Prehospital cardiopulmonary resuscitation in the pediatric trauma patient

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Abstract
Purpose: Children requiring prehospital cardiopulmonary resuscitation (CPR) after traumatic injury have been shown to have poor survival. However, outcome of children still receiving CPR on-arrival by emergency medical service to the emergency department (ED) has not been demonstrated in a published clinical series.

Methods: An 11-year retrospective analysis from a level I pediatric trauma center of the outcomes of children requiring prehospital CPR after traumatic injury was undertaken. Outcome variables were stratified by survival, death, and CPR on-arrival.

Results: Of 169 children requiring prehospital CPR, there were 28 survivors and 141 deaths. Of 69 children requiring CPR on-arrival to the ED, there were no survivors. There were 70 females and 99 males. Mean age of survivors was 3.4 years; nonsurvivors, 8.8 years; and 4.6 years for CPR on-arrival. Thirty-nine percent of all injuries were sustained in motor vehicle collisions; 20%, motor pedestrian collisions; 19%, assaults; 7%, falls; 4%, all terrain vehicle/motorcycle/bicycle; and 4%, gunshot wounds. Forty-two percent of all patients expired in the ED, whereas 34% expired in the intensive care unit. Eighty-seven percent of CPR on-arrival patients expired in the ED. Fifty-five percent of survivors had full neurologic recovery.

Conclusion: Although mortality was extremely high for children requiring CPR in the field after traumatic injury, it was absolute for those arriving at the ED still undergoing CPR.

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CPR (1.5%-25%), cessation or withholding of CPR efforts after traumatic injury in a child is a difficult and emotionally charged issue [5-11]. Unfortunately, clearcut resuscitation guidelines for children requiring CPR after traumatic injury do not exist. In this study, we document the outcome of children requiring prehospital CPR treated at an ACS-COT–designated pediatric level I trauma center after traumatic injury. The purposes of this study were to determine the outcome of this unique pediatric patient population and examine the efficacy of prolonging CPR resuscitation efforts on arrival to the emergency department (ED).

1. Methods

We conducted a retrospective analysis of all children (age range, 0-18 years) presenting to a level I pediatric trauma center, between April 1996 and December 2007, after traumatic injury in whom prehospital CPR was initiated. Patients’ medical records and prehospital event records were reviewed. Injuries were categorized as penetrating or blunt. Age; sex; ethnicity; transport time, month, mechanism, and location of injury; cardiac rhythm on arrival; injury severity score (ISS); operative interventions; location of death; and neurologic and overall outcomes were examined. In addition, children identified as arriving to the level I pediatric trauma center ED still requiring CPR were then examined separately and compared with all patients requiring posttrauma CPR. This study has been reviewed and approved by the local institutional review board.

2. Results

A total of 169 children (age range, 0-18 years) requiring prehospital CPR after traumatic injury were identified. Twenty-eight children survived and 141 expired (16.5% survival). Sixty-nine children, approximately 49% of all nonsurvivors, presented to the ED pulseless and required continued CPR on-arrival; there were no survivors in this group. The mean (SD) age of all patients was 10 (2.2) years. The mean (SD) age of survivors was 3.4 (0.6) years versus 8.8 (1.7) years for expired patients. Cardiopulmonary resuscitation on-arrival mean (SD) age was 4.6 (0.4) years.

There were 70 females and 99 males. Ethnicity was uniformly distributed between black (29.2%), Hispanic (29.2%), and white (33.9%), with 1.2% Asian and 5.3% other/unknown. Overall mortality was equally distributed along ethnic lines (Fig. 1).

Thirty-three percent of all patients were treated between May and July. Thirty-nine percent of all injuries were sustained in motor vehicle collisions (MVCs); 20%, motor pedestrian collisions (MPCs); 19%, assaults; 7%, falls; 4%, all terrain vehicle/motorcycle/bicycle; and 4%, gunshot wounds (GSWs). Ten of 65 MVC patients survived; 3 of 35 MPC children survived; 1 of 7 all terrain vehicle/motorcycle/bicycle/bike patients survived; 8 of 32 assault children survived; 5 of 12 falls; and 0 of 7 GSW patients survived (Fig. 2).

One hundred one patients were transported to the level I ED directly from the scene of injury; 66 were initially treated at another facility and transferred; 2 were transported from home. There were 51 CPR on-arrival “scene response” patients; 17 transferred from an outside ED and 1 from home. Transport times for the survivors were 148 ± 24.6 minutes, 98 ± 9.9 minutes for the expired patients and 87 ± 21 minutes for CPR on-arrival patients. All expired patients, 19 of 29

![Fig. 1](image1.png)  
**Fig. 1** Ethnicity of children requiring prehospital CPR for traumatic injury.

