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Outcomes after Prehospital Traumatic Cardiac Arrest in the Netherlands: a Retrospective Cohort Study

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ABSTRACT

Background: Traumatic cardiac arrest (TCA) is a severe and life-threatening situation that mandates urgent action. Outcomes after on-scene treatment of TCA in the Netherlands are currently unknown. The aim of the current study was to investigate the rate of survival to discharge in patients who suffered from traumatic cardiac arrest and who were subsequently treated on-scene by the Dutch Helicopter Emergency Medical Services (HEMS).

Methods: A retrospective cohort study was performed including patients ≥ 18 years with TCA for which the Dutch HEMS were dispatched between January 1st 2014 and December 31st 2018. Patients with TCA after hanging, submersion, conflagration or electrocution were excluded. The primary outcome measure was survival to discharge after prehospital TCA. Secondary outcome measures were return of spontaneous circulation (ROSC) on-scene and neurological status at hospital discharge.

Results: Nine-hundred-fifteen patients with confirmed TCA were included. ROSC was achieved on-scene in 261 patients (28.5%). Thirty-six (3.9%) patients survived to hospital discharge of which 17 (47.2%) had a good neurological outcome. Age < 70 years (0.7% vs. 5.2%; p=0.041) and a shockable rhythm on first ECG (OR 0.65 95%CI 0.02-0.28; p<0.001) were associated with increased odds of survival.

Conclusion: Neurologic intact survival is possible after prehospital traumatic cardiac arrest. Younger patients and patients with a shockable ECG rhythm have higher survival rates after TCA.

Level of evidence: prognostic study, level III.

Introduction

Cardiac arrest after trauma is a severe and life-threatening situation that mandates urgent action. Rather than being a single, well-defined condition, traumatic cardiac arrest (TCA) represents the final stage of severe, decompensated hypovolemic, hypoxic and/or obstructive shock [1]. Unlike in medical cardiac arrest, early and appropriate action to address the origin of shock ("reversible causes") may be more important than direct initiation of chest compressions and electro cardioversion [2]. Reversible causes for circulatory arrest in the trauma setting include 1) hypoxia due to airway obstruction or apnea (resulting from severe traumatic brain injury or high spinal cord injuries), 2) exsanguination from major vessel injuries or pelvic fractures and 3) obstructive shock due to cardiac tamponade or tension pneumothorax. These injuries or injury sequelae can and should be addressed as soon as possible, preferably before the patient is transported to the hospital.

The Netherlands covers approximately 41,000 square kilometers and has about 17 million inhabitants. Prehospital ground emergency medical services (EMS) are staffed with specialized

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nurses, who have a background in intensive care and/or emergency medicine and who are thoroughly trained in prehospital trauma life support (PHTLS). All ground EMS are supplemented by four physician-led Helicopter EMS (HEMS) operations across the country. A HEMS team consists of a board-certified trauma surgeon or anesthesiologist, a specialized nurse and a helicopter pilot. The primary purpose of the Dutch HEMS operation is to provide specialized medical care on-scene, including advanced and medication assisted airway management and specific procedures such as chest tube drainage and transfusion of red packed cells. In patients with suspected TCA, HEMS are always dispatched.

Over the past years, the prehospital management of patients with TCA has gained a lot of attention in the Netherlands through more in depth education and training for both EMS and HEMS personnel, based on the latest European resuscitation committee guidelines [3]. Whether this has led to survival rates comparable to those published in recent literature is currently unknown [4–6]. Therefore, the aim of the current study was to investigate the rate of survival to discharge in patients who suffered from traumatic cardiac arrest and who were subsequently treated on-scene by the Dutch HEMS.

Methods

A retrospective cohort study was conducted with patients with TCA for whom the Dutch HEMS was dispatched between January 1st, 2014 and December 31st, 2018. HEMS medical databases from three HEMS stations (Rotterdam, Amsterdam and Nijmegen) were queried for patients ≥ 18 years and who had a circulatory arrest after blunt or penetrating trauma.

