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AWARD NUMBER:

TITLE:

The Impact of Transport Time on Outcomes Following Evacuation from Point of Injury (POI)

PRINCIPAL INVESTIGATOR:

Maj. Joseph K. Maddry, MD

RECIPIENT:

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PREPARED FOR: U.S. Army Medical Research and Materiel Command
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13. SUPPLEMENTARY NOTES

14. ABSTRACT
Our primary objective is to characterize patients evacuated from point of injury (POI) who were transported to a medical treatment facility (MTF) in Afghanistan from January 2011 to December 2014, and determine how transport time influences patient outcomes up through 30 days, disposition and mortality up through 6 months and up through 1 year. The Specific Aims of this study are as follows: (1) To determine the effect of transport time in patients with major traumatic extremity amputation and (2) To determine the effect of transport time in patients with non-compressible torso injury (NCTI).

15. SUBJECT TERMS

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1. INTRODUCTION:

In combat operations, patients with traumatic injuries require urgent clinical care and expeditious evacuation to improve survival. To date, no research has been done describing the effect of transport time on patient outcomes with traumatic extremity amputation and non-compressible torso injury. Our primary objective is to characterize patients evacuated from point of injury (POI) who were transported to a medical treatment facility (MTF) in Afghanistan from January 2011 to December 2014, and determine how transport time influences patient outcomes. The Specific Aims of this study are as follows: (1) To determine the effect of transport time in patients with major traumatic extremity amputation and (2) To determine the effect of transport time in patients with non-compressible torso injury (NCTI).

2. KEYWORDS:

- Critical Illness
- En route Care
- Pre-hospital Care
- Blast injuries
- Trauma
- Clinical Practice Guidelines
- Patient Transport
- Combat Casualty Care
- Aeromedical Evacuation (AE)
- Amputation
- Hemorrhage
- Non-compressible Torso Injury
- Transport time
- MEDEVAC

3. OVERALL PROJECT SUMMARY:

Project was awarded on 9 November 2015. IRB approval was obtained in advance for the AIMs of the study. Facility coordination with United States Army Institute of Surgical Research (USAISR) was established upon receiving funds from the Congressionally Directed Medical Research Programs (CDMRP). A research nurse coordinator was hired in support of the award. The project initiation meeting was conducted with USAMRMC Human Research Protection Office (HRPO), which issued approval to start project.

An Access database was constructed in order to capture patient enrollment. A retrospective review of the records of U.S. military and U.S. contractors who were evacuated from the point of injury in Afghanistan to a MTF between January 2011 and December 2014 was performed. Pre-hospital clinical data was recorded and grouped accordingly. Post-flight data for the groups was compared to identify trends to determine if the duration of evacuation influences clinical care and patient outcomes.
Additional patient charts were identified and entered into the database in order to obtain

the largest possible sample. The additional charts were merged and a quality control audit was conducted. Statistical analysis of the data was completed.

Dr. Maddry disseminated research findings at the JPC-6 CCCRP Portfolio Review and to Air Mobility Command (AMC). A regulatory audit was conducted by the 59th Clinical Research Division, no discrepancies were reported.

4. KEY RESEARCH ACCOMPLISHMENTS:

The Impact of Transport Time on Outcomes Following Evacuation from Point of Injury	% Completion	Site 1
Major Task 1- Determine the effect of transport time in patients with major traumatic extremity amputation.		
Subtask 1: Submit documents for IRB* approval	100%	Maj Maddry / RNC
Milestone # 1 IRB approval obtained*	100%	Maj Maddry
Subtask 2: Submit documents for HRPO** approval	100%	Maj Maddry / RNC
*Milestone # 2 HRPO** approval obtained*	100%	Maj Maddry
Subtask 3: Staff Hiring	100%	Maj Maddry
Subtask 4: Identify patient populations from Joint Trauma System (JTS)	100%	Maj Maddry / RNC
Subtask 5: Collect, extract, and clean pre-hospital data from JTS/TMDS	100%	RNC
Milestone #3 Summary of comparison groups and complications submitted to USA MRMC	100%	Maj Maddry
Subtask 6: Link 30-day outcomes with DoDTR	100%	RNC
Subtask 7: QA of data entry, interim statistical analysis	100%	RNC / Statistician
Milestone #4 Disseminate interim findings through formal scientific presentation	100%	Maj Maddry
Subtask 8: QA of data entry, final statistical analysis, and final study report	100%	RNC / Statistician
Subtask 9: Prepare scientific abstracts and peer review publications for dissemination	100%	Maj Maddry / RNC
Milestone #5 Summary of results to USAMRMC and Joint En route Care Community to incorporate in combat medic training and clinical practice guidelines	100%	Maj Maddry
Major Task 2 - Determine the effect of transport time in patients with non-compressible torso injury.		
Subtask 1: Submit documents for IRB* approval	100%	Maj Maddry / RNC
Milestone # 1 IRB approval obtained*	100%	Maj Maddry
Subtask 2: Submit documents for HRPO** approval	100%	Maj Maddry / RNC

*Milestone # 2 HRPO** approval obtained*	100%	Maj Maddry
Subtask 3: Staff Hiring	100%	Maj Maddry
Subtask 4: Identify patient populations from Joint Trauma System (JTS)	100%	Maj Maddry / RNC
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Milestone #5 Summary of results to USAMRMC and Joint En route Care Community to incorporate in combat medic training and clinical practice guidelines	100%	Maj Maddry
Major Task 3 - Reporting		
Subtask 1: Submit Y1Q1 Quarterly Report	100%	Maj Maddry / RNC
Subtask 2: Submit Y1Q2 Quarterly Report	100%	Maj Maddry / RNC
Subtask 3: Submit Y1Q3 Quarterly Report	100%	Maj Maddry / RNC
Subtask 4: Submit Y1 Annual Report	100%	Maj Maddry / RNC
Subtask 5: Submit Y2Q1 Quarterly Report	100%	Maj Maddry / RNC
Subtask 6: Submit Y2Q2 Quarterly Report	100%	Maj Maddry / RNC
Subtask 7: Submit Y2Q3 Quarterly Report	100%	Maj Maddry / RNC
Subtask 8: Submit Final Report	100%	Maj Maddry / RNC

5. CONCLUSION:

During the final year of this study, all data abstraction was completed, data was reviewed for accuracy, and final analysis was performed. . The manuscript was accepted for publication to a national journal, in press. A complete dataset will be transferred to the Joint Trauma System Military En route Care Registry (Project MERCuRY) as outlined in the protocol. Findings will be presented to CoERCCC and TCCC for review and CPG consideration.