![Fig. 2](image2.png)  
**Fig. 2** Mechanism of injury and mortality. ATV indicates all terrain vehicle; MCC, motorcycle collision.

### Table 1: Mortality by site of origin: scene versus outside hospital transfer

<table>
<thead>
<tr>
<th></th>
<th>Survived (% age)</th>
<th>Expired</th>
<th>CPR o/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scene</td>
<td>15 (17)</td>
<td>86</td>
<td>51</td>
</tr>
<tr>
<td>Transfer</td>
<td>13 (25)</td>
<td>53</td>
<td>17</td>
</tr>
<tr>
<td>Home</td>
<td>1 (50)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>140</td>
<td>69</td>
</tr>
</tbody>
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survivors, and all CPR on-arrival patients were intubated before arrival (Table 1).

Injury severity score for survivors (mean 19) was uniformly distributed across four ISS ranges (0-8, 9-15, 16-25, >25), whereas ISS of nonsurvivors (mean, 30) were disproportionately distributed in the higher ISS groupings. Injury severity score of CPR on-arrival patients were disproportionately distributed in the higher ISS groupings (mean, 26; Fig. 3). Forty-two percent of patients expired in the ED, whereas 34% expired in the intensive care unit. Twelve of 28 survivors required operative intervention for injuries, whereas only 12 of 141 nonsurvivors were brought to the operating room. Nonsurvivors admitted to the pediatric intensive care unit (PICU) expired approximately 12 hours and 6 minutes after admission.

The mortality associated with prehospital CPR for traumatic injury, when assessed in terms of injury patterns, was 92% for those sustaining multiple injuries without associated traumatic brain injury (TBI), whereas mortality of prehospital CPR related to multiple injuries with TBI was 87%. The lowest mortality was observed in those who sustained isolated injury, exclusive of isolated TBI (73%). The group with multi-injury exclusive of TBI also had the highest percentage of patients requiring CPR on-arrival to the ED (Table 2). Although nonsurvivors sustained a higher frequency of diffuse axonal injury (DAI) compared with survivors, the incidence of subdural hemorrhage was higher in survivors. Both groups had a similar rates of injury exclusive of TBI and approximately one third of both groups had nonspecific or unknown degree of TBI. No child with an open head wound (crush, GSW, open fracture) survived (Table 3).

Fifty-nine of 69 CPR on-arrival patients presented to the level I ED in asystole; 7, in PEA; 1, in ventricular fibrillation; 1, with sinus bradycardia; and 1, with a wide complex agonal cardiac rhythm (Fig. 4). Sixty (87%) of the 69 patients receiving CPR on-arrival expired in the ED. The remaining 9 regained sufficient hemodynamic stability to be transported to the PICU directly, or to the operating room (n = 5) then PICU. All CPR on-arrival patients admitted to the PICU, including those who underwent operative intervention, expired a mean of 8 hours and 48 minutes after admission.

Fifty-five percent of survivors had full neurologic recovery at discharge, 10% had moderate disability; 28% had severe disability, and 7% were vegetative (Fig. 5). Patients described as having full neurologic recovery (n = 16) at hospital discharge were characterized by as follows: mean age, 3.6 years; mechanism of injury: MVC n = 5; fall n = 5; assault n = 5; prehospital origins: scene

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Mortality by injury pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survived (%) age</td>
<td>Expired</td>
</tr>
<tr>
<td>Isolated TBI</td>
<td>11 (17)</td>
</tr>
<tr>
<td>Multi-injury/TBI</td>
<td>9 (13)</td>
</tr>
<tr>
<td>Multi-injury/No TBI</td>
<td>2 (8)</td>
</tr>
<tr>
<td>Isolated injury/no TBI</td>
<td>3 (27)</td>
</tr>
<tr>
<td>No injury</td>
<td>2 (100)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Mortality associated with TBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survived (%) age</td>
<td>Expired (%) age</td>
</tr>
<tr>
<td>No TBI</td>
<td>4 (14)</td>
</tr>
<tr>
<td>Unknown/nonspecific</td>
<td>10 (34)</td>
</tr>
<tr>
<td>TBI</td>
<td>14 (21)</td>
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<tr>
<td>SAH</td>
<td>3 (10)</td>
</tr>
<tr>
<td>DAI</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Contusion</td>
<td>1 (3)</td>
</tr>
<tr>
<td>EDH</td>
<td>1 (3)</td>
</tr>
<tr>
<td>SDH</td>
<td>8 (28)</td>
</tr>
<tr>
<td>Anoxia</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Open wound</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
</tr>
</tbody>
</table>

SAH indicates subarachnoid hemorrhage; EDH, epidural hemorrhage; SDH, subdural hemorrhage.

