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Factors associated with outcomes in traumatic cardiac arrest patients without prehospital return of spontaneous circulation

Yi-Chuan Chen[a,b], Kai-Hsiang Wu[a], Kuang-Yu Hsiao[a,b], Ming-Szu Hung[c,d,*], Yi-Chen Lai[a], Yuan-Shun Chen[a], Chih-Yao Chang[a]

[a] Department of Emergency Medicine, Chang Gung Memorial Hospital, No. 6, W. Sec., Jiapu Rd., Puzih City, Chiayi County 613, Taiwan
[b] Department of Nursing, Chang Gung University of Science and Technology, Chiayi Campus, Chiayi, Taiwan
[c] Division of Thoracic Oncology, Department of Pulmonary and Critical Care Medicine, Chang Gung Memorial Hospital, No. 6, W. Sec., Jiapu Rd., Puzih City, Chiayi County 613, Taiwan
[d] Chang Gung University College of Medicine, No. 5, Fusing St., Gueishan Township, Taoyuan County 333, Taiwan

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ABSTRACT

Background: Prognostic factors for the outcomes in traumatic cardiac arrest (TCA) patients transported to hospitals without prehospital return of spontaneous circulation (ROSC) remain uncertain. The aim of this study is to investigate factors associated with outcomes in TCA patients without prehospital ROSC.
Methods: We conducted a retrospective cohort study using a multi-institutional, 5-year database. Only TCA patients without prehospital ROSC were included. The primary outcome was ROSC in the emergency department (ED), and the secondary outcome was 30-day survival. Logistic regression analysis was performed to determine the factors associated with primary and secondary outcomes.
Results: Among 463 TCA patients, 73 (16%) had ROSC during ED resuscitation, and among those with sustained ROSC, 10 (14%) survived for at least 30 days. Injury severity score ≧ 16 (OR, 0.06; 95% CI: 0.02–0.20), trauma center admission (OR, 2.69; 95% CI: 1.03–7.03), length of ED resuscitation (OR, 0.98; 95% CI: 0.96-0.99), and total resuscitation length > 20 min (OR, 0.21; 95% CI: 0.08–0.54) were associated with ROSC.
Conclusions: In TCA patients transported to hospitals without prehospital ROSC, resuscitation attempts could be beneficial. We should aim to resuscitate patients as soon as possible with appropriate treatments for trauma patients, early activation of trauma team, and then, as a result, shorter resuscitation time will be achieved.

Background

In industrialized countries, out-of-hospital cardiac arrest (OHCA) is a leading cause of mortality and an increasing issue of public health concern [1,2]. Medical cardiac arrests account for most cardiac arrest cases presenting to the emergency department (ED), whereas traumatic cardiac arrests (TCAs) only account for a small proportion [3]. Despite advances in modern medical knowledge and interventional techniques, the overall rates of survival to hospital discharge of TCA patients are still low, at approximately 2% [4]. The survival rates for blunt trauma patients with no visible signs of life were also extremely low, ranging from 0% to 2% [5,6], and among the survivors, the neurological deficits were generally severe and permanent [5]. More recent publications, using data from prospectively registered trauma systems, have reported TCA survival rates comparable to those for out-of-hospital medical cardiac arrest [7,8]. Data from the England prehospital trauma database, Spanish prehospital trauma database, and the trauma registry data from North America revealed an overall survival between 5.7% and 7.5% [7–9]. Some studies have demonstrated that resuscitation of patients who experience TCA is not futile and that good outcomes may be achieved in selected patient groups, especially in those with penetrating injuries [10,11]. Overall, the outcomes of OHCA patients are associated with multiple variables, including age, comorbidities, initial rhythm recorded on the monitor, and the return of spontaneous circulation (ROSC) [12]. Among these variables, the most influential prerequisite associated with survival from OHCA is ROSC in the field,

* Corresponding author at: Division of Thoracic Oncology, Department of Pulmonary and Critical Care Medicine, Chang Gung Memorial Hospital, No. 6, W. Sec., Jiapu Rd., Puzih City, Chiayi County 613, Taiwan.
E-mail addresses: giomacky@cgmh.org.tw (Y.-C. Chen), charleswu@cgmh.org.tw (K.-H. Wu), n12050@cgmh.org.tw (K.-Y. Hsiao), m12049@adm.cgmh.org.tw (M.-S. Hung), 2wsx3edc@cgmh.org.tw (Y.-C. Lai), mp5835@cgmh.org.tw (Y.-S. Chen), Mp8658@cgmh.org.tw (C.-Y. Chang).