6. PUBLICATIONS, ABSTRACTS, AND PRESENTATIONS:

a. Manuscripts:

"Impact of prehospital medical evacuation (MEDEVAC) transport time on combat mortality in patients with non-compressible torso injury and traumatic amputations" accepted to Military Medical Research in January 2018. In press.

b. Presentations:

Poster and Podium Presentation – "The Impact of Transport Time on Outcomes Following Evacuation from Point of Injury" at GSRES (Graduate School Research Education Symposium), San Antonio, TX, 19 Apr 2018

Poster and Podium Presentation – "The Impact of Transport Time on Outcomes Following Evacuation from Point of Injury" at SURF (San Antonio Military Health System & Universities Research Forum), San Antonio, TX, 16 June 2017

Podium Presentation – "The Impact of Transport Time on Outcomes Following Evacuation from Point of Injury" at TSNRP (Tri-Service Nursing Research Program), Ellicott City, MD, 24 April 2017 -28 April 2017

Poster Presentation – "The Impact of Transport Time on Outcomes Following Evacuation from Point of Injury" at MHSRS (Military Health System Research Symposium), Kissimmee, FL, August 15-18, 2016

7. INVENTIONS, PATENTS AND LICENSES:

None to Report at this time

8. REPORTABLE OUTCOMES:

We reviewed 1267 PCRs, of which 669 had an ISS of 10 or greater and were included in the analysis. In this study, 15.5% sustained only amputation injuries (n=104, AMP only), 10.8% amputation and non-compressible torso injuries (n=72, AMP+NCTI), and 73.7%

did not sustain either an amputation or a non-compressible torso injury (n=493, Non-AMP/NCTI). Of the 176 patients with AMP, 40.9% (n=72) also had NCTI. Most injured patients were male (98.8%) with a median age of 24 years old, and these proportions were not different among the groups (Table 1). With a median transport time of 36 min, there was no significant difference in elapsed time from POI to MTF among the three groups (p=0.7793). Casualties were transported to a Role 2 (52.0%) or Role 3 (48.0%) facility. The predominant mechanism of injury was explosion (72.3%) followed by penetrating injuries (26.5%). AMP+NCTI patients were more severely injured (median ISS of 33), followed by AMP and Non-AMP/NCTI.

Evaluating study injury groups by transport time, the median ISS was higher in AMP+NCTI at each time interval (Table 2). AMP and AMP+NCTI were more likely to be transported to a Role 3 (74.5% and 66.2%, respectively) compared to Non-AMP/NCTI (39.7%, P<0.0001). The Non-AMP/NCTI group was least likely to have received tourniquets, blood products, intravenous access fluids, or an airway procedure during prehospital transport. In proportional hazard models, the AMP and Non-AMP/NCTI groups combined were more likely to discharge from the ICU more quickly (risk ratio 2.29, 1.79-2.97) compared to the AMP+NCTI group (p<0.0001).

Conclusion

A decreased transport time from the point of injury to the medical treatment facility was associated with decreased mortality in those patients who suffered a combination of an amputation injury and a non-compressible torso injury. No significant association between transport time and outcomes was found in patients who did not sustain a non-compressible torso injury. Priority for rapid evacuation of combat casualties should be given to those with non-compressible torso injury.

Table 1. Descriptive summary of study population: US casualties transported from point-of-injury to MTF via MEDEVAC

	All %, 95% CI (count) or median [IQR] n=669	**AMP+NCTI** %, 95% CI (count) or median [IQR] n=72	**AMP** %, 95% CI (count) or median [IQR] n=104	**Non-AMP/NCTI** %, 95% CI (count) or median [IQR] n=493	**p-value**
Male	99, 98-100 (661/665)	100, 95-100 (72/72)	100, 96-100 (103/103)	99, 98-100 (486/490)	0.2935
Age	24 [22-28]	23 [21-27]	24 [21-27]	24 [22-28]	0.1128
Injury to MTF (minutes)	41 [31-56]	34 [28-45]	34 [27-46]	44 [33-59]	<0.0001
9-Line to MTF (minutes)	36 [29-47]	32 [25-40]	32 [27-44]	38 [30-51]	<0.0001

Injury Description*					
Blast	72, 69-76 (484/669)	100, 95-100 (72/72)	95, 89-98 (99/104)	63, 59-68 (313/493)	<0.0001
Penetrating	26, 23-30 (177/669)	0, 0-5 (0/72)	4, 2-9 (4/104)	35, 31-39 (173/493)	<0.0001
Blunt	1, 0.6-2 (8/669)	0, 0-5 (0/72)	1, 0.2-5 (1/103)	1 0.6-3 7/493)	0.7749
ISS	17 [12-27]	33 [25-40]	18 [14-27]	17 [12-24]	<0.0001
GCS of 3	3, 2-5 (17/552)	2, 0.2-8 (1/65)	3, 1-9 (3/89)	3, 1-6 (13/398)	0.7042
Head Injury (AIS of Head ≥2)	65, 56-74 (240/369)	74, 60-85 (32/43)	62, 50-73 (38/61)	64, 52-75 (170/265)	0.1169
Prehospital Hypotension (% SBP<90)	25, 21-29 (117/472)	47, 35-60 (26/55)	27, 18-37 (22/82)	21, 17-25 (69/335)	0.0015
30-Day Mortality	5, 3-7 (31/662)	8, 4-17 (6/72)	4, 2-10 (4/103)	4, 3-7 (21/487)	0.3045

