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Clinical paper

Cardiac massage for trauma patients in the battlefield: An assessment for survivors



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Abstract

Introduction: Survival from traumatic cardiopulmonary arrest (TCA) has been reported at a rate as low as 0–2.6% in the civilian pre-hospital setting, and many consider resuscitation of this group to be futile. The aim of this investigation was to describe patients who received cardiac massage during TCA in a battlefield setting; we also aimed to identify predictors of survival.

Methods: We conducted a review of the Department of Defense Trauma Registry to identify patients who received cardiac massage in the battlefield between 2007 and 2014. Patients were also grouped according to location of cardiac arrest: pre-hospital (PH) and in-hospital (IH). The groups were compared and evaluated by injury, transport time, type of resuscitation, and pre-hospital procedures. Outcome variables included survival to discharge and 30-day survival. Categorical variables were analysed using chi-square or Fisher's exact tests. Wilcoxon tests were performed for continuous variables. Regression modelling was used to assess for predictors of survival.

Results: 75 of all 582 patients (13%, 95% CI 10–16) survived to 30 days, and all survivors were transported out of the battlefield; 23 PH (7.8%, 95% CI 5.2–12) and 52 IH (17%, 95% CI 13–22) patients survived to 30 days ($p < 0.001$). Closed-chest cardiac massage with the administration of intravenous medications was associated with 30-day survival among IH patients.

Conclusions: We report a 13% survival to 30 days among all patients receiving cardiac massage in a battlefield setting. Closed-chest cardiac massage predicted survival among IH TCA victims who also received intravenous medications in this review of combat-related TCA.

Keywords: Cardiopulmonary resuscitation, Heart massage, Heart arrest, Trauma, Survival, Mortality, Battlefield, Military

Introduction

Traumatic injury is 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 (TCA) patients remains controversial.^{1–4} Survival rates in

observational studies have been reported as low as 0%–2.6% among civilian TCA victims, leading some investigators to state that pre-hospital resuscitation of TCA 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 TCA,⁹

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however, acceptance of these guidelines has been limited by more recent reports which have described improved survival rates with good neurologic outcomes even when cardiac massage had been performed in a breach of the published guidelines.^{10–16}

Guidelines regarding the treatment of TCA victims are even more controversial in the military setting where the mechanism of injury and injury patterns are dissimilar to civilian injuries.¹⁷ The current Tactical Combat Casualty Care guidelines regarding cardiac massage on the battlefield is that resuscitation of victims with no signs of life, “should not be attempted,” however, these guidelines are based on inadequate evidence.¹⁸ Prior to this study, there have only been three case series of TCA survival in the military setting; all are European. A prospective report of 52 TCA 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 study reported that 18 of 78 (24%) TCA patients receiving cardiac massage survived.¹⁹ The largest, and most recent study, reported a 10.6% survival in a retrospective review of the United Kingdom (UK) Joint Theatre Trauma Registry.²⁰ An additional study described survival in 11 of 26 patients who experienced TCA and underwent resuscitative thoracotomy in the emergency department.²¹ To date, the survival rate of patients who received cardiac massage from the United States military trauma registry, and how it compares to the European experience, is unknown.

The primary aim of our investigation was to describe patients, from the United States military trauma registry, who received closed or open-chest cardiac massage during TCA battlefield setting and to report survival to discharge as well as 30-day survival outcomes among these patients; our secondary aims were to identify predictors of survival among these same patients, and to compare survivors that received cardiac massage in the pre-hospital setting with those that received cardiac massage in the hospital only.

Methods

Study population

We conducted a review of the Department of Defense Trauma Registry (DoDTR) to identify all patients who had received closed or open-chest cardiac massage between January 01, 2007 through January 31, 2014. The DoDTR, formerly known as the Joint Theatre Trauma Registry (JTTR), is the data repository for DoD trauma-related injuries.^{22,23} The DoDTR is inclusive of patients who were treated for traumatic injuries by the United States Military Health System during Operation Enduring Freedom (OEF) (Afghanistan conflict from 2001 to present), Operation Iraqi Freedom (OIF) (Iraq conflict from 2003 to 2010) and Operation New Dawn (OND) (Iraq conflict from 2010 to present).

