REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
30/11/2018	Journal	30/11/2018

4. TITLE AND SUBTITLE
Determining Predictors of Survival among Traumatic Cardiopulmonary Arrest Patients in a Combat Theater Environment

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Lt Col Maddry, Joseph K

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
59th Clinical Investigations and Research Support
1100 Wilford Hall Loop, Bldg 4430
JBSA – Lackland, TX 78236-9908
210-292-7141

8. PERFORMING ORGANIZATION REPORT NUMBER
18253

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
59th Clinical Investigations and Research Support
1100 Wilford Hall Loop, Bldg 4430
JBSA – Lackland, TX 78236-9908
210-292-7141

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release. Distribution is unlimited.

13. SUPPLEMENTARY NOTES
DTIC (Close-Out Report)

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			SSgt Toth
					19b. TELEPHONE NUMBER *(Include area code)* 210-292-7141

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59th Medical Wing Science and Technology

JBSA-Lackland, Texas 78236-5415

En route Care Research Center

SCIENTIFIC AND TECHNICAL REPORT

Determining Predictors of Survival among Traumatic Cardiopulmonary Arrest Patients in a Combat Theater Environment

Kenton Anderson, MD
Alejandra Mora, MS
Maj Joseph K Maddry, MD

September 2018

Approved for public release; distribution is unlimited

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MICHAEL W. TRADER, GS-12, DAF
Program Analyst, Medical Modernization
59th Medical Wing

AMBER MALLORY, Ph.D., GS-15, DAF
Director, Trauma and Clinical Care Research
59th Medical Wing

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
09-06-2018	Closeout	January 2015-September 2018

4. TITLE AND SUBTITLE
Determining Predictors of Survival Among Traumatic Cardiopulmonary Arrest Patients in a Combat Theater Environment

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Anderson, K.
Mora, A.
Maddry, Joseph K.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
59th MDW/ST, En route Care Research Center
1100 Wilford Hall Loop, Bldg. 4554
JBSA Lackland AFB, TX 78236

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Medical Support Agency (AFMSA)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution A. Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Survival from traumatic cardiopulmonary arrest has been reported at a rate of 0-4% in the civilian pre-hospital setting, and many consider resuscitation of this group to be futile. No prior studies have assessed the patients that have received cardiopulmonary resuscitation (CPR) in a combat setting for predictors of survival. We conducted an IRB-approved query of the Department of Defense Trauma Registry to identify patients who received CPR in the pre-hospital setting or during the first 24 hours of injury in a combat theater setting, between 2007 and 2014. Data included demographics, injury description, duration of transport and CPR, procedures performed, complications, survival to admission and survival to discharge from the combat setting. Patients were also grouped according to location of their first cardiac arrest event: pre-hospital (PH) and in-hospital (IH). The groups were compared and evaluated by injury location and severity, transport time, type of resuscitation, procedures, complications, and survival to admission and discharge. Logistic regression was performed to identify individual predictors of survival. We identified 589 traumatically-injured subjects who received CPR in the combat setting. Seven subjects were withdrawn from the analysis because cardiopulmonary arrest developed more than 24 hours post-injury. Review of patient data found that on average, subjects were 24 [21-28] years of age, male (98%), and US military (67%). In total, 74 subjects (13%) survived and were transported out of the theater of operations. A

total of 281 were PH and 301 were IH. Survival to hospital discharge was lower in PH than IH (45% vs. 71%, <0.0001) and survival out of theater was also lower in PH than IH (8% vs. 17%, 0.0007). Of the PH subjects, survival to admission was associated with injuries to the face with hemostatic dressing (<0.0001) or injuries to the chest with hemostatic dressing (<0.0001). Survival to discharge was also associated with spinal immobilization (<0.0001). Among the IH group, survival was associated with closed chest cardiac massage (<0.0001) and the infusion of therapeutic substances (<0.0001). Differences in injury severity, transport time, any other procedures including open-chest cardiac massage, and complications did not predict survival in either group (>0.05). Injuries to the face or chest with the use of hemostatic dressings was found to be a predictor of survival to admission among PH subjects. Injuries to the chest and abdomen or abdomen alone as well as the use of spinal immobilization among PH subjects were found to be predictors of survival to discharge. Among the IH group, closed chest cardiac massage and the infusion of therapeutic substances were predictors of survival to discharge.