Traumatic cardiac arrest was defined as a traumatic injured patient (blunt of penetrating) with agonal or absent spontaneous respiration and absence of a central pulse. Patients with cardiac arrest resulting from hanging, submersion, conflagration, or electrocution were excluded. Patients with a suspected medical cause for cardiac arrest, patients who were dead upon arrival of EMS or HEMS-crews, patients with a missing primary outcome measure (survival) and patients who received bystander CPR but had ROSC upon arrival of EMS or HEMS-crews (whichever arrived first) were also excluded.

Patients were declared death on scene when there was massive trauma incompatible with survival (e.g. decapitation, penetrating heart injury, loss of brain tissue) and/or signs of life were absent for > 15 minutes upon arrival of first ground EMS or HEMS . Resuscitation was terminated when no ROSC was achieved after all reversible causes had been addressed and when no detectable ultra-sonographic cardiac activity was seen, according to the latest European Council Guidelines for Resuscitation[2].

Prehospital thoracotomy was performed in patients with penetrating “cardiac-box” injuries with loss of vital signs < 10 minutes before HEMS arrival. In selected blunt or penetrating trauma cases with isolated abdominal or pelvic bleeding and loss of vital signs < 10 minutes resuscitative thoracotomy with aortic cross clamping was performed.

The primary outcome measure was survival to discharge after prehospital TCA. Secondary outcome measures were durable return of spontaneous circulation (ROSC) on scene and neurological status at hospital discharge (Glasgow Outcome Scale). Additionally, a sub analysis was performed to determine factors associated with survival to discharge.

For each transported patient, dispatch-reports and digital hospital charts were reviewed. Data regarding patient demographics, trauma mechanism, dispatch times, vital signs, performed interventions, and outcome were collected. Data were analyzed using SPSS version 25.0 (IBM, SPSS, Chicago, III, USA). Reported percentages in both text and tables were based on known values for the denominator. Chi-squared analyses, one-way analyses of variance (ANOVA) and Kruskal–Wallis analyses were used for demographic and clinical characteristics. Logistic regression and multiple linear regression were used to estimate the association between mortality and other variables. A p-value of < 0.05 was considered to be statistically significant.

Table 1
Demographics and baseline characteristics of all patients.

Entire cohort (n=915)	
Age (year)	47 (30-63)
Gender	
Male	684 (76.4%)
Female	211 (23.6%)
Undocumented	20
Trauma Mechanism	
Road traffic accident	479 (52.3%)
Fall from height	224 (24.5%)
Blunt otherwise	61 (6.7%)
Stab wound	75 (8.2%)
Gunshot wound	69 (7.5%)
Penetrating otherwise	7 (0.8%)
Time between HEMS dispatch and arrival (minutes)	
Time (minutes)	15 (11-20)
0-10 minutes	158 (19.1%)
11-15 minutes	288 (34.8%)
> 15 minutes	382 (46.1%)
Undocumented	87
First ECG rhythm	
Asystole	402 (50.3%)
PEA	367 (45.9%)
Shockable (VF/VT)	30 (3.8%)
Undocumented	116

Data are shown as median (P_{25}-P_{75}) or as n (%). HEMS: helicopter emergency service.
PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

Ethics

This study was exempted by the Medical Research Ethics Committee (MREC) of all participating institutions.

Results

Patient characteristics

In total 915 patients with confirmed TCA were treated by the three participating Dutch HEMS services and were included in this study. Baseline characteristics are presented in Table 1. The median age was 47 years (range 30-63 years) and 684 (76.4%) patients were male. Road traffic accidents were the most common trauma mechanism leading to TCA (n=479, 52.3%). Penetrating injury was the cause for TCA in 16.5% of the patients (n=151). In approximately half of patients HEMS were present within 15 minutes. A shockable rhythm (ventricular fibrillation (VF) and ventricular tachycardia (VT)) on ECG was observed in 30 (3.8%) patients, whereas asystole was observed in 402 (50.3.%) patients and pulseless electrical activity in 367 (45.9%) patients.