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regardless of the subsequent in-hospital care [2]. However, the substantial factors for outcomes in TCA patients without prehospital ROSC remain unclear. The aim of our study was to evaluate the rates of ROSC and 30-day survival and determine the factors associated with outcomes in patients without prehospital ROSC after TCA.

Methods

Patients

We performed a retrospective cohort investigation of all adult TCA patients (>18 years old) admitted to the EDs using a prospective registry system in 5 hospitals from January 2010 to December 2014. This study was conducted in 5 branches of Chang Gung Memorial Hospital, with 3 trauma centers, 1 regional hospital, and 1 local hospital. A trauma center was defined as a hospital equipped with at least one well-trained trauma team, with 24/7 accessibility and availability of general surgeons, neurosurgeons, cardiovascular surgeons, thoracic surgeons, orthopedic surgeons, anesthesiologists, and radiologists. A non-trauma center, such as a reginal hospital or a local hospital, was defined as a hospital without a trauma team or without 24/7 availability of surgeons, anesthesiologists, and radiologists. TCA was defined as cardiac arrest that was a consequence of a prior traumatic event at the scene in the prehospital phase. Individuals who had obvious signs of death, such as rigor mortis or decapitation, were excluded because they would not have been transported to the hospitals. Individuals suffering from hanging, asphyxia, and drowning, were excluded. Individuals with any type of burn injuries, including scald burns, chemical burns, and electrical burns, were included and were classified as other trauma to distinguish from blunt trauma and penetrating trauma. Individuals with prehospital ROSC before arrival to the hospital were also excluded. After arrival to the hospital, patients who received no further resuscitation attempts, including chest compressions, defibrillation, or assisted ventilation with endotracheal intubation, were excluded. The study was approved by the Chang Gung Medical Foundation Institutional Review Board (IRB No. 201600741B0C501), and the requirement for written informed consent was waived by the IRB because of the retrospective and observational nature of this study.

Data collection

Prehospital information, which was mainly based on Utstein style, including event location, witness status, shockable rhythm on initial cardiac monitor, bystander cardiopulmonary resuscitation (CPR), emergency medical service (EMS) response time, EMS scene time, EMS transport time, and prehospital length of resuscitation, was collected from EMS records. Demographic data; injury severity score; causes and types of trauma; baseline medical conditions, including history of myocardial infarction, heart failure, stroke, chronic obstructive pulmonary disease, renal disease, and malignancy; and ED resuscitation reports, were obtained from medical records of participating hospitals.

Definition of traumatic cardiac arrest

In this study, TCA was defined as cardiac arrests caused by presumable traumatic events at scene in prehospital phase. Individuals with vital signs during initial assessment by emergency medical technicians or paramedics in the field were excluded.

Outcomes

The primary outcome of this study was sustained return of spontaneous circulation, which was defined as ROSC > 2 h. The secondary outcome was 30-day survival. The 30-day survival was defined as the rate of survival within the first 30 days of incidence of traumatic event.

Statistical analysis

Categorical variables were presented as percentages. Continuous variables were presented as medians with interquartile ranges. Mann–Whitney *U*-test and Fisher's exact test were used to compare the statistically significant differences between the ROSC and non-ROSC groups, and 30-day survival and 30-day mortality groups. A logistic regression model was then developed. All variables with p value < 0.25 in the univariate analysis were entered into a multivariable logistic regression model [13]. The linear relationship between each independent variable and the logit of the outcome variable is checked with a Box-Tidwell test.