15. SUBJECT TERMS
Traumatic Cardiopulmonary Resuscitation, CPR, en route care

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Joseph K. Maddry, MD
U	U	U	SAR		19b. TELEPHONE NUMBER *(Include area code)* 210-539-4403

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1.0 SUMMARY

Background: Trauma represents the leading cause of death for all people between the ages of 1-46 as well as the leading cause of cardiac arrest in military conflicts, yet the approach to resuscitation of traumatic cardiopulmonary arrest (TCPA) patients remains controversial. Survival rates have been reported to be between 0% - 2.6% among civilian TCPA victims. In 2003, the National Association of Emergency Medical Services Physicians and the American College of Surgeons Committee on Trauma established guidelines regarding the withholding or termination of out-of-hospital resuscitation in TCPA; however, in light of some reports of improved outcomes, this guidance remains controversial. Guidelines regarding the treatment of TCPA victims are even more controversial in the military setting where the mechanism of injury and injury patterns are dissimilar to civilian injuries. The current tactical combat casualty care (TCCC) guidelines regarding CPR on the battlefield is that resuscitation of victims with no signs of life, "should not be attempted (TCCC 2017);" however, these guidelines may be based on inadequate evidence. Studies involving military TCPA patients have reported survival rates from 8 to as high as 24%.

The primary aim of our investigation was to describe patients who received CPR during TCPA in a combat theatre setting. Additionally, we also aimed to identify predictors of survival among those same patients.

Methods: We conducted a retrospective review of all patients in the DoD trauma registry who received cardiopulmonary resuscitation (CPR), (open or closed cardiac massage) within 24 hours of sustaining a traumatic injury, between January 01, 2007 and January 31, 2014. Subjects were grouped according to the geographic location where they first received CPR – either pre-hospital (PH) or in-hospital (IH). Categorical variables were analyzed using chi-square or Fisher's exact tests (for sample sizes less than 5) and reported as percentages with confidence intervals. Continuous variables were analyzed using Student's t-test or Wilcoxon tests and reported as mean ± standard deviation (SD). After evaluating the measures of central tendency, continuous variables were analyzed using Wilcoxon rank sum test.

Results:

- 582 subjects received cardiopulmonary resuscitation (CPR), (open or closed cardiac massage) within 24 hours of sustaining a traumatic injury.
- A total of 281 subjects experienced their first TCPA event in the prehospital setting and 301 experienced their first TCPA event in the hospital.
- Of the 281(48%) subjects that received prehospital CPR and CPR was continued after arrival to MTF in 246 (88%) subjects.
- There was no difference in gender, ethnicity, injury severity, or anatomic location of injury between the PH and IH groups.
- 45% of PH subjects survived to discharge from the first facility and 8% survived out of theater.
- 71% of the IH subjects survived to discharge from the first facility and 17% survived out of theater.

- Of the 35 subjects that only received CPR in the PH setting, 22 (63%) survived to discharge and 10 (29%) survived to 30 days.
- Of the 246 that continued to receive CPR once they arrived at the hospital, 94 (38%) survived to discharge and 12 (5%) survived to 30 days.
- Among all subjects, those who survived to 30 days had a higher ISS, received more PH procedures and had more complications.
- PH survival was associated with injuries to the face/chest ($p<0.0001$), hemostatic dressings ($p<0.0001$), spinal immobilization ($p<0.0001$), and blood product administration ($p<0.0001$).
- IH survival was associated with closed chest compressions ($p<0.0001$), infusion of therapeutic substances ($p<0.0001$), and blood product administration ($p<0.0001$).
- The PH survivors that arrived to Landstuhl Regional Medical Center had two more procedures performed in theater (4.0 vs. 2.0, $p<0.0008$) and experienced less complications up to 30 days following injury (1.0 vs. 3.5, $p=0.0194$) compared to the IH survivors.
- Non-survivors in the IH group were more likely to have documented bleeding ($p<0.0001$) and, albeit small numbers, trended toward an increase incidence of coagulopathy (18% vs 42%, $p=0.0631$).
- Considering prehospital versus hospital CPR and adjusting for ISS, patients that receive blood products had 2.3 times higher odds of survival (CI 1.62-3.27).
- In particular, the IH group had 2.1 higher odds of survival when accounting for blood product administration (CI 1.1-4.0).

