Clinical paper

Outcomes following military traumatic cardiorespiratory arrest: A prospective observational study☆

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ABSTRACT

Aim: To determine the characteristics of military traumatic cardiorespiratory arrest (TCRA), and to identify factors associated with successful resuscitation.
Methods: Data was collected prospectively for adult casualties suffering TCRA presenting to a military field hospital in Helmand Province, Afghanistan between 29 November 2009 and 13 June 2010.
Results: Data was available for 52 patients meeting the inclusion criteria. The mean age (range) was 25 (18–36) years. The principal mechanism of injury was improvised explosive device (IED) explosion, the lower limbs were the most common sites of injury and exsanguination was the most common cause of arrest. Fourteen (27%) patients exhibited ROSC and four (8%) survived to discharge. All survivors achieved a good neurological recovery by Glasgow Outcome Scale. Three survivors had arrested due to exsanguination and one had arrested due to pericardial tamponade. All survivors had arrested after commencing transport to hospital and the longest duration of arrest associated with survival was 24 min. All survivors demonstrated PEA rhythms on ECG during arrest. When performed, 6/24 patients had ultrasound evidence of cardiac activity during arrest; all six with cardiac activity subsequently exhibited ROSC and two survived to hospital discharge.
Conclusion: Overall rates of survival from military TCRA were similar to published civilian data, despite military TCRA victims presenting with high Injury Severity Scores and exsanguination due to blast and fragmentation injuries. Factors associated with successful resuscitation included arrest beginning after transport to hospital, the presence of electrical activity on ECG, and the presence of cardiac movement on ultrasound examination.

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1. Introduction

Trauma causes more than 5 million deaths per year worldwide and is a major cause of death during military conflicts.[1] Cardiorespiratory arrest following trauma occurs in 1–4% of patients transported to civilian trauma centres, where it is associated with a very poor overall prognosis.[2–5] Although outcomes following traumatic cardiorespiratory arrest (TCRA) have been studied extensively in civilian settings, there is limited data on outcomes following military TCRA.

The loss of central pulses and respiratory effort precede death due to blunt or penetrating trauma through a number of mechanisms, including exsanguination, cardiac injury, pneumothorax, brain injury and asphyxia. Attempted resuscitation will ultimately prove unsuccessful in the majority of these patients, but for a small proportion of TCRA victims, timely and appropriate interventions may be life-saving.[6,7]

Attempted resuscitation from TCRA consumes a large amount of medical resources, and is not without risk to healthcare providers.[8,9] This is especially true in the military setting where casualty numbers may be high, evacuation may be dangerous and resources are finite. Guidelines aimed at reducing the provision of futile care[5] have been limited in their acceptance following reports of a number of survivors who would have met the proposed criteria for withdrawal of care.[7,10,11] Current European Resuscitation

Council guidelines recognise the lack of reliable predictors of survival following TCRA.[12]

We conducted a prospective, observational study of military TCRA casualties treated at the multinational Role 3 hospital in Helmand Province, Afghanistan, in order to determine the characteristics of military TCRA, and to identify factors associated with successful resuscitation.

2. Methods

Camp Bastion UK Multinational Role 3 Hospital is the major military trauma centre for Helmand Province, Afghanistan. The hospital receives military and civilian casualties, who are usually transported to hospital from the point of wounding by helicopter-based medical retrieval teams.

Data was collected prospectively between 29 November 2009 and 13 June 2010 for adult casualties (>18 yrs) suffering TCRA, defined as the loss of palpable central pulses and respiratory effort following trauma. Patients were included if they were assessed or treated by the hospital's medical retrieval teams or by the hospital's trauma team. Patients were excluded if they were declared deceased at the point of wounding by field medical personnel prior to the arrival of the retrieval service, or if they arrested only after the withdrawal of active management.

Patients were identified by direct liaison with hospital and retrieval service personnel, and by daily analysis of hospital and retrieval service clinical records. Data was collected in accordance with the Utstein template and included: mechanism and nature of injuries; physiological findings; electrocardiographic (ECG) and cardiac ultrasound findings; time intervals; resource utilisation and clinical outcomes including neurological recovery.[13] Institutional approval for the study was granted by the Royal Centre for Defence Medicine, Birmingham, UK (registration number RCDM/Res/Audit/1036/12/0005).

3. Results

During the study period, a total of 55 cases of TCRA were identified meeting the inclusion criteria for the study. Notes were unavailable in three cases, and the remaining 52 cases were included for analysis. All patients were male and the mean age (range) was 25 (18–36) years. The principal mechanism of injury was improvised explosive device (IED) explosion and the lower limbs were the most common sites of injury (Table 1). The median Injury Severity Score (ISS) was 33. Exsanguination was the most common cause of arrest (Table 2).