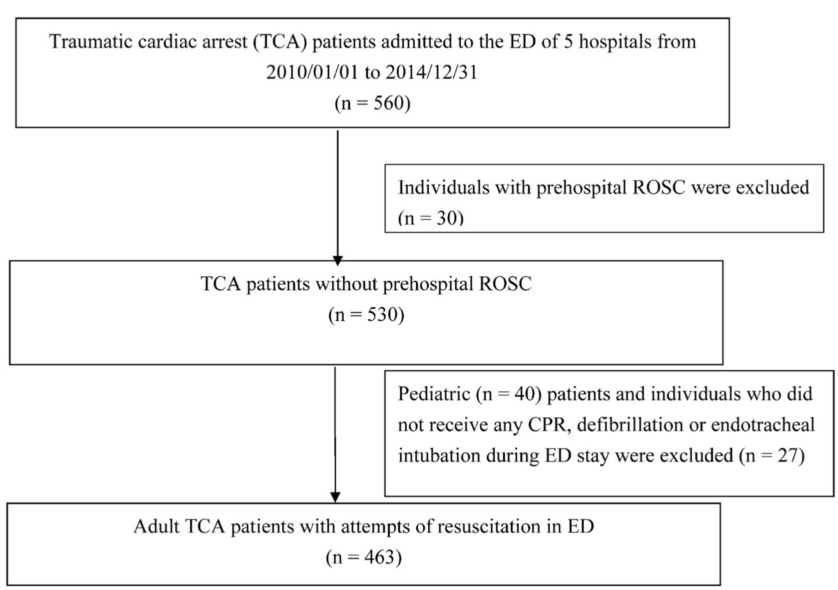

Fig. 1. Flowchart of identification of study sample. ED: emergency department; ROSC: return of spontaneous circulation; CPR: cardiopulmonary resuscitation.

Logistic regression models were fitted using ROSC as a dependent variable. A p value < 0.05 was considered significant. All analyses were performed by using SPSS version 20 (IBM SPSS Statistics, IBM Corporation, Armonk, New York).

Results

Patient characteristics

Fig. 1 illustrates the selection process for the study participants. A total of 560 TCA patients presenting to the ED during the study period were identified, of which 530 (95%) patients suffered TCA and did not have prehospital ROSC. Among the 530 TCA patients, 40 (8%) were pediatric (age: ≤18 years), and 27 (5%) patients did not receive any further resuscitation during the ED stay. A total of 463 patients constituted the study cohort. Among the 463 patients, 73 (16%) experienced sustained ROSC, and 10 (2%) survived for at least 30 days.

Table 1 lists the prehospital variables, demographic characteristics, comorbidities, resuscitation site, causes and types of trauma, ED resuscitation management, and total length of resuscitation of the non-ROSC and ROSC groups. The ROSC group had a higher rate of bystander CPR compared with the non-ROSC group (8% vs 3%, p = 0.054).

Table 2 reveals the prehospital variables, demographic characteristics, comorbidities, resuscitation site, causes and types of trauma, ED resuscitation management, and total length of resuscitation of the 30-day mortality and 30-day survival groups. A public location of the traumatic event was seen to be significantly lower in the 30-day survival group compared to the 30-day mortality group (60% vs 90%, p = 0.028).

Table 3 summarizes the results of logistic regression for factors associated with ROSC (Table 3). Box-Tidwell test revealed that the effects of quantitative variables, including response time, transport time, prehospital length of resuscitation and length of ED resuscitation, were linear (p = 0.30, 0.06, 0.96, 0.42, respectively). After entering all the variables with p value < 0.25 in Table 1, injury severity score ≧ 16 (adjusted odds ratio [OR], 0.06; 95% confidence interval [CI]: 0.02–0.20), trauma center admission (OR, 2.69; 95% CI: 1.03–7.03), length of ED resuscitation (OR, 0.98; 95% CI: 0.96-0.99), and total resuscitation length > 20 min (OR, 0.21; 95% CI: 0.08–0.54) were associated with sustained ROSC.