The DoDTR includes documentation regarding demographics, injury-producing incidents, diagnoses, treatments, and outcomes of injuries sustained by US/non-US military and US/non-US civilian personnel in wartime and peacetime from the point of injury to final disposition. Trained DoDTR staff review battlefield medical records to abstract diagnostic and procedure documentation using International Classification of Diseases (ICD) -9, Current Procedural Terminology (CPT), and Abbreviated Injury Scale (AIS) codes for registry inclusion. Prior to 2007, the DoDTR did not capture prehospital data in unique, designated fields. For reference, a Role 2 Medical Treatment Facility (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. This study was approved by the Institutional Review Board for the United States Army Institute of Surgical Research.

All adult United States military, North Atlantic Treaty Organization (NATO) military, coalition forces, contractors and foreign nationals who received either closed or open-chest cardiac massage within 24 h of sustaining a traumatic injury during the study period were eligible for inclusion. The DoDTR was queried to identify patients of interest using ICD-9 codes that were predetermined by the study investigators (Appendix 1), and patients in the query were included if they were confirmed to have received either closed or open-chest cardiac massage within 24 h of injury. Patients were only included if cardiac massage was performed within 24 h of their traumatic injury to ensure that the compressions were most likely performed in response to the acute injury; for the same reason, patients were excluded if they first received cardiac massage after they had been admitted to the intensive care unit (ICU).

Data collection and definitions

Data abstraction from the DoDTR query was conducted by a single, trained abstractor and entered into a standardized data collection form (Appendix 2).²⁴ The abstractor was not a study investigator and was blinded to the objectives and outcomes of the study. All data abstracted were objective. In the case of missing data, the corresponding space on the form was left empty. All data analysis was performed after data abstraction was complete and verified.

Patients were grouped according to the geographic location where they first received cardiac massage — either pre-hospital (PH) or in-hospital (IH). This grouping was done because the temporal relationship between injury and cardiac massage, the healthcare providers, and resources available between the PH and IH groups are substantially different. Data abstracted included demographics, injury description, anatomic location of injury, transport time, pre-hospital procedures, resuscitation type, initial MTF, and survival outcomes (Appendix 2). Independent variables within each of these categories are listed in [Tables 1–3](#).

Outcomes

Primary outcome variables included survival to discharge from first admitting MTF and 30-day survival. Survival to discharge included transfer to other healthcare facilities. Secondary outcomes included predictors of survival. We also compared survival between patients who received cardiac massage in the pre-hospital setting only with those that received cardiac massage in the hospital.

Statistical analysis

Categorical variables were analysed using chi-square or Fisher’s exact tests (for sample sizes less than 5) and reported as percentages with 95% confidence intervals (95CI). After evaluating the measures of central tendency, continuous variables were analysed using Student’s t-test or Wilcoxon rank-sum tests and reported as mean \pm standard deviation (SD). In regression modelling, we included variables representative of patient demographics (e.g. age, gender), injuries (e.g. mechanism of injury, injury location, injury type),

Table 1 – Descriptive statistics of the study population.