Fig. 3 Injury severity score of children requiring prehospital CPR for traumatic injury.

Fig. 4 Initial cardiac rhythm and mortality. PEA indicates paroxysmal electrical activity; SB, sinus bradycardia; ST, sinus tachycardia; uk, unknown; VF, ventricular fibrillation.
3. Discussion

In a recent position paper, the National Association of Emergency Medical Services Physicians and the ACS-COT recommended specific criteria for withholding or termination of CPR efforts after traumatic injury [4]. These recommendations are primarily derived from observations of adults. Numerous additional publications addressing the prehospital care of the apneic, pulseless trauma patient similarly document the futility of prehospital CPR after traumatic injury [1-3,8,12]. Recommendations concerning prehospital care of the injured patient are similarly derived from study of adults in these works and, therefore, have limited application for care of the pediatric trauma patient population.

Prehospital resuscitation paradigms for EMS providers in our review dictate initiation of CPR at the scene or en route for all pediatric trauma patients with absence of spontaneous respiratory efforts and loss of palpable pulses. These prehospital procedures are performed for all pulseless patients, unless the most obvious signs of death (rigor mortis, dependent lividity, or decapitation) were present. Trauma patients in extremis are, by design, routinely transported to the nearest hospital. An informal review of all pretransfer hemodynamic stabilization efforts undertaken at outside facilities showed that guidelines set by American Heart Association and American College of Surgery Committee on Trauma were grossly adhered to regardless of size or location of the ED involved in the initial assessment [13,14]. Transfer of all patients from initial receiving EDs to the level I pediatric center ED were routinely effected by the most rapid mode of transportation, often via air carrier, and frequently despite obvious unresponsiveness to ongoing CPR efforts.

In the present review, we document protracted prehospital transport times, likely resulting from several factors. The overall catchment area for the receiving ACS-COT-certified level I pediatric trauma center in the current study encompasses both congested urban areas and open rural areas over a large geographic area. Many emergency scene responses and hospital to hospital transports are enacted by level I trauma center-based transport teams specifically trained in the care of pediatric trauma. This necessitates a ground or helicopter-based round trip for many responses likely further adding to transport times for these critically injured children. The availability of these pediatric-specific air transport teams, the local traffic limitations for ground-based pediatric-specific transport, and the physical distances involved in these responses may all contribute to this occurrence. Furthermore, scene response emergency medical staff often attempt scene stabilization interventions (ie, intubation, intravenous, and/or intraosseous access, etc). For a child in extremis, these efforts are often difficult under optimal conditions and can be time-consuming in scene response situations. Although local EMS often direct all CPR patients to the nearest medical facility for stabilization, a lack of outside ED expertise, hospital support, or physician certification with pediatric trauma at local facilities may dictate transport directly to level I care despite closer proximity of these institutions to the scene of injury, thereby prolonging transport times.

Despite the occasional outside ED unwillingness or inability to care for pediatric injury, we observe a higher percentage of survivors transferred from outside medical facilities compared with those transported directly from the scene of injury. Correspondingly, these survivors have the most prolonged transport times. We speculate that this is a self-selecting cohort of children who responded positively to initial hemodynamic stabilization interventions at the outside facility and were sufficiently stable to survive transfer for definitive care despite the length of time required for transport. A limitation of the current study is a lack of documentation concerning the length of time for transport from the scene to the outside facility, the amount of time required to stabilize these children at those institutions, the time to affect transfer, and the duration of CPR required.

Although hemodynamically unstable children and occasionally those poorly responsive to CPR efforts are frequently transported to this level I center for higher level of care, there are undoubtedly children who do not survive sufficiently long enough to be transferred to level I care. Conversely, there are possibly those who respond sufficiently well to prehospital CPR who are not transferred to the level I center. These potential survivors and uncounted mortalities represent a limitation of the current study; however, it is unlikely that they exist in
sufficient numbers to modify the observation concerning the lethality associated with the need for CPR on-arrival after traumatic injury.