Table 1
Characteristics of patients with and without return of spontaneous circulation (ROSC).

Characteristic	Non-ROSC		ROSC		p value
	N = 390 (84%)		N = 73 (16%)		
	n	%	n	%	
Location: public	352	90	62	85	0.24
Witnessed	48	12	10	14	0.87
Shockable rhythm	13	3	3	4	0.95
Bystander CPR	10	3	6	8	0.054
Response time (minutes)	9 (median)	6-10 (IQR)	9 (median)	4-10 (IQR)	0.14
Scene time (minutes)	14 (median)	10-20 (IQR)	12 (median)	10-18 (IQR)	0.33
Transport time (minutes)	5 (median)	2-10 (IQR)	4 (median)	1-7 (IQR)	0.004
Prehospital length of resuscitation (minutes)	8 (median)	8-14 (IQR)	8 (median)	4-10 (IQR)	0.001
Male	288	74	50	69	0.42
Age	49 (median)	35-62 (IQR)	50 (median)	34-58 (IQR)	0.78
Injury severity score (ISS) ≧ 16	384	98	56	77	<0.001
Medical history					
MI	1	0	2	3	0.12
Heart failure	12	3	3	4	0.86
CVA	15	4	5	7	0.39
COPD	35	9	6	8	1.0
Renal disease	13	3	3	4	0.95
Malignancy	17	4	3	4	1.0
Resuscitation site					
Trauma center	315	81	66	90	0.06
Causes of trauma					
Traffic accident	242	62	45	62	1.00
Pedestrian	21	5	4	6	
Bicycle	14	4	3	4	
Motor vehicles	199	51	34	47	
Other	8	2	4	6	
Fall	89	23	13	18	
Others	59	15	15	21	
Type of trauma					
Blunt trauma	345	89	61	84	0.33
Penetrating trauma	10	3	2	3	
Other trauma	35	9	10	14	
Resuscitation management at ED					
Defibrillation	18	5	6	8	0.32
Length of ED resuscitation (minutes)	33 (median)	24-50 (IQR)	18 (median)	9-30 (IQR)	<0.001
Total length of resuscitation > 20 minutes	371	95	47	64	<0.001

CPR: cardiopulmonary resuscitation; IQR: interquartile range; MI: myocardial infarction; CVA: cerebrovascular accident; COPD: chronic obstructive pulmonary disease; ED: emergency department.
Other trauma: any type of burn injuries, including scald burns, chemical burns, and electrical burns.
The p value presented in Table 1 is the double of the one-tailed exact probability.

Table 2
Basic characteristics of patients with 30-day survival and 30-day mortality.

Characteristic	30-day mortality		30-day survival		p value
	N = 453 (97.8%)		N = 10 (2.2%)		
	n	%	n	%	
Location: public	408	90	6	60	0.028
Witnessed	56	12	2	20	0.77
Shockable rhythm	15	3	1	10	0.60
Bystander CPR	15	3	1	10	0.60
Response time (minutes)	9 (median)	6-10 (IQR)	4.5 (median)	1-6 (IQR)	0.014
Scene time (minutes)	14 (median)	10-19 (IQR)	14.5 (median)	9-20 (IQR)	0.91
Transport time (minutes)	5 (median)	2-9 (IQR)	2 (median)	1-4 (IQR)	0.015
Prehospital length of resuscitation (minutes)	8 (median)	8-13 (IQR)	5 (median)	1-10 (IQR)	0.13
Male	332	73	6	60	0.54
Age	49 (median)	35-60 (IQR)	53 (median)	39-59 (IQR)	0.55
Injury severity score (ISS)≧ 16	434	96	6	60	<0.001
Medical history					
MI	2	0	1	10	0.13
Heart failure	15	3	0	0	1.00
CVA	19	4	1	10	0.72
COPD	40	9	1	10	1.00
Renal disease	16	4	0	0	1.00
Malignancy	19	4	1	10	0.72
Resuscitation site					
Trauma center	372	82	9	90	0.89
Causes of trauma					
Traffic accident	283	62	4	40	0.26
Pedestrian	25	6	0	0	
Bicycle	17	4	0	0	
Motor vehicles	229	51	4	40	
Other	12	3	0	0	
Fall	100	38	2	20	
Others	70	16	4	40	
Type of trauma					
Blunt trauma	399	88	7	70	0.23
Penetrating trauma	12	3	0	0	
Other trauma	42	9	3	30	
Resuscitation management at ED					
Defibrillation	24	5	0	0	1.00
Length of ED resuscitation (minutes)	30 (median)	21–48 (IQR)	6 (median)	6-9 (IQR)	<0.001
Total length of resuscitation > 20 minutes	415	92	3	30	<0.001