Conclusions:

- Resuscitation of TCPA patients in a combat theatre is not futile; we report a 13% survival to 30 days among all patients receiving CPR in theater.
- Prudent and timely prehospital interventions confer survival in patients that experience TCPA in the field.
- Blood product administration to TCPA patients in the hospital may address potential patient bleeding and coagulopathy to confer survival in IH TCPA patients.
- There may be differences between the civilian and military TCPA populations which make civilian TCPA protocols less applicable to the military population.

Evidence-Based Recommendations:

- A more comprehensive evaluation of combat casualties experiencing TCPA should be conducted, as well as a detailed review of related published evidence.
- Clinical Practice Guidelines for combat casualty care should consider the uniqueness of the casualty, the environment and military provider training and skills. Civilian guidelines are useful, but may not account for variants found in battlefield care.

2.0 INTRODUCTION

While trauma represents the greatest threat to life for all people between the ages of 1-46, and the leading cause of cardiac arrest in military conflicts, resuscitation of traumatic cardiopulmonary arrest (TCPA) patients remains controversial (1-4). Survival rates in observational studies have been reported between 0% and 2.6% among civilian TCPA victims, leading some investigators to suggest pre-hospital resuscitation of TCPA victims may be futile and an inappropriate utilization of resources (5-8). In 2003, the National Association of Emergency Medical Services Physicians and the American College of Surgeons Committee on Trauma established guidelines regarding the withholding or termination of out-of-hospital resuscitation in the event of TCPA (9). However, acceptance of these guidelines has been limited by more recent reports that describe improved survival rates with good neurologic outcomes even when cardiopulmonary resuscitation (CPR) has been performed in breach of these published guidelines (4, 10-15).

Guidelines regarding the treatment of TCPA victims are even more controversial in the military setting where the mechanism of injury and injury patterns are dissimilar to civilian injuries (16). Unlike the civilian experience, highly-skilled field medics or physicians are often located nearby and able to rapidly control hemorrhage and initiate resuscitation including blood transfusion on the battlefield (17,18). Recent pre-hospital control of non-compressible hemorrhage using resuscitative endovascular occlusion of the aorta (REBOA) also has the potential to improve TCPA survival even further (19,20). The current tactical combat casualty care (TCCC) guidelines regarding CPR on the battlefield is that resuscitation of victims with no signs of life, “should not be attempted (21);” however, these guidelines are based on inadequate evidence. To support any change to the guidelines or improve TCPA outcomes in the combat theater setting, we must better understand the scope of the TCPA problem.

Although there are multiple reports of TCPA survival in the civilian setting, survival data in the military setting is lacking. Prior to this study, there were only three European reports of survival among TCPA patients in the military setting. A prospective report of 52 TCPA patients that presented to a field hospital in Afghanistan demonstrated an 8% survival to discharge rate; all survivors had good neurologic outcomes (4). Another descriptive report found that 18 of 78 (24%) TCPA patients who received CPR survived (22). The third study described survival in 11 of 26 patients who experienced TCPA and underwent resuscitative thoracotomy in the emergency department (23). More data is needed to better understand the military TCPA population so that the most appropriate treatment can be applied to this group.

3.0 METHODS

3.1 Study Design and Setting

A retrospective review of the Department of Defense Trauma Registry (DoDTR) was conducted to identify all patients who had received cardiopulmonary resuscitation (CPR) between January 01, 2007 and January 31, 2014. The DoDTR, during the study period, included all patients who were treated for traumatic injuries by the United States Military Health System during Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF) and Operation New Dawn (OND). This study was approved by the Institutional Review Board for the United States Army Institute of Surgical Research.

3.2 Selection of Participants

All adults identified in the United States military, North Atlantic Treaty Organization (NATO) military, coalition forces, local civilians, contractors and foreign nationals who received either open or closed cardiac massage within 24 hours of sustaining a traumatic injury during the study period were eligible for inclusion. Subjects were excluded if they first received CPR after they had been admitted to the intensive care unit (ICU) or more than 24 hours after their traumatic injury to ensure that CPR was most likely performed in response to the acute injury.