Fourteen (27%) patients demonstrated temporary or permanent ROSC, of whom four (8%) patients survived to hospital discharge. All four survivors made a neurologically good recovery, as graded by Glasgow Outcome Scale at the time of hospital discharge.[14] For non-survivors, 79% of deaths occurred within 1 h of the arrest, and no death occurred later than 24 h after the arrest. The longest duration of cardiorespiratory arrest associated with survival was 24 min.

Resuscitative thoracotomy (RT) was performed on 12 patients, including all four survivors to hospital discharge. In eight cases RT was performed in the emergency department (ED) with the remainder performed in the operating room. In addition to open-chest CPR, interventions performed during RT for the four survivors included release of pericardial tamponade, non-anatomic lung resection and direct compression of the descending thoracic aorta for control of haemorrhage. Including RT, a total of 30 surgical procedures were performed within the first 24 h after injury.

Twenty-nine (56%) patients received packed red blood cells (PRBC) during the first 24 h after TCRA. For the 51 patients with complete transfusion records, the total quantity of blood and

Table 1
Principal body region injured for all patients.

Body Region	Number (%)
Lower Limb	23 (44%)
Chest	12 (23%)
Head	7 (13%)
Abdomen	4 (8%)
Pelvis	4 (8%)
Neck	2 (4%)

clotting products administered was 453 units of PRBC, 455 units of FFP, 85 donor pools of platelets, 42 donor pools of cryoprecipitate and 105 mg of recombinant human activated factor seven. Survivors and patients exhibiting ROSC received the greatest quantities of PRBC and FFP (Table 3).

4. Discussion

Previously published evidence for outcomes following TCRA in civilian patients is limited to retrospective studies[2–4,6–8,10,11,15–24] with only a small number of survivors in each study. Reported rates of survival to hospital discharge have ranged from 0 to 17%, with most studies reporting rates of considerably less than 10%.[2–4,6–8,10,11,15–23] Rates of neurological disability, where reported, have ranged from 10 to 80% for survivors.[3,4,6,11,15,17,18,24]

Our overall rate of survival to hospital discharge of 8% is broadly similar to the published civilian data, albeit with small numbers involved. Our high rate of favourable neurological outcome for survivors is greater than in most studies, but comparisons are limited here, again by the small numbers involved.

In the civilian literature, isolated, penetrating thoracic injuries appear to be most survivable of causes of TCRA, particularly when the cause of arrest is pericardial tamponade.[7,15,25,26] Significantly worse outcomes have been found for victims of diffuse, blunt trauma, both in studies of RT and in studies of TCRA not limited to RT patients.[3,15,17,24–29] Most survivors of civilian TCRA do not arrest due to exsanguination.[12] Very poor outcomes for exsanguinating TCRA patients have led some authors to conclude that "cardiac arrest due to hypovolaemia is virtually always fatal".[10] Three of our four survivors had arrested due to exsanguination from massive, complex, lower limb injuries.

Previously published work has shown that military trauma patients are injured more severely, and by different mechanisms than civilian equivalents.[30] Three civilian studies of outcomes following TCRA reported ISS for their study population and in each case mean values were reported, ranging from 29 to 36 for all patients.[11,24,31] Because ISS is not normally distributed data, mean values are of limited value for comparison between studies. Nevertheless, our population had a mean ISS of 38, which, when compared with these studies, supports the impression that our patients presented with relatively high injury severity scores.

Extended pre-hospital times and prolonged CPR have been associated with poor outcomes following TCRA.[4,16,24,28,29] Current guidelines state that the maximum CPR time associated with favourable outcome is 16 min.[12] Our poorest outcomes were seen in patients arresting in the field. Only 12% of these patients achieved ROSC and none survived. One survivor who arrested during transport to hospital made a good neurological recovery despite requiring 24 min of CPR, 21 min of which were pre-hospital. Factors contributing to this individual's survival may have included the high level of care that he received during retrieval, including haemorrhage control, tracheal intubation and transfusion of blood products.

ECG evidence of electrical asystole during TCRA has been shown to be associated with poor outcomes, and has been proposed as a pre-hospital tool to identify cases of medical futility.[3,6,31] Guide-

Table 2
Characteristics of TCRA by category of outcome.