AMP+NCTI, traumatic amputation and non-compressible torso injury; AMP, traumatic amputation only; Non-AMP/NCTI, neither traumatic amputation nor non-compressible torso injury; CI, confidence interval; IQR, interquartile range; MTF, medical treatment facility; ISS, injury severity score; GCS, glasgow coma scale; AIS, abbreviated injury scale; SBP, systolic blood pressure
*Blast, Penetrating, Blunt, and Burn are mutually exclusive

Table 2. ISS by injury type and transport time groups

	AMP+NCTI median [IQR], (count)	**AMP** median [IQR], (count)	**Non-AMP/NCTI** median [IQR], (count)	**p-value**
<30 min	33 [24-41], (27)	18 [14-26], (38)	17, [12-26], (122)	<0.0001
30-60 min	33 [24-43], (39)	19 [14-27], (59)	17 [11-22], (312)	<0.0001
>60	29 [28-38], (6)	21 [17-27], (7)	14 [11-22], (59)	0.0003

AMP+NCTI, traumatic amputation and non-compressible torso injury; AMP, traumatic amputation only; Non-AMP/NCTI, neither traumatic amputation nor non-compressible torso injury; IQR, interquartile range

Table 3. Prehospital interventions performed

	All %, 95% CI (count) or median [IQR] n=669	AMP+NCTI %, 95% CI (count) or median [IQR] n=72	AMP %, 95% CI (count) or median [IQR] n=104	Non-AMP/NCTI %, 95% CI (count) or median [IQR] n=493	p-value
Tourniquets	51, 47-55 (342/669)	100, 95-100 (72/72)	91, 84-95 (95/104)	35, 31-40 (175/493)	<0.0001
IV	54, 50-58 (360/669)	62, 54-75 (47/72)	72, 63-80 (75/104)	48, 44-53 (238/493)	<0.0001
Fluids	54, 50-58 (360/669)	65, 54-75 (47/72)	72, 63-80 (75/104)	48, 44-53 (238/493)	<0.0001
Blood	8, 6-10 (53/669)	17, 10-27 (12/72)	27, 19-36 (28/104)	3, 2-4 (13/493)	<0.0001
Chest Needle	4, 3-6 (27/669)	3, 1-10 (2/72)	1, 0.2-5 (1/104)	5, 3-7 (24/493)	0.0914
Any Airway	58, 55-62 (390/669)	78, 67-86 (56/72)	72, 63-80 (75/104)	53, 48-57 (259/493)	<0.0001
Chest Seal	5, 4-7 (35/669)	100, 95-100 (72/72)	2, 1-7 (2/104)	7, 5-9 (33/493)	0.0018
Number of Prehospital Interventions	2 [1-4]	4 [2-4]	4 [2-4]	2 [1-3]	<0.0001

AMP+NCTI, traumatic amputation and non-compressible torso injury; AMP, traumatic amputation only; Non-AMP/NCTI, neither traumatic amputation nor non-compressible torso injury; CI, confidence interval; IQR, interquartile range

9. OTHER ACHIEVEMENTS:

- Awarded the Bronze at the 2016 Military Health System Symposium Award for Excellence- Poster- Bronze Award for “The Impact of Transport Time on Outcomes Following Evacuation from Point of Injury”

- Data collected during this study will be filtered into the database for Project MERCuRY and can be queried to conduct retrospective analysis to support and provide research to investigators, allow for performance improvement initiatives and improve the delivery of en route care.

10. REFERENCES:

None

11. APPENDICES:

Quad Chart
Manuscript

Impact of prehospital medical evacuation (MEDEVAC) transport time on combat mortality in patients with non-compressible torso injury and traumatic amputations: A retrospective study

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[3]Department of Emergency Medicine, University of Colorado School of Medicine, Aurora, CO

Abstract

Background: In combat operations, patients with traumatic injuries require expeditious evacuation to improve survival. Studies have shown that long transport times are associated with increased morbidity and mortality. Limited data exist on the influence of transport time on patient outcomes with specific injury types. The objective of this study was to determine the impact of the duration of time from the initial request for medical evacuation to arrival at a medical treatment facility on morbidity and mortality in casualties with traumatic extremity amputation and non-compressible torso injury (NCTI).

Methods: We completed a retrospective review of MEDEVAC patient care records for United States military personnel who sustained traumatic amputations and NCTI during Operation Enduring Freedom between January 2011 and March 2014. We grouped patients as traumatic amputation and NCTI (AMP+NCTI), traumatic amputation only (AMP), and neither AMP nor NCTI (Non-AMP/NCTI). Analysis was performed using chi-squared tests, Fisher's exact tests, Cochran-Armitage Trend tests, Shapiro-Wilks tests, Wilcoxon and Kruskal-Wallis techniques and Cox proportional hazards regression modeling.

Results: We reviewed 1267 records, of which 669 had an ISS of 10 or greater and were included in the analysis. In the study population, 15.5% sustained only amputation injuries (n=104, AMP only), 10.8% sustained amputation and NCTI (n=72, AMP+NCTI), and 73.7% did not sustain either an amputation or an NCTI (n=493, Non-AMP/NCTI). AMP+NCTI had the highest mortality (16.7%) with transport time greater than 60 min. While the AMP+NCTI group had decreasing survival with longer transport times, AMP and Non-AMP/NCTI did not exhibit the same trend.

Conclusions: A decreased transport time from the point of injury to a medical treatment facility was associated with decreased mortality in patients who suffered a combination of amputation injury and NCTI. No significant association between transport time and outcomes was found in patients who did not sustain NCTI. Priority for rapid evacuation of combat casualties should be given to those with NCTI.