Prehospital interventions

On-scene interventions performed by HEMS-crews are listed in Table 2. Endotracheal intubation was performed in the majority of patients (n=678; 83.9%). Thoracic decompression was performed by needle-thoracostomy in 101 (11.5%) patients and by finger-thoracostomy in 413 (47.2%) patients. Prehospital transfusion of red packed cells was performed in 94 (10.5%) patients. In 63 (6.9%) patients, prehospital thoracotomy was performed, of which

Table 2
Interventions performed on-scene by EMS and HEMS crews.

	Entire cohort (n=915)
Airway management	
Bag mask ventilation only	61 (7.5%)
Supraglottic airway device (LMA)	47 (5.8%)
Endotracheal intubation	678 (83.9%)
Surgical airway	22 (2.7%)
Undocumented	107
Thoracic decompression	
None	361 (41.3%)
Needle thoracostomy	101 (11.5%)
Finger thoracostomy	413 (47.2%)
Undocumented	40
Prehospital thoracotomy	
Yes	63 (6.9%)
No	852 (93.1%)
Prehospital transfusion of packed red cells	
Yes	94 (10.5%)
No	804 (89.5%)
Unknown / undocumented	17

Data are shown as n (%)
ER, emergency room; LMA, Larngeal Mask Airway.

55 (87%) thoracotomies were performed in patients with penetrating trauma. Point of care ultrasound was reported to be used as a diagnostic adjunct in 30.3% (n= 277) of patients.

Blunt versus penetrating injury

Table 3 compares baseline characteristics and on-scene interventions between patients with blunt and penetrating injury. Patients with penetrating injury were younger (median age 40 years vs 49 years; p<0.001) and more often of the male gender (82.6% vs 75.2%; p=0.05). In addition, patients with penetrating injury were more likely to undergo on scene thoracotomy (36.4% vs 1.0%; p<0.001) and to receive packed red cells on-scene (16.8% vs 9.2%; p=0.009).

Outcomes

Return of spontaneous circulation (ROSC) was achieved on scene in 261 (28.5%) patients. 328 (35.8%) patients were transported to a hospital. None of the patients who were transported without ROSC survived to discharge. Of the patients who were transported to a hospital, 135 (41.2%) died in the emergency room (ER) or operation theatre, 155 (47.3%) died in the intensive care unit and 2 (0.6%) died in the nursing ward.

A total of 36 patients survived to discharge (3.9% of all patients, 10.9% of transported patients, 13.7% of transported patients with ROSC). Of these, 17 (47.2%) patients had a good neurological outcome (Glasgow outcome scale 5), 10 (27.8%) patients had a moderate neurological outcome (Glasgow outcome scale 4), and seven (19.4%) patients had a poor neurological outcome (Glasgow outcome scale 2-3). Two of the surviving patients had undergone a prehospital thoracotomy. Both had cardiac tamponade with ROSC upon decompression of the pericardium and had a good neurologic recovery. Prehospital thoracotomy for blunt trauma did not yield any survivors.

Use of hospital resources

Of 328 patients that were transported to the hospital, 127 (38.7%) patients received transfusion of red packed cells within the first 24 hours after being admitted to the hospital. Of these, eighteen (14.2%) patients survived to discharge. Median ICU stay for survivors was 9.5 days (P25-P75 2-23), of whom 18 (50%) patients stayed in the ICU for over one week. Median ICU stay for non-survivors admitted to the ICU was 2 days (P25-P75 2-4). Twenty-two (14%) non-survivors stayed in the ICU for more than one week.

Factors associated with survival to discharge

Table 4 and 5 compare baseline characteristics and on-scene interventions for survivors and non-survivors. Young age and an initial shockable ECG rhythm were associated with an increased chance of survival. More specifically, the median age of survivors (36yrs P25-P75 24-50yrs) was significantly lower than the median age of non-survivors (48yrs P25-P75 30-64yrs, p=0.006). Survival was especially poor in the elderly: Only 1 of 142 patients of 70 years or older survived (GOS 4), compared with 34 patients who had an age lower than 70 years (0.7% vs. 5.2%; p=0.041). Patients with a shockable initial ECG rhythm had a 13.3% chance of survival. Survival was 4.1% for patients with any organized ECG activity without output on initial ECG (OR 0.65 95%CI 0.02-0.28; p<0.001) and only 1% for patients with asystole as initial ECG rhythm (OR 0.28 95%CI 0.09-0.90; p=0.032). Although there was a trend towards a higher chance of survival in patients with a penetrating trauma mechanism, this difference was not statistically significant (OR 2.0 95%CI 0.95-4.3; p=0.069). Gender, on-scene endotracheal intubation and type of receiving hospital (trauma center vs non-trauma center) were not associated with increased or decreased odds of survival. Also, time between HEMS dispatch and HEMS arrival was not associated with survival. However, there were no survivors if the time between dispatch and arrival exceeded 25 minutes.