3.3 Measurements

Data abstraction from the DoDTR was conducted by a single abstractor and entered into a standardized data collection form. In the case of missing data, the corresponding space on the form was left empty. All data abstracted were objective. There were no conflicting or ambiguous data used in this study. The abstractor was not a study investigator and was blinded to the objectives and outcomes of the study. All data analysis was performed after data abstraction was complete.

Data abstracted included demographics, injury description, and anatomic location of injury, transport time, pre-hospital procedures, resuscitation type, complications, initial medical treatment facility (MTF), and survival outcomes. Independent variables within each of these categories are listed in Tables 1-3. For reference, a Role 2 MTF can provide damage control resuscitation as well as laboratory and imaging services, has limited holding capacity and no intensive care unit. A Role 3 MTF has all the capabilities of a Role 2 MTF, all major specialties available, and greater holding capacity as well as an intensive care unit.

3.4 Outcomes

Outcome variables included survival to discharge and 30-day survival. Survival to discharge included transfer to MTFs with higher levels of care.

3.5 Analysis

Subjects were grouped according to the geographic location where they first received CPR – either pre-hospital (PH) or in-hospital (IH). Categorical variables were analyzed using chi-square or Fischer's exact tests (for sample sizes less than 5) and reported as percentages with confidence intervals. Continuous variables were analyzed using Student's t-test or Wilcoxon tests and reported as mean ± standard deviation (SD). After evaluating the measures of central tendency, continuous variables were analyzed using Wilcoxon rank sum test.

4.0 RESULTS

4.1 Characteristics of Study Subjects

During the study period a total of 589 subjects received CPR; seven were withdrawn from the analysis (Figure 1). Five subjects were excluded because they had CPR performed more than 24 hours after their injury, and two more were excluded because they received CPR after they had been admitted to the intensive care unit. Thirty-five (12%) of the 281 PH subjects received CPR only in the PH setting, whereas the remaining 246 (88%) continued to receive CPR once they had arrived to the hospital emergency department.

Demographics and injury description of the study subjects are listed in Table 1. There was no difference in gender, ethnicity, injury severity, or anatomic location of injury between the PH and IH groups. A greater number of the PH subjects served in Operation Enduring Freedom (OEF - Afghanistan) and more of the IH subjects served in Operation Iraqi Freedom (OIF – Iraq). PH subjects had more pre-hospital procedures performed, received fewer blood products, had longer transport times, and had fewer complications than IH subjects (Table 1).

