Injury, Int. J. Care Injured (2006) **37**, 448—454

ELSEVIER

INJURY
INTERNATIONAL JOURNAL OF THE CARE OF THE INJURED

www.elsevier.com/locate/injury

Cardiopulmonary resuscitation after traumatic cardiac arrest is not always futile

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Accepted 16 November 2005

KEYWORDS
Trauma;
Cardiopulmonary resuscitation;
Resuscitation guidelines

Summary

Introduction: The use of guidelines regarding the termination or withholding of cardiopulmonary resuscitation (CPR) in traumatic cardiac arrest patients remains controversial. This study aimed to describe the outcomes for victims of penetrating and blunt trauma who received prehospital CPR.
Methods: We conducted a retrospective review of a statewide major trauma registry using data from 2001 to 2004. Subjects suffered penetrating or blunt trauma, received CPR in the field by paramedics and were transported to hospital. Demographics, vital signs, injury severity, prehospital time, length of stay and mortality data were collected and analysed.
Results: Eighty-nine patients met inclusion criteria. Eighty percent of these were blunt trauma victims, with a mortality rate of 97%, while penetrating trauma patients had a mortality rate of 89%. The overall mortality rate was 95%. Sixty-six percent of patients had a length of stay of less than 1 day. Four patients survived to discharge, of which two were penetrating and two were blunt injuries. Hypoxia and electrical injury were probable associated causes of two cardiac arrests seen in survivors of blunt injury.
Conclusions: While only a small number of penetrating and blunt trauma patients receiving CPR survived to discharge, this therapy is not always futile. Prehospital emergency personnel need to be aware of possible hypoxic and electrical causes for cardiac arrest appearing in combination with traumatic injuries.

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0020–1383/$ — see front matter
doi:10.1016/j.injury.2005.11.011

Introduction

In 2001, The National Association of Emergency Medical Services Physicians (NAEMSP) and the American College of Surgeons Committee on Trauma established guidelines regarding the termination or withholding of out of hospital resuscitation in traumatic cardiopulmonary arrest cases (Table 1).[8] This came in response to increasing evidence of low survival rates and exceedingly poor outcomes following cardiopulmonary resuscitation (CPR) in trauma victims.[17] Blanket administration of CPR in the prehospital setting for cases widely predicted as having poor survival and neurological recovery, represents potential medical futility with both economic and personal risks.[4]

However, the adoption of these guidelines remains controversial. While trauma represents the greatest threat to life for all people between 1 and 44 years of age, the incidence of successful CPR in blunt and penetrating injuries remains largely unreported. A trauma registry (VSTR), developed in 2001, was ideally placed to investigate the outcomes for all major trauma, including those who receive CPR in the field. Results from this analysis contribute to a growing literature regarding the impact of prehospital CPR on trauma victims and examine the issue from an Australian perspective.

Table 1 NAEMSP and ACSCOT guidelines for the termination of prehospital CPR[8]

No.	Guideline descriptor
1	Resuscitation efforts may be withheld in any blunt trauma patient who, based on out-of-hospital personnel's thorough primary assessment, is found apneic, pulseless, and without organized ECG activity upon the arrival of EMS at the scene
2	Victims of penetrating trauma found apneic and pulseless by EMS, based on their patient assessment, should be rapidly assessed for the presence of other signs of life such as pupillary reflexes, spontaneous movement or organised ECG activity. If any of these signs are present, the patient should have resuscitation performed and be transported to the nearest emergency department or trauma centre. If these signs of life are absent, resuscitation efforts may be withheld
3	Resuscitation efforts should be withheld in victims of penetrating or blunt trauma with injuries obviously incompatible with life, such as decapitation or hemicorporectomy
4	Resuscitation efforts should be withheld in victims of penetrating or blunt trauma with evidence of a significant time lapse since pulselessness, including dependent lividity, rigor mortis and decomposition
5	Cardiopulmonary arrest patients in whim the mechanism of injury does not correlate with clinical condition suggesting a non-traumatic case of the arrest should have standard resuscitation initiated
6	Termination of resuscitation efforts should be considered in trauma patients with EMS-witnessed cardiopulmonary arrest and 15 min of unsuccessful resuscitation and cardiopulmonary resuscitation (CPR)
7	Traumatic cardiopulmonary arrest patients with a transport time to an emergency department or trauma centre of more than 15 min after arrest is identified may be considered non-salvageable, and termination of resuscitation should be considered
8	Guidelines and protocols for TCPA patients who should be transported must be individualised for each EMS system. Airway management and intravenous (i.v.) line placement should be accomplished during transport when possible
9	Special consideration must be given to victims of drowning and lightning strike and in situations where significant hypothermia may alter the prognosis
10	EMS providers should be thoroughly familiar with guidelines and protocols affecting the decision to withhold or terminate resuscitation
11	All termination protocols should be developed and implemented under the guidance of the system EMS medical director. On-line medical control may be necessary to determine the appropriateness of termination of resuscitation
12	Policies and protocols for termination of resuscitation efforts must include notification of the appropriate law enforcement agencies and notification of the medical examiner or coroner for final disposition of the body
13	Families of the deceased should have access to resources, including clergy, social workers, and other counselling personnel as needed. EMS providers should have access to resources for debriefing and counselling as needed
14	Adherence to policies and protocols governing termination of resuscitation should be monitored through a quality review system