Key words Transport time, Non-compressible torso injury, Traumatic amputation, Combat

Background

In combat operations, patients with traumatic injuries require urgent clinical care and expeditious evacuation to improve survival [1]. In recent wars in Iraq and Afghanistan, prehospital providers such as ground medics and aeromedical evacuation (AE) teams were often the first responders. Aeromedical evacuation platforms such as MEDEVAC allow for urgent evacuation to medical treatment facilities (MTF) that can provide the more complex, necessary lifesaving interventions that are not otherwise possible at point of injury (POI) or en route. Transport times may vary depending on environmental factors and the ability to land in combatant locations [2]. Urgent response and transport can be delayed due to tactical issues, which may interfere with timely life-saving care. Previous studies have shown that long transport times are associated with increased morbidity and mortality [3]. There are limited data on the influence of transport time on patient outcomes with specific types of injury.

Compared to civilian trauma, combat-related injuries are unique due to the explosive weapons and high velocity projectiles used in war. Blast related injuries were the leading mechanism of injury sustained during recent military conflicts [4-6]. As a result, traumatic extremity amputation is common among the combat injured. Between 2000 and 2011, over 1600 cases of military traumatic amputation were reported [7]. At the POI, ground medics or fellow combatants applied tourniquets to prevent hemorrhage; however, swift evacuation for surgical hemorrhage control may influence a patient's long-term outcome.

Non-compressible torso hemorrhage (NCTH) consists of those injuries resulting in intrathoracic or intra-abdominal hemorrhage that cannot be controlled with manual pressure. NCTH has been defined as vascular disruption from 1 or more of the following anatomic categories: the thoracic cavity, solid organ injury $\geq$ grade 4 (liver, kidney, spleen), named axial torso vessel, and pelvic fracture with ring disruption. [8]. NCTH is the most common cause of potentially survivable death in both military and civilian trauma [8-13]. The mortality of combat NCTH is over 85%, and almost 90% of deaths occur before arrival to an MTF [12]. Prehospital management of non-compressible torso injury (NCTI) therefore presents the greatest opportunity to improve survival from combat trauma. Understanding the effect of prehospital transport time may assist in improving the management of this highly lethal injury pattern.

While previous research has demonstrated a direct relationship between transport time and combat mortality, the specific wartime injuries for which decreased evacuation time confers a benefit is not yet known [14]. The primary objective of this study was to determine the impact of the duration of time from the initial request for medical evacuation to arrival at an MTF on morbidity and mortality through thirty days after injury, in those casualties with traumatic extremity amputation and non-compressible torso injury.

Methods

We obtained approval from the Wilford Hall Ambulatory Surgical Center Institutional Review Board (IRB) and conducted this study under the approved protocol. We completed a retrospective review of MEDEVAC patient care records (PCRs) for United States (US) military personnel who sustained traumatic amputations and NCTI in the Operation Enduring Freedom (OEF) Theater of Operations between January 2011 and March 2014. This study was an additional (or extension) analysis performed on a dataset (convenience sample of consecutive records) previously compiled [15]. In the previous study, we excluded PCRs of casualties who were documented to be non-survivors at the POI or were transported to an MTF solely to be pronounced dead. This was to exclude casualties who did not receive any interventions and for whom transport time would not have made a difference in outcome.

To identify the patient population of interest, we queried the Department of Defense Trauma Registry (DoDTR) with specified ICD-9/10 codes and Abbreviated Injury Score (AIS) codes (Additional File 1) [12]. The retrieved list of patients was matched with our study electronic database containing data from abstracted PCRs. Patient data from the POI to the first MTF was abstracted from PCRs by trained research team members and entered into an electronic database (Microsoft Excel 2010, Redmond, WA). Data points included demographics, injury description, provider type, procedures, medications administered, clinical events, analgesics administered, and in-theater survival. Transport time was estimated by using the time stamp of the 9-Line call (request for medical evacuation) to time of arrival at the first MTF. The 9-Line call time was the most consistently available (98%) and was highly correlated (R-value: 0.9757; 95% confidence interval (0.9729-0.9782) with injury time, if not the same time as the documented time of injury. Clinical events were identified from provider narrative and descriptions of events documented in the PCR. Missing or unavailable data were reconciled using the Theater Medical Data System (TMDS). We implemented a quality assurance (QA) process to ensure consistency among abstractors, to include secondary abstractor review and reconciliation of 100% of records [15].

In our study database, we included an injury severity score (ISS) and maximum AIS for each of the six body regions provided by DoDTR. For this study, we excluded casualties with an ISS less than 10 to focus on comparable study groups and concentrate on severely injured casualties who would have benefited from shorter transport. The dataset also included supplemental outcome data such as vital signs, complications, ventilator days, intensive care unit (ICU) days, hospital days, mortality, and disposition at discharge from each MTF and up to 30 days. For statistical analysis, we grouped patients as traumatic amputation and NCTI (AMP+NCTI), traumatic amputation only (AMP), and neither AMP nor NCTI (Non-AMP/NCTI). No patients in our study had NCTI without AMP. We also binned patients using transport time intervals: <30 min, 30-60 min, and >60 min. We evaluated categorical data using chi-squared and, as appropriate, Fisher's exact tests. The Cochran-Armitage Trend test was applied to evaluate the association between survival rates and transport-time intervals. Proportions were reported as percentages along with 95% confidence interval. Following the Shapiro-Wilks test and normality plot assessments, we compared continuous variables using Wilcoxon and Kruskal-Wallis techniques. Regression analyses were limited due to low mortality; thus, we performed Cox proportional hazards regression modeling for time to discharge from ICU and hospital days. Analyses were conducted using JMP version 13 (SAS Institute Inc., Cary, NC).