Figure 1. Subject Characteristics

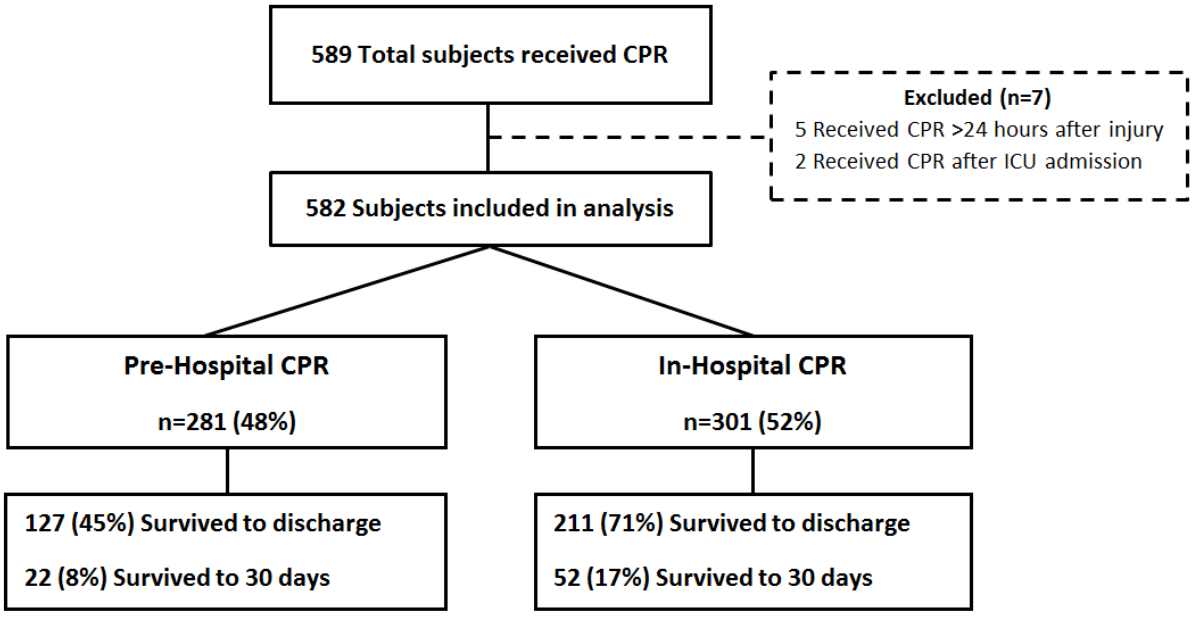

Table 1. Demographics

Subjects *	**All** Mean±SD; Median [IQR] or % (95% CI) **n=582**	**PH CPR** Mean±SD; Median [IQR] or % (95% CI) **n=281**	**IH CPR** Mean±SD; Median [IQR] or % (95% CI) **n=301**	**p-value**
Demographics				
Mean age, years	26±7.6; 24 [21-28]	26±8.5; 24 [21-28]	26±6.7; 23 [21-28]	0.9005
Male	98 (97-99)	98 (95-99)	98 (96-99)	0.6747
White	63 (58-68)	66 (58-73)	61 (54-67)	0.3532
Black	4 (2-6)	4 (2-8)	4 (2-7)	0.9108
Asian/Pacific Islander	1 (0.3-3)	1 (0.1-4)	1 (0.3-4)	0.6887
Other ethnicity	32 (28-38)	30 (23-38)	35 (28-42)	0.3548
OEF	63 (59-66)	70 (65-75)	55 (50-61)	0.0003
OIF	37 (33-41)	30 (25-35)	44 (38-49)	0.0005
OND	1 (0.3-2)	0.4 (0.1-2)	1 (0.3-3)	0.3375

Categorical data analyzed using chi-square (Fisher's Exact for sample size less than 5). Following evaluation of central tendency, continuous variables analyzed using Wilcoxon

4.2 Main Results

Survival was higher for IH subjects than PH subjects. One hundred twenty-seven (45%) of the 281 PH subjects and 214 (71%) of the IH subjects survived to discharge (Table 1). Seventy-five of all 582 subjects (13%) survived to 30 days, and all survivors were transported out of the combat theater; 23 PH (8%) and 52 IH (17%) subjects survived to 30 days (Figure 1, Table 1). Of the 35 subjects that only received CPR in the PH setting, 22 (63%) survived to discharge and 10 (29%) survived to 30 days. Of the 246 that continued to receive CPR once they arrived to the hospital, 94 (38%) survived to discharge and 12 (5%) survived to 30 days.

Among all subjects, those who survived to 30 days had a higher ISS, received more PH procedures and had more complications (Tables 2 & 3). Among the PH group, those that were initially treated at a Role 2 MTF were less likely to survive (5%) compared to those who were initially treated at a Role 3 MTF (41%) ($p<0.0001$). Of the PH survivors, the average number of ventilator days was 5.7 (SD ±4.2), the number of ICU days was 8.3 (SD ±7.6), and the number of hospital days was 12.1 (SD ±12.8). Among the IH group, those that were initially treated at a Role 3 MTF were less likely to survive (12%) compared to those who were initially treated at a Role 2 MTF (25%) ($p<0.03$). Of the IH survivors, the average number of ventilator days was 11 (SD±12), the number of ICU days was 15 SD ±18), and the number of hospital days was 28 (SD ±41).

Among the PH subjects, survival to discharge was associated with injuries to the face (95CI 0.58-1.7, $p<0.0001$) and chest (95CI 0.40-1.2, $p<0.0001$) with hemostatic dressings. Injuries to the chest ($p=0.01$, 95CI 0.23-1.1) and abdomen (95CI 0.26-1.7, $p<0.01$) with c-spine immobilization were associated with 30-day survival among PH subjects. Among the IH subjects, 30-day survival was associated with closed chest compressions and infusion of therapeutic substances. Injury severity, injury type, other injury locations, other procedures, other resuscitation types, transport time and complications were not associated with survival to discharge or 30 days in either the PH or IH groups.