	All Mean ± SD; or % (95% CI) n = 582	PH Mean ± SD; or % (95% CI) n = 281	IH Mean ± SD; or % (95% CI) n = 301	p-value
Demographics				
Age, years	26 ± 7.6	26 ± 8.5	26 ± 6.7	0.90
Male	98 (97–99)	98 (95–99)	98 (96–99)	0.67
White	63 (58–68)	66 (58–73)	61 (54–67)	0.35
Black	3.8 (2.2–6.3)	3.9 (1.8–8.2)	3.7 (1.8–7.4)	0.91
Asian/Pacific Islander	0.87 (0.30–2.5)	0.65 (0.11–3.6)	1.1 (0.29–3.7)	0.69
Other ethnicity	32 (28–38)	30 (23–38)	35 (28–42)	0.35
OEF	63 (59–66)	70 (65–75)	55 (50–61)	<0.001*
OIF	37 (33–41)	30 (25–35)	44 (38–49)	<0.001*
OND	0.69 (0.27–1.7)	0.36 (0.06–2.0)	1.0 (0.34–2.8)	0.34
Injury description				
Injury severity score	24 ± 19	25 ± 20	23 ± 18	0.70
Battle injury	88 (85–90)	85 (81–89)	90 (87–93)	0.06
Blast injury	57 (53–61)	55 (49–61)	58 (52–64)	0.47
Penetrating trauma	35 (31–39)	35 (29–40)	36 (30–41)	0.79
Blunt trauma	7.2 (5.4–9.6)	9.3 (6.4–13)	5.3 (3.3–8.5)	0.07
Burn	0.68 (0.27–1.8)	0.72 (0.20–2.6)	0.66 (0.18–2.4)	1.00
Other injury	0.34 (0.09–1.2)	0.36 (0.06–2.0)	0.33 (0.06–1.9)	1.00
Anatomical location of injury				
Head	37 (34–41)	35 (30–41)	40 (34–45)	0.21
Face	13 (10–16)	10 (7–14)	15 (12–20)	0.07
Chest	30 (26–34)	29 (24–35)	31 (26–36)	0.72
Abdomen	29 (25–33)	25 (20–30)	33 (28–38)	0.05
Extremities	44 (40–48)	41 (35–46)	47 (41–52)	0.13
Skin	58 (54–62)	56 (50–62)	60 (55–66)	0.30
Pre-hospital procedures				
Number performed	2.5 ± 1.9	3.0 ± 1.9	1.9 ± 1.8	<0.0001*
C-Spine immobilization	9.0 (7.0–11)	9.3 (6.4–13)	8.3 (6–12)	0.69
Abdominal/pelvic splints	0.34 (0.09–1.2)	0.36 (0.6–2.0)	0.33 (0.06–1.9)	0.96
Central venous catheterization	0.34 (0.09–1.2)	0.71 (0.20–2.6)	0.00	0.23
Cricothyrotomy	11 (9–14)	15 (11–20)	7.6 (5.2–11)	<0.01*
Needle thoracostomy	5.4 (3.9–7.6)	9.3 (6.4–13)	2.0 (0.92–4.3)	<0.0001*
Thoracostomy tube	3.6 (2.3–5.3)	5.7 (3.5–9.1)	1.7 (0.71–3.8)	0.01
Extremity splints	0.17 (0.03–0.96)	0.00	0.33 (0.06–1.9)	1.00
Hemostatic agents	21 (18–25)	18 (14–23)	25 (20–30)	0.04
Endotracheal intubation	29 (25–33)	42 (36–48)	17 (13–22)	<0.0001*
Intraosseous infusion	26 (23–30)	37 (31–42)	16 (13–21)	<0.0001*
Oxygen delivery	18 (15–22)	26 (21–31)	11 (7.9–15)	<0.0001*
Tourniquet	32 (28–36)	33 (28–39)	31 (26–37)	0.63
Warming	33 (29–37)	30 (25–35)	36 (31–41)	0.10
Resuscitation type				
Closed chest cardiac massage	89 (87–92)	88 (84–92)	91 (87–94)	0.34
Open chest cardiac massage	20 (16–23)	20 (16–26)	19 (15–24)	0.76
Unspecified cardiac massage	4.9 (3.4–7.1)	3.4 (1.7–6.5)	6.1 (3.9–9.5)	0.13
Cardiac defibrillation	7.4 (5.4–9.9)	5.5 (3.2–9.1)	8.9 (6.1–13)	0.13
Administration of IV medication	12 (9–15)	11 (8–16)	12 (8–16)	0.81
Infusion of blood products	53 (49–57)	46 (41–52)	59 (54–65)	<0.01*
Transport time				
Transport time, minutes	53 ± 57	58 ± 64	49 ± 49	<0.01*
1st medical treatment facility				
Role 2	11 (9.0–14)	7.8 (5–12)	15 (11–19)	<0.01*
Role 3	89 (86–91)	92 (88–95)	85 (81–89)	<0.01*
Survival outcomes				