Methods

Setting

This study was conducted within the Victorian State Trauma System, which serves a population of approximately 5 million. Prehospital emergency care is administered by both road and air ambulance services supporting one paediatric and two major adult trauma services with another 126 metropolitan and rural health services. The EMS is two tiered, and paramedics with advanced trauma life support skills (intubation, intravenous (i.v.) cannulation and decompression of tension pneumothorax) are dispatched to all patients with suspected major trauma. The protocol for penetrating trauma specifically mandates that scene time not be prolonged for i.v. access and fluid therapy.

Population

All patients meeting major trauma inclusion criteria for VSTR were included. Major trauma is defined as: death following injury; admittance to intensive care unit for greater than 24 h requiring mechanical ventilation; serious injury to two or more body systems, ISS $>$ 15; urgent surgery for intracranial, intrathoracic, intra-abdominal injuries, or fixation of spinal or pelvic fractures.[3] All blunt and penetrating trauma patients receiving CPR in the field and transported to hospital were reviewed for this analysis. Patients with documented primary injury resulting from a near-drowning, hanging, burns or electrocution injury were excluded. Patients with unequivocally fatal injuries in whom CPR was not commenced were also excluded.

Data collection

Demographic data including age, gender, Injury Severity Score (ISS), type of injury (penetrating or blunt), time at scene, time to hospital, length of stay in days and mortality outcome (survived or died) were recorded. Systolic blood pressure (SBP) and heart rate (HR) were also recorded for each patient at scene and in the emergency department (ED). The modified Functional Measure (FM) as described by the American College of Surgeons was reported where available.

Statistical analyses

Means and standard deviations (S.D.) were reported. Statistical analysis compared group differences for penetrating and blunt injury mechanisms. Mortality rates were calculated for group data as well as individual injury mechanisms. Chi-Square or Fisher's exact and ANOVA or Kruskall–Wallis statistical tests were used to determine differences for categorical and continuous variables respectively, with a $p < 0.05$ regarded as statistically significant.

Ethics

Ethics approval for the VSTR database was obtained from the Monash University Standing Committee on Ethical Research Involving Humans, and the Human Research Ethics committees of all participating institutions.

Results

Between July 2001 and December 2004, there were 5349 major trauma cases transported to hospital and recorded by VSTR. Blunt injuries (n = 4787) accounted for the majority of major trauma (89%), while 6.6% were recorded as penetrating (n = 355). There were 1327 traumatic cardiac arrest cases (234 penetrating, 1032 blunt and 61 unknown) where an ambulance was called to scene. Of these, 89 patients received CPR in the field and were subsequently transferred to an ED (thus included in VSTR). These patients formed the population in this analysis.

Within this study sample of 89, there were four survivors, resulting in a mortality rate of 95%. For blunt injuries (n = 71), there was a mortality rate of 97%, whereas, penetrating injuries (n = 18) had an

Table 2 Patient demographics

Injury type	Age (years) (mean ± S.D.)	Gender (M/F)	Scene time (min) (n = 74) (mean ± S.D.)	Transport time (min) (n = 83) (mean ± S.D.)	Length of stay (days) (n = 89) (mean ± S.D.)	ISS (mean ± S.D.)
Blunt	37.06 (22.44)	50/21[a]	28.05 (15.86)	16.44 (15.89)	1.49 (4.45)	38.32 (19.08)[b]
Penetrating	35.67 (13.07)	17/1[a]	20.53 (14.05)	11.24 (6.23)	2.11 (4.98)	29.06 (20.74)[b]
Overall	36.77 (20.79)	67/22	26.32 (15.70)	15.37 (14.58)	1.62 (4.54)	36.35 (20.80)

No significant difference between age, scene time or transport time and length of stay.
[a] Fisher's exact: p = 0.036.
[b] Kruskall–Wallis: p = 0.021.