CPR: cardiopulmonary resuscitation; IQR: interquartile range; MI: myocardial infarction; CVA: cerebrovascular accident; COPD: chronic obstructive pulmonary disease; ED: emergency department.
Other trauma: any type of burn injuries, including scald burns, chemical burns, and electrical burns.
The p value presented in Table 2 is the double of the one-tailed exact probability.

Discussion

This study has demonstrated a 2% 30-day survival for individuals presenting with TCA without prehospital ROSC from a multi-institutional registry system during a 5-year period. This survival is consistent with that reported in a recent large-scale study in North America using data from two registry systems [8]. In the North American report, the survival rate was 1.8% (95% CI, 1.1%–3.0%) in the Resuscitation Outcomes Consortium Epistry-Trauma, while the rate was 1.6% in the Prospective Observational Prehospital and Hospital Registry for Trauma [8]. It is likewise comparable to the 2.3% survival from prehospital medical cardiac arrest in another investigation in Taiwan in 2016 [14]. A report from Japan in 2013 demonstrated a 30-day survival rate of 1.9% in all OHCA patients (including TCA and non-TCA) without prehospital ROSC [15]. In contrast, in TCA patients with prehospital ROSC, the survival rate was increased, ranging from 3.9% to 16.6% [7,16,17].

Our study also demonstrated that a total of 73 (16%) patients had sustained ROSC during ED resuscitation, although they did not have prehospital ROSC. The rate of ROSC in our study was comparable to a recent nationwide population-based study in Qatar (14.9%) [18]. The rate of ROSC in TCA patients was actually high, ranging from 19.6% to 31.4% [15,19,20]. These findings suggest that the resuscitation attempts in TCA patients could be beneficial if performed promptly and if early aggressive management could be directed toward reversible causes of TCA.

Table 3
Logistic regression analysis of factors associated with return of spontaneous circulation (ROSC).

Variables	Adjusted odds ratio	95% CI
Injury severity score (ISS)≧ 16	0.06	0.02–0.20
Trauma center admission	2.69	1.03–7.03
Length of ED resuscitation (minutes)	0.98	0.96–0.99
Total length of resuscitation > 20 min	0.21	0.08–0.54

CPR: cardiopulmonary resuscitation; ED: emergency department.

In our study, an increased injury severity score was associated with unfavorable ROSC, which is consistent with a previous study [19]. Another finding of this study was that a longer length of ED resuscitation was associated with a lower rate of ROSC. However, a longer length of ED resuscitation may be associated with more severe traumatic injury, which may need more cares and interventions. We believed that a shorter length of ED resuscitation was resulted from an earlier ROSC.

The pathophysiology of TCA is different to medical causes of cardiac arrest, and different treatment priorities may also be needed [21]. Most of patients suffering medical cardiac arrests have a full circulating volume, and therefore restoring a proportion of cardiac output by external chest compressions is one of the key elements of resuscitation [22,23]. In contrast, critical hypovolemia, tension pneumothorax or cardiac tamponade are main causes of reversible TCA in the majority of traumatic patients [24,25]. Delivering cardiopulmonary resuscitation alone is insufficient to mend these reversible causes. To provide the most effective treatment, a well-established protocol to initiate potential massive transfusion, to stop hemorrhage, and an experienced team for TCA resuscitation, detecting free fluid in the abdomen, pericardial effusion and pneumothorax and assessing cardiac contractility and filling by real time ultrasound are warranted [26,27].