Table 1 (continued)

	All Mean ± SD; or % (95% CI) n = 582	PH Mean ± SD; or % (95% CI) n = 281	IH Mean ± SD; or % (95% CI) n = 301	p-value
Survival to discharge	58 (54–62)	45 (39–51)	71 (65–75)	<0.0001 [*]
Survival to 30-days	13 (10–16)	7.8 (5.2–12)	17 (13–22)	<0.001 [*]

PH = Pre-hospital cardiac massage, IH = In-hospital cardiac massage, SD = Standard Deviation, CI = Confidence interval, OEF = Operation Enduring Freedom, OIF = Operation Iraqi Freedom, OND = Operation New Dawn.
^{*} p < 0.05.

physiologic disposition when available (e.g. Glasgow Coma Scale score, vital signs), and medical interventions (e.g. blood product administration, closed-chest cardiac massage). When evaluating the logistic regression models, variables were selected based on findings from collinearity tests, significance, and clinical value. We began with saturated models and progressively we manually removed variables based on findings from overall model significance, variable significance, receiver operating characteristic (ROC) curve assessment, confidence interval comparisons, and Akaike's information criterion (AIC) for model error mitigation and a measure of best-fit. We strived for parsimonious model selection. We reported regression model results as odds ratios (OR) with 95CI, and we included area under the curve (AUC) for whole model results.

Results

Characteristics of study patients

During the study period a total of 30,279 patients were entered into the DoDTR, 589 patients received cardiac massage; seven were withdrawn from the analysis, so a total of 582 subjects were included in the analysis (Fig. 1). Five patients were excluded because they had cardiac massage performed more than 24 h after their injury, and two more were excluded because they received cardiac massage after they had been admitted to the intensive care unit. Thirty-five (12%) of the 281 PH patients received cardiac massage only in the PH setting, whereas the remaining 246 (88%) continued to receive cardiac massage once they had arrived at the hospital emergency department.

Demographics and injury description of the study patients 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 patients served in Operation Enduring Freedom (OEF - Afghanistan) and more of the IH patients served in Operation Iraqi Freedom (OIF - Iraq). PH patients had more pre-hospital procedures performed, received fewer blood products, and had longer transport times than IH patients (Table 1).

Main results

Survival was higher for IH patients than PH patients. One hundred twenty-seven (45%) of the 281 PH patients and 214 (71%) of the 301 IH patients survived to discharge (Table 1). Seventy-five of all 582 patients (13%) survived to 30 days, and all survivors were transported out of the battlefield; 23 PH (8%) and 52 IH (17%) patients survived to 30 days (Fig. 1, Table 1). Of the 35 patients that received

cardiac massage only in the PH setting, 22 (63%) survived to discharge and 10 (29%) survived to 30 days. Of the 246 that continued to receive cardiac massage once they arrived at the hospital, 94 (38%) survived to discharge and 12 (5%) survived to 30 days.

Among all patients, those who survived to 30 days had a higher ISS and received more PH procedures (Tables 2 and 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). Among the IH group, those that were initially treated at a Role 3 MTF were less likely to survive (15%) compared to those who were initially treated at a Role 2 MTF (30%) (p < 0.03).