89% mortality rate ($p = 0.181$). Table 2 outlines patient demographics, ISS, prehospital time (divided into 'scene time' and 'transport time') and length of stay in days. No significant differences were found between blunt and penetrating trauma victims with regard to age ($p = 0.802$), scene time ($p = 0.083$), transport time ($p = 0.366$) or length of stay ($p = 0.889$). Sixty-six patients had a LOS of <1 day with a mortality rate of 100%; 18 had a length of stay of 1–7 days with a mortality rate of 94%; and five had a length of stay of 8 days or more with a mortality rate of 40%. Penetrating injuries had a significantly higher proportion of males ($p = 0.036$) and a lower ISS ($p = 0.021$) than blunt trauma. Tables 3 and 4 summarize SBP and HR, respectively, as measured in the field and on arrival at the ED for blunt and penetrating injuries. No significant differences could be found for SBP or HR between penetrating and blunt victims. Sixty-six percent of patients had no recordable SBP at the scene, while 49% had no recordable SBP on arrival at hospital. No recordable HR was present for 43% of patients at the scene, while this decreased to 39% of patients at hospital.

Table 5 provides details of the survivors in this analysis. Of the four survivors, two sustained blunt injuries, while two suffered penetrating injuries. All were male. Ages ranged from 16 to 45 with three survivors under 27 years, and ISS's from 17 to 29 (all below the average ISS). Injuries were sustained following a fall, crush injury and stab wounds to the abdomen and heart. Length of stay for survivors ranged from 4 to 18 days. All had good outcomes, being discharged directly home or with a short period of rehabilitation. The modified Functional Measure (FM) was recorded for two survivors at discharge each with a score of 12/12 (full function).

The first blunt injury survivor, a 16-year-old male who fell while surfing on the roof of a train, possibly sustained an electrical as well as a blunt injury (although this was not documented). Without documentation of an electrical injury it was not possible to exclude this patient prior to analysis. The second

Table 3 Prehospital and hospital systolic blood pressure (SBP)

Injury type	Blood pressure at scene (mmHg) *n* (%)				Blood pressure at hospital (mmHg) *n* (%)			
	Unrecorded/ un-recordable	1–50	51–90	>90	Unrecorded/ un-recordable	1–50	51–90	>90
Blunt	51 (72)	0 (0)	10 (14)	10 (14)	40 (56)	3 (4)	9 (13)	19 (27)
Penetrating	15 (83)	0 (0)	1 (6)	2 (11)	14 (78)	0 (0)	2 (11)	2 (11)
Total	66 (74)	0 (0)	11 (12)	12 (14)	54 (61)	3 (3)	11 (12)	21 (24)

No significant difference for SBP at scene or hospital for blunt or penetrating injuries.

Table 4 Prehospital and hospital heart rate (HR)

Injury type	Heart rate at scene (b/min) *n* (%)			Heart rate at hospital (b/min) *n* (%)		
	Unrecorded/ un-recordable	<100	>100	Unrecorded/ un-recordable	<100	>100
Blunt	37 (52)	15 (21)	19 (27)	33 (47)	20 (28)	18 (25)
Penetrating	10 (55)	5 (28)	3 (17)	11 (61)	4 (22)	3 (17)
Total	47 (53)	20 (22)	22 (25)	44 (49)	24 (27)	21 (24)

No significant difference for HR at scene or hospital for blunt or penetrating injuries.

Table 5 CPR survivor specifics

Injury type	Age	ISS	Gender	FM	Specifics	Outcome
Blunt	16	26	M	N/A	Fell from train (train surfing). Loss of consciousness, bilateral lung contusion and scalp laceration	Rehabilitation (10 days)
Blunt	45	26	M	12	Crush between cherry picker and steel beam. Neck/laryngeal injury	Rehabilitation (13 days)
Penetrating	20	17	M	N/A	Fell on bottle (abdominal injury). Urgent laparotomy	Home (4 days)
Penetrating	26	29	M	12	Stab to heart. Laparotomy/thoracotomy	Home (18 days)

blunt victim, a 45-year-old male, sustained a crush injury to the neck/larynx while trapped in a cherry picker against a steel beam. Therefore, it is likely that asphyxia contributed to cardiac arrest. The victim was discovered with no discernable HR or SBP and received a cricothyroidotomy before transfer to the ED. Paramedics spent 45 min at the scene for this patient and 9 min in transit. By arrival at hospital, his SBP had risen to 176 and his HR was 63.