Suspected reason of TCA in surviving patients

Table 6 lists the suspected reasons for cardiac arrest among the 36 surviving patients. More than half of patients developed TCA due to hypoxia, most often resulting from traumatic brain injury induced apnea. Hypovolemia was the second most common reason for TCA (24.2%).

Discussion

This study investigated the rate of survival to discharge in 915 patients who suffered from traumatic cardiac arrest and who were subsequently treated on scene by the Dutch physician-based helicopter emergency medical services. Survival to discharge was 3.9% (n=36) among all patients. In patients with prehospital TCA who were transported to a hospital after spontaneous circulation was restored on-scene, survival to discharge was 13.7%. Approximately half of all survivors had a normal neurological function during follow-up.

Survival percentages in the current study are somewhat lower than mentioned in recent reports on this subject from other prehospital trauma systems. A large multi-center registry study including 2300 patients from the US and Canada reported a survival rate of approximately 6% [4]. A 2017 retrospective study from the UK including 705 patients reported a 7.5% 30-day survival [5]. A study from Sweden reported a 3.7% survival rate after prehospital TCA [6]. Moreover, a systematic review including 34 studies published between 1964 and 2011 on traumatic out-of-hospital cardiopulmonary arrest found a 7.8% survival rate. As in our study, moderate disability was present in about 13% of survivors and severe disability was present in about one third of survivors in the previously mentioned systematic review [7]. While it is certainly informative to compare our results to these studies, it should be taken into account that factors such as the in- or exclusion of patients declared dead on scene, geographical differences between countries and type of prehospital service (physician, nurse

Table 3
Demographics of subgroups by trauma mechanism blunt vs penetrating (n=915).

	Blunt (n=764; 83.5%)	Penetrating (n=151; 16.5%)	p-value
Age (year)	49 (30-66)	40 (26-50)	<0.001*
Gender			
Male	565 (75.2%)	119 (82.6%)	0.070**
Female	186 (24.8%)	25 (17.4%)	
Undocumented	13	7	
Airway management			
Bag mask ventilation only or supraglottic airway device (LMA)	87 (12.9%)	22 (16.5%)	0.320**
Endotracheal intubation or surgical airway	589 (87.1%)	111 (83.5%)	
Undocumented	88	18	
Thoracic decompression			
None or needle thoracostomy	385 (52.2%)	77 (56.2%)	0.438**
Finger thoracostomy	353 (47.8%)	60 (43.8%)	
Undocumented	26	14	
Prehospital Thoracotomy			
Yes	8 (1.0%)	55 (36.4%)	<0.001***
No	756 (99.0%)	96 (63.6%)	
Prehospital transfusion of packed cells			
Yes	69 (9.2%)	25 (16.8%)	0.009**
No	680 (90.8%)	124 (83.2%)	
Unknown / undocumented	15	2	
Transport to hospital			
Yes	269 (35.2%)	59 (39.1%)	0.417**
No	495 (64.8%)	92 (60.9%)	
Time Dispatch – Arrival HEMS			
Time (minutes)	15 (11-20)	12 (9-19)	<0.001*
0-10 minutes	116 (16.9%)	42 (30.4%)	
11-15 minutes	241 (34.9%)	47 (34.1%)	
> 15 minutes	333 (48.3%)	49 (35.5%)	
Undocumented	74	13	
First ECG rhythm			
Asystole or PEA	643 (96.3%)	126 (96.2%)	1.000***
Shockable (VF/VT)	25 (3.7%)	5 (3.8%)	
Undocumented	96	20	

Data are shown as median (P_{25}-P_{75}) or as n (%).
HEMS, helicopter emergency service; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.
* Mann-Whitney U-test
** Chi-square test with Yates correction
*** Fisher's Exact test; Shockable vs non-shockable rhythm

Table 4
Comparison of base-line characteristics between survivors and non-survivors after prehospital TCA.