Predictors of survival

In the PH group, survival to discharge was associated with injuries to the face (OR 9.1, 95CI 3.1–27) and chest (OR 2.1 95CI 1.3–3.6) with haemostatic dressings (OR 9.0, 95CI 4.0–20). Injuries to the chest (OR 10.2, 95CI 3.6–29) and abdomen (OR 4.2, 95CI 1.7–10.1) with c-spine immobilization (OR 7.7, 95CI 2.8–20.6) were associated with 30-day survival among PH patients. In the IH group, 30-day survival was associated with the combination of closed-chest cardiac massage and the administration of intravenous medications (OR 3.1, 95CI 1.4–6.7; AUC 0.61). Injury severity, injury type, other injury locations, other procedures, other resuscitation types, and transport time were not associated with survival to discharge or 30 days in either the PH or IH groups.

Discussion

In our study we found that cardiac massage among TCA patients in a battlefield setting is not futile. We report a 13% survival to 30 days among all patients receiving cardiac massage in the battlefield; 8% among PH patients and 17% among IH patients. We also found that closed-chest cardiac massage with intravenous medications was associated with 30-day survival among IH patients.

Cardiac massage for TCA patients remains a controversial topic, especially in the battlefield environment. Smaller reports from the United Kingdom suggest that survival from TCA in the battlefield may be more common than survival in the civilian setting.^{4,19–21} Our study supports these prior findings.

Our study, and the smaller prior reports with similar findings, suggest that there may be differences between the civilian and military TCA populations which make civilian TCA protocols less applicable to the military population. These differences may be highlighted by the

Table 2 – Descriptive statistics of prehospital cardiac massage subjects.

	Non-Survivor Mean ± SD; or % (95% CI) n = 259	Survivor Mean ± SD; or % (95% CI) n = 22	p-value
Demographics			
Age, years	26 ± 6.6	34 ± 19	0.06
Male	98 (95–99)	100 (85–100)	1.0
White	68 (60–75)	42 (19–68)	0.08
Black	4.2 (2.0–8.9)	0.00	1.0
Asian/Pacific Islander	0.07 (0.12–3.9)	0.00	1.0
Other ethnicity	27 (21–35)	58 (32–81)	0.03 [*]
OIF	31 (25–36)	18 (7–39)	0.33
OEF	69 (64–75)	77 (57–90)	0.43
OND	0.00	4.6 (0.81–22)	0.08
Injury description			
ISS	25 ± 21	28 ± 12	0.04 [*]
Battle injury	86 (81–89)	82 (61–93)	0.54
Blast injury	54 (48–60)	64 (43–80)	0.40
Penetrating trauma	36 (30–42)	18 (7.3–39)	0.11
Blunt trauma	8.9 (6.0–13)	14 (4.8–33)	0.48
Burn	0.39 (0.01–2.2)	4.6 (0.81–22)	0.15
Other injury	0.39 (0.01–2.2)	0.00	1.0
Anatomical location of injury			
Head	33 (28–39)	55 (35–73)	0.05
Face	7.7 (5.1–12)	41 (23–61)	<0.0001 [*]
Chest	25 (20–31)	77 (57–90)	<0.0001 [*]
Abdomen	22 (18–28)	55 (35–73)	<0.01 [*]
Extremities	38 (33–44)	68 (47–84)	<0.01 [*]
Skin	55 (49–61)	64 (43–80)	0.44
Pre-hospital procedures			
Number performed	2.9 ± 1.9	4.1 ± 1.7	<0.01 [*]
C-spine immobilization	7.0 (4.4–11)	36 (20–57)	<0.001 [*]
Abdominal/pelvic splints	0.00	4.6 (0.81–22)	0.08
Central venous catheterization	0.39 (0.01–2.2)	4.6 (0.81–22)	0.15
Cricothyrotomy	15 (11–19)	18 (7.3–39)	0.75
Needle thoracostomy	9.7 (6.6–14)	4.6 (0.81–22)	0.39
Thoracostomy tube	5.0 (3.0–8.4)	14 (4.8–33)	0.14
Extremity splints	0.00	0.00	–
Hemostatic agents	17 (13–22)	32 (16–53)	0.01 [*]
Endotracheal intubation	41 (35–47)	50 (31–69)	0.43
Intraosseous infusion	37 (31–43)	32 (16–53)	0.62
Oxygen delivery	25 (20–31)	36 (20–57)	0.26
Tourniquet	34 (28–40)	27 (13–48)	0.54
Warming	28 (23–34)	45 (27–65)	0.05
Resuscitation type			
Closed chest cardiac massage	89 (84–92)	75 (47–91)	0.19
Open chest cardiac massage	20 (16–26)	17 (4.7–45)	1.0
Unspecified cardiac massage	3.5 (1.0–6.8)	0.00	1.0
Cardiac defibrillation	5.3 (3.1–9.1)	8.3 (1.5–35)	0.50
Administration of IV medication	8.9 (5.8–13)	50 (25–75)	<0.001 [*]
Infusion of blood products	44 (38–50)	68 (47–84)	0.03 [*]
Transport time			
Transport time, minutes	57 ± 66	64 ± 45	0.43
1st medical treatment facility			
Role 2	59 (39–77)	41 (24–61)	<0.0001 [*]
Role 3	95 (92–97)	5.0 (3.0–8.4)	<0.0001 [*]