Cardiopulmonary arrest after traumatic injury in the pediatric population has a mortality of 75% to 98% [5-7,9-11,15]. Our data showing 83% mortality corroborate this dismal reality for children requiring prehospital CPR after trauma-induced cardiopulmonary arrest. Our data demonstrate that for posttraumatic injury resulting in cardiopulmonary collapse, overall mortality was highest in the preadolescence age patient, for those with injuries sustained in association with a motor vehicle (passenger or pedestrian), for those with injury resulting from firearms, those with ISS greater than 16, injuries sustained during summer months, those with the most rapid EMS transport times, those undergoing direct EMS transport from injury scene to the level I trauma center, and those who failed to regain cardiovascular activity before arrival at the ED. Ultimately, 42% of all patients expired shortly after arrival to the ED, whereas one third expired in the PICU. We observed that 8% of all nonsurvivors were sufficiently responsive to ED resuscitation efforts and had injury amenable to surgical correction to undergo operative intervention. There were no intraoperative deaths. Nonsurvivors admitted to the PICU, operative patients included, survived approximately 12 hours despite continued resuscitative efforts.

Nearly half of all nonsurvivors had no response to prehospital CPR efforts and presented to the ED without detectable pulses. Eighty-five percent of these CPR on-arrival patients were noted to be in asystole at the time of ED presentation. Despite presenting with no detectable pulse, 9 of the 69 CPR on-arrival patients regained sufficient cardiovascular function after ED resuscitation to be admitted to PICU for critical care interventions and observation. Five of this group had surgically amenable injury and underwent surgical intervention. Two had craniotomy, 2 had exploratory celiotomy, and 1 had thoracotomy. Despite successful ED restoration of vitals signs, operative intervention, and PICU care, no CPR on-arrival patients survived longer than 9 hours after ED presentation.

We identify a large percentage of survivors documented as sustaining subdural hemorrhage head injury compared with nonsurvivors. However, although almost half of survivors required operative intervention, few involved craniotomy. A much smaller percentage of nonsurvivors were considered operative candidates, perhaps reflecting the higher percentage of nonoperative TBI injury, particularly DAI, sustained by these children. A third of both survivors and nonsurvivors are noted to have “Unknown/non-specific TBI.” Included in this category are children documented as sustaining “closed head injury—not otherwise specified,” “severe head injury,” skull fracture with and without mention of intracranial injury, cervical spine injury (often associated with TBI, but not specifically recorded), and those with “non-specific craniofacial” trauma. For nonsurvivors, obtaining accurate data concerning the specifics of TBI may reflect the inherent difficulty of procuring a complete diagnostic evaluation on critically injured children in the ED setting. Although exact numbers were not obtainable through the current database, it has been our practice not to transport critically injured, hemodynamically unstable children through the ED to radiology department for a TBI-defining head computed tomography. For survivors, this category may represent patients with suspected TBI whose symptoms cleared before obtaining, or were not visible on (ie, “concussion”) definitive radiologic studies. The lack of definitive TBI characterization for such large numbers of patients in this study represents a limitation related to the nature of retrospective database analysis. Although we document a distinct number of patients sustaining anoxic brain injury ascribed to a specific mechanism of injury (ie, hanging and suffocation), we are unable to determine if anoxic TBI related to prolonged CPR was a direct contributor to the mortality observed with prehospital CPR after traumatic injury.

The mortality associated with prehospital CPR for traumatic injury, when assessed in terms of injury patterns, was highest for those sustaining multiple injuries without TBI. Included in this category are children who sustained various combinations of long bone fractures, pelvic fractures, solid organ injuries, soft tissue crush injuries/avulsions/lacerations/contusions, intestinal injuries, and spine injuries. However, prehospital CPR related to multi-injury with TBI and isolated TBI had significant mortality as well. The lowest mortality was associated with prehospital CPR related to an isolated traumatic injury (radial artery laceration, scalp laceration, airway obstruction, pulmonary contusion, spleen laceration), exclusive of isolated TBI. Within the limitations of our database, we observed no multi-injury pattern, with or without TBI, that seemed to be predictive of survivability. Patients presenting with TBI, with or without other associated injuries, and those with an isolated injury had equivalent percentages of patients requiring CPR on-arrival. The group with the highest mortality, those with multi-injuries exclusive of TBI, also had the highest percentage requiring CPR on-arrival to the ED.