One penetrating injury survivor suffered a direct cardiac puncture. The patient was a 26-year-old male with a cumulative prehospital time of 25 min. At the scene and the ED there was no recordable SBP or HR. The patient responded to immediate thorocotomy in the ED. The patient was discharged 18 days following injury with a FM of 12/12. The second penetrating injury survivor fell on a bottle and required urgent laparotomy for major lacerations to the common femoral vein and artery. This patient had an ISS of 17, no recordable SBP at the scene and a HR of 75. Upon admission to hospital HR was 175, however, hospital records failed to report a SBP. The patient was discharged home after 4 days in hospital.

Discussion

The high mortality rate (95%) for victims of penetrating and blunt injuries who require CPR in the field found in this study was consistent with the prognosis reported by other authors.[8] The vast majority of patients included in this analysis (74%) died within the first day of admission to hospital. Penetrating injuries have previously been associated with an improved chance of survival.[1] Current policies which allow for the termination of CPR in blunt trauma patients who are found with pulseless electrical activity and bradycardia, recognise the poor prognosis of these injuries.[13] However, a statistically significant difference in mortality rates for blunt and penetrating trauma victims was not seen in this analysis because of small numbers. Clearly, those receiving CPR in the field are at a high risk of mortality, and often demonstrate severe hypotension, bradycardia and have major injuries as assessed by the ISS. Despite the use of CPR, these patients have a poor chance of survival.

Predictors of poor outcome following trauma have been reported to include male gender, age and a high ISS.[6,12] Due to the presence of only four survivors in this study it was not possible to identify predictors of survival. However, each of these survivors represented a unique case and warrants further discussion.

There were two survivors of blunt injuries. For the 16 year old, who fell while train surfing, signs of life may have been absent at the scene due in part to the effects of an electrical injury, rather than blunt trauma severity.[18] NAEMSP guidelines allow for the administration of CPR to a trauma patient if the mechanism of injury does not appear to correlate with the clinical condition (such as in this case), or if other signs of life (pupillary reflex, spontaneous movement or organised ECG activity) are present.[8]

In the second blunt injury survivor (a 45-year-old male who sustained an external laryngeal trauma) the primary pathology was probably a hypoxic cardiac arrest from respiratory obstruction. A previous statewide analysis of external laryngeal trauma has found this injury to carry a low incidence (1/137,000) and a reasonable chance of survival (survival rate of 97.96%).[10] Due to this mechanism of injury, the likelihood of recovery is not comparable to traumatic cardiac arrest secondary to haemorrhage and/or head injury. Interestingly, with a total prehospital time of 54 min, NAEMSP guidelines, which withhold CPR based on prolonged scene and transport time, may have limited the use of resuscitation in this patient.

The remaining two survivors sustained penetrating injuries. The direct cardiac puncture victim demonstrated no signs of life at the scene or the ED and was discharged home after 18 days. The final survivor sustained significant abdominal trauma and was discharged home after 4 days of hospitalisation. Penetrating injuries that rupture abdominal vasculature, such as in this case, often lead to severe haemorrhage and death at the scene.[5] In a study by Eachempati et al., those dying from penetrating abdominal injuries were reported to have a lower initial blood pressure, greater blood loss and a greater number of vessels damaged. In the event that a penetrating trauma victim is found pulseless and apneic, but with other signs of life such as in this case, CPR is warranted.[8] CPR for this patient was clearly indicated and contributed to a positive outcome.

Current opinion suggests that good neurological outcome following trauma may be affected by core body temperature, with clinical and experimental data demonstrating neuroprotective benefits of hypothermia during ischaemic incidents, such as cardiac arrest.[7] For the two blunt trauma victims, VSTR data recorded temperatures of 36 and 34.4 °C at hospital, but did not report any data from the prehospital setting. No temperature specific data was available for the remaining survivors. While an independent medical record review may be able to give greater insight into this aspect of prehospital management, the influence of hypothermia on

patient outcome in the present study remains unknown.

Thirty patients (34%) in this study had no recordable SBP, no HR at the scene and were transferred to hospital. Of these, 13 (43%) regained some form of vital sign at hospital. Despite evidence of extremis, this group yielded three of the four survivors in this study. Seventy-three patients (82%) demonstrated a detectable SBP *or* HR at some point in their medical management, thus justifying the need for hospitalisation. Fourteen (16%) patients in this study did not regain vital signs at any stage of their medical management despite aggressive resuscitative efforts (two patients had missing data). Attempts to revive unsalvageable patients can result in the consumption of large amounts of prehospital, ICU and ED care, as well as medical products including blood, medications and equipment. Previous authors have suggested that the survival of a select few needs to be weighed against the burden of resuscitation.[8] While this analysis did not review monetary costs associated with CPR or hospital care, previous assessments have estimated these at being US $4150 per patient.[14] Lengthy hospitalisations were not noted in this study, with the overall length of stay averaging 1.62 days. Further, over the 3-year period, there were only 89 of 5349 presentations requiring CPR. Thus hospital costs were not exceptional.