Table 2. Descriptive statistics of Prehospital CPR Subjects

	Non-Survivor Mean±SD; Median [IQR] or % (95% CI) **n=259**	**Survivor** Mean±SD; Median [IQR] or % (95% CI) **n=22**	**p-value**
Demographics			
Age, years	26±6.6; 24 [21-28]	34±19.2; 25 [23-38]	0.0559
Male	98 (95-99)	100 (85-100)	1.000
White	68 (60-75)	42 (19-68)	0.0778
Black	4 (2-9)	0	1.000
Asian/Pacific Islander	1 (0.1-4)	0	1.000
Other ethnicity	27 (21-35)	58 (32-81)	0.0327
OIF	31 (25-36)	18 (7-39)	0.3301
OEF	69 (64-75)	77 (57-90)	0.4333
OND	0	5 (1-22)	0.0783
Injury Description			
ISS	25±20.5; 19 [9-29]	28±12.4; 26[19-38]	0.0409
Battle Injury	86 (81-89)	82 (61-93)	0.5423
Blast Injury	54 (48-60)	64 (43-80)	0.4014
Penetrating Trauma	36 (0-42)	18 (7-39)	0.1064
Blunt Trauma	9 (6-13)	14 (5-33)	0.4845
Burn	0.4 (0.01-2)	5 (1-22)	0.1507
Other Injury	0.4 (0.01-2)	0	1.000
AIS Head	33 (28-39)	55 (35-73)	0.0494
AIS Face	8 (5-12)	41 (23-61)	<0.0001
AIS Chest	25 (20-31)	77 (57-90)	<0.0001
AIS Abdomen	22 (18-28)	55 (35-73)	0.0019
AIS Extremities	38 (33-44)	68 (47-84)	0.0064
AIS Skin	55 (49-61)	64 (43-80)	0.4414
Pre-hospital Procedures			
Number performed	2.9±1.9; 3 [2-4]	4.1±1.7; 4 [3-5]	0.0019
C-spine immobilization	7 (4-11)	36 (20-57)	0.0002
Abdominal/pelvic splints	0	5 (1-22)	0.0783
Central venous catheterization	0.4 (0.01-2)	5 (1-22)	0.1507
Cricothyrotomy	15 (11-19)	18 (7-39)	0.7539
Needle thoracostomy	10 (7-14)	5 (1-22)	0.3861
Thoracostomy tube	5 (3-8)	14 (5-33)	0.1449
Extremity splints	0	0	-
Pressure Packing	21 (16-26)	0	0.0105
Hemostatic dressing	17 (13-22)	32 (16-53)	0.0954
Endotracheal intubation	41 (35-47)	50 (31-69)	0.4307

Intraosseous infusion	37 (31-43)	32 (16-53)	0.6209
Oxygen delivery	25 (20-31)	36 (20-57)	0.2629
Tourniquet	34 (28-40)	27 (13-48)	0.5393
Warming	28 (23-34)	45 (27-65)	0.0469
Transport time, minutes	57±65.9; 47 [30-65]	64±45.2; 56 [37-88]	0.4287
Resuscitation Type			
Closed chest compressions	89 (84-92)	75 (47-91)	0.1914
Open chest compressions	20 (16-26)	17 (5-45)	1.000
Unspecified chest compressions	4 (2-7)	0	1.000
Other electric countershock of heart	5 (3-9)	8 (1-35)	0.4987
Nonmechanical methods of resuscitation	4 (2-8)	0	1.000
Infusion of therapeutic agents	9 (6-13)	50 (25-75)	0.0004
Infusion of blood products	44 (38-50)	68 (47-84)	0.0309
Number of Resuscitation Procedures	1.3±0.6; 1 [1-2]	1.5±0.90; 1 [1-2]	0.5220
Complications			
Number recorded	0.2±0.75; 0 [0-0]	2.0±2.7; 1 [0-3]	<0.0001
At least one recorded	12 (9-17)	68 (47-84)	<0.0001