Survival at 30 days was used to establish survival status. SD = Standard Deviation, CI = Confidence interval, OEF = Operation Enduring Freedom, OIF = Operation Iraqi Freedom, OND = Operation New Dawn, IV = intravenous. Categorical variables were analysed using chi-square or Fischer's exact tests and reported as percentages with (95% CI). Continuous variables were analysed using Student's t-test or Wilcoxon tests and reported as mean ± (SD).

^{*} p < 0.05.

Table 3 – Descriptive statistics of In-hospital cardiac massage subjects.

	Non-Survivor Mean ± SD; or % (95% CI) n=249	Survivor Mean ± SD; or % (95% CI) n=52	p-value
Demographics			
Age, years	26 ± 6.4	27 ± 8.0	0.71
Male	98 (95–99)	100 (93–100)	0.59
White	62 (54–69)	54 (36–70)	0.40
Black	3.7 (1.7–7.8)	3.8 (0.63–18)	1.0
Asian/Pacific Islander	1.2 (0.34–4.4)	0.00	1.0
Other ethnicity	33 (26–41)	43 (27–61)	0.32
OIF	47 (40–53)	29 (18–42)	0.03 [*]
OEF	52 (46–58)	71 (58–82)	0.01 [*]
OND	1.2 (0.41–3.5)	0.00	1.0
Injury description			
ISS	22 ± 18	30 ± 15	<0.0001 [*]
Battle injury	90 (85–93)	94 (84–98)	0.44
Blast injury	56 (50–62)	69 (56–80)	0.07
Penetrating trauma	38 (32–44)	25 (15–38)	0.07
Blunt trauma	5.6 (3.4–9.2)	3.9 (1.1–13)	1.0
Burn	0.40 (0.1–2.2)	1.9 (0.3–10)	0.33
Other injury	0.40 (0.1–2.2)	0.00	1.0
Anatomical location of injury			
Head	39 (33–45)	46 (33–59)	0.31
Face	11 (8–15)	37 (25–50)	<0.0001 [*]
Chest	23 (18–28)	67 (54–78)	<0.0001 [*]
Abdomen	27 (22–33)	60 (46–72)	<0.0001 [*]
Extremities	39 (33–45)	85 (72–92)	<0.0001 [*]
Skin	56 (50–62)	79 (66–88)	<0.01 [*]
Pre-hospital procedures			
Number performed	1.8 ± 1.8	2.5 ± 2.1	0.04 [*]
C-spine immobilization	6.8 (4.3–11)	16 (8.0–28)	0.06 [*]
Abdominal/pelvic splints	0.40 (0.07–2.2)	0.00	1.0
Central venous catheterization	0.00	0.00	–
Cricothyrotomy	8.8 (5.9–13)	1.9 (0.34–10)	0.15
Needle thoracostomy	2.4 (1.1–5.2)	0.00	0.59
Thoracostomy tube	1.6 (0.63–4.1)	1.9 (0.34–10)	1.0
Extremity splints	0.40 (0.07–2.2)	0.00	1.0
Pressure packing	0.00	8.0 (5.0–12)	0.03 [*]
Hemostatic dressing	23 (18–28)	35 (23–48)	0.08
Endotracheal intubation	17 (13–22)	17 (9–30)	0.94
Intraosseous infusion	15 (11–20)	21 (12–34)	0.31
Oxygen delivery	8.0 (5.3–12)	25 (15–38)	<0.01 [*]
Tourniquet	28 (23–34)	46 (33–59)	0.01 [*]
Warming	48 (35–61)	33 (28–39)	0.05
Resuscitation type			
Closed chest cardiac massage	89 (85–93)	98 (90–100)	0.06
Open chest cardiac massage	21 (16–27)	9.8 (4.3–21)	0.05
Unspecified cardiac massage	7.4 (4.8–11)	0.00	0.05
Cardiac defibrillation	8.3 (5.4–12)	12 (5.5–23)	0.44
Administration of IV medication	9.1 (6–13)	24 (14–37)	<0.01 [*]
Infusion of blood products	57 (50–63)	73 (60–83)	0.02 [*]
Transport time			
Transport time, minutes	48 ± 49	54 ± 49	0.50
1st medical treatment facility			
Role 2	70 (56–82)	30 (18–44)	0.03 [*]
Role 3	85 (80–87)	15 (11–20)	0.03 [*]