Results

We reviewed 1267 PCRs, of which 669 had an ISS of 10 or greater and were included in the analysis. In this study, 15.5% sustained only amputation injuries (n=104, AMP only), 10.8% amputation and non-compressible torso injuries (n=72, AMP+NCTI), and 73.7% did not sustain either an amputation or a non-compressible torso injury (n=493, Non-AMP/NCTI). Of the 176 patients with AMP, 40.9% (n=72) also had NCTI. Most injured patients were male (98.8%) with a median age of 24 years old, and these proportions were not different among the groups (Table 1). With a median transport time of 36 min, there was no significant difference in elapsed time from POI to MTF among the three groups (p=0.7793). Casualties were transported to a Role 2 (52.0%) or Role 3 (48.0%) facility. The predominant mechanism of injury was explosion (72.3%) followed by penetrating injuries (26.5%). AMP+NCTI patients were more severely injured (median ISS of 33), followed by AMP and Non-AMP/NCTI.

Table 1 Descriptive summary of study population: US casualties transported from point-of-injury to MTF via MEDEVAC

	All %, 95% CI (count) or median [IQR] n=669	**AMP+NCTI** %, 95% CI (count) or median [IQR] n=72	**AMP** %, 95% CI (count) or median [IQR] n=104	**Non-AMP/NCTI** %, 95% CI (count) or median [IQR] n=493	**p-value**
Male	99, 98-100 (661/665)	100, 95-100 (72/72)	100, 96-100 (103/103)	99, 98-100 (486/490)	0.2935
Age	24 [22-28]	23 [21-27]	24 [21-27]	24 [22-28]	0.1128
Injury to MTF (minutes)	41 [31-56]	34 [28-45]	34 [27-46]	44 [33-59]	<0.0001
9-Line to MTF (minutes)	36 [29-47]	32 [25-40]	32 [27-44]	38 [30-51]	<0.0001
Injury Description*					
Blast	72, 69-76 (484/669)	100, 95-100 (72/72)	95, 89-98 (99/104)	63, 59-68 (313/493)	<0.0001
Penetrating	26, 23-30 (177/669)	0, 0-5 (0/72)	4, 2-9 (4/104)	35, 31-39 (173/493)	<0.0001
Blunt	1, 0.6-2 (8/669)	0, 0-5 (0/72)	1, 0.2-5 (1/103)	1 0.6-3 7/493)	0.7749
ISS	17 [12-27]	33 [25-40]	18 [14-27]	17 [12-24]	<0.0001
GCS of 3	3, 2-5 (17/552)	2, 0.2-8 (1/65)	3, 1-9 (3/89)	3, 1-6 (13/398)	0.7042
Head Injury (AIS of Head ≥2)	65, 56-74 (240/369)	74, 60-85 (32/43)	62, 50-73 (38/61)	64, 52-75 (170/265)	0.1169
Prehospital Hypotension (% SBP<90)	25, 21-29 (117/472)	47, 35-60 (26/55)	27, 18-37 (22/82)	21, 17-25 (69/335)	0.0015

30-Day Mortality	5, 3-7 (31/662)	8, 4-17 (6/72)	4, 2-10 (4/103)	4, 3-7 (21/487)	0.3045

AMP+NCTI, traumatic amputation and non-compressible torso injury; AMP, traumatic amputation only; Non-AMP/NCTI, neither traumatic amputation nor non-compressible torso injury; CI, confidence interval; IQR interquartile range; MTF, medical Treatment Facility; ISS, injury Severity Score; GCS, Glasgow Coma Scale; AIS, abbreviated Injury Scale; SBP, systolic blood pressure

Blast, penetrating, and blunt are mutually exclusive

Evaluating study injury groups by transport time, the median ISS was higher in AMP+NCTI at each time interval (Table 2). AMP and AMP+NCTI were more likely to be transported to a Role 3 (74.5% and 66.2%, respectively) compared to Non-AMP/NCTI (39.7%, P<0.0001). The Non-AMP/NCTI group was least likely to have received tourniquets, blood products, intravenous access fluids, or an airway procedure during prehospital transport. Likewise, the Non-AMP/NCTI group had the least number of prehospital procedures performed (Table 3). When comparing by transport time groups, casualties were transported to Role 2 (50.6%, <30 min; 51.9%, 30-60 min; 56.3%, >60 min) or Role 3 facility (49.4%, <30 min; 48.1%, 30-60 min; 43.8%, >60 min) in equal proportions (p=0.7411). Blood product administration was more likely in the 30-60 min (10.0%) group compared to <30 min (4.8%) or >60 min (4.2%, p=0.0339). We did not note any other incidence rate differences in prehospital procedures performed between the study transport-time groups. AMP+NCTI had more days spent in the ICU and in the hospital (Figure 1). AMP+NCTI had the highest mortality (16.7%) with transport time greater than 60 min. While the AMP+NCTI group had decreasing survival with longer transport times, AMP and Non-AMP/NCTI did not exhibit the same trend (Figure 2).

Table 2 ISS by injury type and transport time groups (n, median (IQR))

Duration	**AMP+NCTI** (n=72)	**AMP** (n=104)	**Non-AMP/NCTI** (n=493)	p value
<30 min	33 (24-41) (27)	18 (14-26) (38)	17 (12-26) (122)	<0.0001
30-60 min	33 (24-43) (39)	19 (14-27) (59)	17 (11-22) (312)	<0.0001
>60 min	29 (28-38) (6)	21 (17-27) (7)	14 (11-22) (59)	0.0003

AMP+NCTI, traumatic amputation and non-compressible torso injury; AMP, traumatic amputation only; Non-AMP/NCTI, neither traumatic amputation nor non-compressible torso injury; IQR, interquartile range