For the current study, we examined data from all children evaluated in the ED at a level I pediatric trauma center for more than 11 years. One unexpected observation is that the number of children injured sufficiently to require prehospital CPR was quite small relative to the thousands of children evaluated in the ED for traumatic injury over this time. Likewise, the typical child reported in the literature presenting to an ED after sustaining traumatic injury does not often require prehospital CPR. Not unexpectedly, these patients have been shown to have correspondingly negligible mortality related to their traumatic injury. Furthermore, more severely injured trauma patient presenting to the ED with apnea, but with demonstrable pulses and no need for CPR, have been similarly shown to have outstanding survival [15]. Our data demonstrate that children sustaining a
traumatic injury resulting in prehospital CPR survival were associated with the younger “toddler” age group, falls, longer EMS transport times, spontaneous prehospital respiratory effort, and hemodynamic recovery before ED arrival. Forty-two percent of survivors underwent operative intervention for surgically amenable injury: 5 had craniotomy, 3 had soft tissue injury repair, 1 had spine stabilization, 1 had extremity fracture stabilization, 1 had an extremity vascular injury repair, and 1 underwent a celotomy, which revealed no injury. One third of survivors presented with a stable airway and did not require intubation for respiratory support. Interestingly, we observe a uniform distribution across all ISS groups for survivors with more than half of those survivors having an ISS greater than 16. These findings suggest that almost half of all survivors had either an exceedingly rapid response to prehospital CPR or prehospital findings that may not have warranted CPR intervention at all. Consistent with this speculation is the observation that 55% of survivors had full neurologic recovery at discharge. Patients with full neurologic recovery were characterized by a younger age, spontaneous respiratory effort without intubation, and an ISS less than 25. Favorable neurologic outcome was not associated with any particular mode of injury with MVC, falls and assaults being equivalent. Unfortunately, survivors were also distinguished by poorer neurologic outcomes, with slightly less than half being described as having moderate disability, severe disability, or vegetative at hospital discharge. Although not specifically addressed by the available data, anecdotally a number of children had prehospital CPR initiated by well-intentioned bystanders. Although a history of CPR by bystanders may not portend doom, it is clear from our data that CPR continues en route by experienced medics does.

Continuation, cessation, or withholding of CPR resuscitative efforts in the ED after traumatic injury in a child is a difficult and emotionally charged issue. Cliquet resuscitation guidelines to support ongoing resuscitative efforts in the ED for children requiring CPR after traumatic injury do not exist. Our observations highlight the futility of continued CPR efforts for children presenting pulseless on-arrival to ED. We acknowledge the possibility, in an urban setting, that a child may have a short transport time and require ongoing CPR on-arrival to the ED with a reversible situation, such as a misplaced endotracheal tube, a tension pneumothorax, or a pericardial tamponade. From our data, it was impossible to determine if such situations existed for the CPR on-arrival cohort who responded to ED resuscitation efforts sufficiently to survive through operative interventions and PICU admission. We recognize this as one of several inherent limitations of a retrospective database review of this type. For this reason, we strongly recommend adherence to established acute care algorithms describing rapid evaluation for reversible physiology for all patients entering the ED with ongoing CPR as recommended by ACS-COT Advanced Trauma Life Support guidelines [4,16]. For this patient population, a rapid direct laryngoscopy and end-tidal CO2 monitor to ensure that an airway is appropriately established, bilateral decompression of the chest with needle thoracostomy to rule out tension pneumothorax, and a focused abdominal sonography for trauma (FAST) examination of the peritoneum and pericardium to rule out an exsanguinating intraabdominal bleed or cardiac tamponade may be prudent. Performance of these rapid and simple diagnostic tests will be invaluable to ED personnel and family. Despite utilization of these practices for all critically injured children evaluated in the ED, our data demonstrate the futility of continued CPR efforts for children presenting pulseless on-arrival to ED.

We conclude, therefore, the ongoing utilization of resuscitation resources for this specific cohort after a traumatic injury to be largely unwarranted. Furthermore, although prehospital and on-arrival resuscitation efforts may result in the restoration of vital signs for children observed to have successful response to in-the-field CPR efforts, in most cases, these responses are transient and do not portend successful long-term outcome. Our data suggest that the likelihood of a unsuccessful outcome must be considered by all caregivers before continuation of prolonged resuscitative efforts for this patient population as well. Once any simply treatable reversible processes are excluded, ED and trauma physicians may find these data useful during the difficult process of treating and determining when to terminate treatment of this unique and difficult population of critically injured children.

References