		All Patients (N = 52)	No ROSC (N = 38)	ROSC (N = 14)	Survivors (N = 4)
Age[a]					
Age	Mean (range) in yrs	24.5 (18–36)	24.6 (19–36)	24.1 (18–35)	24.5 (20–35)
Mechanism of injury					
IED	Number (%)	34 (65%)	24 (63%)	10 (71%)	4 (100%)
GSW	Number (%)	17 (33%)	13 (34%)	4 (29%)	0
Grenade	Number (%)	1 (2%)	1 (3%)	0	0
Injury severity scores[b]					
ISS (2005)	Median (range)	33 (9–75)	41 (9–75)	20 (13–59)	16.5 (13–24)
NISS (2005)	Median (range)	50 (16–75)	57 (9–75)	38.5 (17–66)	31.5 (17–41)
Cause of arrest					
Exsanguination	Number (%)	42 (81%)	30 (79%)	12 (86%)	3 (75%)
Brain injury	Number (%)	7 (13%)	6 (16%)	1 (7%)	0
Airway obstruction	Number (%)	1 (2%)	1 (3%)	0	0
Cardiac tamponade	Number (%)	1 (2%)	0	1 (7%)	1 (25%)
C-Spine injury	Number (%)	1 (2%)	1 (3%)	0	0
Location of arrest					
Ground	Number (%)	29 (56%)	24 (63%)	5 (36%)	0
Transfer to hospital	Number (%)	16 (31%)	13 (34%)	3 (21%)	1 (25%)
Field hospital	Number (%)	7 (13%)	1 (3%)	6 (43%)	3 (75%)
Time intervals[c]					
Arrest to ROSC	Median (range) in mins	9 (2–24)	n/a	9 (2–24)	8 (5–24)
Initial ECG during arrest[d]					
Asystole	Number (%)	29 (63%)	28 (82%)	1 (8%)	0
Sinus-based > 40bpm	Number (%)	13 (28%)	4 (12%)	9 (75%)	3 (75%)
Agonal	Number (%)	4 (9%)	2 (6%)	2 (17%)	1 (25%)
VF/VT	Number (%)	0	0	0	0
Cardiac activity on ultrasound[e]					
No activity	Number (%)	18 (75%)	18 (100%)	0	0
Activity	Number (%)	6 (25%)	0	6 (100%)	2 (100%)
Resuscitative thoracotomy					
RT done	Number (%)	12 (23%)	3 (8%)	9 (64%)	4 (100%)

[a] From 45 patients of known age.
[b] From 35 patients with complete data.
[c] From 11 patients with complete data.
[d] From 46 patients with recorded findings.
[e] From 24 patients with recorded findings.

Table 3
Packed Red Blood Cell (PRBC) and Fresh Frozen Plasma (FFP) transfusion by patient group.

Patient Group	Number	Number (%) transfused	Total PRBC given (units)	Mean PRBC per patient (units)	Total FFP given (units)	Mean FFP per patient (units)
All patients	51[a]	28 (55%)	453	9	455	9
No ROSC	38	16 (42%)	54	1	51	1
ROSC	13[a]	12 (92%)	399	31	404	31
Received RT	11[a]	11 (100%)	295	27	297	27
Survivors	3[a]	3 (100%)	140	47	136	45

[a] Excludes one patient with incomplete transfusion record.

lines produced in 2003 by the American College of Surgeons and the National Association of EMS Physicians (ACS/NAEMSP), recommended that resuscitation should be withheld for TCRA patients with an ECG rate of less than 40 bpm in the field.[5] The survival of one patient who displayed an agonal rhythm on ECG is at odds with the ACS/NAEMSP guidelines. Other authors have also found occasional survivors of TCRA despite an ECG rate of less than 40 bpm.[7,10,29] Electrical asystole was universally associated with death in our patients.

ED ultrasound is a proven investigation in trauma resuscitation, and is a sensitive test for pericardial tamponade.[32–34] There is also emerging evidence for its use as a prognostic tool in TCRA.[35] In 24 of our patients, cardiac ultrasound was performed during arrest. Six (25%) of these patients had ultrasound evidence of cardiac activity and subsequently exhibited ROSC with two surviving to hospital discharge. There were no patients who exhibited ROSC from the 18 patients without cardiac activity on ultrasound.

A large amount of healthcare resources were used to treat these 52 patients. All but one were transported by helicopter (the other was transported by land), and a total of 30 surgical procedures were performed, including 12 resuscitative thoracotomies and substantial use of blood and clotting products.

Our study has a number of significant limitations. In addition to the usual constraints of an observational study, our conclusions were limited by the small number of patients included overall, and by the very small number of survivors to hospital discharge. When assessing factors associated with outcome, there is also the potential for confounding due to the interpretation of this information at the time of treating the patient. Finally, our observations were made at a single field hospital during a particular conflict and our results may not apply to different military circumstances or to other emergency medical systems.

5. Conclusions

Rates of survival from military TCRA were similar to published civilian data, with 8% of patients surviving to discharge. This was despite military TCRA victims typically presenting with high Injury

Severity Scores and exsanguination due to blast and fragmentation injuries. Factors associated with successful resuscitation from military TCRA included arrest beginning after transport to hospital, the presence of electrical activity on ECG, and the presence of cardiac movement on ultrasound. Attempted resuscitation from TCRA is costly in terms of healthcare resources, and there are no absolute predictors of successful or unsuccessful resuscitation. Decision-making on the withholding or withdrawal of care from TCRA patients remains dependent on a rapid appraisal of the clinical and tactical situation by medical teams at the time of presentation.

Conflicts of interest statement

The authors declare no conflicts of interest. The views expressed in this paper are those of the authors and may not reflect the views of the Ministry of Defence.

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