Table 3 Prehospital interventions performed

Item	**All** %, 95% CI (count) or median [IQR] n=669	**AMP+NCTI** %, 95% CI (count) or median [IQR] n=72	**AMP** %, 95% CI (count) or median [IQR] n=104	**Non-AMP/NCTI** %, 95% CI (count) or median [IQR] n=493	**p-value**
Tourniquets	51, 47-55 (342/669)	100, 95-100 (72/72)	91, 84-95 (95/104)	35, 31-40 (175/493)	<0.0001
IV	54, 50-58 (360/669)	62, 54-75 (47/72)	72, 63-80 (75/104)	48, 44-53 (238/493)	<0.0001
Fluids	54, 50-58 (360/669)	65, 54-75 (47/72)	72, 63-80 (75/104)	48, 44-53 (238/493)	<0.0001
Blood	8, 6-10 (53/669)	17, 10-27 (12/72)	27, 19-36 (28/104)	3, 2-4 (13/493)	<0.0001
Chest Needle	4, 3-6 (27/669)	3, 1-10 (2/72)	1, 0.2-5 (1/104)	5, 3-7 (24/493)	0.0914
Any Airway	58, 55-62 (390/669)	78, 67-86 (56/72)	72, 63-80 (75/104)	53, 48-57 (259/493)	<0.0001
Chest Seal	5, 4-7 (35/669)	100, 95-100 (72/72)	2, 1-7 (2/104)	7, 5-9 (33/493)	0.0018
Number of Prehospital Interventions	2 [1-4]	4 [2-4]	4 [2-4]	2 [1-3]	<0.0001

AMP+NCTI, traumatic amputation and non-compressible torso injury; AMP, traumatic amputation only; Non-AMP/NCTI, neither traumatic amputation nor non-compressible torso injury; CI, confidence interval; IQR, interquartile range

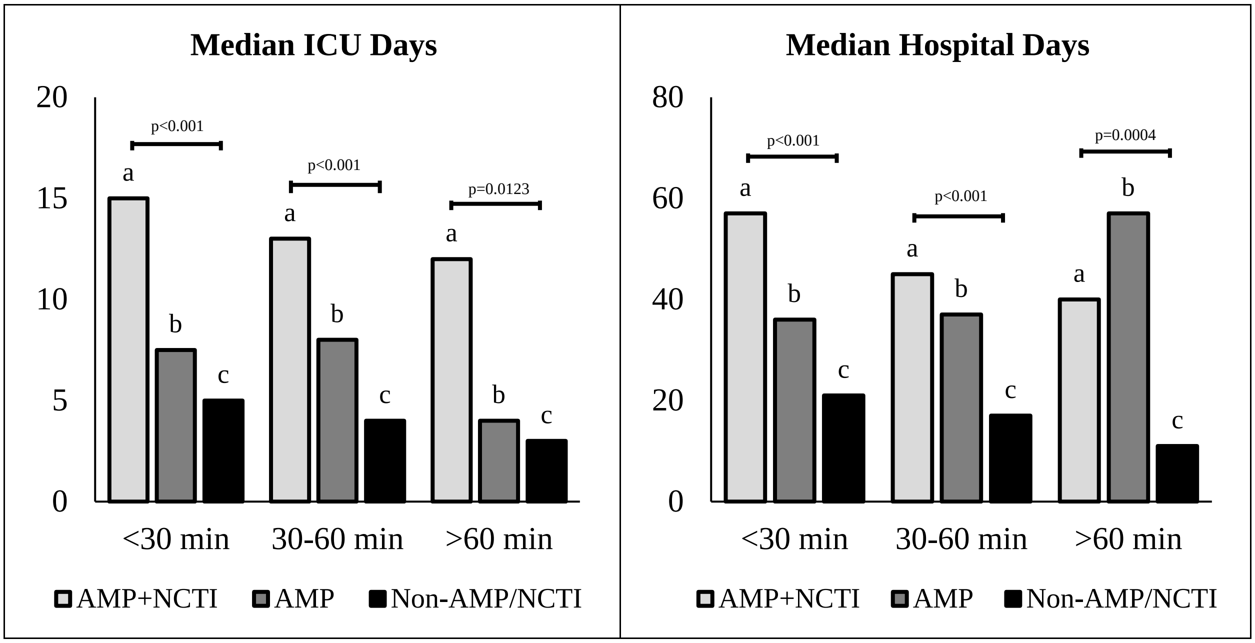

Figure 1 Hospital stay outcomes following prehospital transport of study groups
ICU
a: AMP+NCTI, <30 min vs 30-60 min vs >60 min, p=0.1884
b: AMP, <30 min vs 30-60 min vs >60 min, p=0.3479
c: None, <30 min vs 30-60 min vs >60 min, p=0.0667

Hospital Days
a: AMP+NCTI, <30 min vs 30-60 min vs >60 min, p=0.2412
b: AMP, <30 min vs 30-60 min vs >60 min, p=0.3704
c: None, <30 min vs 30-60 min vs >60 min, p=0.0036

Min, minutes; AMP+NCTI, traumatic amputation and non-compressible torso injury; AMP, traumatic amputation only; Non-AMP/NCTI, neither traumatic amputation nor non-compressible torso injury