	Survivors (n=36; 3.9%)	Non-survivors (n=879; 96.1%)	p-value
Age (years)	36 (24-50)	48 (30-64)	0.006*
Gender			
Male	27 (75.0%)	657 (76.5%)	0.842**
Female	9 (25.0%)	202 (23.5%)	
Undocumented	0	20	
Trauma Mechanism			
Blunt	26 (72.2%)	738 (84.0%)	0.103***
Road traffic accident	17 (65.4%)	462 (62.6%)	
Fall from height	5 (19.2%)	219 (29.7%)	
Blunt otherwise	4 (15.4%))	57 (7.7%)	
Penetrating	10 (27.8%)	141 (16.0%)	
Stab wound	7 (70%)	68 (48.2%)	
Gunshot wound	2 (20%)	67 (47.5%)	
Penetrating otherwise	1 (10%)	6 (4.3%)	
Time between HEMS dispatch and arrival (minutes)			
Time (minutes)	14 (9-19)	15 (11-20)	0.297*
0-10 minutes	9 (29.0%)	149 (18.7%)	
11-15 minutes	9 (29.0%)	279 (35.0%)	
> 15 minutes	13 (41.9%)	369 (46.3%)	
Undocumented	5	82	
First ECG rhythm			
Asystole or PEA	19 (82.6%)	750 (96.6%)	0.018**
Shockable (VF/VT)	4 (17.4%)	26 (3.4%)	
Undocumented	13	103	

Data are shown as n (%) or median (P_{25}-P_{75}).
HEMS, helicopter emergency service; EMD, electromechanical dissociation.
* Mann-Whitney U test
** Fisher's Exact test
*** Chi-square test with Yates correction

Table 5
Comparison of prehospital interventions by survivors and non-survivors after prehospital TCA.

	Survivors (n=36; 3.9%)	Non-survivors (n=879; 96.1%)	p-value
Airway management			
Bag mask ventilation only or supraglottic airway device (LMA)	2 (5.9%)	107 (13.8%)	0.286*
Endotracheal intubation or surgical airway	32 (94.1%)	668 (86.3%)	
Undocumented	2	104	
Thoracic decompression			
None or needle thoracostomy	23 (67.6%)	439 (52.2%)	0.111**
Finger thoracostomy	11 (32.4%)	402 (47.8%)	
Undocumented	2	38	
Prehospital thoracotomy			
Yes	2 (5.6%)	61 (6.9%)	1.000*
No	34 (94.4%)	818 (93.1%)	
Prehospital transfusion of packed red cells			
Yes	6 (16.7%)	88 (10.2%)	0.330*
No	30 (83.3%)	774 (89.8%)	
Unknown / undocumented	0	17	

Data are shown as n (%).
LMA, Laryngeal Mask Airway.
* Fisher's exact test
** Chi-square test with Yates continuity correction

Table 6
Suspected reasons for prehospital traumatic cardiac arrest in 36 survivors.

	Survivors (n=36)
Cardiac tamponade	4 (12.1%)
Commotio cordis	1 (3.0%)
Hypovolemia	8 (24.2%)
Hypoxia due to other causes	3 (9.1%)
Hypoxia due to traumatic brain injury induced apnea / unconscious airway obstruction	15 (45.5%)
Tension pneumothorax	2 (6.1%)
Undocumented or unclear	3

or paramedic based) all may significantly impact on the presented survival percentages: Due to short distances in the Netherlands, ground EMS resuscitation has often not yet or has just been initiated upon arrival of HEMS-crews. Together with the "always start, unless" paradigm a high on-scene mortality-rate may be expected. Conversely, patients who regain spontaneous circulation after on-scene resuscitation have a much higher chance of surviving to discharge (13.7%). To further improve outcomes after TCA, first responders and laymen should be adequately trained to treat massive bleeding and airway obstruction. Ground EMS crews should be made even more aware that survival is possible after TCA if correct measures are taken early.

