573	50.6	48	44.7	0.7614
Blood products	34.5	29.5	35.3	0.7766	46.9	68.6	68.4	0.0040*
Massive transfusion	2.4	0	2.9	0.4249	9.9	15.7	13.2	0.5126

Values given are median [interquartile range] or column percent.

*Comparisons are significant at p<0.05.

Table 2. In-flight interventions for TBI without polytrauma and polytrauma patients, grouped by time to transport

Variable	TBI without polytrauma (n=179)				Polytrauma (n=259)			
	≤1 day (n=84)	2 days (n=61)	≥3 days (n=34)	p	≤1 day (n=81)	2 days (n=102)	≥3 days (n=76)	p
Minimum in-flight SpO2	99.0 [97.0-100.0]	98.0 [97.0-100.0]	96.0 [94.0-99.0]	0.0004*	98.0 [96.0-100.0]	98.0 [96.0-100.0]	98.0 [96.0-99.0]	0.3102
Supplementary O2	11.9	18	41.2	0.0013*	13.6	14.7	14.5	0.9754
Mechanical ventilation	66.7	59	29.4	0.0010*	77.8	77.5	78.9	0.9705
Blood products	13.1	4.9	0	0.0305*	14.8	31.4	15.8	0.0088*
Sedation (push)	13.1	3.3	14.7	0.0922	21	13.7	17.1	0.4297
Sedation (drip)	67.9	67.2	32.4	0.0008*	86.4	76.5	77.6	0.2084
Paralytics	16.7	1.6	5.9	0.0070*	11.1	4.9	10.5	0.2453

Values given are median [interquartile range] or column percent.
*Comparisons are significant at p<0.05.

Table 3. In-flight events for TBI without polytrauma and polytrauma patients, grouped by time to transport

Variable	TBI without polytrauma (n=179)				Polytrauma (n=259)			
	≤1 day (n=84)	2 days (n=61)	≥3 days (n=34)	p	≤1 day (n=81)	2 days (n=102)	≥3 days (n=76)	p
SpO2 < 93%	3.6	3.3	8.8	0.4600	0	3.9	3.9	0.1807
SBP ≤ 90 mmHg	2.4	6.6	0	0.2882	13.6	3.9	1.3	0.0029*
PCO2 > 40 mmHg	35.7	45.9	23.5	0.0914	58	55.9	55.3	0.9334
PaO2 < 80 mmHg	8.3	9.8	17.6	0.3211	19.8	29.4	23.7	0.3127
PaO2 > 180 mmHg	11.9	3.3	2.9	0.1004	8.6	4.9	2.6	0.2529

Values given are column percent.

*Comparisons are significant at p<0.05.

Table 4. Patient outcomes for TBI without polytrauma and polytrauma patients, grouped by time to transport

Variable	TBI without polytrauma (n=179)				Polytrauma (n=259)			
	≤1 day (n=84)	2 days (n=61)	≥3 days (n=34)	p	≤1 day (n=81)	2 days (n=102)	≥3 days (n=76)	p
Total ventilator days	4.0 [2.0-8.8]	5.0 [0.0-7.0]	1.5 [0.0-6.0]	0.1859	6.0 [3.0-10.0]	8.0 [3.0-13.0]	9.0 [5.3-14.0]	0.0958
Total ICU days	6.0 [4.0-10.0]	7.0 [5.5-10.5]	7.0 [4.8-11.3]	0.9237	9.0 [5.0-15.5]	12.0 [6.0-20.0]	11.0 [8.0-21.8]	0.0929
Total hospital days	6.0 [4.0-15.0]	11.0 [4.0-18.0]	10.5 [6.0-24.0]	0.1869	17.0 [6.0-33.5]	26.5 [7.8-43.0]	23.5 [8.0-51.8]	0.0008*
Mortality	6	3.3	0	0.3578	3.7	3.9	3.9	0.9999

Values given are median [interquartile range] or column percent.

*Comparisons are significant at p<0.05.

2.0 LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

- AE Aeromedical evacuation
- AIS Abbreviated injury scale
- CAR Cabin altitude restriction
- CCATT Critical Care Air Transport Teams
- CPG Clinical Practice Guideline
- DoDTR Department of Defense Trauma Registry
- DTIC Defense Technical Information Center
- GCS Glasgow Coma Scale
- ICU Intensive Care Unit
- IQR Interquartile Range
- LRMC Landstuhl Regional Medical Center
- MHS Military Health System
- MTF Military Treatment Facility
- PHI Protected Health Infromation
- TBI Traumatic Brain Injury