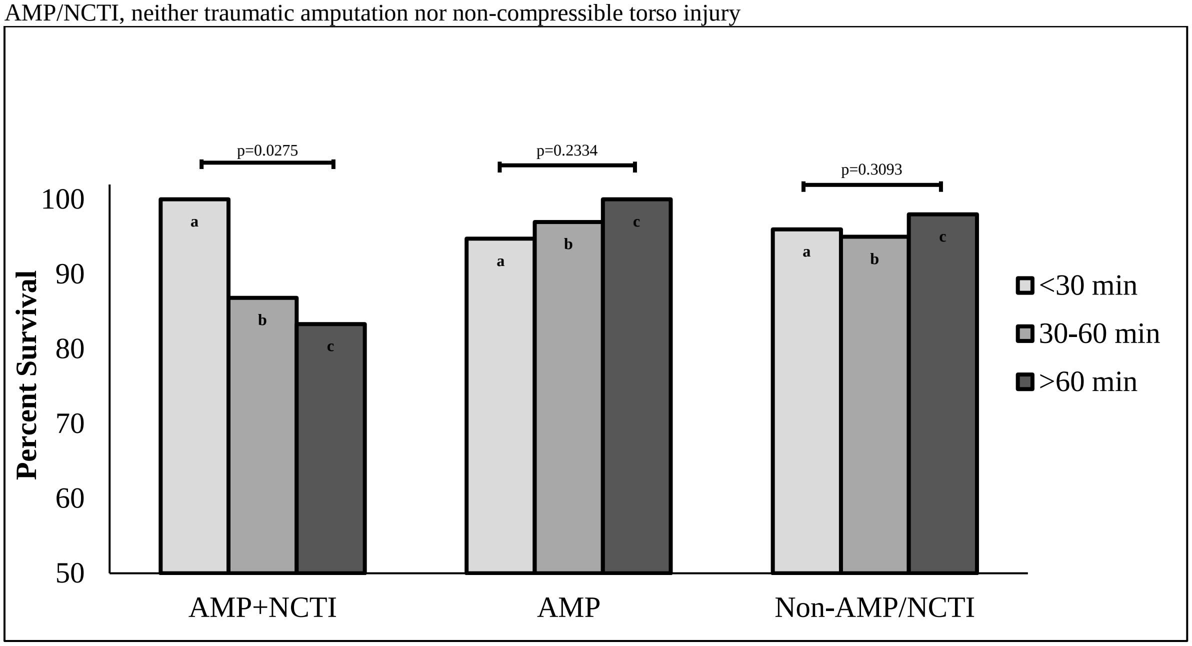

Figure 2 Study group percent survival by transport time

AMP+NCTI, amputation and non-compressible torso injury; AMP, traumatic amputation only; Non-AMP/NCTI, neither traumatic amputation nor non-compressible torso injury; min, minutes

In proportional hazard models, the AMP and Non-AMP/NCTI groups combined were more likely to discharge from the ICU more quickly (risk ratio 2.29, 1.79-2.97) compared to the AMP+NCTI group (p<0.0001). We had similar findings in models of time to hospital discharge. AMP and Non-AMP/NCTI combined were more likely to discharge from the hospital more quickly (risk ratio 2.5, 1.94-3.26) than the AMP+NCTI group (p<0.0001).

Adjusting for injury group and ISS, patients with a transport time interval >60 min were likely to discharge from the ICU more quickly (risk ratio 1.43, 1.03-1.99) compared to <30 min transports (p=0.0329). Additionally, while neither tourniquet alone nor blood alone decreased risks, patients who had any combination of tourniquet and blood product administration prehospital were likely to discharge from the ICU more quickly (risk ratio 2.71, 1.03-7.1; p=0.0425).

In time-to-hospital-discharge models, after adjusting for injury group and ISS, patients with transport time interval 30-60 and >60 min were likely to discharge from the hospital more quickly (risk ratio 1.34, 1.12-1.61; p=0.0016 and 1.62, 1.16-2.23; respectively) compared to <30 min transports (p=0.0053). Prehospital procedures did not reduce the risk of a longer hospital stay.

Additional sub analysis

Evaluating moderate-to-severe head injury with concomitant amputation/s, there was no significant in-theater mortality difference (2.9% versus 0.0%; p=1.000). A larger sample size with a greater mortality rate may yield different results. However, decreased level of consciousness (GCS of 3) combined with hypotension (SBP<90) was associated with increased odds of mortality (4.17 (1.84-9.45), p=0.0006). Hypotension alone did not increase odds of mortality.

Subsequently, we assessed the influence of concomitant upper and lower limb amputations. Sustaining both upper and lower limb amputations presented with the highest in-theater mortality (combined, 11.4%; lower amputation, 2.9%; upper amputation, 0.0%; p=0.0288). Faster evacuation times did not confer a survival benefit to patients who sustained combined upper and lower limb amputations (p=0.7541).

Discussion

Our results demonstrate a statistical association between shorter transport times and AMP+NCTI survival; however, transport time was not associated with outcomes in those patients with isolated extremity amputations. Our results may guide future evacuation prioritization based on those who stand to gain the greatest benefit from expeditious evacuation or from far forward prehospital interventions when rapid evacuation is not feasible.

While previous civilian and military studies have evaluated the impact of the “golden hour,” our study evaluated the impact of transport time during a unique time in military medical history. On June 15, 2009, Secretary of Defense Robert M. Gates established a policy that the time from medical evacuation request until the injured patient arrived at a treatment facility should be less than 60 min [16]. Our study evaluates the impact of medical transport times over a narrow timeframe of less than 90 min. Our data are also unique given that our patient sample occurred after the widespread use of tourniquets, the forward deployment of blood product administration, the increased utilization of paramedics and nurses for medical evacuation, and the increased transport of patients directly to a combat support hospital instead of to a forward surgical team [14]. These interventions, aimed at decreasing preventable combat mortality, likely altered the impact of medical evacuation times on patient outcomes.

Despite recent advancement in prehospital combat casualty care, our study reflects the continued importance of minimizing prehospital evacuation times in patients with NCTI. Previous autopsybased studies have determined that most potentially preventable combat deaths occurred due to exsanguination from the torso [17,18]. Our finding of a direct association between transport time and mortality in NCTI supports these results. However, civilian literature has demonstrated mixed results, with most studies finding no significant association between transport time and mortality in patients with thoracoabdominal injury [19]. The generalization of these findings to the civilian population is questionable, as injuries from explosive devices or high velocity rifles are uncommon in the civilian environment but account for most injuries in our dataset.