Data from the current study indicates lower patient age and an initially shockable ECG rhythm to be associated with increased odds of survival. A recent systematic review and meta-analysis including 53 studies by Tran *et al*. identified an initial shockable cardiac rhythm as a powerful predictor of survival in prehospital TCA, amid multiple other factors such as cardiac motion on ultrasound, witnessed arrest and bystander CPR [8]. Although studies like this are very insightful, identifying potential survivors on scene (and maybe more important, those with no chance of neurologic intact survival) remains extremely challenging. Unfortunately, this study does not provide a definitive answer to this question, but it illustrates that a resuscitation attempt should always be initiated as soon as possible, unless there are obvious non-survivable injuries, as neurologic survival is possible even when the initial prospect looks very bleak [9]. Conversely, in patients who remain pulseless after all potentially reversible causes of TCA have been addressed and treated accordingly, the threshold to quickly terminate resuscitation on-scene must be low. Once resuscitation is initiated, point of care ultrasound can be a useful adjunct in these patients, as pulseless trauma patients without cardiac motion on ultrasound and without any electric activity on ECG seem to have zero chance of survival [10].

Interestingly, administration of epinephrine and prehospital intubation were previously associated with decreased odds of survival [8]. While we did not have data on epinephrine administration available for this study, the evidence that epinephrine may actually harm the patient with TCA is accumulating [11]. The same point could be made with regard to endotracheal intubation of trauma patients with TCA [12]. In the current study, many patients underwent some form of advanced airway management, however, an association with survival was not found. Nevertheless, findings like these fuel the debate about what would be the best approach for the pulseless trauma patient in the prehospital environment. The absence of any survival benefit related to epinephrine administration and airway management, as well as high survival percentages from trauma systems without a physician on scene are in support of a more minimalistic approach where patients are transported to the nearest hospital without any on scene interventions apart from chest compression and non-invasive ventilation [4]. On the other hand, transportation of patients without circulation (Scoop & run) did not yield any survivors in this study. Therefore, addressing reversible causes directly on-scene may lead to quicker ROSC with less hypoxic tissue damage and thus better (neurologic) outcomes. Which strategy is most successful most likely depends on a multitude of factors, including the trauma mechanism, injuries, time required to arrive on scene, and distance to the nearest trauma center. Several studies have shown that a "scoop and run" approach is preferable in patients with penetrating injury, especially when in hemorrhagic shock [13–15]. An exception to this may be the pulseless patients with cardiac tamponade due to a stab wound, as swift on-scene thoracotomy and decompression of the pericardium can result in ROSC quite successfully [16,17]. For patients with TCA after blunt trauma it is much more difficult to decide which strategy is best, as different injuries may dictate different approaches with regard to on-scene procedures and time.

This study has several strengths and limitations. At first, this was not a registry study, but rather the biggest available retrospective database study on this subject. We were able to confirm from the source data that all included patients fulfilled the criteria for TCA. By excluding patients with a suspected or confirmed medical cause of cardiac arrest and patients who only had bystander CPR but ROSC upon arrival of EMS crews, we are certain that all included patients really had circulatory arrest resulting from trauma. A second limitation is that a lot of data were missing, especially regarding some variables mentioned in the Utstein consensus statement on reporting on out of hospital cardiac arrest, such as time to chest compressions and duration of CPR [18]. While this makes it difficult to compare patients on an individual basis, the results of this study are reliable and informative with regard to outcomes.

Conclusion

A small proportion of patients suffering from TCA survive after prehospital resuscitation and half of these patients have an intact neurological function. Patients younger than 70 years and patients with a shockable ECG rhythm seem to have higher survival rates after TCA.

Declaration of Competing statement

There are no conflicts of interest in the materials or subject matter dealt with the manuscript.

Contributor ship statement

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data. All authors were involved in drafting the article or critically revising it for important intellectual content. And, finally, all authors approved the version to be published.

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