Survival at 30 days was used to establish survival status. SD = Standard Deviation, CI = Confidence interval, OEF = Operation Enduring Freedom, OIF = Operation Iraqi Freedom, OND = Operation New Dawn, IV = intravenous. Categorical variables were analysed using chi-square or Fischer's exact tests and reported as percentages with (95% CI). Continuous variables were analysed using Student's t-test or Wilcoxon tests and reported as mean ± (SD).

^{*} p < 0.05.

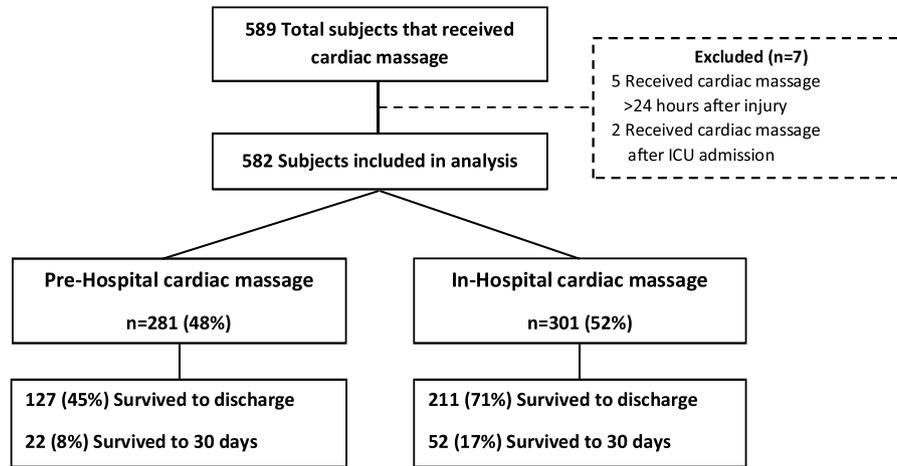


Fig. 1 – Study population and outcomes.