Our study found no association between transport time and mortality in patients who suffered AMP without NCTI. This may be because our patient sample was taken after the widespread implementation of rapid tourniquet use. Rapid control of hemorrhage with tourniquet application likely allows for survival during extended evacuation. While previous studies have found that a considerable number of combatants died from extremity exsanguination, this was prior to the widespread adoption of easily and rapidly applied tourniquets [17,18]. Studies conducted later during the conflict in Afghanistan found high rates of tourniquet use, which likely accounts for our findings [20].

Previous studies evaluate the impact of medical evacuation capabilities upon mortality in relation to AIS and ISS. However, AIS and ISS are not tools available to combat medics at the time of injury. Medics are trained to routinely assess for NCTI, AMP, and other injuries. The results of our study can easily be disseminated to military medics and assist them in determining the appropriate level of triage and the urgency of rapid medical evacuation. NCTI may not have been identified or diagnosed by MEDEVAC providers; thus, expanded training to include use of ultrasound may be advisable for the continued optimization of care. Use of ultrasound has been fielded by medics and by other en route team members in the past. Several studies have supported the use of ultrasound by prehospital medics and non-clinical service members with minimal training [21-24]. In addition, ultrasound devices that are aided or have artificial intelligence such as the Butterfly [25] remove the learning curve for medics and provide results for clinical decision making. However, broad use and sustainment of skills is a challenge and an opportunity. Ultrasound is being used in military en route and austere settings, and newer off-the-shelf technology is making it easier for our medics. Furthermore, combining the findings of our study with previous research allows one to reasonably conclude that those patients with NCTI should receive the most advanced medical capabilities available.

Other studies have predominately focused on in-theater outcomes (approximately 24-72 hours after injury); conversely, our study evaluated the impact of transport time on 30-day outcomes. Shorter transport time could improve in-theater survival without impacting 30-day outcomes. We found an association between shorter transport times and 30-day mortality in patients with AMP + NCTI. Beyond mortality benefit, our study also found a direct relationship between transport time and duration of hospital and ICU stay in the AMP+NCTI group. Rapid transport of these patients has the potential to improve the patients' quality of life and decrease utilization of medical resources. While increased equipment and personnel are necessary to decrease evacuation time, the cost may be offset by fewer hospital days and decreased utilization of inpatient medical resources .

Our study has several limitations. Most of our patients were evacuated within 1 hour. While a shorter evacuation time was not associated with decrease mortality in the AMP group, these results cannot be generalized to prolonged transport times (2+ hours). Lengthy transport times may still impact patients without NCTI in resource-limited areas of operation, such as the Pacific or Africa. Most of our patients suffered blast injuries, and our results may not be generalizable to those suffering from gun-shot wounds, aircraft crashes, and other forms of combat trauma. However, given the effectiveness and ease of the use of explosives, they are likely to remain a common source of combat casualties.

Furthermore, studies evaluating transport time are observational and not randomized; therefore, the potential for selection bias exists. Particularly, patients with more severe injury may be evacuated more rapidly as fellow combatants and medical personnel act with greater urgency in caring for this subgroup. Thus, those with the greatest injury and highest risk of death may be transported more quickly than those with less severe injuries (a basic premise of triage). In addition, shorter evacuation times along with the combat setting may have limited the opportunity for interventions such as blood product administration. However, there was no significant difference in ISS between the transport times, making this bias unlikely. Lastly, this study is reflective of combat-injured military members and may have limited generalizability in the civilian trauma populations.

Future research should evaluate the impact of rapid access to blood products, forward deployment of advanced medical providers and surgical capabilities, utilization of advanced en route care capabilities, and prehospital medical devices on the treatment of NCTI. The impact of transport time should also be evaluated in circumstances when these resources are available, as they may change the significance of evacuation time. As the military engages in operations resulting in significantly extended evacuation times of hours to days (i.e., Africa and the Pacific Ocean), military researchers and leaders will need to determine the effect of prolonged transport time on patient outcomes. Finally, studies evaluating the potential use of unmanned aerial vehicles or other tools to ensure rapid evacuation of combat casualties in resource-limited environments should be conducted.

Given that our study found that short evacuation times appear to confer the greatest benefit in those patients suffering from NCTI + AMP and other studies have found NCTI to be a leading cause of preventable combat mortality [7,9], when feasible, evacuation times of patients with NCTI should remain under 30 min. In those circumstances where transport of NCTI patients from the POI to a Role 2/3 facility is not possible, rapid access to blood products, forward deployed advanced medical providers and advanced en route care capabilities, and/or prehospital medical devices, and/or procedures for the control of NCTI may decrease mortality [1,2,13].

Conclusion

A decreased transport time from the point of injury to the medical treatment facility was associated with decreased mortality in those patients who suffered a combination of an amputation injury and a non-compressible torso injury. No significant association between transport time and outcomes was found in patients who did not sustain a non-compressible torso injury. Priority for rapid evacuation of combat casualties should be given to those with non-compressible torso injury.

Abbreviation

AE: aeromedical evacuation; AIS: abbreviated injury score; AMP: amputation; DoDTR: Department of Defense Trauma Registry; ICU: intensive care unit; IRB: institutional review board; ISS: injury severity score; MTF: medical treatment facility; NCTH: non-compressible torso hemorrhage; NCTI: non-compressible torso injury; OEF: Operation Enduring Freedom; POI: point of injury; PCR: patient care record; TMDS: Theater Medical Data System

Ethics approval and consent to participate

This study was approved by the Wilford Hall Ambulatory Surgical Center Institutional Review Board and conducted under the approved protocol

Consent for publication

Not applicable

Availability of data and material

All relevant data are presented in the text and the tables

Competing interests

The authors declare that there are no conflicts of interest according to the guidelines of the international Committee of Medical Journal Editors.

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Authors' contributions

JKM, VSB, SCS, AGM and CAP contributed to the study design. JKM provided study oversight. SCS performed the literature review. AGM performed the data analysis. CAP, JDL and AGM performed quality assurance review. All authors were involved in data interpretation, writing, and critical revisions.

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Disclaimer

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