CPR has been practiced by emergency medical personnel for the last 40 years. Despite this, this study has identified a low rate of CPR in the field, with just 1.73% of all blunt and penetrating injuries receiving CPR. In such cases, evidence from this study as well as others, suggests that the chance of survival is poor.[19] Moreover, when CPR is administered and survival achieved, the physiologic contribution of prehospital CPR to that survival remains questionable.[16] The two survivors from blunt trauma in this study may have pathophysiology secondary to hypoxia and electrical injuries, not comparable to haemorrhage or head injury traumas. The improved outcome following resuscitation for penetrating injury compared with blunt traumas found in other studies, justifies the role of CPR in the field for this group.[1] Victims of blunt and penetrating trauma who have no spontaneous breathing, pulse or ECG activity represent a gravely injured population, and have traditionally received CPR in an effort to prolong life until transfer to definitive care. Restricting the use of CPR in trauma victims remains controversial as potentially life saving interventions should be available to all patients.[17] Noteworthy is the similarity between survival rates for traumatic and non-traumatic cardiac arrests, with the survival rate of 5% in blunt and penetrating trauma found in this study, comparable to 3% in non-traumatic cardiac arrests for the same region.[2] In some studies, survival following CPR in non-traumatic cardiac arrests has been reported to be as low as 1%.[11] CPR for selected trauma patients seems justifiable.

In an attempt to restrict futile medical techniques, NAEMSP guidelines are intended to direct the use of CPR to those patients where a reasonable chance of revival and subsequent transfer to hospital exists. In addition, patients demonstrating a low probability of survival coupled with a high risk for poor quality of life, may now have resuscitative efforts withheld.[9] Prehospital CPR guidelines based on the absence of circulatory and respiratory responses may reduce the incidence of CPR in the field. However, risks remain of withholding resuscitation when it may prove beneficial. Of this study's four survivors, two had the potential for the termination of CPR at the scene, if adherence to NAEMSP guidelines concerning detectable HR and SBP was performed. Importantly, pupillary reactivity and at-scene ECG activity were not recorded from ambulance records into the VSTR. With other authors naming both as clinical indicators of survival following traumatic cardiac arrest, collection of these measures in VSTR data may aid future analyses.[4] While prognosis following CPR is poor for trauma patients, each trauma system needs to provide prehospital emergency personnel with guidelines which reflect systems specific transport, provider and definitive care capabilities.[8]

A recent study by Pickens et al. in the USA attempted to identify predictors for survival following CPR administered to 184 trauma victims in the field. Problems were identified with prehospital assessments, leading the investigators to conclude that decisions concerning patient treatment should be made in the controlled environment of the emergency department.[15] Of particular note in this study was that 13 of the 14 survivors would not have been resuscitated if the NAEMSP/ACSCOT guidelines had been strictly applied. Further, the authors believed that the recommended guidelines were not applicable for rapid transport trauma systems, such as in Victoria. Our study confirms this. For application outside the USA in regionalised trauma systems, the NAEMSP guidelines require review and modification to suit existing trauma management.

There were a number of limitations in this study. Variables such as duration of arrest and length of resuscitative effort may also contribute to mortality and confound comparisons between injury mechanisms, and were not collected in this investigation.[4] While there were a large number of penetrating and blunt injuries sustained in Victoria, during the study

period, the low numbers who received CPR and were admitted to hospital limited the capacity of this investigation to identify statistically significant differences. The limited use of CPR for blunt and penetrating traumas seen in this study may reflect paramedic judgements which potentially restrict the use of resuscitation in cases they deem to be unsalvageable. However, the decision making of paramedics to withhold treatment in some patients who die at scene is not documented.

Conclusion

Over a 3-year period, in a population of 5 million people, there were four survivors of penetrating and blunt trauma who received prehospital CPR. Of these, two were penetrating injuries, with one demonstrating signs of life. Two were exceptional blunt injury circumstances, probably experiencing cardiac arrest secondary to electrocution and hypoxia. The current NAEMSP guidelines for withholding or terminating resuscitation in prehospital traumatic cardiac arrest require careful consideration when applied in the field.

Acknowledgements

The Victorian State Trauma Registry is funded by the Victorian Trauma Foundation and the Department of Human Services, Victoria. Thanks to Andrew Hannaford for preparation of the data set. Thanks also to Vanessa Barnes (the Victorian Ambulance Cardiac Arrest Registry VACAR) for non-VSTR data.

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