young average age of our cohort, the majority of which experienced blast injuries which are not common in the civilian setting. Many of our young military patients 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.^{4,19} 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 (EMS) systems. A report from the UK had similar survival results (7.5%) among civilian TCA victims; in that study the helicopter EMS team consisted of a physician and a flight paramedic which 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. Additionally, battlefield medics are often in close proximity to injured patients, can 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 which suggests that injury type may not be important in deciding how to manage TCA in the battlefield. The anatomic location of injury did predict survival to discharge and 30 days among PH patients. Those who sustained injuries to the face or chest with haemostatic dressings in place were more likely to survive to discharge. Injuries that are isolated to the face are intuitively more likely to survive; however, it is less obvious why patients with injuries to the chest were more likely to survive to discharge. Even more intriguing, patients with injuries to either the chest or abdomen were more likely to survive to 30 days, yet this finding somewhat mirrors the UK Joint Theatre Trauma Registry review of TCA where injuries to the abdomen or extremities were associated with survival.²⁰ The chest and abdomen are both areas where non-compressible haemorrhage occurs; previous reports indicate that non-compressible haemorrhage is a leading cause of potentially survivable deaths on the battlefield.^{25–28} It is possible that our data are confounded by the large presence of blast injuries; if the haemorrhage that caused TCA in most of our chest and abdominal injuries was primarily due to extremity injuries where tourniquets were applied appropriately, these patients may have survived more

frequently than if the haemorrhage was primarily due to intra-thoracic or intra-abdominal vascular injuries. A more detailed investigation will be required to elucidate these details. For patients who survived to 30 days after IH cardiac massage, closed-chest cardiac massage with the administration of intravenous medications predicted survival. This combination of interventions reflects typical advanced cardiac life support for non-traumatic cardiac arrest. Open-chest cardiac massage was not as common as closed-chest massage and did not predict survival in either the PH or IH groups which suggests that many of the IH patients may have already had their haemorrhage controlled prior to experiencing cardiac arrest. Again, a more detailed investigation will be required to elucidate these details.

Limitations

Our study has several limitations. First, although our PH 30-day survival rates are similar to recent studies that include all TCA patients, we were only able to include patients that received cardiac massage^{4,10}; thus, it is likely that our results could over-estimate survival if we were to consider all TCA patients. The DoDTR does not include patients who are not transported to an MTF, so patients who were considered non-salvageable in the field could not be included in this study — for reference, a recent study from the Armed Forces Medical Examiner System (AFMES), between 2001 and 2011, reported that 87% of battlefield mortalities occur pre-MTF.²⁷ Additionally, there may be some patients who were in TCA and resuscitated without cardiac massage that were not captured by this review. There is no specific code for TCA in the DoDTR, and attempting to objectively abstract TCA patients from all traumatic injuries is impossible since documented vital signs and GCS in the DoDTR are not specific to the time of TCA or resuscitation. Fortunately, this limitation does not affect the finding that resuscitation of military TCA patients has notable benefit. Second, survival bias limits the ability to compare PH and IH groups, however, this study was intended to serve as an exploratory effort rather than a definitive guide to treatment among these groups. Regardless, this study provides evidence to support the utility of cardiac massage in both groups during TCA. Third, although we report 30-day survival, we were unable to determine the functional outcome of the survivors — some of the survivors may have a poor neurologic

state. Fourth, there may be a temporal contribution to survival that is not evident in our analysis. Advances in technology and training may have contributed to survival over time; alternatively, a de-emphasis on cardiac massage in TCA guidelines during the study period may have also affected survival. Lastly, our findings are somewhat unique to a military battlefield, however, it is possible that our findings may be translatable to the civilian environment where military-grade weapons and improvised explosive devices have been used with increased frequency in recent terror attacks.

Conclusions

We report a 13% survival to 30 days among all patients receiving cardiac massage in a battlefield setting. Cardiac massage predicted survival among IH TCA victims who also received intravenous medications in this retrospective review of military TCA.

Conflicts of interest

None declared by any author.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.resuscitation.2019.02.029>.

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