*Survival at 30 days was used to establish survival status

Table 3. Descriptive statistics of In-hospital CPR subjects

	Non-Survivor Mean±SD; Median [IQR] or % (95% CI) **n=249**	**Survivor** Mean±SD; Median [IQR] or % (95% CI) **n=52**	**p-value**
Demographics			
Age, years	26±6.4; 23 [21-28]	27±8.0; 24 [21-32]	0.7068
Male	98 (95-99)	100 (93-100)	0.5918
White	62 (54-69)	54 (36-70)	0.4043
Black	4 (2-8)	4 (1-18)	1.000
Asian/Pacific Islander	1 (0.3-4)	0	1.000
Other ethnicity	33 (26-41)	43 (27-61)	0.3236
OIF	47 (40-53)	29 (18-42)	0.0169
OEF	52 (46-58)	71 (58-82)	0.0110
OND	1 (0.4-3)	0	1.000
Injury Description			
ISS	22±18.1; 19 [9-26]	30±14.6; 29 [21-38]	<0.0001
Battle Injury	90 (85-93)	94 (84-98)	0.4386
Blast Injury	56 (50-62)	69 (56-80)	0.0707
Penetrating Trauma	38 (32-44)	25 (15-38)	0.0740
Blunt Trauma	6 (3-9)	4 (1-13)	1.000
Burn	0.4 (0.1-2)	2 (0.3-10)	0.3161
Other Injury	0.4 (0.1-2)	0	1.000
AIS Head	39 (33-45)	46 (33-59)	0.3115
AIS Face	11 (8-15)	37 (25-50)	<0.0001
AIS Chest	23 (18-28)	67 (54-78)	<0.0001
AIS Abdomen	27 (22-33)	60 (46-72)	<0.0001
AIS Extremities	39 (33-45)	85 (72-92)	<0.0001
AIS Skin	56 (50-62)	79 (66-88)	0.0017
Pre-hospital Procedures			
Number performed	1.8±1.8; 2 [0-3]	2.5±2.1; 2 [1-4]	0.0475
C-spine immobilization	7 [4-11]	16 (8-28)	0.0596
Abdominal/pelvic splints	0.4 (0.1-2)	0	1.000
Central venous catheterization	0	0	-
Cricothyrotomy	9 (6-13)	2 (0.3-10)	0.1457
Needle thoracostomy	2 (1-5)	0	0.5945
Thoracostomy tube	2 (1-4)	2 (0.3-10)	1.000
Extremity splints	0.4 (0.1-2)	0	1.000
Pressure Packing	0	8 (5-12)	0.0307
Hemostatic dressing	23 (18-28)	35 (23-48)	0.0840
Endotracheal intubation	17 (13-22)	17 (9-30)	0.9388

Intraosseous infusion	15 (11-20)	21 (12-34)	0.3087
Oxygen delivery	8 (5-12)	25 (15-38)	0.0012
Tourniquet	28 (23-34)	46 (33-59)	0.0128
Warming	48 (35-61)	33 (28-39)	0.0469
Transport time, minutes	48±49.4; 35 [23-60]	54±48.5; 38 [23-66]	0.4929
Resuscitation Type			
Closed chest compressions	89 (85-93)	98 (90-100)	0.0595
Open chest compressions	21 (16-27)	10 (4-21)	0.0473
Unspecified chest compressions	7 (5-11)	0	0.0504
Other electric countershock of heart	8 (5-12)	12 (6-23)	0.4401
Nonmechanical methods of resuscitation	4 (1-13)	4 (2-7)	1.000
Infusion of therapeutic agents	6 (6-13)	24 (14-37)	0.0071
Infusion of blood products	57 (50-63)	73 (60-83)	0.0248
Number of Resuscitation Procedures	1±0.7; 1 [1-2]	1.5±0.7; 1 [1-2]	0.4292
Complications			
Number recorded	1±1.4; 0 [0-1]	4±3.2; 4 [1-6]	<0.0001
At least one recorded	29 (23-34)	81 (68-89)	<0.0001

*Survival at 30 days was used to establish survival status

5.0 DISCUSSION

Resuscitation of TCPA patients remains a controversial topic, especially in the battlefield environment. Smaller reports from the United Kingdom suggest that survival from TCPA in the battlefield may be more common than survival in the civilian setting (4, 22, 23). Our study supports these findings as we were able to demonstrate an 8% 30-day survival prevalence among subjects who received CPR in the pre-hospital setting and prevalence increases to 13% when patients who received CPR shortly after arriving to the hospital are included.