Although there are no established factors associated with TCA outcomes, a favorable outcome has been correlated with isolated penetrating trauma, shorter prehospital times, and shorter periods of cardiopulmonary resuscitation [18,24,28,29]. In addition, our study also observed that admission to trauma center was associated with favorable ROSC. Previous studies have been shown that trauma centers improve outcome of severely traumatic patients compare to non-trauma centers [30,31]. In our study, a trauma center is equipped with a well-trained trauma team, with 24/7 accessibility and availability of all surgeons, anesthesiologists, and radiologists, increasing the possibility of quick ROSC. In contrast, in a non-trauma center, a trauma team, 24/7 availability of all kinds of surgeons and other specialists, are not mandatory, and delay of ROSC may exist due to lack of obtainable resources and assistances. Further studies are still needed to clarify the difference of outcomes of TCA patients between trauma and non-trauma centers.

One recent study in Australia demonstrated that age $\geq$ 65 years (OR, 1.56, 95% CI: 1.01–2.43) and shockable rhythm (OR, 3.65, 95% CI: 1.64–8.11) were associated with increased rate of ROSC as a result of multivariable logistic regression [20]. Another research demonstrated that shockable rhythm was associated with a higher rate of survival in TCA patients [18]. Shockable rhythm seemed to have no association with outcomes in our study, whereas the ROSC group had a higher rate of bystander CPR compared with the non-ROSC group (8% vs 3%, p = 0.054). These findings imply the importance of Utstein factors in TCA and further investigations are warranted.

There are several potential limitations of this study. The major limitation of our study is that of its observational and retrospective nature. Moreover, associations do not correspond to causality, and unmeasured confounders may exist. The small number of survivors limited further exploration of prognostic factors using multivariable analysis for 30-day survival. An insufficient number of patients has been a problem throughout the literature with regard to TCA [18,20]. Furthermore, because of the duration of the study, inconsistencies in treatment due to different guidelines may be present, resulting in variations in the outcomes.

Conclusion

This observational cohort study reveals an ROSC rate of 16% and a 30-day survival rate of 2% in 463 TCA patients without prehospital ROSC. It also demonstrates that an injury severity score < 16, trauma center admission, a shorter length of ED resuscitation, and total resuscitation length < 20 min, are associated with favorable ROSC. To transport TCA patients to the trauma centers, simple and accurate transport criteria for EMS are required. To achieve early and sustained ROSC, a well-trained trauma team and organized algorithms for identification and management of reversible causes should be settled. Further studies, including investigations of the role of established protocols on outcome improvement, and the association between trauma center transport and the outcomes in TCA patients, are suggested.

Author contributions

Yi-Chuan Chen conceived the study, designed the method, managed the data including quality control, chaired the data oversight committee, and drafted the manuscript.

Kai-Hsiang Wu conceived the study, designed the method, supervised the conduct of the data collection, analyzed the data, and drafted the manuscript.

Kuang-Yu Hsiao conceived the study, designed the method, and supervised the conduct of the data collection.

Ming-Szu Hung conceived the study, designed the method, managed the data including quality control, provided statistical advice on study design, analyzed the data, and drafted the manuscript

Yi-Chen Lai conceived the study, designed the method, provided statistical advice on study design, and drafted the manuscript.

Yuan-Shun Chen conceived the study, designed the method, and supervised the conduct of the data collection.

Chih-Yao Chang conceived the study, designed the method, and supervised the conduct of the data collection.

All authors approved the final version of the manuscript. MSH takes responsibility for the paper as a whole.

Conflict of interest

The authors declare that they have no conflict of interest.

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