Our study, coupled with smaller prior reports with similar findings, suggest that there may be differences between the civilian and military TCPA populations making civilian TCPA protocols less applicable to the military population. These differences may be highlighted by the young average age of our cohort, the majority of which experienced blast injuries that are uncommon among civilian settings. Many of our young military subjects likely maintained higher levels of physical fitness and had greater physiologic reserve than their civilian counterparts at the time of injury. In addition, prior reports have suggested that early advanced intervention may improve outcomes (4, 22). The military-trained medics and pre-hospital physicians who respond to battlefield injuries are able to perform more advanced procedures and provide higher levels of care than is typical in the United States civilian emergency medical services systems. A report from the UK had similar survival results (7.5%) among civilian TCPA victims where the helicopter EMS team consisted of a physician and a flight paramedic who were able to perform advanced procedures, including on-scene thoracotomy (12). These results may suggest that the capability to perform advanced lifesaving procedures at the location of injury could improve survival. Moreover, battlefield medics are often in close proximity to injured patients allowing them to respond almost immediately, and may be more emotionally-invested in saving the lives of victims who are often close friends.

In our study, injury type (blast, blunt, penetrating, etc.) was not associated with survival in either the PH or IH groups, suggesting that injury type may not be a deciding factor on how to manage TCPA in the battlefield. The anatomic location of injury did predict survival to discharge and 30 days among PH subjects. Those who sustained injuries to the face or chest with hemostatic dressings in place were more likely to survive to discharge. Injuries that were isolated to the face were intuitively more likely to survive; however, it was less obvious why patients with injuries to the chest were more likely to survive to discharge. Even more intriguing, subjects with injuries to either the chest or abdomen were more likely to survive to 30 days, both areas where non-compressible hemorrhage occurs. Previous reports have indicated that non-compressible hemorrhage is a leading cause of potentially survivable deaths on the battlefield (24-26, 28). It is possible that our data are confounded by the large presence of blast injuries. Hemorrhage that caused TCPA in most of our chest and abdominal injuries was primarily due to extremity injuries where tourniquets were applied appropriately. Therefore, it is possible that these patients survived more frequently than if the hemorrhage had been primarily due to intra-thoracic or intra-abdominal vascular injuries. A more detailed investigation will be required to elucidate these details. For subjects who survived to 30 days after IH CPR, closed chest compressions with the administration of therapeutic substances predicted survival. This combination of

interventions reflects typical advanced cardiac life support for non-traumatic cardiac arrest. Open chest compressions were not as common as closed chest compressions and did not predict survival in either the PH or IH groups suggesting that many of the IH subjects may have already had their hemorrhage controlled prior to experiencing cardiac arrest. Again, a more detailed investigation would be required to elucidate these details.

Conclusions

Resuscitation of TCPA patients in a combat theatre is not futile as we report a 13% survival to 30 days among all patients receiving CPR in theatre. Chest compressions predicted survival among IH TCPA victims who also received a transfusion of therapeutic substances in this retrospective review of military TCPA.

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APPENDIX: Publications and Presentations

A.1 Publications

Anderson, KL, Mora AG, Bebarta VB, Maddry JK. Cardiopulmonary Resuscitation for Trauma Patients in the Combat Theater: An Assessment for Survivors. Being submitted to Annals of Emergency Medicine

A.2 Presentations

1. Anderson, KL, Bloom AD, Mora AG, Ervin AT, Minnick JT, Maddry JK. Predictors of survival among traumatic cardiopulmonary arrest victims in a combat theater. Poster. ACEP, October 2015.
2. Anderson, KL, Mora AG, Bebarta VB, Maddry JK. Predictors of survival among traumatic cardiopulmonary arrest victims in a combat theater. Poster. SURF, June 2018.

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

AIS	Abbreviated Injury Severity
CPR	Cardiopulmonary Resuscitation
DODTR	Department of Defense Trauma Registry
ICU	Intensive Care Unit
IH	In-Hospital
ISS	Injury Severity Score
MTF	Medical Treatment Facility
NATO	North Atlantic Treaty Organization
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OND	Operation New Dawn
PH	Pre-Hospital
SD	Standard Deviation
TCCC	Tactical Combat Casualty Care
TCPA	Traumatic Cardiopulmonary Resuscitation